
STM32F030x4/x6/x8/xC and STM32F070x6/xB
advanced ARM[®]-based 32-bit MCUs

Introduction

This reference manual targets application developers. It provides complete information on how to use the STM32F030x4/x6/x8/xC and STM32F070x6/xB microcontroller memory and peripherals.

It applies to STM32F030x4/x6/x8/xC and STM32F070x6/xB devices.

For the purpose of this manual, STM32F030x4/x6/x8/xC and STM32F070x6/xB microcontrollers are referred to as STM32F0x0.

The STM32F0x0 is a family of microcontrollers with different memory sizes, packages and peripherals.

For ordering information, mechanical and electrical device characteristics, please refer to the corresponding datasheet.

For information on the ARM[®] Cortex[®]-M0 core, please refer to the ARM[®] Cortex[®]-M0 *technical reference manual*.

Related documents

- ARM[®] Cortex[®]-M0 technical reference manual, available from ARM website at www.arm.com
- STM32F0xx Cortex-M0 programming manual (PM0215)
- STM32F030x4/x6/x8/xC and STM32F070x6/xB datasheets available from STMicroelectronics website at www.st.com

Contents

1	Documentation conventions	33
1.1	List of abbreviations for registers	33
1.2	Glossary	33
1.3	Peripheral availability	33
2	System and memory overview	34
2.1	System architecture	34
2.2	Memory organization	36
2.2.1	Introduction	36
2.2.2	Memory map and register boundary addresses	37
2.3	Embedded SRAM	41
2.4	Flash memory overview	42
2.5	Boot configuration	43
3	Embedded Flash memory	45
3.1	Flash main features	45
3.2	Flash memory functional description	45
3.2.1	Flash memory organization	45
3.2.2	Flash program and erase operations	48
3.3	Memory protection	55
3.3.1	Read protection	55
3.3.2	Write protection	57
3.3.3	Option byte write protection	57
3.4	Flash interrupts	57
3.5	Flash register description	58
3.5.1	Flash access control register (FLASH_ACR)	58
3.5.2	Flash key register (FLASH_KEYR)	58
3.5.3	Flash option key register (FLASH_OPTKEYR)	59
3.5.4	Flash status register (FLASH_SR)	60
3.5.5	Flash control register (FLASH_CR)	60
3.5.6	Flash address register (FLASH_AR)	62
3.5.7	Flash Option byte register (FLASH_OBR)	62
3.5.8	Write protection register (FLASH_WRPR)	63

	3.5.9	Flash register map	64
4		Option bytes	65
	4.1	Option byte description	66
	4.1.1	User and read protection option byte	66
	4.1.2	User data option byte	67
	4.1.3	Write protection option byte	67
	4.1.4	Option byte map	68
5		Cyclic redundancy check calculation unit (CRC)	69
	5.1	Introduction	69
	5.2	CRC main features	69
	5.3	CRC functional description	70
	5.3.1	CRC block diagram	70
	5.3.2	CRC internal signals	70
	5.3.3	CRC operation	70
	5.4	CRC registers	72
	5.4.1	Data register (CRC_DR)	72
	5.4.2	Independent data register (CRC_IDR)	72
	5.4.3	Control register (CRC_CR)	73
	5.4.4	Initial CRC value (CRC_INIT)	73
	5.4.5	CRC register map	74
6		Power control (PWR)	75
	6.1	Power supplies	75
	6.1.1	Independent A/D converter supply and reference voltage	75
	6.1.2	Voltage regulator	76
	6.2	Power supply supervisor	76
	6.2.1	Power on reset (POR) / power down reset (PDR)	76
	6.3	Low-power modes	77
	6.3.1	Slowing down system clocks	78
	6.3.2	Peripheral clock gating	79
	6.3.3	Sleep mode	79
	6.3.4	Stop mode	80
	6.3.5	Standby mode	82
	6.3.6	RTC wakeup from low-power mode	83

6.4	Power control registers	84
6.4.1	Power control register (PWR_CR)	84
6.4.2	Power control/status register (PWR_CSR)	85
6.4.3	PWR register map	86
7	Reset and clock control (RCC)	87
7.1	Reset	87
7.1.1	Power reset	87
7.1.2	System reset	87
7.1.3	RTC domain reset	88
7.2	Clocks	89
7.2.1	HSE clock	92
7.2.2	HSI clock	93
7.2.3	PLL	94
7.2.4	LSE clock	94
7.2.5	LSI clock	95
7.2.6	System clock (SYSCLK) selection	95
7.2.7	Clock security system (CSS)	95
7.2.8	ADC clock	96
7.2.9	RTC clock	96
7.2.10	Independent watchdog clock	96
7.2.11	Clock-out capability	96
7.2.12	Internal/external clock measurement with TIM14	97
7.3	Low-power modes	98
7.4	RCC registers	99
7.4.1	Clock control register (RCC_CR)	99
7.4.2	Clock configuration register (RCC_CFGR)	101
7.4.3	Clock interrupt register (RCC_CIR)	104
7.4.4	APB peripheral reset register 2 (RCC_APB2RSTR)	106
7.4.5	APB peripheral reset register 1 (RCC_APB1RSTR)	108
7.4.6	AHB peripheral clock enable register (RCC_AHBENR)	111
7.4.7	APB peripheral clock enable register 2 (RCC_APB2ENR)	112
7.4.8	APB peripheral clock enable register 1 (RCC_APB1ENR)	114
7.4.9	RTC domain control register (RCC_BDCR)	117
7.4.10	Control/status register (RCC_CSR)	119
7.4.11	AHB peripheral reset register (RCC_AHBRSTR)	120
7.4.12	Clock configuration register 2 (RCC_CFGR2)	122

7.4.13	Clock configuration register 3 (RCC_CFGR3)	123
7.4.14	Clock control register 2 (RCC_CR2)	123
7.4.15	RCC register map	125
8	General-purpose I/Os (GPIO)	127
8.1	Introduction	127
8.2	GPIO main features	127
8.3	GPIO functional description	127
8.3.1	General-purpose I/O (GPIO)	129
8.3.2	I/O pin alternate function multiplexer and mapping	129
8.3.3	I/O port control registers	130
8.3.4	I/O port data registers	130
8.3.5	I/O data bitwise handling	131
8.3.6	GPIO locking mechanism	131
8.3.7	I/O alternate function input/output	131
8.3.8	External interrupt/wakeup lines	132
8.3.9	Input configuration	132
8.3.10	Output configuration	133
8.3.11	Alternate function configuration	133
8.3.12	Analog configuration	134
8.3.13	Using the HSE or LSE oscillator pins as GPIOs	135
8.3.14	Using the GPIO pins in the RTC supply domain	135
8.4	GPIO registers	136
8.4.1	GPIO port mode register (GPIOx_MODER) (x = A..D, F)	136
8.4.2	GPIO port output type register (GPIOx_OTYPER) (x = A..D, F)	136
8.4.3	GPIO port output speed register (GPIOx_OSPEEDR) (x = A..D, F)	137
8.4.4	GPIO port pull-up/pull-down register (GPIOx_PUPDR) (x = A..D, F)	137
8.4.5	GPIO port input data register (GPIOx_IDR) (x = A..D, F)	138
8.4.6	GPIO port output data register (GPIOx_ODR) (x = A..D, F)	138
8.4.7	GPIO port bit set/reset register (GPIOx_BSRR) (x = A..D, F)	138
8.4.8	GPIO port configuration lock register (GPIOx_LCKR) (x = A..B)	139
8.4.9	GPIO alternate function low register (GPIOx_AFRL) (x = A..D,)	140
8.4.10	GPIO alternate function high register (GPIOx_AFRH) (x = A..D, F)	141

8.4.11	GPIO port bit reset register (GPIOx_BRR) (x = A..D, F)	141
8.4.12	GPIO register map	142
9	System configuration controller (SYSCFG)	144
9.1	SYSCFG registers	144
9.1.1	SYSCFG configuration register 1 (SYSCFG_CFGR1)	144
9.1.2	SYSCFG external interrupt configuration register 1 (SYSCFG_EXTICR1)	147
9.1.3	SYSCFG external interrupt configuration register 2 (SYSCFG_EXTICR2)	147
9.1.4	SYSCFG external interrupt configuration register 3 (SYSCFG_EXTICR3)	148
9.1.5	SYSCFG external interrupt configuration register 4 (SYSCFG_EXTICR4)	149
9.1.6	SYSCFG configuration register 2 (SYSCFG_CFGR2)	150
9.1.7	SYSCFG register maps	151
10	Direct memory access controller (DMA)	152
10.1	Introduction	152
10.2	DMA main features	152
10.3	DMA functional description	153
10.3.1	DMA transactions	153
10.3.2	Arbiter	154
10.3.3	DMA channels	154
10.3.4	Programmable data width, data alignment and endians	156
10.3.5	Error management	157
10.3.6	DMA interrupts	157
10.4	DMA registers	161
10.4.1	DMA interrupt status register (DMA_ISR)	161
10.4.2	DMA interrupt flag clear register (DMA_IFCR)	162
10.4.3	DMA channel x configuration register (DMA_CCRx) (x = 1..5, where x = channel number)	163
10.4.4	DMA channel x number of data register (DMA_CNDTRx) (x = 1..5, where x = channel number)	165
10.4.5	DMA channel x peripheral address register (DMA_CPARx) (x = 1..5, where x = channel number)	165
10.4.6	DMA channel x memory address register (DMA_CMARx) (x = 1..5, where x = channel number)	166
10.4.7	DMA channel selection register (DMA_CSELR)	167

10.4.8	DMA register map	168
11	Interrupts and events	170
11.1	Nested vectored interrupt controller (NVIC)	170
11.1.1	NVIC main features	170
11.1.2	SysTick calibration value register	170
11.1.3	Interrupt and exception vectors	170
11.2	Extended interrupts and events controller (EXTI)	172
11.2.1	Main features	172
11.2.2	Block diagram	173
11.2.3	Event management	173
11.2.4	Functional description	173
11.2.5	External and internal interrupt/event line mapping	175
11.3	EXTI registers	176
11.3.1	Interrupt mask register (EXTI_IMR)	176
11.3.2	Event mask register (EXTI_EMR)	176
11.3.3	Rising trigger selection register (EXTI_RTSR)	176
11.3.4	Falling trigger selection register (EXTI_FTSR)	177
11.3.5	Software interrupt event register (EXTI_SWIER)	178
11.3.6	Pending register (EXTI_PR)	178
11.3.7	EXTI register map	180
12	Analog-to-digital converter (ADC)	181
12.1	Introduction	181
12.2	ADC main features	182
12.3	ADC pins and internal signals	183
12.4	ADC functional description	184
12.4.1	Calibration (ADCAL)	184
12.4.2	ADC on-off control (ADEN, ADDIS, ADRDY)	185
12.4.3	ADC clock (CKMODE)	187
12.4.4	Configuring the ADC	188
12.4.5	Channel selection (CHSEL, SCANDIR)	189
12.4.6	Programmable sampling time (SMP)	189
12.4.7	Single conversion mode (CONT=0)	190
12.4.8	Continuous conversion mode (CONT=1)	190
12.4.9	Starting conversions (ADSTART)	190

12.4.10	Timings	191
12.4.11	Stopping an ongoing conversion (ADSTP)	192
12.5	Conversion on external trigger and trigger polarity (EXTSEL, EXTEN)	192
12.5.1	Discontinuous mode (DISCEN)	193
12.5.2	Programmable resolution (RES) - fast conversion mode	194
12.5.3	End of conversion, end of sampling phase (EOC, EOSMP flags)	195
12.5.4	End of conversion sequence (EOSEQ flag)	196
12.5.5	Example timing diagrams (single/continuous modes hardware/software triggers)	196
12.6	Data management	198
12.6.1	Data register and data alignment (ADC_DR, ALIGN)	198
12.6.2	ADC overrun (OVR, OVRMOD)	198
12.6.3	Managing a sequence of data converted without using the DMA	199
12.6.4	Managing converted data without using the DMA without overrun	199
12.6.5	Managing converted data using the DMA	199
12.7	Low-power features	201
12.7.1	Wait mode conversion	201
12.7.2	Auto-off mode (AUTOFF)	201
12.8	Analog window watchdog (AWDEN, AWDSGL, AWDCH, AWD_HTR/LTR, AWD)	203
12.9	Temperature sensor and internal reference voltage	204
12.10	ADC interrupts	206
12.11	ADC registers	207
12.11.1	ADC interrupt and status register (ADC_ISR)	207
12.11.2	ADC interrupt enable register (ADC_IER)	208
12.11.3	ADC control register (ADC_CR)	210
12.11.4	ADC configuration register 1 (ADC_CFGR1)	212
12.11.5	ADC configuration register 2 (ADC_CFGR2)	216
12.11.6	ADC sampling time register (ADC_SMPR)	216
12.11.7	ADC watchdog threshold register (ADC_TR)	217
12.11.8	ADC channel selection register (ADC_CHSELR)	218
12.11.9	ADC data register (ADC_DR)	218
12.11.10	ADC common configuration register (ADC_CCR)	219
12.11.11	ADC register map	220
13	Advanced-control timers (TIM1)	221
13.1	TIM1 introduction	221

13.2	TIM1 main features	221
13.3	TIM1 functional description	223
13.3.1	Time-base unit	223
13.3.2	Counter modes	225
13.3.3	Repetition counter	235
13.3.4	Clock sources	237
13.3.5	Capture/compare channels	240
13.3.6	Input capture mode	243
13.3.7	PWM input mode	244
13.3.8	Forced output mode	245
13.3.9	Output compare mode	245
13.3.10	PWM mode	246
13.3.11	Complementary outputs and dead-time insertion	250
13.3.12	Using the break function	252
13.3.13	Clearing the OCxREF signal on an external event	255
13.3.14	6-step PWM generation	257
13.3.15	One-pulse mode	258
13.3.16	Encoder interface mode	259
13.3.17	Timer input XOR function	262
13.3.18	Interfacing with Hall sensors	262
13.3.19	TIMx and external trigger synchronization	264
13.3.20	Timer synchronization	267
13.3.21	Debug mode	267
13.4	TIM1 registers	268
13.4.1	TIM1 control register 1 (TIM1_CR1)	268
13.4.2	TIM1 control register 2 (TIM1_CR2)	269
13.4.3	TIM1 slave mode control register (TIM1_SMCR)	271
13.4.4	TIM1 DMA/interrupt enable register (TIM1_DIER)	274
13.4.5	TIM1 status register (TIM1_SR)	276
13.4.6	TIM1 event generation register (TIM1_EGR)	277
13.4.7	TIM1 capture/compare mode register 1 (TIM1_CCMR1)	279
13.4.8	TIM1 capture/compare mode register 2 (TIM1_CCMR2)	282
13.4.9	TIM1 capture/compare enable register (TIM1_CCER)	284
13.4.10	TIM1 counter (TIM1_CNT)	287
13.4.11	TIM1 prescaler (TIM1_PSC)	287
13.4.12	TIM1 auto-reload register (TIM1_ARR)	288
13.4.13	TIM1 repetition counter register (TIM1_RCR)	288

13.4.14	TIM1 capture/compare register 1 (TIM1_CCR1)	288
13.4.15	TIM1 capture/compare register 2 (TIM1_CCR2)	289
13.4.16	TIM1 capture/compare register 3 (TIM1_CCR3)	289
13.4.17	TIM1 capture/compare register 4 (TIM1_CCR4)	290
13.4.18	TIM1 break and dead-time register (TIM1_BDTR)	290
13.4.19	TIM1 DMA control register (TIM1_DCR)	292
13.4.20	TIM1 DMA address for full transfer (TIM1_DMAR)	293
13.4.21	TIM1 register map	294
14	General-purpose timers (TIM3)	296
14.1	TIM3 introduction	296
14.2	TIM3 main features	296
14.3	TIM3 functional description	297
14.3.1	Time-base unit	297
14.3.2	Counter modes	299
14.3.3	Clock sources	310
14.3.4	Capture/compare channels	313
14.3.5	Input capture mode	315
14.3.6	PWM input mode	317
14.3.7	Forced output mode	318
14.3.8	Output compare mode	318
14.3.9	PWM mode	319
14.3.10	One-pulse mode	323
14.3.11	Clearing the OCxREF signal on an external event	324
14.3.12	Encoder interface mode	325
14.3.13	Timer input XOR function	327
14.3.14	Timers and external trigger synchronization	328
14.3.15	Timer synchronization	331
14.3.16	Debug mode	337
14.4	TIM3 registers	338
14.4.1	TIM3 control register 1 (TIM3_CR1)	338
14.4.2	TIM3 control register 2 (TIM3_CR2)	340
14.4.3	TIM3 slave mode control register (TIM3_SMCR)	341
14.4.4	TIM3 DMA/Interrupt enable register (TIM3_DIER)	343
14.4.5	TIM3 status register (TIM3_SR)	344
14.4.6	TIM3 event generation register (TIM3_EGR)	347
14.4.7	TIM3 capture/compare mode register 1 (TIM3_CCMR1)	348

14.4.8	TIM3 capture/compare mode register 2 (TIM3_CCMR2)	351
14.4.9	TIM3 capture/compare enable register (TIM3_CCER)	352
14.4.10	TIM3 counter (TIM3_CNT)	354
14.4.11	TIM3 prescaler (TIM3_PSC)	354
14.4.12	TIM3 auto-reload register (TIM3_ARR)	354
14.4.13	TIM3 capture/compare register 1 (TIM3_CCR1)	354
14.4.14	TIM3 capture/compare register 2 (TIM3_CCR2)	355
14.4.15	TIM3 capture/compare register 3 (TIM3_CCR3)	355
14.4.16	TIM3 capture/compare register 4 (TIM3_CCR4)	356
14.4.17	TIM3 DMA control register (TIM3_DCR)	356
14.4.18	TIM3 DMA address for full transfer (TIM3_DMAR)	357
14.4.19	TIM3 register map	359
15	Basic timer (TIM6/TIM7)	361
15.1	TIM6/TIM7 introduction	361
15.2	TIM6/TIM7 main features	361
15.3	TIM6/TIM7 functional description	362
15.3.1	Time-base unit	362
15.3.2	Counter modes	364
15.3.3	Clock source	368
15.3.4	Debug mode	368
15.4	TIM6/TIM7 registers	369
15.4.1	TIM6/TIM7 control register 1 (TIMx_CR1)	369
15.4.2	TIM6/TIM7 DMA/Interrupt enable register (TIMx_DIER)	370
15.4.3	TIM6/TIM7 status register (TIMx_SR)	371
15.4.4	TIM6/TIM7 event generation register (TIMx_EGR)	371
15.4.5	TIM6/TIM7 counter (TIMx_CNT)	371
15.4.6	TIM6/TIM7 prescaler (TIMx_PSC)	372
15.4.7	TIM6/TIM7 auto-reload register (TIMx_ARR)	372
15.4.8	TIM6/TIM7 register map	373
16	General-purpose timer (TIM14)	374
16.1	TIM14 introduction	374
16.2	TIM14 main features	374
16.3	TIM14 functional description	375
16.3.1	Time-base unit	375

16.3.2	Counter modes	377
16.3.3	Clock source	380
16.3.4	Capture/compare channels	380
16.3.5	Input capture mode	382
16.3.6	Forced output mode	383
16.3.7	Output compare mode	383
16.3.8	PWM mode	384
16.3.9	Debug mode	385
16.4	TIM14 registers	386
16.4.1	TIM14 control register 1 (TIM14_CR1)	386
16.4.2	TIM14 interrupt enable register (TIM14_DIER)	387
16.4.3	TIM14 status register (TIM14_SR)	387
16.4.4	TIM14 event generation register (TIM14_EGR)	388
16.4.5	TIM14 capture/compare mode register 1 (TIM14_CCMR1)	389
16.4.6	TIM14 capture/compare enable register (TIM14_CCER)	392
16.4.7	TIM14 counter (TIM14_CNT)	393
16.4.8	TIM14 prescaler (TIM14_PSC)	393
16.4.9	TIM14 auto-reload register (TIM14_ARR)	393
16.4.10	TIM14 capture/compare register 1 (TIM14_CCR1)	394
16.4.11	TIM14 option register (TIM14_OR)	394
16.4.12	TIM14 register map	395
17	General-purpose timers (TIM15/16/17)	397
17.1	TIM15/16/17 introduction	397
17.2	TIM15 main features	397
17.3	TIM16 and TIM17 main features	399
17.4	TIM15/16/17 functional description	401
17.4.1	Time-base unit	401
17.4.2	Counter modes	403
17.4.3	Repetition counter	407
17.4.4	Clock sources	408
17.4.5	Capture/compare channels	410
17.4.6	Input capture mode	413
17.4.7	PWM input mode (only for TIM15)	414
17.4.8	Forced output mode	415
17.4.9	Output compare mode	416
17.4.10	PWM mode	417

17.4.11	Complementary outputs and dead-time insertion	418
17.4.12	Using the break function	421
17.4.13	One-pulse mode	424
17.4.14	TIM15 external trigger synchronization	426
17.4.15	Timer synchronization (TIM15)	428
17.4.16	Debug mode	428
17.5	TIM15 registers	429
17.5.1	TIM15 control register 1 (TIM15_CR1)	429
17.5.2	TIM15 control register 2 (TIM15_CR2)	430
17.5.3	TIM15 slave mode control register (TIM15_SMCR)	432
17.5.4	TIM15 DMA/interrupt enable register (TIM15_DIER)	433
17.5.5	TIM15 status register (TIM15_SR)	433
17.5.6	TIM15 event generation register (TIM15_EGR)	436
17.5.7	TIM15 capture/compare mode register 1 (TIM15_CCMR1)	437
17.5.8	TIM15 capture/compare enable register (TIM15_CCER)	440
17.5.9	TIM15 counter (TIM15_CNT)	443
17.5.10	TIM15 prescaler (TIM15_PSC)	443
17.5.11	TIM15 auto-reload register (TIM15_ARR)	443
17.5.12	TIM15 repetition counter register (TIM15_RCR)	444
17.5.13	TIM15 capture/compare register 1 (TIM15_CCR1)	444
17.5.14	TIM15 capture/compare register 2 (TIM15_CCR2)	445
17.5.15	TIM15 break and dead-time register (TIM15_BDTR)	445
17.5.16	TIM15 DMA control register (TIM15_DCR)	448
17.5.17	TIM15 DMA address for full transfer (TIM15_DMAR)	448
17.5.18	TIM15 register map	449
17.6	TIM16 and TIM17 registers	451
17.6.1	TIM16 and TIM17 control register 1 (TIM16_CR1 and TIM17_CR1)	451
17.6.2	TIM16 and TIM17 control register 2 (TIM16_CR2 and TIM17_CR2)	452
17.6.3	TIM16 and TIM17 DMA/interrupt enable register (TIM16_DIER and TIM17_DIER)	453
17.6.4	TIM16 and TIM17 status register (TIM16_SR and TIM17_SR)	454
17.6.5	TIM16 and TIM17 event generation register (TIM16_EGR and TIM17_EGR)	455
17.6.6	TIM16 and TIM17 capture/compare mode register 1 (TIM16_CCMR1 and TIM17_CCMR1)	456
17.6.7	TIM16 and TIM17 capture/compare enable register (TIM16_CCER and TIM17_CCER)	460
17.6.8	TIM16 and TIM17 counter (TIM16_CNT and TIM17_CNT)	462

17.6.9	TIM16 and TIM17 prescaler (TIM16_PSC and TIM17_PSC)	462
17.6.10	TIM16 and TIM17 auto-reload register (TIM16_ARR and TIM17_ARR)	462
17.6.11	TIM16 and TIM17 repetition counter register (TIM16_RCR and TIM17_RCR)	463
17.6.12	TIM16 and TIM17 capture/compare register 1 (TIM16_CCR1 and TIM17_CCR1)	463
17.6.13	TIM16 and TIM17 break and dead-time register (TIM16_BDTR and TIM17_BDTR)	464
17.6.14	TIM16 and TIM17 DMA control register (TIM16_DCR and TIM17_DCR)	466
17.6.15	TIM16 and TIM17 DMA address for full transfer (TIM16_DMAR and TIM17_DMAR)	466
17.6.16	TIM16 and TIM17 register map	468
18	Infrared interface (IRTIM)	470
19	Independent watchdog (IWDG)	471
19.1	Introduction	471
19.2	IWDG main features	471
19.3	IWDG functional description	471
19.3.1	IWDG block diagram	471
19.3.2	Window option	472
19.3.3	Hardware watchdog	473
19.3.4	Behavior in Stop and Standby modes	473
19.3.5	Register access protection	473
19.3.6	Debug mode	473
19.4	IWDG registers	474
19.4.1	Key register (IWDG_KR)	474
19.4.2	Prescaler register (IWDG_PR)	475
19.4.3	Reload register (IWDG_RLR)	476
19.4.4	Status register (IWDG_SR)	477
19.4.5	Window register (IWDG_WINR)	478
19.4.6	IWDG register map	479
20	System window watchdog (WWDG)	480
20.1	Introduction	480
20.2	WWDG main features	480

20.3	WWDG functional description	480
20.3.1	Enabling the watchdog	481
20.3.2	Controlling the downcounter	481
20.3.3	Advanced watchdog interrupt feature	481
20.3.4	How to program the watchdog timeout	482
20.3.5	Debug mode	483
20.4	WWDG registers	483
20.4.1	Control register (WWDG_CR)	483
20.4.2	Configuration register (WWDG_CFR)	484
20.4.3	Status register (WWDG_SR)	484
20.4.4	WWDG register map	485
21	Real-time clock (RTC)	486
21.1	Introduction	486
21.2	RTC main features	487
21.3	RTC implementation	487
21.4	RTC functional description	488
21.4.1	RTC block diagram	488
21.4.2	GPIOs controlled by the RTC	490
21.4.3	Clock and prescalers	491
21.4.4	Real-time clock and calendar	492
21.4.5	Programmable alarm	492
21.4.6	Periodic auto-wakeup	493
21.4.7	RTC initialization and configuration	493
21.4.8	Reading the calendar	495
21.4.9	Resetting the RTC	496
21.4.10	RTC synchronization	496
21.4.11	RTC reference clock detection	497
21.4.12	RTC smooth digital calibration	498
21.4.13	Time-stamp function	500
21.4.14	Tamper detection	500
21.4.15	Calibration clock output	502
21.4.16	Alarm output	502
21.5	RTC low-power modes	503
21.6	RTC interrupts	503
21.7	RTC registers	503

21.7.1	RTC time register (RTC_TR)	503
21.7.2	RTC date register (RTC_DR)	504
21.7.3	RTC control register (RTC_CR)	506
21.7.4	RTC initialization and status register (RTC_ISR)	509
21.7.5	RTC prescaler register (RTC_PRER)	511
21.7.6	RTC wakeup timer register (RTC_WUTR)	512
21.7.7	RTC alarm A register (RTC_ALRMAR)	513
21.7.8	RTC write protection register (RTC_WPR)	514
21.7.9	RTC sub second register (RTC_SSR)	514
21.7.10	RTC shift control register (RTC_SHIFTR)	515
21.7.11	RTC timestamp time register (RTC_TSTR)	516
21.7.12	RTC timestamp date register (RTC_TSDR)	517
21.7.13	RTC time-stamp sub second register (RTC_TSSSR)	518
21.7.14	RTC calibration register (RTC_CALR)	519
21.7.15	RTC tamper and alternate function configuration register (RTC_TAFCR)	520
21.7.16	RTC alarm A sub second register (RTC_ALRMASR)	523
21.7.17	RTC register map	523
22	Inter-integrated circuit (I2C) interface	526
22.1	Introduction	526
22.2	I2C main features	526
22.3	I2C implementation	527
22.4	I2C functional description	527
22.4.1	I2C block diagram	528
22.4.2	I2C2 block diagram	529
22.4.3	I2C clock requirements	529
22.4.4	Mode selection	530
22.4.5	I2C initialization	531
22.4.6	Software reset	535
22.4.7	Data transfer	536
22.4.8	I2C slave mode	538
22.4.9	I2C master mode	547
22.4.10	I2C_TIMINGR register configuration examples	559
22.4.11	SMBus specific features	560
22.4.12	SMBus initialization	563
22.4.13	SMBus: I2C_TIMEOUTR register configuration examples	565

22.4.14	SMBus slave mode	566
22.4.15	Error conditions	573
22.4.16	DMA requests	575
22.4.17	Debug mode	576
22.5	I2C low-power modes	577
22.6	I2C interrupts	577
22.7	I2C registers	578
22.7.1	Control register 1 (I2C_CR1)	578
22.7.2	Control register 2 (I2C_CR2)	581
22.7.3	Own address 1 register (I2C_OAR1)	584
22.7.4	Own address 2 register (I2C_OAR2)	585
22.7.5	Timing register (I2C_TIMINGR)	586
22.7.6	Timeout register (I2C_TIMEOUTR)	587
22.7.7	Interrupt and status register (I2C_ISR)	588
22.7.8	Interrupt clear register (I2C_ICR)	590
22.7.9	PEC register (I2C_PECR)	591
22.7.10	Receive data register (I2C_RXDR)	592
22.7.11	Transmit data register (I2C_TXDR)	592
22.7.12	I2C register map	593
23	Universal synchronous asynchronous receiver transmitter (USART)	595
23.1	Introduction	595
23.2	USART main features	595
23.3	USART implementation	597
23.4	USART functional description	598
23.4.1	USART character description	599
23.4.2	USART transmitter	600
23.4.3	USART receiver	603
23.4.4	USART baud rate generation	609
23.4.5	Tolerance of the USART receiver to clock deviation	611
23.4.6	USART auto baud rate detection	612
23.4.7	Multiprocessor communication using USART	612
23.4.8	USART parity control	615
23.4.9	A.15.6: USART synchronous mode code example USART synchronous mode	615
23.4.10	USART Single-wire Half-duplex communication	618

23.4.11	USART continuous communication in DMA mode	618
23.4.12	RS232 hardware flow control and RS485 driver enable using USART	621
23.5	USART low-power modes	623
23.6	USART interrupts	624
23.7	USART registers	625
23.7.1	Control register 1 (USART_CR1)	625
23.7.2	Control register 2 (USART_CR2)	628
23.7.3	Control register 3 (USART_CR3)	630
23.7.4	Baud rate register (USART_BRR)	633
23.7.5	Receiver timeout register (USART_RTOR)	633
23.7.6	Request register (USART_RQR)	634
23.7.7	Interrupt and status register (USART_ISR)	635
23.7.8	Interrupt flag clear register (USART_ICR)	638
23.7.9	Receive data register (USART_RDR)	639
23.7.10	Transmit data register (USART_TDR)	640
23.7.11	USART register map	640
24	Serial peripheral interface (SPI)	642
24.1	Introduction	642
24.2	SPI main features	642
24.3	SPI implementation	643
24.4	SPI functional description	643
24.4.1	General description	643
24.4.2	Communications between one master and one slave	644
24.4.3	Standard multi-slave communication	646
24.4.4	Multi-master communication	647
24.4.5	Slave select (NSS) pin management	648
24.4.6	Communication formats	649
24.4.7	Configuration of SPI	651
24.4.8	Procedure for enabling SPI	652
24.4.9	Data transmission and reception procedures	652
24.4.10	SPI status flags	662
24.4.11	SPI error flags	663
24.4.12	NSS pulse mode	664
24.4.13	TI mode	664
24.4.14	CRC calculation	665

24.5	SPI interrupts	667
24.6	SPI registers	668
24.6.1	SPI control register 1 (SPIx_CR1)	668
24.6.2	SPI control register 2 (SPIx_CR2)	670
24.6.3	SPI status register (SPIx_SR)	673
24.6.4	SPI data register (SPIx_DR)	674
24.6.5	SPI CRC polynomial register (SPIx_CRCPR)	674
24.6.6	SPI Rx CRC register (SPIx_RXCRCR)	675
24.6.7	SPI Tx CRC register (SPIx_TXCRCR)	675
24.6.8	SPI register map	676
25	Universal serial bus full-speed device interface (USB)	677
25.1	Introduction	677
25.2	USB main features	677
25.3	USB implementation	677
25.4	USB functional description	678
25.4.1	Description of USB blocks	679
25.5	Programming considerations	680
25.5.1	Generic USB device programming	680
25.5.2	System and power-on reset	681
25.5.3	Double-buffered endpoints	686
25.5.4	Isochronous transfers	688
25.5.5	Suspend/Resume events	689
25.6	USB registers	692
25.6.1	Common registers	692
25.6.2	Buffer descriptor table	705
25.6.3	USB register map	708
26	Debug support (DBG)	710
26.1	Overview	710
26.2	Reference ARM documentation	711
26.3	Pinout and debug port pins	711
26.3.1	SWD port pins	712
26.3.2	SW-DP pin assignment	712
26.3.3	Internal pull-up & pull-down on SWD pins	712
26.4	ID codes and locking mechanism	712

26.4.1	MCU device ID code	713
26.5	SWD port	714
26.5.1	SWD protocol introduction	714
26.5.2	SWD protocol sequence	714
26.5.3	SW-DP state machine (reset, idle states, ID code)	715
26.5.4	DP and AP read/write accesses	715
26.5.5	SW-DP registers	717
26.5.6	SW-AP registers	718
26.6	Core debug	718
26.7	BPU (Break Point Unit)	719
26.7.1	BPU functionality	719
26.8	DWT (Data Watchpoint)	719
26.8.1	DWT functionality	719
26.8.2	DWT Program Counter Sample Register	719
26.9	MCU debug component (DBGMCU)	719
26.9.1	Debug support for low-power modes	720
26.9.2	Debug support for timers, watchdog and I ² C	720
26.9.3	Debug MCU configuration register (DBGMCU_CR)	721
26.9.4	Debug MCU APB1 freeze register (DBGMCU_APB1_FZ)	722
26.9.5	Debug MCU APB2 freeze register (DBGMCU_APB2_FZ)	724
26.9.6	DBG register map	724
27	Device electronic signature	726
27.1	Memory size data register	726
27.1.1	Flash size data register	726
Appendix A	Code examples	727
A.1	Introduction	727
A.2	Flash operation code example	727
A.2.1	Flash memory unlocking sequence code	727
A.2.2	Main Flash programming sequence code example	727
A.2.3	Page erase sequence code example	728
A.2.4	Mass erase sequence code example	729
A.2.5	Option byte unlocking sequence code example	729
A.2.6	Option byte programming sequence code example	730
A.2.7	Option byte erasing sequence code example	730

A.3	Clock controller	731
A.3.1	HSE start sequence code example	731
A.3.2	PLL configuration modification code example	732
A.3.3	MCO selection code example	732
A.3.4	Clock measurement configuration with TIM14 code example	733
A.4	GPIO	734
A.4.1	Lock sequence code example	734
A.4.2	Alternate function selection sequence code example	734
A.4.3	Analog GPIO configuration code example	735
A.5	DMA	735
A.5.1	DMA Channel Configuration sequence code example	735
A.6	Interrupts and event	736
A.6.1	NVIC initialization example	736
A.6.2	External interrupt selection code example	736
A.7	ADC	737
A.7.1	ADC Calibration code example	737
A.7.2	ADC enable sequence code example	737
A.7.3	ADC disable sequence code example	738
A.7.4	ADC Clock selection code example	738
A.7.5	Single conversion sequence code example - Software trigger	739
A.7.6	Continuous conversion sequence code example - Software trigger	739
A.7.7	Single conversion sequence code example - Hardware trigger	740
A.7.8	Continuous conversion sequence code example - Hardware trigger	740
A.7.9	DMA one shot mode sequence code example	741
A.7.10	DMA circular mode sequence code example	741
A.7.11	Wait mode sequence code example	741
A.7.12	Auto Off and no wait mode sequence code example	742
A.7.13	Auto Off and wait mode sequence code example	742
A.7.14	Analog watchdog code example	742
A.7.15	Temperature configuration code example	743
A.7.16	Temperature computation code example	743
A.8	Timers	744
A.8.1	Upcounter on TI2 rising edge code example	744
A.8.2	Up counter on each 2 ETR rising edges code example	745
A.8.3	Input capture configuration code example	745
A.8.4	Input capture data management code example	746

A.8.5	PWM input configuration code example	747
A.8.6	PWM input with DMA configuration code example	747
A.8.7	Output compare configuration code example	748
A.8.8	Edge-aligned PWM configuration example	748
A.8.9	Center-aligned PWM configuration example	749
A.8.10	ETR configuration to clear OCxREF code example	750
A.8.11	Encoder interface code example	750
A.8.12	Reset mode code example	751
A.8.13	Gated mode code example	751
A.8.14	Trigger mode code example	752
A.8.15	External clock mode 2 + trigger mode code example	752
A.8.16	One-Pulse mode code example	753
A.8.17	Timer prescaling another timer code example	753
A.8.18	Timer enabling another timer code example	754
A.8.19	Master and slave synchronization code example	755
A.8.20	Two timers synchronized by an external trigger code example	756
A.8.21	DMA burst feature code example	757
A.9	IRTIM code example	758
A.9.1	TIM16 and TIM17 configuration code example	758
A.9.2	IRQHandler for IRTIM code example	759
A.10	DBG code example	760
A.10.1	DBG read device ID code example	760
A.10.2	DBG debug in Low-power mode code example	760
A.11	I2C code example	760
A.11.1	I2C configured in master mode to receive code example	760
A.11.2	I2C configured in master mode to transmit code example	760
A.11.3	I2C configured in slave mode code example	761
A.11.4	I2C master transmitter code example	761
A.11.5	I2C master receiver code example	761
A.11.6	I2C slave transmitter code example	762
A.11.7	I2C slave receiver code example	762
A.11.8	I2C configured in master mode to transmit with DMA code example	762
A.11.9	I2C configured in slave mode to receive with DMA code example	763
A.12	IWDG code example	763
A.12.1	IWDG configuration code example	763
A.12.2	IWDG configuration with window code example	764

A.13	RTC code example	764
A.13.1	RTC calendar configuration code example	764
A.13.2	RTC alarm configuration code example	765
A.13.3	RTC WUT configuration code example	765
A.13.4	RTC read calendar code example	765
A.13.5	RTC calibration code example	766
A.13.6	RTC tamper and time stamp configuration code example	766
A.13.7	RTC tamper and time stamp code example	767
A.13.8	RTC clock output code example	767
A.14	SPI code example	767
A.14.1	SPI master configuration code example	767
A.14.2	SPI slave configuration code example	768
A.14.3	SPI full duplex communication code example	768
A.14.4	SPI interrupt code example	768
A.14.5	SPI master configuration with DMA code example	768
A.14.6	SPI slave configuration with DMA code example	769
A.15	USART code example	769
A.15.1	USART transmitter configuration code example	769
A.15.2	USART transmit byte code example	769
A.15.3	USART transfer complete code example	769
A.15.4	USART receiver configuration code example	770
A.15.5	USART receive byte code example	770
A.15.6	USART synchronous mode code example	770
A.15.7	USART DMA code example	771
A.15.8	USART hardware flow control code example	771
A.16	WWDG code example	771
A.16.1	WWDG configuration code example	771
	Revision history	772

List of tables

Table 1.	STM32F0x0 memory boundary addresses.	37
Table 2.	STM32F0x0 peripheral register boundary addresses.	39
Table 3.	Boot modes.	43
Table 4.	Flash memory organization (STM32F030x4, STM32F030x6, STM32F070x6 and STM32F030x8 devices).	46
Table 5.	Flash memory organization (STM32F070xB, STM32F030xC devices)	47
Table 6.	Flash memory read protection status	55
Table 7.	Access status versus protection level and execution modes	56
Table 8.	Flash interrupt request	57
Table 9.	Flash interface - register map and reset values	64
Table 10.	Option byte format	65
Table 11.	Option byte organization.	65
Table 12.	Option byte map and ST production values	68
Table 13.	CRC internal input/output signals	70
Table 14.	CRC register map and reset values	74
Table 15.	Low-power mode summary	78
Table 16.	Sleep-now.	80
Table 17.	Sleep-on-exit.	80
Table 18.	Stop mode	81
Table 19.	Standby mode.	82
Table 20.	PWR register map and reset values	86
Table 21.	RCC register map and reset values	125
Table 22.	Port bit configuration table	128
Table 23.	GPIO register map and reset values	142
Table 24.	SYSCFG register map and reset values.	151
Table 25.	Programmable data width & endian behavior (when bits PINC = MINC = 1)	156
Table 26.	DMA interrupt requests.	157
Table 27.	Summary of the DMA requests for each channel on STM32F030x4/6, STM32F070x6, STM32F070xB and STM32F030x8 devices	159
Table 28.	Summary of the DMA requests for each channel on STM32F030xC devices	160
Table 29.	DMA register map and reset values	168
Table 30.	DMA register map and reset values (registers available on STM32F070xB and STM32F030xC devices only)	168
Table 31.	DMA register map and reset values(register available on STM32F030xC devices only)	169
Table 32.	Vector table.	170
Table 33.	External interrupt/event controller register map and reset values.	180
Table 34.	ADC internal signals	183
Table 35.	ADC pins.	183
Table 36.	Latency between trigger and start of conversion	188
Table 37.	Configuring the trigger polarity	193
Table 38.	External triggers	193
Table 39.	tSAR timings depending on resolution	194
Table 40.	Analog watchdog comparison.	203
Table 41.	Analog watchdog channel selection	204
Table 42.	ADC interrupts	206
Table 43.	ADC register map and reset values	220

Table 44.	Counting direction versus encoder signals	260
Table 45.	TIMx Internal trigger connection	273
Table 46.	Output control bits for complementary OCx and OCxN channels with break feature.	286
Table 47.	TIM1 register map and reset values	294
Table 48.	Counting direction versus encoder signals	326
Table 49.	TIM3 internal trigger connection	343
Table 50.	Output control bit for standard OCx channels.	353
Table 51.	TIM3 register map and reset values	359
Table 52.	TIM6/TIM7 register map and reset values	373
Table 53.	Output control bit for standard OCx channels.	392
Table 54.	TIM14 register map and reset values	395
Table 55.	TIMx Internal trigger connection	432
Table 56.	Output control bits for complementary OCx and OCxN channels with break feature.	442
Table 57.	TIM15 register map and reset values	449
Table 58.	Output control bits for complementary OCx and OCxN channels with break feature.	461
Table 59.	TIM16 and TIM17 register map and reset values	468
Table 60.	IWDG register map and reset values	479
Table 61.	WWDG register map and reset values	485
Table 62.	STM32F0x0 RTC implementation	487
Table 63.	RTC pin PC13 configuration	490
Table 64.	LSE pin PC14 configuration	491
Table 65.	LSE pin PC15 configuration	491
Table 66.	Effect of low-power modes on RTC	503
Table 67.	Interrupt control bits	503
Table 68.	RTC register map and reset values	523
Table 69.	STM32F0x0 I2C implementation	527
Table 70.	Comparison of analog vs. digital filters	531
Table 71.	I2C-SMBUS specification data setup and hold times	534
Table 72.	I2C configuration table	538
Table 73.	I2C-SMBUS specification clock timings	549
Table 74.	Examples of timings settings for fI2CCLK = 8 MHz	559
Table 75.	Examples of timings settings for fI2CCLK = 16 MHz	559
Table 76.	Examples of timings settings for fI2CCLK = 48 MHz	560
Table 77.	SMBus timeout specifications	562
Table 78.	SMBUS with PEC configuration	564
Table 79.	Examples of TIMEOUTA settings for various I2CCLK frequencies (max t _{TIMEOUT} = 25 ms)	565
Table 80.	Examples of TIMEOUTB settings for various I2CCLK frequencies	565
Table 81.	Examples of TIMEOUTA settings for various I2CCLK frequencies (max t _{IDLE} = 50 μs)	566
Table 82.	low-power modes	577
Table 83.	I2C Interrupt requests	577
Table 84.	I2C register map and reset values	593
Table 85.	STM32F0x0 USART implementation	597
Table 86.	Noise detection from sampled data	608
Table 87.	Error calculation for programmed baud rates at f _{CK} = 48 MHz in both cases of oversampling by 16 or by 8.	610
Table 88.	Tolerance of the USART receiver when BRR [3:0] = 0000.	611
Table 89.	Tolerance of the USART receiver when BRR [3:0] is different from 0000	611
Table 90.	Frame formats	615
Table 91.	Effect of low-power modes on the USART	623

Table 92.	USART interrupt requests	624
Table 93.	USART register map and reset values	640
Table 94.	STM32F0x0 SPI implementation	643
Table 95.	SPI interrupt requests	667
Table 96.	SPI register map and reset values	676
Table 97.	STM32F0x0 USB implementation	677
Table 98.	Double-buffering buffer flag definition	687
Table 99.	Bulk double-buffering memory buffers usage	687
Table 100.	Isochronous memory buffers usage	689
Table 101.	Resume event detection	691
Table 102.	Reception status encoding	703
Table 103.	Endpoint type encoding	704
Table 104.	Endpoint kind meaning	704
Table 105.	Transmission status encoding	704
Table 106.	Definition of allocated buffer memory	707
Table 107.	USB register map and reset values	708
Table 108.	SW debug port pins	712
Table 109.	DEV_ID and REV_ID field values	713
Table 110.	Packet request (8-bits)	714
Table 111.	ACK response (3 bits)	715
Table 112.	DATA transfer (33 bits)	715
Table 113.	SW-DP registers	717
Table 114.	32-bit debug port registers addressed through the shifted value A[3:2]	718
Table 115.	Core debug registers	718
Table 116.	DBG register map and reset values	725
Table 117.	Document revision history	772

List of figures

Figure 1.	System architecture	34
Figure 2.	Memory map	36
Figure 3.	Programming procedure	50
Figure 4.	Flash memory Page Erase procedure	52
Figure 5.	Flash memory Mass Erase procedure	53
Figure 6.	CRC calculation unit block diagram	70
Figure 7.	Power supply overview	75
Figure 8.	Power on reset/power down reset waveform	76
Figure 9.	Simplified diagram of the reset circuit	88
Figure 10.	Clock tree (STM32F030x4, STM32F030x6 and STM32F030x8 devices)	90
Figure 11.	Clock tree (STM32F070x6, STM32F070xB and STM32F030xC)	91
Figure 12.	HSE/ LSE clock sources	92
Figure 13.	Frequency measurement with TIM14 in capture mode	97
Figure 14.	Basic structure of an I/O port bit	128
Figure 15.	Input floating/pull up/pull down configurations	132
Figure 16.	Output configuration	133
Figure 17.	Alternate function configuration	134
Figure 18.	High impedance-analog configuration	135
Figure 19.	DMA block diagram	153
Figure 20.	DMA request mapping	158
Figure 21.	Extended interrupts and events controller (EXTI) block diagram	173
Figure 22.	External interrupt/event GPIO mapping	175
Figure 23.	ADC block diagram	184
Figure 24.	ADC calibration	185
Figure 25.	Enabling/disabling the ADC	186
Figure 26.	ADC clock scheme	187
Figure 27.	Analog to digital conversion time	191
Figure 28.	ADC conversion timings	192
Figure 29.	Stopping an ongoing conversion	192
Figure 30.	Single conversions of a sequence, software trigger	196
Figure 31.	Continuous conversion of a sequence, software trigger	196
Figure 32.	Single conversions of a sequence, hardware trigger	197
Figure 33.	Continuous conversions of a sequence, hardware trigger	197
Figure 34.	Data alignment and resolution	198
Figure 35.	Example of overrun (OVR)	199
Figure 36.	Wait mode conversion (continuous mode, software trigger)	201
Figure 37.	Behavior with WAIT=0, AUTOFF=1	202
Figure 38.	Behavior with WAIT=1, AUTOFF=1	202
Figure 39.	Analog watchdog guarded area	203
Figure 40.	Advanced-control timer block diagram	222
Figure 41.	Counter timing diagram with prescaler division change from 1 to 2	224
Figure 42.	Counter timing diagram with prescaler division change from 1 to 4	224
Figure 43.	Counter timing diagram, internal clock divided by 1	226
Figure 44.	Counter timing diagram, internal clock divided by 2	226
Figure 45.	Counter timing diagram, internal clock divided by 4	227
Figure 46.	Counter timing diagram, internal clock divided by N	227
Figure 47.	Counter timing diagram, update event when ARPE=0 (TIMx_ARR not preloaded)	228

Figure 48.	Counter timing diagram, update event when ARPE=1 (TIMx_ARR preloaded)	228
Figure 49.	Counter timing diagram, internal clock divided by 1	229
Figure 50.	Counter timing diagram, internal clock divided by 2	230
Figure 51.	Counter timing diagram, internal clock divided by 4	230
Figure 52.	Counter timing diagram, internal clock divided by N	230
Figure 53.	Counter timing diagram, update event when repetition counter is not used	231
Figure 54.	Counter timing diagram, internal clock divided by 1, TIMx_ARR = 0x6	232
Figure 55.	Counter timing diagram, internal clock divided by 2	233
Figure 56.	Counter timing diagram, internal clock divided by 4, TIMx_ARR=0x36	233
Figure 57.	Counter timing diagram, internal clock divided by N	234
Figure 58.	Counter timing diagram, update event with ARPE=1 (counter underflow)	234
Figure 59.	Counter timing diagram, Update event with ARPE=1 (counter overflow)	235
Figure 60.	Update rate examples depending on mode and TIMx_RCR register settings	236
Figure 61.	Control circuit in normal mode, internal clock divided by 1	237
Figure 62.	TI2 external clock connection example	238
Figure 63.	Control circuit in external clock mode 1	239
Figure 64.	External trigger input block	239
Figure 65.	Control circuit in external clock mode 2	240
Figure 66.	Capture/compare channel (example: channel 1 input stage)	241
Figure 67.	Capture/compare channel 1 main circuit	241
Figure 68.	Output stage of capture/compare channel (channel 1 to 3)	242
Figure 69.	Output stage of capture/compare channel (channel 4)	242
Figure 70.	PWM input mode timing	244
Figure 71.	Output compare mode, toggle on OC1	246
Figure 72.	Edge-aligned PWM waveforms (ARR=8)	248
Figure 73.	Center-aligned PWM waveforms (ARR=8)	249
Figure 74.	Complementary output with dead-time insertion	251
Figure 75.	Dead-time waveforms with delay greater than the negative pulse	251
Figure 76.	Dead-time waveforms with delay greater than the positive pulse	251
Figure 77.	Output behavior in response to a break	254
Figure 78.	Clearing TIMx_OCxREF	256
Figure 79.	6-step generation, COM example (OSSR=1)	257
Figure 80.	Example of one pulse mode	258
Figure 81.	Example of counter operation in encoder interface mode	261
Figure 82.	Example of encoder interface mode with TI1FP1 polarity inverted	261
Figure 83.	Example of hall sensor interface	263
Figure 84.	Control circuit in reset mode	264
Figure 85.	Control circuit in gated mode	265
Figure 86.	Control circuit in trigger mode	266
Figure 87.	Control circuit in external clock mode 2 + trigger mode	267
Figure 88.	General-purpose timer block diagram (TIM3)	297
Figure 89.	Counter timing diagram with prescaler division change from 1 to 2	298
Figure 90.	Counter timing diagram with prescaler division change from 1 to 4	299
Figure 91.	Counter timing diagram, internal clock divided by 1	300
Figure 92.	Counter timing diagram, internal clock divided by 2	300
Figure 93.	Counter timing diagram, internal clock divided by 4	301
Figure 94.	Counter timing diagram, internal clock divided by N	301
Figure 95.	Counter timing diagram, Update event when ARPE=0 (TIMx_ARR not preloaded)	302
Figure 96.	Counter timing diagram, Update event when ARPE=1 (TIMx_ARR preloaded)	302

Figure 97.	Counter timing diagram, internal clock divided by 1	303
Figure 98.	Counter timing diagram, internal clock divided by 2	304
Figure 99.	Counter timing diagram, internal clock divided by 4	304
Figure 100.	Counter timing diagram, internal clock divided by N	305
Figure 101.	Counter timing diagram, Update event when repetition counter is not used	305
Figure 102.	Counter timing diagram, internal clock divided by 1, TIMx_ARR=0x6	307
Figure 103.	Counter timing diagram, internal clock divided by 2	307
Figure 104.	Counter timing diagram, internal clock divided by 4, TIMx_ARR=0x36	308
Figure 105.	Counter timing diagram, internal clock divided by N	308
Figure 106.	Counter timing diagram, Update event with ARPE=1 (counter underflow)	309
Figure 107.	Counter timing diagram, Update event with ARPE=1 (counter overflow)	309
Figure 108.	Control circuit in normal mode, internal clock divided by 1	310
Figure 109.	TI2 external clock connection example	311
Figure 110.	Control circuit in external clock mode 1	312
Figure 111.	External trigger input block	312
Figure 112.	Control circuit in external clock mode 2	313
Figure 113.	Capture/compare channel (example: channel 1 input stage)	314
Figure 114.	Capture/compare channel 1 main circuit	314
Figure 115.	Output stage of capture/compare channel (channel 1)	315
Figure 116.	PWM input mode timing	317
Figure 117.	Output compare mode, toggle on OC1	319
Figure 118.	Edge-aligned PWM waveforms (ARR=8)	320
Figure 119.	Center-aligned PWM waveforms (ARR=8)	322
Figure 120.	Example of one-pulse mode	323
Figure 121.	Clearing TIMx_OCxREF	325
Figure 122.	Example of counter operation in encoder interface mode	327
Figure 123.	Example of encoder interface mode with TI1FP1 polarity inverted	327
Figure 124.	Control circuit in reset mode	328
Figure 125.	Control circuit in gated mode	329
Figure 126.	Control circuit in trigger mode	330
Figure 127.	Control circuit in external clock mode 2 + trigger mode	331
Figure 128.	Master/Slave timer example	332
Figure 129.	Gating timer 3 with OC1REF of timer 1	333
Figure 130.	Gating timer 3 with Enable of timer 1	334
Figure 131.	Triggering timer 3 with update of timer 1	335
Figure 132.	Triggering timer 3 with Enable of timer 1	336
Figure 133.	Triggering timer 1 and 3 with timer 1 TI1 input	337
Figure 134.	Basic timer block diagram	361
Figure 135.	Counter timing diagram with prescaler division change from 1 to 2	363
Figure 136.	Counter timing diagram with prescaler division change from 1 to 4	363
Figure 137.	Counter timing diagram, internal clock divided by 1	364
Figure 138.	Counter timing diagram, internal clock divided by 2	365
Figure 139.	Counter timing diagram, internal clock divided by 4	365
Figure 140.	Counter timing diagram, internal clock divided by N	366
Figure 141.	Counter timing diagram, update event when ARPE = 0 (TIMx_ARR not preloaded)	366
Figure 142.	Counter timing diagram, update event when ARPE=1 (TIMx_ARR preloaded)	367
Figure 143.	Control circuit in normal mode, internal clock divided by 1	368
Figure 144.	General-purpose timer block diagram (TIM14)	375
Figure 145.	Counter timing diagram with prescaler division change from 1 to 2	376
Figure 146.	Counter timing diagram with prescaler division change from 1 to 4	376

Figure 147. Counter timing diagram, internal clock divided by 1	377
Figure 148. Counter timing diagram, internal clock divided by 2	378
Figure 149. Counter timing diagram, internal clock divided by 4	378
Figure 150. Counter timing diagram, internal clock divided by N	378
Figure 151. Counter timing diagram, update event when ARPE=0 (TIMx_ARR not preloaded)	379
Figure 152. Counter timing diagram, update event when ARPE=1 (TIMx_ARR preloaded)	379
Figure 153. Control circuit in normal mode, internal clock divided by 1	380
Figure 154. Capture/compare channel (example: channel 1 input stage)	380
Figure 155. Capture/compare channel 1 main circuit	381
Figure 156. Output stage of capture/compare channel (channel 1)	381
Figure 157. Output compare mode, toggle on OC1	384
Figure 158. Edge-aligned PWM waveforms (ARR=8)	385
Figure 159. TIM15 block diagram	398
Figure 160. TIM16 and TIM17 block diagram	400
Figure 161. Counter timing diagram with prescaler division change from 1 to 2	402
Figure 162. Counter timing diagram with prescaler division change from 1 to 4	402
Figure 163. Counter timing diagram, internal clock divided by 1	404
Figure 164. Counter timing diagram, internal clock divided by 2	405
Figure 165. Counter timing diagram, internal clock divided by 4	405
Figure 166. Counter timing diagram, internal clock divided by N	406
Figure 167. Counter timing diagram, update event when ARPE=0 (TIMx_ARR not preloaded)	406
Figure 168. Counter timing diagram, update event when ARPE=1 (TIMx_ARR preloaded)	407
Figure 169. Update rate examples depending on mode and TIMx_RCR register settings	408
Figure 170. Control circuit in normal mode, internal clock divided by 1	409
Figure 171. TI2 external clock connection example	409
Figure 172. Control circuit in external clock mode 1	410
Figure 173. Capture/compare channel (example: channel 1 input stage)	411
Figure 174. Capture/compare channel 1 main circuit	412
Figure 175. Output stage of capture/compare channel (channel 1)	412
Figure 176. Output stage of capture/compare channel (channel 2 for TIM15)	413
Figure 177. PWM input mode timing	415
Figure 178. Output compare mode, toggle on OC1	417
Figure 179. Edge-aligned PWM waveforms (ARR=8)	418
Figure 180. Complementary output with dead-time insertion	419
Figure 181. Dead-time waveforms with delay greater than the negative pulse	420
Figure 182. Dead-time waveforms with delay greater than the positive pulse	420
Figure 183. Output behavior in response to a break	423
Figure 184. Example of One-pulse mode	424
Figure 185. Control circuit in reset mode	426
Figure 186. Control circuit in gated mode	427
Figure 187. Control circuit in trigger mode	428
Figure 188. IR internal hardware connections with TIM16	470
Figure 189. Independent watchdog block diagram	471
Figure 190. Watchdog block diagram	481
Figure 191. Window watchdog timing diagram	482
Figure 192. RTC block diagram in STM32F030x4/6, STM32F070x6 and STM32F030x8 devices	488
Figure 193. RTC block diagram for STM32F070xB and STM32F030xC devices	489
Figure 194. I2C block diagram	528

Figure 195. I2C2 block diagram	529
Figure 196. I2C bus protocol	530
Figure 197. Setup and hold timings	532
Figure 198. I2C initialization flowchart	535
Figure 199. Data reception	536
Figure 200. Data transmission	537
Figure 201. Slave initialization flowchart	541
Figure 202. Transfer sequence flowchart for I2C slave transmitter, NOSTRETCH=0	542
Figure 203. Transfer sequence flowchart for I2C slave transmitter, NOSTRETCH=1	543
Figure 204. Transfer bus diagrams for I2C slave transmitter	544
Figure 205. Transfer sequence flowchart for slave receiver with NOSTRETCH=0	545
Figure 206. Transfer sequence flowchart for slave receiver with NOSTRETCH=1	546
Figure 207. Transfer bus diagrams for I2C slave receiver	546
Figure 208. Master clock generation	548
Figure 209. Master initialization flowchart	550
Figure 210. 10-bit address read access with HEAD10R=0	550
Figure 211. 10-bit address read access with HEAD10R=1	551
Figure 212. Transfer sequence flowchart for I2C master transmitter for $N \leq 255$ bytes	552
Figure 213. Transfer sequence flowchart for I2C master transmitter for $N > 255$ bytes	553
Figure 214. Transfer bus diagrams for I2C master transmitter	554
Figure 215. Transfer sequence flowchart for I2C master receiver for $N \leq 255$ bytes	556
Figure 216. Transfer sequence flowchart for I2C master receiver for $N > 255$ bytes	557
Figure 217. Transfer bus diagrams for I2C master receiver	558
Figure 218. Timeout intervals for $t_{\text{LOW:SEXT}}$, $t_{\text{LOW:MEXT}}$	563
Figure 219. Transfer sequence flowchart for SMBus slave transmitter N bytes + PEC	567
Figure 220. Transfer bus diagrams for SMBus slave transmitter (SBC=1)	567
Figure 221. Transfer sequence flowchart for SMBus slave receiver N Bytes + PEC	569
Figure 222. Bus transfer diagrams for SMBus slave receiver (SBC=1)	570
Figure 223. Bus transfer diagrams for SMBus master transmitter	571
Figure 224. Bus transfer diagrams for SMBus master receiver	573
Figure 225. I2C interrupt mapping diagram	578
Figure 226. USART block diagram	599
Figure 227. Word length programming	600
Figure 228. Configurable stop bits	601
Figure 229. TC/TXE behavior when transmitting	603
Figure 230. Start bit detection when oversampling by 16 or 8	604
Figure 231. Data sampling when oversampling by 16	607
Figure 232. Data sampling when oversampling by 8	608
Figure 233. Mute mode using Idle line detection	613
Figure 234. Mute mode using address mark detection	614
Figure 235. USART example of synchronous transmission	616
Figure 236. USART data clock timing diagram (M=0)	617
Figure 237. USART data clock timing diagram (M=1)	617
Figure 238. RX data setup/hold time	618
Figure 239. Transmission using DMA	620
Figure 240. Reception using DMA	621
Figure 241. Hardware flow control between 2 USARTs	621
Figure 242. RS232 RTS flow control	622
Figure 243. RS232 CTS flow control	623
Figure 244. USART interrupt mapping diagram	624
Figure 245. SPI block diagram	643
Figure 246. Full-duplex single master/ single slave application	644

Figure 247. Half-duplex single master/ single slave application	645
Figure 248. Simplex single master/single slave application (master in transmit-only/ slave in receive-only mode)	646
Figure 249. Master and three independent slaves.	647
Figure 250. Multi-master application	648
Figure 251. Hardware/software slave select management	649
Figure 252. Data clock timing diagram	650
Figure 253. Data alignment when data length is not equal to 8-bit or 16-bit	651
Figure 254. Packing data in FIFO for transmission and reception	655
Figure 255. Master full-duplex communication	658
Figure 256. Slave full-duplex communication	659
Figure 257. Master full-duplex communication with CRC	660
Figure 258. Master full-duplex communication in packed mode	661
Figure 259. NSSP pulse generation in Motorola SPI master mode.	664
Figure 260. TI mode transfer	665
Figure 261. USB peripheral block diagram	678
Figure 262. Packet buffer areas with examples of buffer description table locations	682
Figure 263. Block diagram of STM32F0x0 MCU and ARM [®] Cortex [®] -M0-level debug support	710

1 Documentation conventions

1.1 List of abbreviations for registers

The following abbreviations are used in register descriptions:

read/write (rw)	Software can read and write to this bit.
read-only (r)	Software can only read this bit.
write-only (w)	Software can only write to this bit. Reading this bit returns the reset value.
read/clear (rc_w1)	Software can read as well as clear this bit by writing 1. Writing '0' has no effect on the bit value.
read/clear (rc_w0)	Software can read as well as clear this bit by writing 0. Writing '1' has no effect on the bit value.
read/clear by read (rc_r)	Software can read this bit. Reading this bit automatically clears it to '0'. Writing this bit has no effect on the bit value.
read/set (rs)	Software can read as well as set this bit. Writing '0' has no effect on the bit value.
Reserved (Res.)	Reserved bit, must be kept at reset value.

1.2 Glossary

This section gives a brief definition of acronyms and abbreviations used in this document:

- **Word:** data of 32-bit length.
- **Half-word:** data of 16-bit length.
- **Byte:** data of 8-bit length.
- **SWD-DP (SWD DEBUG PORT):** SWD-DP provides a 2-pin (clock and data) interface based on the Serial Wire Debug (SWD) protocol. Please refer to the ARM® Cortex®-M0 technical reference manual.
- **IAP (in-application programming):** IAP is the ability to re-program the Flash memory of a microcontroller while the user program is running.
- **ICP (in-circuit programming):** ICP is the ability to program the Flash memory of a microcontroller using the JTAG protocol, the SWD protocol or the bootloader while the device is mounted on the user application board.
- **Option bytes:** product configuration bits stored in the Flash memory.
- **OBL:** option byte loader.
- **AHB:** advanced high-performance bus.
- **APB:** advanced peripheral bus.

1.3 Peripheral availability

For peripheral availability and number across all sales types, please refer to the particular device datasheet.

2 System and memory overview

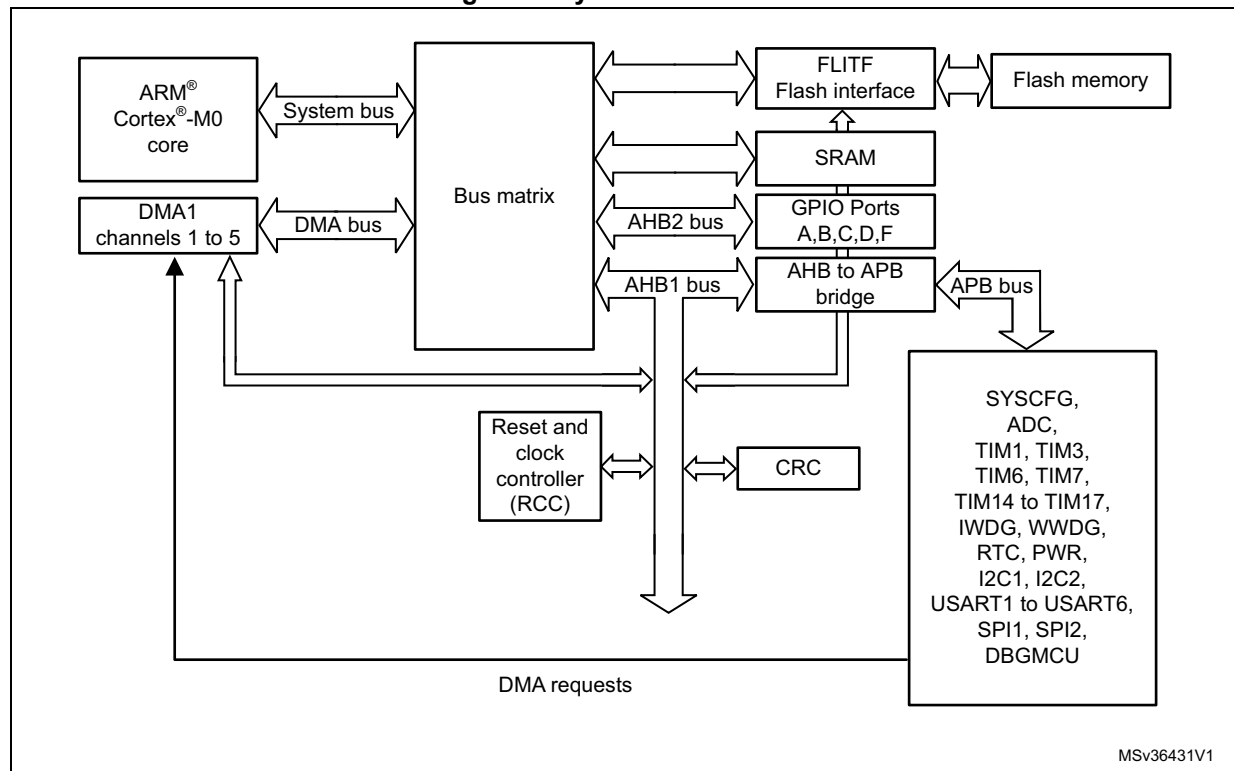
2.1 System architecture

The main system consists of:

- Two masters:
 - ARM® Cortex®-M0 core
 - General-purpose DMA
- Four slaves:
 - Internal SRAM
 - Internal Flash memory
 - AHB1 with AHB to APB bridge which connects all the APB peripherals
 - AHB2 dedicated to GPIO ports

These are interconnected using a multilayer AHB bus architecture as shown in [Figure 1](#):

Figure 1. System architecture



System bus

This bus connects the system bus of the ARM® Cortex®-M0 core (peripherals bus) to a BusMatrix which manages the arbitration between the core and the DMA.

DMA bus

This bus connects the AHB master interface of the DMA to the BusMatrix which manages the access of CPU and DMA to SRAM, Flash memory and peripherals.

BusMatrix

The BusMatrix manages the access arbitration between the core system bus and the DMA master bus. The arbitration uses a Round Robin algorithm. The BusMatrix is composed of two masters (CPU, DMA) and four slaves (FLITF, SRAM, AHB1 with AHB to APB bridge and AHB2).

AHB peripherals are connected on system bus through a BusMatrix to allow DMA access.

AHB to APB bridge (APB)

The AHB to APB bridge provides full synchronous connections between the AHB and the APB bus.

Refer to [Section 2.2.2: Memory map and register boundary addresses](#) for the address mapping of the peripherals connected to this bridge.

After each device reset, all peripheral clocks are disabled (except for the SRAM and Flash). Before using a peripheral you have to enable its clock in the RCC_AHBENR, RCC_APB2ENR or RCC_APB1ENR register.

Note: When a 16- or 8-bit access is performed on an APB register, the access is transformed into a 32-bit access: the bridge duplicates the 16- or 8-bit data to feed the 32-bit vector.

2.2 Memory organization

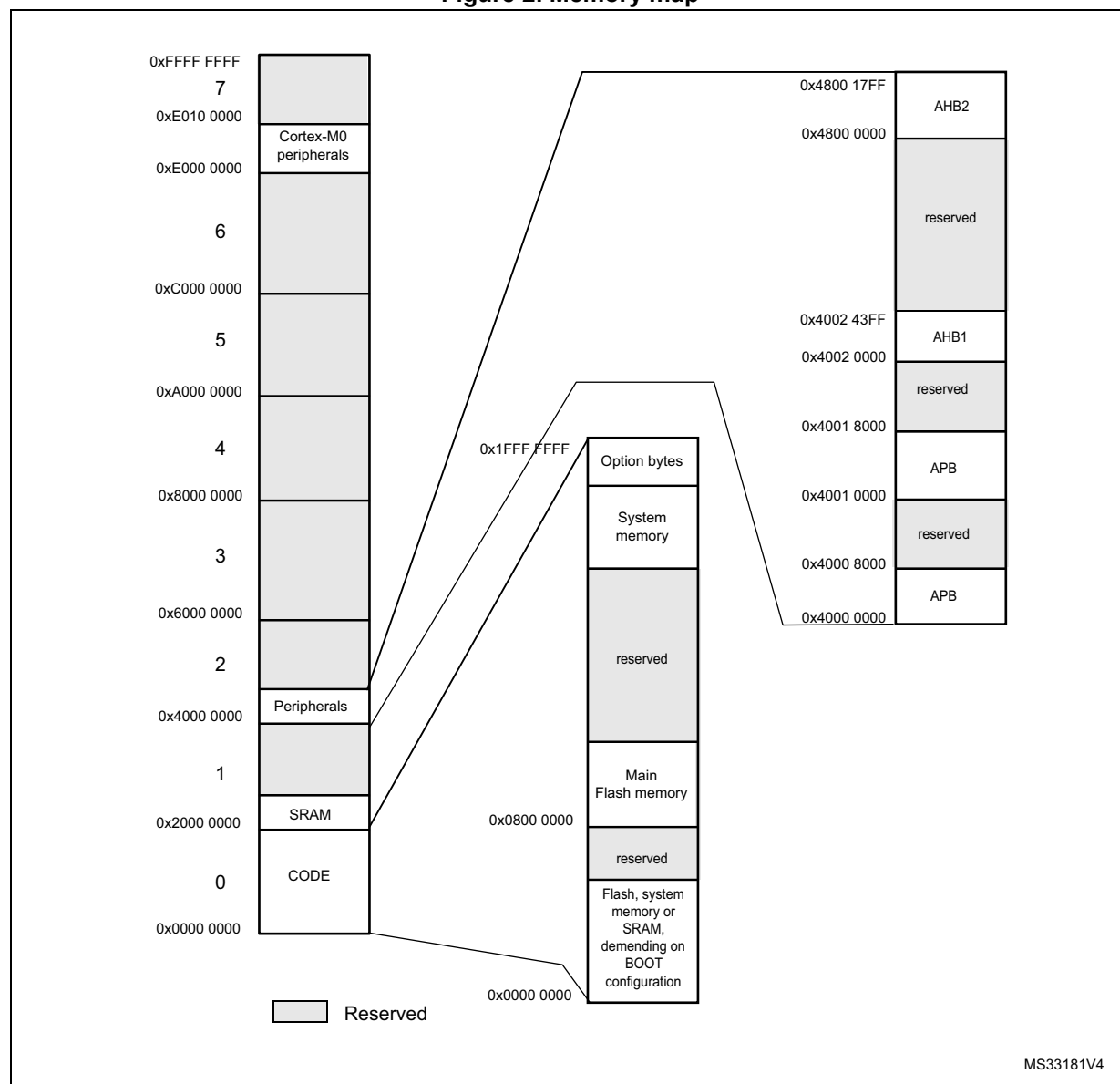
2.2.1 Introduction

Program memory, data memory, registers and I/O ports are organized within the same linear 4-Gbyte address space.

The bytes are coded in memory in Little Endian format. The lowest numbered byte in a word is considered the word's least significant byte and the highest numbered byte the most significant.

The addressable memory space is divided into 8 main blocks, of 512 Mbytes each.

Figure 2. Memory map



All the memory areas that are not allocated to on-chip memories and peripherals are considered “Reserved”. For the detailed mapping of available memory and register areas, please refer to [Memory map and register boundary addresses](#) and peripheral sections.

2.2.2 Memory map and register boundary addresses

See the datasheet corresponding to your device for a comprehensive diagram of the memory map.

The following table gives the boundary addresses of the peripherals available in the devices.

Table 1. STM32F0x0 memory boundary addresses

Device	Boundary address	Size	Memory Area	Register description
STM32F030x4, STM32F030x6	0x2000 1000 - 0x3FFF FFFF	~512 MB	Reserved	-
	0x2000 0000 - 0x2000 0FFF	4 KB	SRAM	Section 2.3 on page 41
	0x1FFF FC00 - 0x1FFF FFFF	1 KB	Reserved	-
	0x1FFF F800 - 0x1FFF FBFF	1 KB	Option bytes	Section 4 on page 65
	0x1FFF EC00 - 0x1FFF F7FF	3 KB	System memory	-
	0x0800 8000 - 0x1FFF EBFF	~384 MB	Reserved	-
	0x0800 0000 - 0x0800 7FFF	32 KB ⁽¹⁾	Main Flash memory	Section 3 on page 45
	0x0000 8000 - 0x07FF FFFF	~128 MB	Reserved	-
	0x0000 0000 - 0x0000 7FFF	32 KB ⁽¹⁾	Main Flash memory, system memory or SRAM depending on BOOT configuration	-
STM32F070x6	0x2000 1800 - 0x3FFF FFFF	~512 MB	Reserved	-
	0x2000 0000 - 0x2000 17FF	6 KB	SRAM	Section 2.3 on page 41
	0x1FFF FC00 - 0x1FFF FFFF	1 KB	Reserved	-
	0x1FFF F800 - 0x1FFF FBFF	1 KB	Option bytes	Section 4 on page 65
	0x1FFF C400 - 0x1FFF F7FF	13 KB	System memory	-
	0x0801 8000 - 0x1FFF C7FF	~384 MB	Reserved	-
	0x0800 0000 - 0x0801 7FFF	32 KB	Main Flash memory	Section 3 on page 45
	0x0001 8000 - 0x07FF FFFF	~128 MB	Reserved	-
	0x0000 0000 - 0x0000 7FFF	32 KB	Main Flash memory, system memory or SRAM depending on BOOT configuration	-

Table 1. STM32F0x0 memory boundary addresses (continued)

Device	Boundary address	Size	Memory Area	Register description
STM32F030x8	0x2000 2000 - 0x3FFF FFFF	~512 MB	Reserved	-
	0x2000 0000 - 0x2000 1FFF	8 KB	SRAM	Section 2.3 on page 41
	0x1FFF FC00 - 0x1FFF FFFF	1 KB	Reserved	-
	0x1FFF F800 - 0x1FFF FBFF	1 KB	Option bytes	Section 4 on page 65
	0x1FFF EC00 - 0x1FFF F7FF	3 KB	System memory	-
	0x0801 0000 - 0x1FFF EBFF	~384 MB	Reserved	-
	0x0800 0000 - 0x0800 FFFF	64 KB	Main Flash memory	Section 3 on page 45
	0x0001 0000 - 0x07FF FFFF	~128 MB	Reserved	-
	0x0000 0000 - 0x0000 FFFF	64 KB	Main Flash memory, system memory or SRAM depending on BOOT configuration	-
STM32F070xB	0x2000 4000 - 0x3FFF FFFF	~512 MB	Reserved	-
	0x2000 0000 - 0x2000 3FFF	16 KB	SRAM	Section 2.3 on page 41
	0x1FFF F800 - 0x1FFF FFFF	2 KB	Option bytes	Section 4 on page 65
	0x1FFF C800 - 0x1FFF F7FF	12 KB	System memory	-
	0x0802 0000 - 0x1FFF C7FF	~384 MB	Reserved	-
	0x0800 0000 - 0x0801 FFFF	128 KB	Main Flash memory	Section 3 on page 45
	0x0002 0000 - 0x07FF FFFF	~128 MB	Reserved	-
	0x0000 0000 - 0x0001 FFFF	128 KB	Main Flash memory, system memory or SRAM depending on BOOT configuration	-
STM32F030xC	0x2000 8000 - 0x3FFF FFFF	~512 MB	Reserved	-
	0x2000 0000 - 0x2000 7FFF	32 KB	SRAM	Section 2.3 on page 41
	0x1FFF F800 - 0x1FFF FFFF	2 KB	Option bytes	Section 4 on page 65
	0x1FFF D800 - 0x1FFF F7FF	8 KB	System memory	-
	0x0804 0000 - 0x1FFF D7FF	~384 MB	Reserved	-
	0x0800 0000 - 0x0803 FFFF	256 KB	Main Flash memory	Section 3 on page 45
	0x0004 0000 - 0x07FF FFFF	~128 MB	Reserved	-
	0x0000 0000 - 0x0003 FFFF	256 KB	Main Flash memory, system memory or SRAM depending on BOOT configuration	-

1. Limited to 16 KB on STM32F030x4 devices.

Table 2. STM32F0x0 peripheral register boundary addresses

Bus	Boundary address	Size	Peripheral	Peripheral register map
-	0xE000 0000 - 0xE00F FFFF	1MB	Cortex [®] -M0 internal peripherals	-
-	0x4800 1800 - 0x5FFF FFFF	~384 MB	Reserved	-
AHB2	0x4800 1400 - 0x4800 17FF	1KB	GPIOF	Section 8.4.11 on page 141
	0x4800 1000 - 0x4800 13FF	1KB	Reserved	-
	0x4800 0C00 - 0x4800 0FFF	1KB	GIOD	Section 8.4.11 on page 141
	0x4800 0800 - 0x4800 0BFF	1KB	GPIOC	Section 8.4.11 on page 141
	0x4800 0400 - 0x4800 07FF	1KB	GPIOB	Section 8.4.11 on page 141
	0x4800 0000 - 0x4800 03FF	1KB	GPIOA	Section 8.4.11 on page 141
-	0x4002 4400 - 0x47FF FFFF	~128 MB	Reserved	-
AHB1	0x4002 3400 - 0x4002 43FF	4 KB	Reserved	-
	0x4002 3000 - 0x4002 33FF	1 KB	CRC	Section 5.4.5 on page 74
	0x4002 2400 - 0x4002 2FFF	3 KB	Reserved	-
	0x4002 2000 - 0x4002 23FF	1 KB	FLASH interface	Section 3.5.9 on page 64
	0x4002 1400 - 0x4002 1FFF	3 KB	Reserved	-
	0x4002 1000 - 0x4002 13FF	1 KB	RCC	Section 7.4.15 on page 125
	0x4002 0400 - 0x4002 0FFF	3 KB	Reserved	-
	0x4002 0000 - 0x4002 03FF	1 KB	DMA	Section 10.4.8 on page 168
-	0x4001 8000 - 0x4001 FFFF	32 KB	Reserved	-

Table 2. STM32F0x0 peripheral register boundary addresses (continued)

Bus	Boundary address	Size	Peripheral	Peripheral register map
APB	0x4001 5C00 - 0x4001 7FFF	9 KB	Reserved	-
	0x4001 5800 - 0x4001 5BFF	1 KB	DBGMCU	-
	0x4001 4C00 - 0x4001 57FF	3 KB	Reserved	-
	0x4001 4800 - 0x4001 4BFF	1 KB	TIM17	Section 17.6.16 on page 468
	0x4001 4400 - 0x4001 47FF	1 KB	TIM16	Section 17.6.16 on page 468
	0x4001 4000 - 0x4001 43FF	1 KB	TIM15	Section 17.5.18 on page 449
	0x4001 3C00 - 0x4001 3FFF	1 KB	Reserved	-
	0x4001 3800 - 0x4001 3BFF	1 KB	USART1	Section 23.7.11 on page 640
	0x4001 3400 - 0x4001 37FF	1 KB	Reserved	-
	0x4001 3000 - 0x4001 33FF	1 KB	SPI1	Section 24.6.8 on page 676
	0x4001 2C00 - 0x4001 2FFF	1 KB	TIM1	Section 13.4.21 on page 294
	0x4001 2800 - 0x4001 2BFF	1 KB	Reserved	-
	0x4001 2400 - 0x4001 27FF	1 KB	ADC	Section 12.11.11 on page 220
	0x4001 1800 - 0x4001 23FF	4 KB	Reserved	-
	0x4001 1400 - 0x4001 17FF	1 KB	USART6	Section 23.7.11 on page 640
	0x4001 0800 - 0x4001 23FF	7 KB	Reserved	-
	0x4001 0400 - 0x4001 07FF	1 KB	EXTI	Section 11.3.7 on page 180
	0x4001 0000 - 0x4001 03FF	1 KB	SYSCFG	Section 9.1.7 on page 151
-	0x4000 8000 - 0x4000 FFFF	32 KB	Reserved	-

Table 2. STM32F0x0 peripheral register boundary addresses (continued)

Bus	Boundary address	Size	Peripheral	Peripheral register map
APB	0x4000 7400 - 0x4000 7FFF	3 KB	Reserved	-
	0x4000 7000 - 0x4000 73FF	1 KB	PWR	Section 6.4.3 on page 86
	0x4000 63FF - 0x4000 6FFF	3 KB	Reserved	-
	0x4000 6000 - 0x4000 63FF	1 KB	USB/SRAM	Section 25.6.3 on page 708
	0x4000 5C00 - 0x4000 5FFF	1 KB	USB	Section 25.6.3 on page 708
	0x4000 5800 - 0x4000 5BFF	1 KB	I2C2	Section 22.7.12 on page 593
	0x4000 5400 - 0x4000 57FF	1 KB	I2C1	Section 22.7.12 on page 593
	0x4000 5000 - 0x4000 53FF	1 KB	USART5	Section 23.7.11 on page 640
	0x4000 4C00 - 0x4000 4FFF	1 KB	USART4	Section 23.7.11 on page 640
	0x4000 4800 - 0x4000 4BFF	1 KB	USART3	Section 23.7.11 on page 640
	0x4000 4400 - 0x4000 47FF	1 KB	USART2	Section 23.7.11 on page 640
	0x4000 3C00 - 0x4000 43FF	2 KB	Reserved	-
	0x4000 3800 - 0x4000 3BFF	1 KB	SPI2	Section 24.6.8 on page 676
	0x4000 3400 - 0x4000 37FF	1 KB	Reserved	-
	0x4000 3000 - 0x4000 33FF	1 KB	IWDG	Section 19.4.6 on page 479
	0x4000 2C00 - 0x4000 2FFF	1 KB	WWDG	Section 20.4.4 on page 485
	0x4000 2800 - 0x4000 2BFF	1 KB	RTC	Section 21.7.17 on page 523
	0x4000 2400 - 0x4000 27FF	1 KB	Reserved	-
	0x4000 2000 - 0x4000 23FF	1 KB	TIM14	Section 16.4.12 on page 395
	0x4000 1800 - 0x4000 1FFF	2 KB	Reserved	-
	0x4000 1400 - 0x4000 17FF	1 KB	TIM7	Section 15.4.8 on page 373
	0x4000 1000 - 0x4000 13FF	1 KB	TIM6	Section 15.4.8 on page 373
	0x4000 0800 - 0x4000 0FFF	2 KB	Reserved	-
	0x4000 0400 - 0x4000 07FF	1 KB	TIM3	Section 14.4.19 on page 359
	0x4000 0000 - 0x4000 03FF	1 KB	Reserved	-

2.3 Embedded SRAM

STM32F030x4 and STM32F030x6 devices feature 4 Kbytes of static SRAM. STM32F030x8 devices feature 8 Kbytes of static SRAM. STM32F030xC devices feature 32 Kbytes of static SRAM. STM32F070x6 devices feature 6 Kbytes of static SRAM. STM32F070xB devices feature 16 Kbytes of static SRAM.

This RAM can be accessed as bytes, half-words (16 bits) or full words (32 bits). This memory can be addressed at maximum system clock frequency without wait state and thus by both CPU and DMA.

Parity check

The user can enable the parity check using the option bit RAM_PARITY_CHECK in the user option byte (refer to [Section 4: Option bytes](#)).

The data bus width is 36 bits because 4 bits are available for parity check (1 bit per byte) in order to increase memory robustness, as required for instance by Class B or SIL norms.

The parity bits are computed and stored when writing into the SRAM. Then, they are automatically checked when reading. If one bit fails, an NMI is generated. The same error can also be linked to the BRK_IN Break input of TIM1/15/16/17, with the SRAM_PARITY_LOCK control bit in the [SYSCFG configuration register 2 \(SYSCFG_CFGR2\)](#). The SRAM Parity Error flag (SRAM_PEF) is available in the [SYSCFG configuration register 2 \(SYSCFG_CFGR2\)](#).

Note: When enabling the RAM parity check, it is advised to initialize by software the whole RAM memory at the beginning of the code, to avoid getting parity errors when reading non-initialized locations.

2.4 Flash memory overview

The Flash memory is composed of two distinct physical areas:

- The main Flash memory block. It contains the application program and user data if necessary.
- The information block. It is composed of two parts:
 - Option bytes for hardware and memory protection user configuration.
 - System memory which contains the proprietary boot loader code.Please, refer to [Section 3: Embedded Flash memory](#) for more details.

The Flash interface implements instruction access and data access based on the AHB protocol. It implements the prefetch buffer that speeds up CPU code execution. It also implements the logic necessary to carry out the Flash memory operations (Program/Erase) controlled through the Flash registers.

2.5 Boot configuration

In the STM32F0x0, three different boot modes can be selected through the BOOT0 pin and boot configuration bits nBOOT1 in the User option byte, as shown in the following table.

Table 3. Boot modes

Boot mode configuration		Mode
nBOOT1 bit	BOOT0 pin	
x	0	Main Flash memory is selected as boot area ⁽¹⁾
1	1	System memory is selected as boot area
0	1	Embedded SRAM is selected as boot area

1. For STM32F070x6 and STM32F030xC devices, see also Empty check description.

The boot mode configuration is latched on the 4th rising edge of SYSCLK after a reset. It is up to the user to set boot mode configuration related to the required boot mode.

The boot mode configuration is also re-sampled when exiting from Standby mode. Consequently they must be kept in the required Boot mode configuration in Standby mode. After this startup delay has elapsed, the CPU fetches the top-of-stack value from address 0x0000 0000, then starts code execution from the boot memory at 0x0000 0004.

Depending on the selected boot mode, main Flash memory, system memory or SRAM is accessible as follows:

- Boot from main Flash memory: the main Flash memory is aliased in the boot memory space (0x0000 0000), but still accessible from its original memory space (0x0800 0000). In other words, the Flash memory contents can be accessed starting from address 0x0000 0000 or 0x0800 0000.
- Boot from system memory: the system memory is aliased in the boot memory space (0x0000 0000), but still accessible from its original memory space (0x1FFF EC00 on STM32F030x4, STM32F030x6 and STM32F030x8 devices, 0x1FFF C400 on STM32F070x6 devices, 0x1FFF C800 on STM32F070xB and 0x1FFF D800 on STM32F030xC devices).
- Boot from the embedded SRAM: the SRAM is aliased in the boot memory space (0x0000 0000), but it is still accessible from its original memory space (0x2000 0000).

Empty check

On STM32F070x6 and STM32F030xC devices only, internal empty check flag is implemented to allow easy programming of the virgin devices by the boot loader. This flag is used when BOOT0 pin is defining Main Flash memory as the target boot area. When the flag is set, the device is considered as empty and System memory (boot loader) is selected instead of the Main Flash as a boot area to allow user to program the Flash memory.

This flag is updated only during Option bytes loading: it is set when the content of the address 0x08000 0000 is read as 0xFFFF FFFF, otherwise it is cleared. It means a power on or setting of OBL_LAUNCH bit in FLASH_CR register is needed to clear this flag after programming of a virgin device to execute user code after System reset.

Note: *If the device is programmed for a first time but the Option bytes are not reloaded, the device will still select System memory as a boot area after a System reset. In the STM32F070x6, the boot loader code is able to detect this situation. It then changes the boot memory*

mapping to Main Flash and performs a jump to user code programmed there. In the STM32F030xC, a POR must be performed or the Option bytes reloaded before applying the system reset.

Physical remap

Once the boot mode is selected, the application software can modify the memory accessible in the code area. This modification is performed by programming the MEM_MODE bits in the [SYSCFG configuration register 1 \(SYSCFG_CFGR1\)](#). Unlike Cortex® M3 and M4, the M0 CPU does not support the vector table relocation. For application code which is located in a different address than 0x0800 0000, some additional code must be added in order to be able to serve the application interrupts. A solution will be to relocate by software the vector table to the internal SRAM:

- Copy the vector table from the Flash (mapped at the base of the application load address) to the base address of the SRAM at 0x2000 0000.
- Remap SRAM at address 0x0000 0000, using SYSCFG configuration register 1.
- Then once an interrupt occurs, the Cortex®-M0 processor will fetch the interrupt handler start address from the relocated vector table in SRAM, then it will jump to execute the interrupt handler located in the Flash.

This operation should be done at the initialization phase of the application. Please refer to AN4065 and attached IAP code from www.st.com for more details.

Embedded boot loader

The embedded boot loader is located in the System memory, programmed by ST during production. It is used to reprogram the Flash memory using one of the following serial interfaces:

- USART on pins PA14/PA15 or PA9/PA10
- I2C on pins PB6/PB7 (STM32F070xx and STM32F030xC devices only)
- USB DFU interface (STM32F070xx devices only)

For further details, please refer to AN2606.

3 Embedded Flash memory

3.1 Flash main features

- Up to 256 Kbyte of Flash memory
- Memory organization:
 - Main Flash memory block:
Up to 64 Kword (64 K × 32 bits)
 - Information block:
Up to 3 Kword (3 K × 32 bits) for the system memory
 - Up to 2 × 8 byte for the option byte

Flash memory interface features:

- Read interface with prefetch buffer
- Option byte Loader
- Flash Program / Erase operation
- Read / Write protection
- Low-power mode

3.2 Flash memory functional description

3.2.1 Flash memory organization

The Flash memory is organized as 32-bit wide memory cells that can be used for storing both code and data constants.

The memory organization of STM32F030x4, STM32F030x6, STM32F070x6 and STM32F030x8 devices is based on a main Flash memory block containing up to 64 pages of 1 Kbyte or up to 16 sectors of 4 Kbytes (4 pages). The sector is the granularity of the write protection (see [Section 3.3: Memory protection on page 55](#)).

The memory organization of STM32F070xB and STM32F030xC devices is based on a main Flash memory block containing up to 128 pages of 2 Kbytes or up to 64 sectors of 4 Kbytes (2 pages). The sector is the granularity of the write protection (see [Section 3.3: Memory protection on page 55](#)).

The information block is divided into two parts:

1. System memory: used to boot the device in System memory boot mode. The area is reserved for use by STMicroelectronics and contains the boot loader which is used to reprogram the Flash memory through the selected communication interface. It is programmed by ST when the device is manufactured, and protected against spurious write/erase operations. For further details, please refer to AN2606.
2. Option byte

Table 4. Flash memory organization (STM32F030x4, STM32F030x6, STM32F070x6 and STM32F030x8 devices)

Flash area	Flash memory addresses	Size (byte)	Name	Description ⁽¹⁾
Main Flash memory	0x0800 0000 - 0x0800 03FF	1 Kbyte	Page 0	Sector 0
	0x0800 0400 - 0x0800 07FF	1 Kbyte	Page 1	
	0x0800 0800 - 0x0800 0BFF	1 Kbyte	Page 2	
	0x0800 0C00 - 0x0800 0FFF	1 Kbyte	Page 3	
	.	.	.	.
	0x0800 7000 - 0x0800 73FF	1 Kbyte	Page 28	Sector 7 ⁽¹⁾
	0x0800 7400 - 0x0800 77FF	1 Kbyte	Page 29	
	0x0800 7800 - 0x0800 7BFF	1 Kbyte	Page 30	
	0x0800 7C00 - 0x0800 7FFF	1 Kbyte	Page 31	
	.	.	.	.
	0x0800 F000 - 0x0800 F3FF	1 Kbyte	Page 60	Sector 15
	0x0800 F400 - 0x0800 F7FF	1 Kbyte	Page 61	
	0x0800 F800 - 0x0800 FBFF	1 Kbyte	Page 62	
	0x0800 FC00 - 0x0800 FFFF	1 Kbyte	Page 63	
Information block	0x1FFF EC00 - 0x1FFF F7FF	3 Kbyte ⁽²⁾	-	System memory
	0x1FFF C400 - 0x1FFF F7FF	13 Kbyte ⁽³⁾	-	System memory
	0x1FFF F800 - 0x1FFF F80F	2 x 8 byte	-	Option byte

1. On STM32F030x4 devices, the main Flash memory space is limited to sector 3. On STM32F030x6 and STM32F070x6 devices, the main Flash memory is limited to sector 7.

2. STM32F030x4, STM32F030x6 and STM32F030x8 devices

3. STM32F070x6 devices

Table 5. Flash memory organization (STM32F070xB, STM32F030xC devices)

Flash area	Flash memory addresses	Size (byte)	Name	Description
Main Flash memory	0x0800 0000 - 0x0800 07FF	2 Kbytes	Page 0	Sector 0
	0x0800 0800 - 0x0800 0FFF	2 Kbytes	Page 1	
	.	.	.	.
	.	.	.	.
	.	.	.	.
	0x0801 F000 - 0x0801 F7FF	2 Kbytes	Page 62	Sector 31 ⁽¹⁾
	0x0801 F800 - 0x0801 FFFF	2 Kbytes	Page 63	
	.	.	.	.
Information block	0x0803 F000 - 0x0803 F7FF	2 Kbytes	Page 126	-
	0x0803 F800 - 0x0803 FFFF	2 Kbytes	Page 127	-
	0x1FFF C800 - 0x1FFF F7FF	12 Kbytes ⁽²⁾	-	System memory
	0x1FFF D800 - 0x1FFF F7FF	8 Kbytes ⁽³⁾	-	System memory
	0x1FFF F800 - 0x1FFF F80F	2 x 8 byte	-	Option byte

1. The main Flash memory space of STM32F070xB is limited to sector 31.

2. STM32F070xB devices only.

3. STM32F030xC devices only.

Read operations

The embedded Flash module can be addressed directly, as a common memory space. Any data read operation accesses the content of the Flash module through dedicated read senses and provides the requested data.

The instruction fetch and the data access are both done through the same AHB bus. Read accesses can be performed with the following options managed through the Flash access control register (FLASH_ACR):

- Instruction fetch: Prefetch buffer enabled for a faster CPU execution
- Latency: number of wait states for a correct read operation (from 0 to 1)

Instruction fetch

The ARM® Cortex®-M0 fetches the instruction over the AHB bus. The prefetch block aims at increasing the efficiency of instruction fetching.

Prefetch buffer

The prefetch buffer is 3-block wide where each block consists of 4 bytes. The prefetch blocks are direct-mapped. A block can be completely replaced on a single read to the Flash memory as the size of the block matches the bandwidth of the Flash memory.

The implementation of this prefetch buffer makes a faster CPU execution possible as the CPU fetches one word at a time with the next word readily available in the prefetch buffer. This implies that the acceleration ratio will be of the order of 2 assuming that the code is aligned at a 32-bit boundary for the jumps.

However the prefetch buffer has an impact on the performance only when the wait state number is 1. In the other case (no wait state) the performance remains the same whatever the prefetch buffer status. There could be some impacts on the power consumption but this is strongly dependent from the actual application code.

Prefetch controller

The prefetch controller decides to access the Flash memory depending on the available space in the prefetch buffer. The Controller initiates a read request when there is at least one block free in the prefetch buffer.

After reset, the state of the prefetch buffer is on.

The prefetch buffer is usually switched on/off during the initialization routine, while the microcontroller is running on the internal 8 MHz RC (HSI) oscillator.

Access latency

In order to maintain the control signals to read the Flash memory, the ratio of the prefetch controller clock period to the access time of the Flash memory has to be programmed in the Flash access control register with the LATENCY[2:0] bits. This value gives the number of cycles needed to maintain the control signals of the Flash memory and correctly read the required data. After reset, the value is zero and only one cycle without additional wait states is required to access the Flash memory.

3.2.2 Flash program and erase operations

The STM32F0x0 embedded Flash memory can be programmed using in-circuit programming or in-application programming.

The **in-circuit programming (ICP)** method is used to update the entire contents of the Flash memory, using the SWD protocol or the boot loader to load the user application into the microcontroller. ICP offers quick and efficient design iterations and eliminates unnecessary package handling or socketing of devices.

In contrast to the ICP method, **in-application programming (IAP)** can use any communication interface supported by the microcontroller (I/Os, USB, USART, I²C, SPI, etc.) to download programming data into memory. IAP allows the user to re-program the Flash memory while the application is running. Nevertheless, part of the application has to have been previously programmed in the Flash memory using ICP.

The program and erase operations can be performed over the whole product voltage range. They are managed through the following seven Flash registers:

- Key register (FLASH_KEYR)
- Option byte key register (FLASH_OPTKEYR)
- Flash control register (FLASH_CR)
- Flash status register (FLASH_SR)
- Flash address register (FLASH_AR)
- Option byte register (FLASH_OBR)
- Write protection register (FLASH_WRP)

An ongoing Flash memory operation will not block the CPU as long as the CPU does not access the Flash memory.

On the contrary, during a program/erase operation to the Flash memory, any attempt to read the Flash memory will stall the bus. The read operation will proceed correctly once the program/erase operation has completed. This means that code or data fetches cannot be made while a program/erase operation is ongoing.

For program and erase operations on the Flash memory (write/erase), the internal RC oscillator (HSI) must be ON.

Unlocking the Flash memory

After reset, the Flash memory is protected against unwanted write or erase operations. The FLASH_CR register is not accessible in write mode, except for the OBL_LAUNCH bit, used to reload the option bits. An unlocking sequence should be written to the FLASH_KEYR register to open the access to the FLASH_CR register. This sequence consists of two write operations:

- Write KEY1 = 0x45670123
- Write KEY2 = 0xCDEF89AB

Any wrong sequence locks up the FLASH_CR register until the next reset.

In the case of a wrong key sequence, a bus error is detected and a Hard Fault interrupt is generated. This is done after the first write cycle if KEY1 does not match, or during the second write cycle if KEY1 has been correctly written but KEY2 does not match.

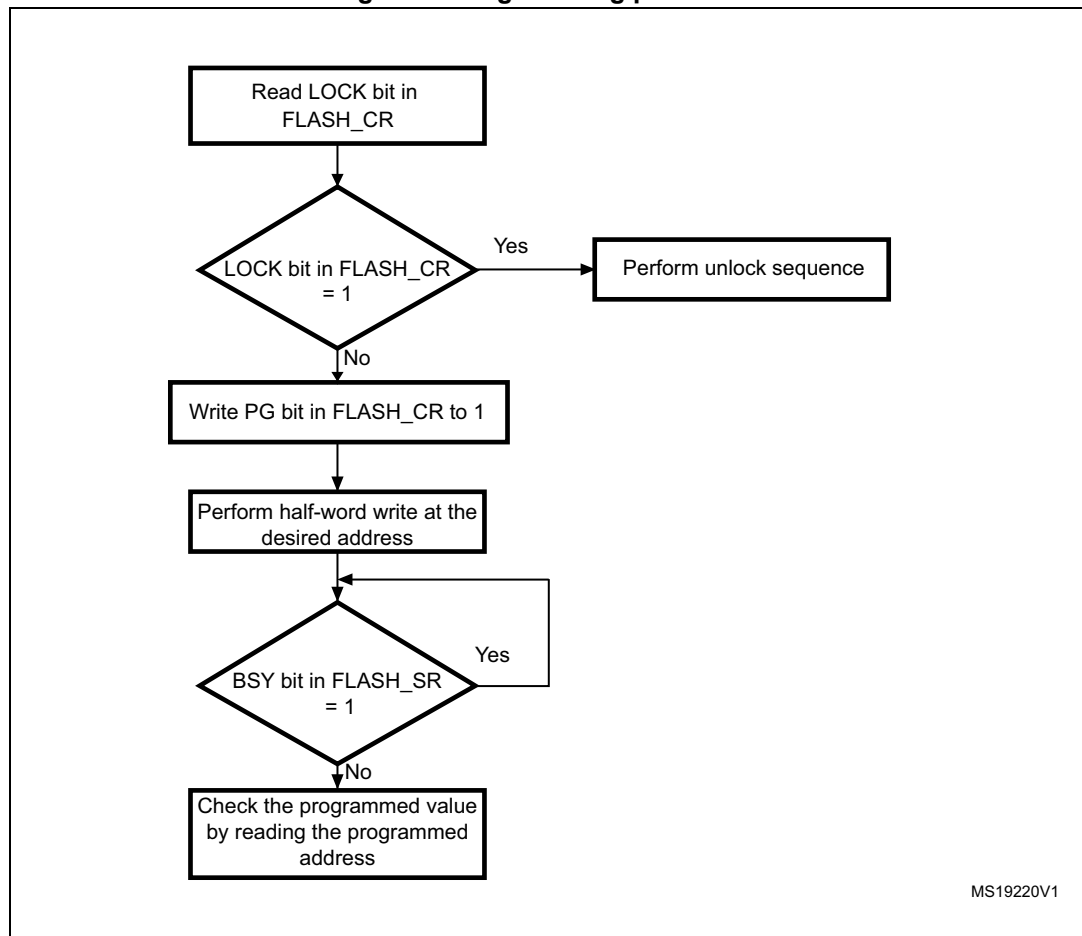
The FLASH_CR register can be locked again by user software by writing the LOCK bit in the FLASH_CR register to 1.

For code example refer to the Appendix section [A.2.1: Flash memory unlocking sequence code](#).

Main Flash memory programming

The main Flash memory can be programmed 16 bits at a time. The program operation is started when the CPU writes a half-word into a main Flash memory address with the PG bit of the FLASH_CR register set. Any attempt to write data that are not half-word long will result in a bus error generating a Hard Fault interrupt.

Figure 3. Programming procedure



The Flash memory interface preliminarily reads the value at the addressed main Flash memory location and checks that it has been erased. If not, the program operation is skipped and a warning is issued by the PGERR bit in FLASH_SR register. The only exception to this is when 0x0000 is programmed. In this case, the location is correctly programmed to 0x0000 and the PGERR bit is not set.

If the addressed main Flash memory location is write-protected by the FLASH_WRP register, the program operation is skipped and a warning is issued by the WRPRTERR bit in the FLASH_SR register. The end of the program operation is indicated by the EOP bit in the FLASH_SR register.

The main Flash memory programming sequence in standard mode is as follows:

1. Check that no main Flash memory operation is ongoing by checking the BSY bit in the FLASH_SR register.
2. Set the PG bit in the FLASH_CR register.
3. Perform the data write (half-word) at the desired address.
4. Wait until the BSY bit is reset in the FLASH_SR register.
5. Check the EOP flag in the FLASH_SR register (it is set when the programming operation has succeeded), and then clear it by software.

Note: The registers are not accessible in write mode when the BSY bit of the FLASH_SR register is set.

For code example refer to the Appendix section [A.2.2: Main Flash programming sequence code example](#).

Flash memory erase

The Flash memory can be erased page by page or completely (Mass Erase).

Page Erase

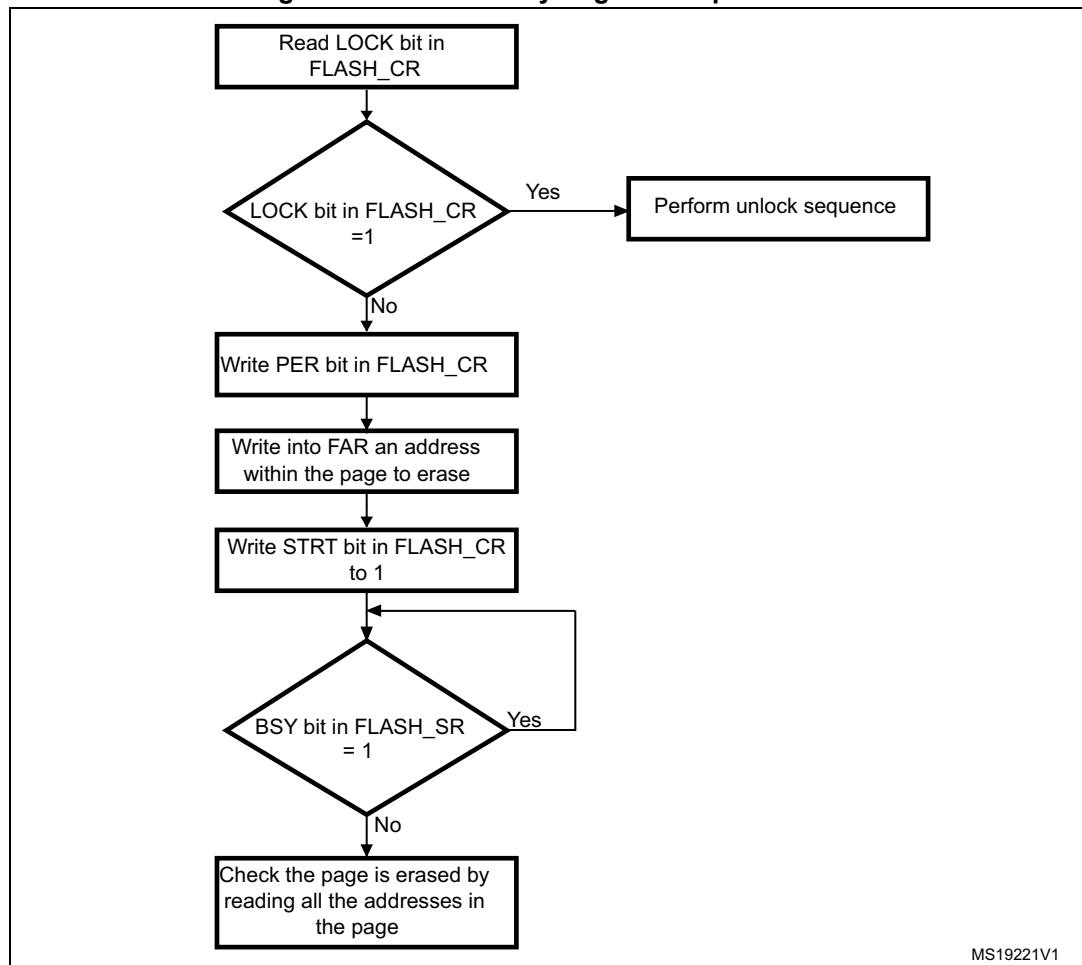
To erase a page, the procedure below should be followed:

1. Check that no Flash memory operation is ongoing by checking the BSY bit in the FLASH_CR register.
2. Set the PER bit in the FLASH_CR register.
3. Program the FLASH_AR register to select a page to erase.
4. Set the STRT bit in the FLASH_CR register (see note below).
5. Wait for the BSY bit to be reset.
6. Check the EOP flag in the FLASH_SR register (it is set when the erase operation has succeeded).
7. Clear the EOP flag.

Note: The software should start checking if the BSY bit equals "0" at least one CPU cycle after setting the STRT bit.

For code example refer to the Appendix section [A.2.3: Page erase sequence code example](#).

Figure 4. Flash memory Page Erase procedure



Mass Erase

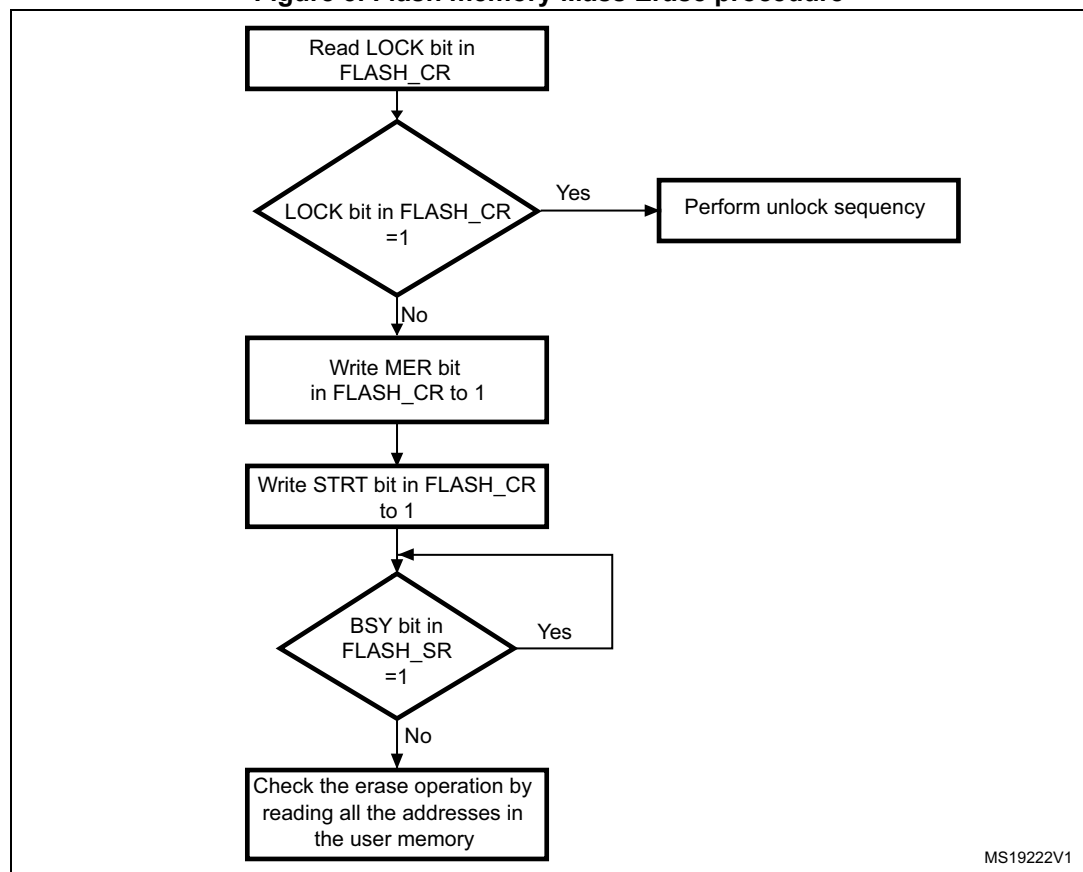
The Mass Erase command can be used to completely erase the pages of the Main Flash memory. The information block is unaffected by this procedure. The following sequence is recommended:

1. Check that no Flash memory operation is ongoing by checking the BSY bit in the FLASH_SR register.
2. Set the MER bit in the FLASH_CR register.
3. Set the STRT bit in the FLASH_CR register.
4. Wait until the BSY bit is reset in the FLASH_SR register.
5. Check the EOP flag in the FLASH_SR register (it is set when the programming operation has succeeded).
6. Clear the EOP flag.

Note: The software should start checking if the BSY bit equals "0" at least one CPU cycle after setting the STRT bit.

For code example refer to the Appendix section [A.2.4: Mass erase sequence code example](#).

Figure 5. Flash memory Mass Erase procedure



Option byte programming

The option byte are programmed differently from normal user addresses. The number of option byte is limited to 8 (1, 2 or 4 for write protection, 1 for read protection, 1 for hardware configuration and 2 free byte for user data). After unlocking the Flash access, the user has to authorize the programming of the option byte by writing the same set of KEYS (KEY1 and KEY2) to the FLASH_OPTKEYR register to set the OPTWRE bit in the FLASH_CR register (refer to [Unlocking the Flash memory](#) for key values). Then the user has to set the OPTPG bit in the FLASH_CR register and perform a half-word write operation at the desired Flash address.

The value of the addressed option byte is first read to check it is really erased. If not, the program operation is skipped and a warning is issued by the WRPRTERR bit in the FLASH_SR register. The end of the program operation is indicated by the EOP bit in the FLASH_SR register.

The option byte is automatically complemented into the next flash memory address before the programming operation starts. This guarantees that the option byte and its complement are always correct.

The sequence is as follows:

1. Check that no Flash memory operation is ongoing by checking the BSY bit in the FLASH_SR register.
2. Unlock the OPTWRE bit in the FLASH_CR register.
3. Set the OPTPG bit in the FLASH_CR register.
4. Write the data (half-word) to the desired address.
5. Wait for the BSY bit to be reset.
6. Read the programmed value and verify.

For code example refer to the Appendix section [A.2.6: Option byte programming sequence code example](#).

When the Flash memory read protection option is changed from protected to unprotected, a Mass Erase of the main Flash memory is performed before reprogramming the read protection option. If the user wants to change an option other than the read protection option, then the mass erase is not performed. The erased state of the read protection option byte protects the Flash memory.

Erase procedure

The option byte erase sequence is as follows:

1. Check that no Flash memory operation is ongoing by reading the BSY bit in the FLASH_SR register
2. Unlock the OPTWRE bit in the FLASH_CR register
3. Set the OPTER bit in the FLASH_CR register
4. Set the STRT bit in the FLASH_CR register
5. Wait for the BSY bit to be reset
6. Read the erased option byte and verify

For code example refer to the Appendix section [A.2.7: Option byte erasing sequence code example](#).

3.3 Memory protection

The user area of the Flash memory can be protected against read by untrusted code. The pages of the Flash memory can also be protected against unwanted write due to loss of program counter contexts. The write-protection granularity is one sector (four pages).

3.3.1 Read protection

The read protection is activated by setting the RDP option byte and then, by applying a system reset to reload the new RDP option byte.

Note: If the read protection is set while the debugger is still connected through SWD, apply a POR (power-on reset) instead of a system reset.

There are three levels of read protection from no protection (level 0) to maximum protection or no debug (level 2). Refer to [Table 7: Access status versus protection level and execution modes](#).

The Flash memory is protected when the RDP option byte and its complement contain the pair of values shown in [Table 6](#).

Table 6. Flash memory read protection status

RDP byte value	RDP complement value	Read protection level
0xAA	0x55	Level 0 (ST production configuration)
Any value except 0xAA or 0xCC	Any value (not necessarily complementary) except 0x55 and 0x33	Level 1
0xCC	0x33	Level 2

The System memory area is read accessible whatever the protection level. It is never accessible for program/erase operation

Level 0: no protection

Read, program and erase operations into the main Flash memory area are possible.

The option byte are as well accessible by all operations.

Level 1: read protection

This is the default protection level when RDP option byte is erased. It is defined as well when RDP value is at any value different from 0xAA and 0xCC, or even if the complement is not correct.

- **User mode:** Code executing in user mode can access main Flash memory and option byte with all operations.
- **Debug, boot RAM and boot loader modes:** In debug mode (with SWD) or when code is running from boot RAM or boot loader, the main Flash memory is totally inaccessible. In these modes, even a simple read access generates a bus error and a Hard Fault interrupt. The main Flash memory is program/erase protected to prevent malicious or unauthorized users from reprogramming any of the user code with a dump routine. Any

attempted program/erase operation sets the PGERR flag of Flash status register (FLASH_SR).

When the RPD is reprogrammed to the value 0xAA to move back to Level 0, a mass erase of the main Flash memory is performed.

Level 2: no debug

In this level, the protection level 1 is guaranteed. In addition, the CortexM0 debug capabilities are disabled. Consequently, the debug port (SWD), the boot from RAM (boot RAM mode) and the boot from System memory (boot loader mode) are no more available.

In user execution mode, all operations are allowed on the Main Flash memory. On the contrary, only read and program operations can be performed on the option byte. Option byte are not accessible for erase operations.

Moreover, the RDP byte cannot be programmed. Thus, the level 2 cannot be removed at all: it is an irreversible operation. When attempting to program the RDP byte, the protection error flag WRPRERR is set in the Flash_SR register and an interrupt can be generated.

Note: The debug feature is also disabled under reset.

STMicroelectronics is not able to perform analysis on defective parts on which the level 2 protection has been set.

Table 7. Access status versus protection level and execution modes

Area	Protection level	User execution			Debug / Boot From RAM / Boot From System memory		
		Read	Write	Erase	Read	Write	Erase
Main Flash memory	1	Yes	Yes	Yes	No	No	No ⁽⁴⁾
	2	Yes	Yes	Yes	N/A ⁽¹⁾	N/A ⁽¹⁾	N/A ⁽¹⁾
System memory ⁽²⁾	1	Yes	No	No	Yes	No	No
	2	Yes	No	No	N/A ⁽¹⁾	N/A ⁽¹⁾	N/A ⁽¹⁾
Option byte	1	Yes	Yes ⁽³⁾	Yes	Yes ⁽⁴⁾	Yes ⁽⁴⁾	Yes
	2	Yes	Yes ⁽⁵⁾	No	N/A ⁽¹⁾	N/A ⁽¹⁾	N/A ⁽¹⁾

1. When the protection level 2 is active, the Debug port, the boot from RAM and the boot from System memory are disabled.
2. The system memory is only read-accessible, whatever the protection level (0, 1 or 2) and execution mode.
3. The main Flash memory is erased when the RDP option byte is changed from level 1 to level 0 (0xAA).
4. When the RDP level 1 is active, the embedded boot loader don't allow to read or write the Option byte, except to remove the RDP protection (move from level 1 to level 0).
5. All option byte can be programmed, except the RDP byte.

Changing read protection level

It is easy to move from level 0 to level 1 by changing the value of the RDP byte to any value (except 0xCC).

By programming the 0xCC value in the RDP byte, it is possible to go to level 2 either directly from level 0 or from level 1.

On the contrary, the change to level 0 (no protection) is not possible without a main Flash memory Mass erase operation. This Mass erase is generated as soon as 0xAA is programmed in the RDP byte.

Note: To validate the protection level change, the option byte must be reloaded through the "OBL_LAUNCH" bit in Flash control register.

3.3.2 Write protection

The write protection is implemented with a granularity of one sector. It is activated by configuring the WRPx option byte, and then by reloading them by setting the OBL_LAUNCH bit in the FLASH_CR register.

If a program or an erase operation is performed on a protected sector, the Flash memory returns a WRPRTERR protection error flag in the Flash memory Status Register (FLASH_SR).

Write unprotection

To disable the write protection, two application cases are provided:

- Case 1: Read protection disabled after the write unprotection:
 - Erase the entire option byte area by using the OPTER bit in the Flash memory control register (FLASH_CR).
 - Program the code 0xAA in the RDP byte to unprotect the memory. This operation forces a Mass Erase of the main Flash memory.
 - Set the OBL_LAUNCH bit in the Flash control register (FLASH_CR) to reload the option byte (and the new WRP[1:0] byte), and to disable the write protection.
- Case 2: Read protection maintained active after the write unprotection, useful for in-application programming with a user boot loader:
 - Erase the entire option byte area by using the OPTER bit in the Flash memory control register (FLASH_CR).
 - Set the OBL_LAUNCH bit in the Flash control register (FLASH_CR) to reload the option byte (and the new WRP[1:0] byte), and to disable the write protection.

3.3.3 Option byte write protection

The option byte are always read-accessible and write-protected by default. To gain write access (Program/Erase) to the option byte, a sequence of keys (same as for lock) has to be written into the OPTKEYR. A correct sequence of keys gives write access to the option byte and this is indicated by OPTWRE in the FLASH_CR register being set. Write access can be disabled by resetting the bit through software.

3.4 Flash interrupts

Table 8. Flash interrupt request

Interrupt event	Event flag	Enable control bit
End of operation	EOP	EOPIE
Write protection error	WRPRTERR	ERRIE
Programming error	PGERR	ERRIE

3.5 Flash register description

The Flash memory registers have to be accessed by 32-bit words (half-word and byte accesses are not allowed).

3.5.1 Flash access control register (FLASH_ACR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PRFT BS	PRFT BE	Res.	LATENCY[2:0]		
										r	rw		rw	rw	rw

Bits 31:6 Reserved, must be kept at reset value.

Bit 5 **PRFTBS**: Prefetch buffer status

This bit provides the status of the prefetch buffer.

0: Prefetch buffer is disabled

1: Prefetch buffer is enabled

Note: The prefetch status is set to 1 as soon a first fetch request is done

Bit 4 **PRFTBE**: Prefetch buffer enable

0: Prefetch is disabled

1: Prefetch is enabled

Bit 3 Reserved, must be kept at reset value.

Bits 2:0 **LATENCY[2:0]**: Latency

These bits represent the ratio of the SYSCLK (system clock) period to the Flash access time.

000: Zero wait state, if SYSCLK ≤ 24 MHz

001: One wait state, if 24 MHz < SYSCLK ≤ 48 MHz

3.5.2 Flash key register (FLASH_KEYR)

Address offset: 0x04

Reset value: 0xFFFF XXXX

All these register bits are write-only and will return a 0 when read.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FKEY[31:16]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FKEY[15:0]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:0 **FKEY**: Flash key

These bits represent the keys to unlock the Flash.

3.5.3 Flash option key register (FLASH_OPTKEYR)

Address offset: 0x08
Reset value: 0xFFFF XXXX

All these register bits are write-only and will return a 0 when read.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
OPTKEY[31:16]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OPTKEY[15:0]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:0 **OPTKEY**: Option byte key
These bits represent the keys to unlock the OPTWRE.

3.5.4 Flash status register (FLASH_SR)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EOP	WRPRT ERR	Res.	PG ERR	Res.	BSY
										rc_w1	rc_w1		rc_w1		r

Bits 31:6 Reserved, must be kept at reset value.

Bit 5 **EOP**: End of operation

Set by hardware when a Flash operation (programming / erase) is completed.

Reset by writing 1.

*Note: EOP is asserted at the end of each successful program or erase operation*Bit 4 **WRPRTERR**: Write protection error

Set by hardware when programming a write-protected address of the Flash memory.

Reset by writing 1.

Bit 3 Reserved, must be kept at reset value.

Bit 2 **PGERR**: Programming error

Set by hardware when an address to be programmed contains a value different from '0xFFFF' before programming.

Reset by writing 1.

Note: The STRT bit in the FLASH_CR register should be reset before starting a programming operation.

Bit 1 Reserved, must be kept at reset value

Bit 0 **BSY**: Busy

This indicates that a Flash operation is in progress. This is set on the beginning of a Flash operation and reset when the operation finishes or when an error occurs.

3.5.5 Flash control register (FLASH_CR)

Address offset: 0x10

Reset value: 0x0000 0080

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	OBL_LAUNCH	EOPIE	Res.	ERRIE	OPTWRE	Res.	LOCK	STRT	OPTER	OPTPG	Res.	MER	PER	PG
		rw	rw		rw	rw		rw	rw	rw	rw		rw	rw	rw

Bits 31:14 Reserved, must be kept at reset value.

Bit 13 **OBL_LAUNCH**: Force option byte loading

When set to 1, this bit forces the option byte reloading. This operation generates a system reset.

0: Inactive

1: Active

Bit 12 **EOPIE**: End of operation interrupt enable

This bit enables the interrupt generation when the EOP bit in the FLASH_SR register goes to 1.

0: Interrupt generation disabled

1: Interrupt generation enabled

Bit 11 Reserved, must be kept at reset value

Bit 10 **ERRIE**: Error interrupt enable

This bit enables the interrupt generation on an error when PGERR / WRPRTERR are set in the FLASH_SR register.

0: Interrupt generation disabled

1: Interrupt generation enabled

Bit 9 **OPTWRE**: Option byte write enable

When set, the option byte can be programmed. This bit is set on writing the correct key sequence to the FLASH_OPTKEYR register.

This bit can be reset by software

Bit 8 Reserved, must be kept at reset value.

Bit 7 **LOCK**: Lock

Write to 1 only. When it is set, it indicates that the Flash is locked. This bit is reset by hardware after detecting the unlock sequence.

In the event of unsuccessful unlock operation, this bit remains set until the next reset.

Bit 6 **STRT**: Start

This bit triggers an ERASE operation when set. This bit is set only by software and reset when the BSY bit is reset.

Bit 5 **OPTER**: Option byte erase

Option byte erase chosen.

Bit 4 **OPTPG**: Option byte programming

Option byte programming chosen.

Bit 3 Reserved, must be kept at reset value.

Bit 2 **MER**: Mass erase

Erase of all user pages chosen.

Bit 1 **PER**: Page erase

Page Erase chosen.

Bit 0 **PG**: Programming

Flash programming chosen.

3.5.6 Flash address register (FLASH_AR)

Address offset: 0x14

Reset value: 0x0000 0000

This register is updated by hardware with the currently/last used address. For Page Erase operations, this should be updated by software to indicate the chosen page.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FAR[31:16]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FAR[15:0]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:0 **FAR**: Flash Address

Chooses the address to program when programming is selected, or a page to erase when Page Erase is selected.

Note: Write access to this register is blocked when the BSY bit in the FLASH_SR register is set.

3.5.7 Flash Option byte register (FLASH_OBR)

Address offset 0x1C

Reset value: 0xFFFF XX0X

The reset value of this register depends on the value programmed in the option byte.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DATA1								DATA0							
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	RAM PARITY CHECK	VDDA_ MONITOR	nBOOT1	Res.	nRST_ STDBY	nRST_ STOP	WDG_SW	Res.	Res.	Res.	Res.	Res.	RDPRT[1:0]		OPTERR
	r	r	r		r	r	r						r	r	r

Bits 31:24 **DATA1**

Bits 23:16 **DATA0**

Bit 15 Reserved, must be kept at reset value

Bits 14:12 User option byte:

Bit 14: **RAM_PARITY_CHECK**

Bit 13: **VDDA_MONITOR**

Bit 12: **nBOOT1**

Bit 11 Reserved, must be kept at reset value

Bits 10:8 Bit 10: **nRST_STDBY**

Bit 9: **nRST_STOP**

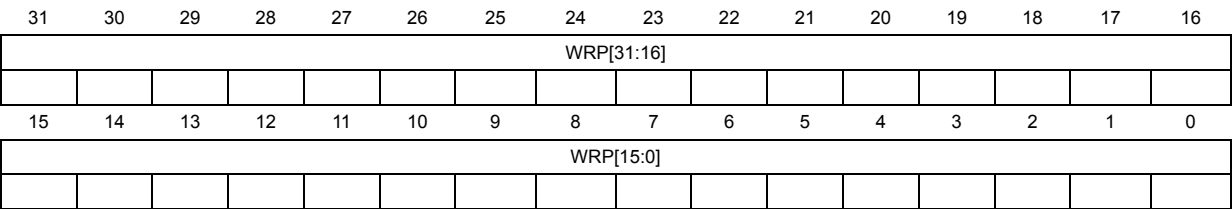
Bit 8: **WDG_SW**

- Bits 7:3 Reserved, must be kept at reset value.
- Bits 2:1 **RDPR**[1:0]: Read protection level status
- 00: Read protection level 0 is enabled (ST production configuration)
 - 01: Read protection level 1 is enabled
 - 11: Read protection level 2 is enabled.
- Bit 0 **OPTERR**: Option byte error
- When set, this indicates that the loaded option byte and its complement do not match. The corresponding byte is set to 0xFF in respective FLASH_OBR or FLASH_WRPR register.

3.5.8 Write protection register (FLASH_WRPR)

Address offset: 0x20
Reset value: 0xFFFF XXXX

The reset value of this register depends on the value programmed in the option byte.



- Bits 31:0 **WRP**: Write protect
- This register contains the write-protection option byte loaded by the OBL.

3.5.9 Flash register map

Table 9. Flash interface - register map and reset values

Off-set	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
0x000	FLASH_ACR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PRFTBS	PRFTBE	HLFCYA	LATENCY [2:0]						
	Reset value																											0	0	0	0	0	0				
0x004	FLASH_KEYR	FKEY[31:0]																																			
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
0x008	FLASH_OPTKEYR	OPTKEY[31:0]																																			
	Reset value	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x				
0x00C	FLASH_SR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EOP	WRPRTERR	Res.	PGERR	ERLYBSY	BSY				
	Reset value																											0	0		0	0	0				
0x010	FLASH_CR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OBL_LAUNCH	EOPIE	Res.	ERRIE	OPTWRE	Res.	LOCK	STRT	OPTER	OPTPG	Res.	MER	PER	PG				
	Reset value																			0	0		0	0		1	0	0	0		0	0	0				
0x014	FLASH_AR	FAR[31:0]																																			
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0			
0x01C	FLASH_OBR	Data1										Data0										Res.	RAM_PARITY_CHECK	VDDA_MONITOR	nBOOT1	Res.	nRST_STDBY	nRST_STOP	WDG_SW	Res.	Res.	Res.	Res.	RDPRT[1:0]			OPTERR
	Reset value	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			
0x020	FLASH_WRP	WRP[31:0]																																			
	Reset value	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X			

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

4 Option bytes

There are up to 8 option bytes. They are configured by the end user depending on the application requirements. As a configuration example, the watchdog may be selected in hardware or software mode.

A 32-bit word is split up as follows in the option byte.

Table 10. Option byte format

31-24	23-16	15 -8	7-0
Complemented option byte 1	Option byte 1	Complemented option byte 0	Option byte 0

The organization of these bytes inside the information block is as shown in [Table 11](#).

The option byte can be read from the memory locations listed in [Table 11](#) or from the Option byte register (FLASH_OBR).

Note: The new programmed option byte (user, read/write protection) are not loaded after a system reset. To reload them, either a POR or setting to '1' the OBL_LAUNCH bit is necessary.

Table 11. Option byte organization

Address	[31:24]	[23:16]	[15:8]	[7:0]
0x1FFF F800	nUSER	USER	nRDP	RDP
0x1FFF F804	nData1	Data1	nData0	Data0
0x1FFF F808	nWRP1	WRP1	nWRP0	WRP0
0x1FFF F80C	nWRP3	WRP3	nWRP2	WRP2

On every power-on reset, the option byte loader (OBL) reads the information block and stores the data into the option byte register (FLASH_OBR) and the write protection register (FLASH_WRP). During option byte loading, the bit-wise complementarity of the option byte and its corresponding complemented option byte is verified. In case of failure, an option byte error (OPTERR) is generated and the corresponding option byte is considered as 0xFF. If the option byte and its complemented option byte are both equal to 0xFF (Electrical Erase state) the option byte error is not generated.

4.1 Option byte description

4.1.1 User and read protection option byte

Flash memory address: 0x1FFF F800
ST production value: 0x00FF 55AA

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
nUSER								USER							
								Res.	RAM PARITY CHECK	VDDA MONITOR	nBOOT1	Res.	nRST_ STDBY	nRST_ STOP	WDG_ SW
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
nRDP								RDP							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

- Bits 31:24 **nUSER**: User option byte complement
- Bit 23 Reserved, must be kept as “1”
- Bits 22:20 **USER**: User option byte (stored in FLASH_OBR[15:8])
- Bit 22: **RAM_PARITY_CHECK**
- 0: RAM parity check enabled
 - 1: RAM parity check disabled
- Bit 21: **VDDA_MONITOR**
- 0: V_{DDA} power supply supervisor disabled
 - 1: V_{DDA} power supply supervisor enabled
- Bit 20: **nBOOT1**
- Together with the BOOT0 signal, it selects the device boot mode. Refer to [Section 2.5: Boot configuration](#) for more details.
- Bit 19 Reserved, must be kept as “1”



Bits 18:16 Bit 18: **nRST_STDBY**

- 0: Reset generated when entering Standby mode.
- 1: No reset generated.

Bit 17: **nRST_STOP**

- 0: Reset generated when entering Stop mode
- 1: No reset generated

Bit 16: **WDG_SW**

- 0: Hardware watchdog
- 1: Software watchdog

Bits 15:8 **nRDP**: Read protection option byte complement

Bits 7:0 **RDP**: Read protection option byte

The value of this byte defines the Flash memory protection level

- 0xAA: level 0 (ST production configuration)
- 0xFF (except 0xAA & 0xCC): Level 1
- 0xCC: Level 2

Note: Read protection level status is stored in bits RDPRT[1:0] of the [Flash Option byte register \(FLASH_OBR\)](#). For more details about read protection, refer to [Section 3.3.1: Read protection](#).

4.1.2 User data option byte

Flash memory address: 0x1FFF F804

ST production value: 0x00FF 00FF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
nData1								Data1							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
nData0								Data0							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:24 **nData1**: User data byte 1 complement

Bits 23:16 **Data1**: User data byte 1 value (stored in FLASH_OBR[31:24])

Bits 15:8 **nData0**: User data byte 0 complement

Bits 7:0 **Data0**: User data byte 0 value (stored in FLASH_OBR[23:16])

4.1.3 Write protection option byte

This set of registers is used to write-protect the Flash memory. Clearing a bit in WRPx field (and at the same time setting a corresponding bit in nWRPx field) will write-protect the given memory sector.

For STM32F030x4, STM32F030x6, STM32F070x6, STM32F030x8 and STM32F070xB devices, WRP bits from 0 to 31 are protecting the Flash memory by sector of 4 kB.

For STM32F030xC devices, WRP bits from 0 to 30 are protecting the first 124 kB by sector of 4 kB and the bit 31 is protecting the last 132 kB.

Refer to [Section 3.3.2: Write protection](#) for more details.

Flash memory address: 0x1FFF F808
ST production value: 0x00FF 00FF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
nWRP1								WRP1							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
nWRP0								WRP0							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:24 **nWRP1**: Flash memory write protection option byte 1 complement

Bits 23:16 **WRP1**: Flash memory write protection option byte 1 value (stored in FLASH_WRP1[15:8])

Bits 15:8 **nWRP0**: Flash memory write protection option byte 0 complement

Bits 7:0 **WRP0**: Flash memory write protection option byte 0 value (stored in FLASH_WRP0[7:0])

Note: *STM32F030x4, STM32F030x6 and STM32F070x6 devices embed WRP0 and nWRP0 only.*

The following Option byte are available on *STM32F070xB* and *STM32F030xC* devices only.

Flash memory address: 0x1FFF F80C
ST production value: 0x00FF 00FF

4.1.4 Option byte map

The following table summarizes the option byte.

Table 12. Option byte map and ST production values

Offset	Option byte	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	User and read protection	nUSER								USER								nRDP								RDP							
										Res.	RAM_PARITY_CHECK	VDDA_MONITOR		nBOOT1		Res.	nRST_STDBY																
	ST production value	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1	1	0	1	0	1	0	1	0
0x04	User data	nData1								Data1								nData0								Data0							
	ST production value	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
0x08	Write protection	nWRP1								WRP1								nWRP0								WRP0							
	ST production value	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
0x0C	Write protection	nWRP3								WRP3								nWRP2								WRP2							
	ST production value	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1

5 Cyclic redundancy check calculation unit (CRC)

5.1 Introduction

The CRC (cyclic redundancy check) calculation unit is used to get a CRC code from 8-, 16- or 32-bit data word and a generator polynomial.

Among other applications, CRC-based techniques are used to verify data transmission or storage integrity. In the scope of the functional safety standards, they offer a means of verifying the Flash memory integrity. The CRC calculation unit helps compute a signature of the software during runtime, to be compared with a reference signature generated at link time and stored at a given memory location.

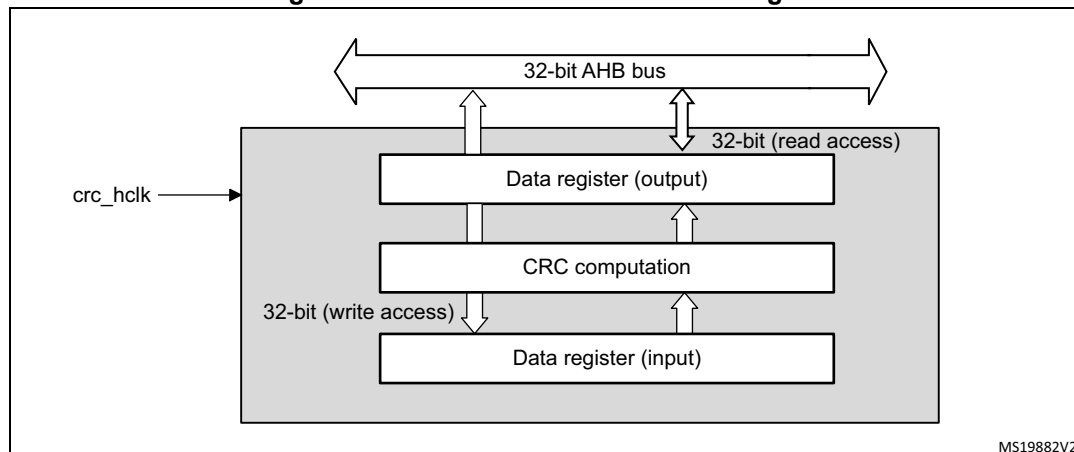
5.2 CRC main features

- Uses CRC-32 (Ethernet) polynomial: 0x4C11DB7
$$X^{32} + X^{26} + X^{23} + X^{22} + X^{16} + X^{12} + X^{11} + X^{10} + X^8 + X^7 + X^5 + X^4 + X^2 + X + 1$$
- Handles 8-, 16-, 32-bit data size
- Programmable CRC initial value
- Single input/output 32-bit data register
- Input buffer to avoid bus stall during calculation
- CRC computation done in 4 AHB clock cycles (HCLK) for the 32-bit data size
- General-purpose 8-bit register (can be used for temporary storage)
- Reversibility option on I/O data

5.3 CRC functional description

5.3.1 CRC block diagram

Figure 6. CRC calculation unit block diagram



5.3.2 CRC internal signals

Table 13. CRC internal input/output signals

Signal name	Signal type	Description
crc_hclk	Digital input	AHB clock

5.3.3 CRC operation

The CRC calculation unit has a single 32-bit read/write data register (CRC_DR). It is used to input new data (write access), and holds the result of the previous CRC calculation (read access).

Each write operation to the data register creates a combination of the previous CRC value (stored in CRC_DR) and the new one. CRC computation is done on the whole 32-bit data word or byte by byte depending on the format of the data being written.

The CRC_DR register can be accessed by word, right-aligned half-word and right-aligned byte. For the other registers only 32-bit access is allowed.

The duration of the computation depends on data width:

- 4 AHB clock cycles for 32-bit
- 2 AHB clock cycles for 16-bit
- 1 AHB clock cycles for 8-bit

An input buffer allows to immediately write a second data without waiting for any wait states due to the previous CRC calculation.

The data size can be dynamically adjusted to minimize the number of write accesses for a given number of bytes. For instance, a CRC for 5 bytes can be computed with a word write followed by a byte write.

The input data can be reversed, to manage the various endianness schemes. The reversing operation can be performed on 8 bits, 16 bits and 32 bits depending on the REV_IN[1:0] bits in the CRC_CR register.

For example: input data 0x1A2B3C4D is used for CRC calculation as:

0x58D43CB2 with bit-reversal done by byte

0xD458B23C with bit-reversal done by half-word

0xB23CD458 with bit-reversal done on the full word

The output data can also be reversed by setting the REV_OUT bit in the CRC_CR register.

The operation is done at bit level: for example, output data 0x11223344 is converted into 0x22CC4488.

The CRC calculator can be initialized to a programmable value using the RESET control bit in the CRC_CR register (the default value is 0xFFFFFFFF).

The initial CRC value can be programmed with the CRC_INIT register. The CRC_DR register is automatically initialized upon CRC_INIT register write access.

The CRC_IDR register can be used to hold a temporary value related to CRC calculation. It is not affected by the RESET bit in the CRC_CR register.

5.4 CRC registers

5.4.1 Data register (CRC_DR)

Address offset: 0x00

Reset value: 0xFFFF FFFF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
DR[31:16]															
rw															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DR[15:0]															
rw															

Bits 31:0 **DR[31:0]**: Data register bits

This register is used to write new data to the CRC calculator.

It holds the previous CRC calculation result when it is read.

If the data size is less than 32 bits, the least significant bits are used to write/read the correct value.

5.4.2 Independent data register (CRC_IDR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IDR[7:0]							
								rw							

Bits 31:8 Reserved, must be kept cleared.

Bits 7:0 **IDR[7:0]**: General-purpose 8-bit data register bits

These bits can be used as a temporary storage location for one byte.

This register is not affected by CRC resets generated by the RESET bit in the CRC_CR register

5.4.3 Control register (CRC_CR)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	REV_OUT	REV_IN[1:0]		Res.	Res.	Res.	Res.	RESET
								rw	rw	rw					rs

Bits 31:8 Reserved, must be kept cleared.

Bit 7 **REV_OUT**: Reverse output data

This bit controls the reversal of the bit order of the output data.

0: Bit order not affected

1: Bit-reversed output format

Bits 6:5 **REV_IN[1:0]**: Reverse input data

These bits control the reversal of the bit order of the input data

00: Bit order not affected

01: Bit reversal done by byte

10: Bit reversal done by half-word

11: Bit reversal done by word

Bits 4:1 Reserved, must be kept cleared.

Bit 0 **RESET**: RESET bit

This bit is set by software to reset the CRC calculation unit and set the data register to the value stored in the CRC_INIT register. This bit can only be set, it is automatically cleared by hardware

5.4.4 Initial CRC value (CRC_INIT)

Address offset: 0x10

Reset value: 0xFFFF FFFF

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CRC_INIT[31:16]															
rw															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CRC_INIT[15:0]															
rw															

Bits 31:0 **CRC_INIT**: Programmable initial CRC value

This register is used to write the CRC initial value.

5.4.5 CRC register map

Table 14. CRC register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
0x00	CRC_DR	DR[31:0]																																	
	Reset value	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1			
0x04	CRC_IDR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IDR[7:0]									
	Reset value																									0	0	0	0	0	0	0	0		
0x08	CRC_CR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	REV_OUT	REV_IN[1:0]		Res.	Res.	Res.	Res.	RESET		
	Reset value																									0	0	0					0		
0x10	CRC_INIT	CRC_INIT[31:0]																																	
	Reset value	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

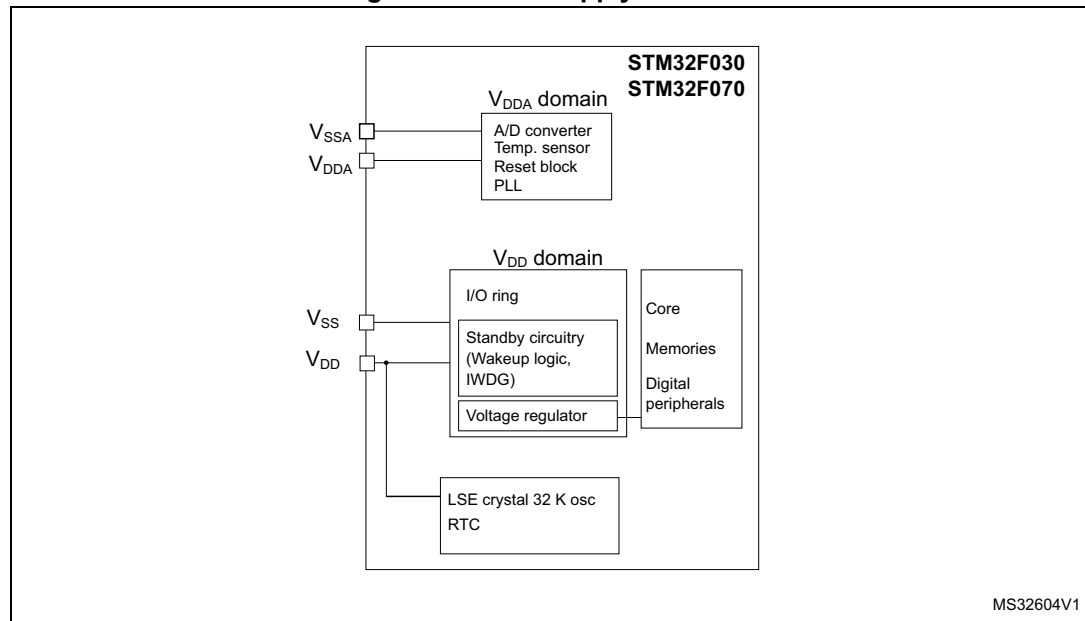
6 Power control (PWR)

6.1 Power supplies

The STM32F030/STM32F070 subfamily embeds a voltage regulator in order to supply the internal 1.8 V digital power domain.

- The STM32F030/STM32F070 devices require a 2.4 V - 3.6 V operating supply voltage (V_{DD}) and a 2.4 V - 3.6 V analog supply voltage (V_{DDA}).

Figure 7. Power supply overview



6.1.1 Independent A/D converter supply and reference voltage

To improve conversion accuracy and to extend the supply flexibility, the ADC has an independent power supply which can be separately filtered and shielded from noise on the PCB.

- The ADC voltage supply input is available on a separate V_{DDA} pin.
- An isolated supply ground connection is provided on pin V_{SSA} .

The V_{DDA} supply/reference voltage must be equal or higher than V_{DD} .

When a single supply is used, V_{DDA} can be externally connected to V_{DD} , through the external filtering circuit in order to ensure a noise free V_{DDA} reference voltage.

When V_{DDA} is different from V_{DD} , V_{DDA} must always be higher or equal to V_{DD} . To keep safe potential difference in between V_{DDA} and V_{DD} during power-up/power-down, an external Schottky diode may be used between V_{DD} and V_{DDA} . Refer to the datasheet for the maximum allowed difference.

6.1.2 Voltage regulator

The voltage regulator is always enabled after Reset. It works in three different modes depending on the application modes.

- In Run mode, the regulator supplies full power to the 1.8 V domain (core, memories and digital peripherals).
- In Stop mode the regulator supplies low-power to the 1.8 V domain, preserving contents of registers and SRAM
- In Standby Mode, the regulator is powered off. The contents of the registers and SRAM are lost except for the Standby circuitry.

6.2 Power supply supervisor

6.2.1 Power on reset (POR) / power down reset (PDR)

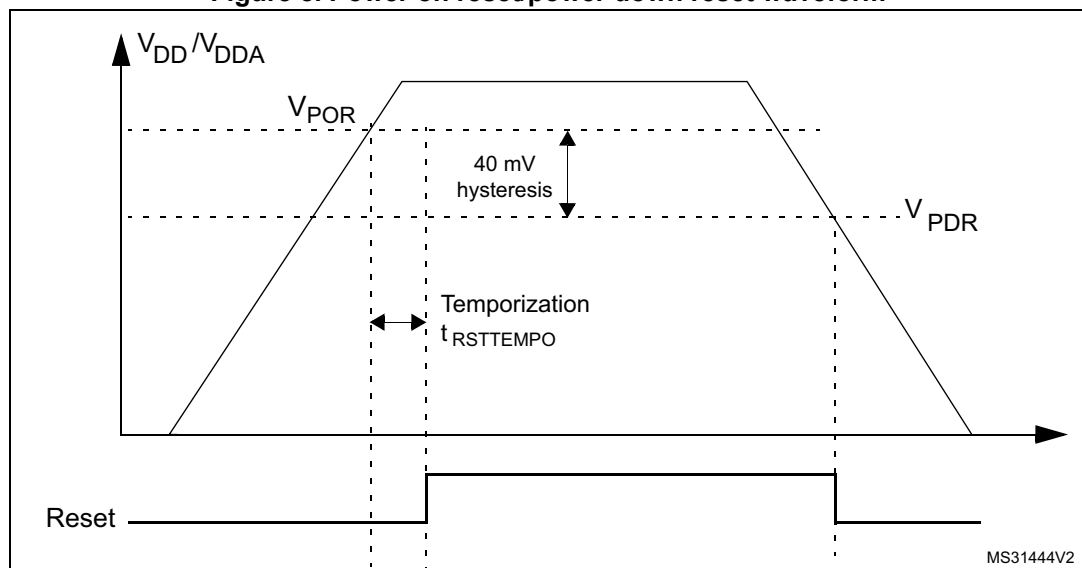
The device has an integrated power-on reset (POR) and power-down reset (PDR) circuits which are always active and ensure proper operation above a threshold of 2 V.

The device remains in Reset mode when the monitored supply voltage is below a specified threshold, $V_{POR/PDR}$, without the need for an external reset circuit.

- The POR monitors only the V_{DD} supply voltage. During the startup phase V_{DDA} must arrive first and be greater than or equal to V_{DD} .
- The PDR monitors both the V_{DD} and V_{DDA} supply voltages. However, the V_{DDA} power supply supervisor can be disabled (by programming a dedicated option bit $V_{DDA\_MONITOR}$) to reduce the power consumption if the application is designed to make sure that V_{DDA} is higher than or equal to V_{DD} .

For more details on the power on / power down reset threshold, refer to the electrical characteristics section in the datasheet.

Figure 8. Power on reset/power down reset waveform



6.3 Low-power modes

By default, the microcontroller is in Run mode after a system or a power Reset. Several low-power modes are available to save power when the CPU does not need to be kept running, for example when waiting for an external event. It is up to the user to select the mode that gives the best compromise between low-power consumption, short startup time and available wakeup sources.

The device features three low-power modes:

- Sleep mode (CPU clock off, all peripherals including ARM® Cortex®-M0 core peripherals like NVIC, SysTick, etc. are kept running)
- Stop mode (all clocks are stopped)
- Standby mode (1.8V domain powered-off)

In addition, the power consumption in Run mode can be reduce by one of the following means:

- Slowing down the system clocks
- Gating the clocks to the APB and AHB peripherals when they are unused.

Table 15. Low-power mode summary

Mode name	Entry	wakeup	Effect on 1.8V domain clocks	Effect on V _{DD} domain clocks	Voltage regulator
Sleep (Sleep now or Sleep-on - exit)	WFI	Any interrupt	CPU clock OFF no effect on other clocks or analog clock sources	None	ON
	WFE	Wakeup event			
Stop	PDDS and LPDS bits + SLEEPDEEP bit + WFI or WFE	Any EXTI line (configured in the EXTI registers)	All 1.8V domain clocks OFF	HSI and HSE oscillators OFF	ON or in low-power mode (depends on Power control register (PWR_CR))
Standby	PDDS bit + SLEEPDEEP bit + WFI or WFE	WKUP pin rising edge, RTC alarm, external reset in NRST pin, IWDG reset			OFF

6.3.1 Slowing down system clocks

In Run mode the speed of the system clocks (SYSCLK, HCLK, PCLK) can be reduced by programming the prescaler registers. These prescalers can also be used to slow down peripherals before entering Sleep mode.

For more details refer to [Section 7.4.2: Clock configuration register \(RCC_CFGR\)](#).

6.3.2 Peripheral clock gating

In Run mode, the AHB clock (HCLK) and the APB clock (PCLK) for individual peripherals and memories can be stopped at any time to reduce power consumption.

To further reduce power consumption in Sleep mode the peripheral clocks can be disabled prior to executing the WFI or WFE instructions.

Peripheral clock gating is controlled by the [AHB peripheral clock enable register \(RCC_AHBENR\)](#), the [APB peripheral clock enable register 2 \(RCC_APB2ENR\)](#) and the [APB peripheral clock enable register 1 \(RCC_APB1ENR\)](#).

6.3.3 Sleep mode

Entering Sleep mode

The Sleep mode is entered by executing the WFI (Wait For Interrupt) or WFE (Wait for Event) instructions. Two options are available to select the Sleep mode entry mechanism, depending on the SLEEPONEXIT bit in the ARM® Cortex®-M0 System Control register:

- Sleep-now: if the SLEEPONEXIT bit is cleared, the MCU enters Sleep mode as soon as WFI or WFE instruction is executed.
- Sleep-on-exit: if the SLEEPONEXIT bit is set, the MCU enters Sleep mode as soon as it exits the lowest priority ISR.

In the Sleep mode, all I/O pins keep the same state as in the Run mode.

Refer to [Table 16](#) and [Table 17](#) for details on how to enter Sleep mode.

Exiting Sleep mode

If the WFI instruction is used to enter Sleep mode, any peripheral interrupt acknowledged by the nested vectored interrupt controller (NVIC) can wake up the device from Sleep mode.

If the WFE instruction is used to enter Sleep mode, the MCU exits Sleep mode as soon as an event occurs. The wakeup event can be generated either by:

- enabling an interrupt in the peripheral control register but not in the NVIC, and enabling the SEVONPEND bit in the ARM® Cortex®-M0 System Control register. When the MCU resumes from WFE, the peripheral interrupt pending bit and the peripheral NVIC IRQ channel pending bit (in the NVIC interrupt clear pending register) have to be cleared.
- or configuring an external or internal EXTI line in event mode. When the CPU resumes from WFE, it is not necessary to clear the peripheral interrupt pending bit or the NVIC IRQ channel pending bit as the pending bit corresponding to the event line is not set.

This mode offers the lowest wakeup time as no time is wasted in interrupt entry/exit.

Refer to [Table 16](#) and [Table 17](#) for more details on how to exit Sleep mode.

Table 16. Sleep-now

Sleep-now mode	Description
Mode entry	WFI (Wait for Interrupt) or WFE (Wait for Event) while: – SLEEPDEEP = 0 and – SLEEPONEXIT = 0 Refer to the ARM® Cortex®-M0 System Control register.
Mode exit	If WFI was used for entry: Interrupt: Refer to Table 32: Vector table If WFE was used for entry: Wakeup event: Refer to Section 11.2.3: Event management
Wakeup latency	None

Table 17. Sleep-on-exit

Sleep-on-exit	Description
Mode entry	WFI (wait for interrupt) while: – SLEEPDEEP = 0 and – SLEEPONEXIT = 1 Refer to the ARM® Cortex®-M0 System Control register.
Mode exit	Interrupt: Refer to Table 32: Vector table .
Wakeup latency	None

6.3.4 Stop mode

The Stop mode is based on the ARM® Cortex®-M0 deep sleep mode combined with peripheral clock gating. The voltage regulator can be configured either in normal or low-power mode. In Stop mode, all clocks in the 1.8 V domain are stopped, the PLL, the HSI and the HSE oscillators are disabled. SRAM and register contents are preserved.

In the Stop mode, all I/O pins keep the same state as in the Run mode.

Entering Stop mode

Refer to [Table 18](#) for details on how to enter the Stop mode.

To further reduce power consumption in Stop mode, the internal voltage regulator can be put in low-power mode. This is configured by the LPDS bit of the [Power control register \(PWR_CR\)](#).

If Flash memory programming is ongoing, the Stop mode entry is delayed until the memory access is finished.

If an access to the APB domain is ongoing, The Stop mode entry is delayed until the APB access is finished.

In Stop mode, the following features can be selected by programming individual control bits:

- Independent watchdog (IWDG): the IWDG is started by writing to its Key register or by hardware option. Once started it cannot be stopped except by a Reset. See [Section 19.3: IWDG functional description](#) in [Section 19: Independent watchdog \(IWDG\)](#).

- real-time clock (RTC): this is configured by the RTCEN bit in the [RTC domain control register \(RCC_BDCR\)](#)
- Internal RC oscillator (LSI): this is configured by the LSION bit in the [Control/status register \(RCC_CSR\)](#).
- External 32.768 kHz oscillator (LSE): this is configured by the LSEON bit in the [RTC domain control register \(RCC_BDCR\)](#).

The ADC can also consume power during Stop mode, unless it is disabled before entering this mode. Refer to [ADC control register \(ADC_CR\)](#) for details on how to disable it.

Exiting Stop mode

Refer to [Table 18](#) for more details on how to exit Stop mode.

When exiting Stop mode by issuing an interrupt or a wakeup event, the HSI oscillator is selected as system clock.

When the voltage regulator operates in low-power mode, an additional startup delay is incurred when waking up from Stop mode. By keeping the internal regulator ON during Stop mode, the consumption is higher although the startup time is reduced.

Table 18. Stop mode

Stop mode	Description
Mode entry	WFI (Wait for Interrupt) or WFE (Wait for Event) while: – Set SLEEPDEEP bit in ARM® Cortex®-M0 System Control register – Clear PDDS bit in Power Control register (PWR_CR) – Select the voltage regulator mode by configuring LPDS bit in PWR_CR Note: To enter Stop mode, all EXTI Line pending bits (in Pending register (EXTI_PR)), all peripherals interrupt pending bits and RTC Alarm flag must be reset. Otherwise, the Stop mode entry procedure is ignored and program execution continues. If the application needs to disable the external oscillator (external clock) before entering Stop mode, the system clock source must be first switched to HSI and then clear the HSEON bit. Otherwise, if before entering Stop mode the HSEON bit is kept at 1, the security system (CSS) feature must be enabled to detect any external oscillator (external clock) failure and avoid a malfunction when entering Stop mode.
Mode exit	If WFI was used for entry: – Any EXTI Line configured in Interrupt mode (the corresponding EXTI Interrupt vector must be enabled in the NVIC). Refer to Table 32: Vector table. If WFE was used for entry: - Any EXTI Line configured in event mode. Refer to Section 11.2.3: Event management on page 173
Wakeup latency	HSI wakeup time + regulator wakeup time from Low-power mode

6.3.5 Standby mode

The Standby mode allows to achieve the lowest power consumption. It is based on the ARM® Cortex®-M0 deepsleep mode, with the voltage regulator disabled. The 1.8 V domain is consequently powered off. The PLL, the HSI oscillator and the HSE oscillator are also switched off. SRAM and register contents are lost except for registers in the Standby circuitry (see [Figure 7](#)).

Entering Standby mode

Refer to [Table 19](#) for more details on how to enter Standby mode.

In Standby mode, the following features can be selected by programming individual control bits:

- Independent watchdog (IWDG): the IWDG is started by writing to its Key register or by hardware option. Once started it cannot be stopped except by a reset. See [Section 19.3: IWDG functional description](#) in [Section 19: Independent watchdog \(IWDG\)](#).
- Real-time clock (RTC): this is configured by the RTCEN bit in the [RTC domain control register \(RCC_BDCR\)](#).
- Internal RC oscillator (LSI): this is configured by the LSION bit in the [Control/status register \(RCC_CSR\)](#).
- External 32.768 kHz oscillator (LSE): this is configured by the LSEON bit in the [RTC domain control register \(RCC_BDCR\)](#).

Exiting Standby mode

The microcontroller exits the Standby mode when an external reset (NRST pin), an IWDG reset, a rising edge on one of the enabled WKUPx pins or an RTC event occurs. All registers are reset after wakeup from Standby except for [Power control/status register \(PWR_CSR\)](#).

After waking up from Standby mode, program execution restarts in the same way as after a Reset (boot pin sampling, option bytes loading, reset vector is fetched, etc.). The SBF status flag in the [Power control/status register \(PWR_CSR\)](#) indicates that the MCU was in Standby mode.

Refer to [Table 19](#) for more details on how to exit Standby mode.

Table 19. Standby mode

Standby mode	Description
Mode entry	WFI (Wait for Interrupt) or WFE (Wait for Event) while: – Set SLEEPDEEP in ARM® Cortex®-M0 System Control register – Set PDDS bit in Power Control register (PWR_CR) – Clear WUF bit in Power Control/Status register (PWR_CSR)
Mode exit	WKUP pin rising edge, RTC alarm event's rising edge, external Reset in NRST pin, IWDG Reset.
Wakeup latency	Reset phase

I/O states in Standby mode

In Standby mode, all I/O pins are high impedance except:

- Reset pad (still available)
- PC13, PC14 and PC15 if configured by RTC or LSE
- WKUPx pins

Debug mode

By default, the debug connection is lost if the application puts the MCU in Stop or Standby mode while the debug features are used. This is due to the fact that the ARM[®] Cortex[®]-M0 core is no longer clocked.

However, by setting some configuration bits in the DBGMCU_CR register, the software can be debugged even when using the low-power modes extensively.

6.3.6 RTC wakeup from low-power mode

The RTC can be used to wakeup the MCU from low-power mode by means of the RTC alarm. For this purpose, two of the three alternative RTC clock sources can be selected by programming the RTCSEL[1:0] bits in the [RTC domain control register \(RCC_BDCR\)](#):

- Low-power 32.768 kHz external crystal oscillator (LSE OSC)
This clock source provides a precise time base with very low-power consumption (less than 1µA added consumption in typical conditions)
- Low-power internal RC Oscillator (LSI)
This clock source has the advantage of saving the cost of the 32.768 kHz crystal. This internal RC Oscillator is designed to add minimum power consumption.

To wakeup from Stop mode with an RTC alarm event, it is necessary to:

- Configure the EXTI Line 17 to be sensitive to rising edge
- Configure the RTC to generate the RTC alarm

To wakeup from Standby mode, there is no need to configure the EXTI Line 17.

6.4 Power control registers

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

6.4.1 Power control register (PWR_CR)

Address offset: 0x00

Reset value: 0x0000 0000 (reset by wakeup from Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res	Res	Res	Res	Res	Res	Res	DBP	Res	Res	Res	Res	CSBF	CWUF	PDDS	LPDS
							rw					rc_w1	rc_w1	rw	rw

Bits 31:9 Reserved, must be kept at reset value.

Bit 8 **DBP**: Disable RTC domain write protection.

In reset state, the RTC registers are protected against parasitic write access. This bit must be set to enable write access to these registers.

0: Access to RTC disabled

1: Access to RTC enabled

Bits 7:4 Reserved, must be kept at reset value

Bit 3 **CSBF**: Clear standby flag.

This bit is always read as 0.

0: No effect

1: Clear the SBF Standby Flag (write).

Bit 2 **CWUF**: Clear wakeup flag.

This bit is always read as 0.

0: No effect

1: Clear the WUF Wakeup Flag **after 2 System clock cycles**. (write)

Bit 1 **PDDS**: Power down deepsleep.

This bit is set and cleared by software. It works together with the LPDS bit.

0: Enter Stop mode when the CPU enters Deepsleep. The regulator status depends on the LPDS bit.

1: Enter Standby mode when the CPU enters Deepsleep.

Bit 0 **LPDS**: Low-power deepsleep.

This bit is set and cleared by software. It works together with the PDDS bit.

0: Voltage regulator on during Stop mode

1: Voltage regulator in low-power mode during Stop mode

Note: When a peripheral that can work in STOP mode requires a clock, the Power controller automatically switch the voltage regulator from Low-power mode to Normal mode and remains in this mode until the request disappears.

6.4.2 Power control/status register (PWR_CSR)

Address offset: 0x04

Reset value: 0x0000 000X (not reset by wakeup from Standby mode)

Additional APB cycles are needed to read this register versus a standard APB read.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	EWUP 7	EWUP 6	EWUP 5	EWUP 4	Res.	EWUP 2	EWUP 1	Res	Res	Res	Res	Res	Res	SBF	WUF
	rw	rw	rw	rw		rw	rw							r	r

Bits 31:15 Reserved, must be kept at reset value.

Bits 14:11 **EWUPx**: Enable WKUPx pin (available only on STM32F070xB and STM32F030xC devices)

These bits are set and cleared by software.

0: WKUPx pin is used for general purpose I/O. An event on the WKUPx pin does not wakeup the device from Standby mode.

1: WKUPx pin is used for wakeup from Standby mode and forced in input pull down configuration (rising edge on WKUPx pin wakes-up the system from Standby mode).

Note: These bits are reset by a system Reset.

Bit 10 Reserved, must be kept at reset value.

Bits 9:8 **EWUPx**: Enable WKUPx pin

These bits are set and cleared by software.

0: WKUPx pin is used for general purpose I/O. An event on the WKUPx pin does not wakeup the device from Standby mode.

1: WKUPx pin is used for wakeup from Standby mode and forced in input pull down configuration (rising edge on WKUPx pin wakes-up the system from Standby mode).

Note: These bits are reset by a system Reset.

Bits 7:2 Reserved, must be kept at reset value.

Bit 1 **SBF**: Standby flag

This bit is set by hardware when the device enters Standby mode and it is cleared only by a POR/PDR (power on reset/power down reset) or by setting the CSBF bit in the [Power control register \(PWR_CR\)](#)

0: Device has not been in Standby mode

1: Device has been in Standby mode

Bit 0 **WUF**: Wakeup flag

This bit is set by hardware to indicate that the device received a wakeup event. It is cleared by a system reset or by setting the CWUF bit in the [Power control register \(PWR_CR\)](#)

0: No wakeup event occurred

1: A wakeup event was received from one of the enabled WKUPx pins or from the RTC alarm.

Note: An additional wakeup event is detected if one WKUPx pin is enabled (by setting the EWUPx bit) when its pin level is already high.

6.4.3 PWR register map

The following table summarizes the PWR register map and reset values.

Table 20. PWR register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x000	PWR_CR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBP	Res.	Res.	Res.	Res.	CSBF	CWUF	PDDS	LPDS	
	Reset value																								0					0	0	0	0	
0x004	PWR_CSR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EWUP7(1)	EWUP6(1)	EWUP5(1)	EWUP4(1)	Res.	EWUP2	EWUP1	Res.	Res.	Res.	Res.	Res.	SBF	WUF		
	Reset value																		0	0	0	0		0	0						0	0	0	0

1. Available on STM32F070xB and STM32F030xC devices only.

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

7 Reset and clock control (RCC)

7.1 Reset

There are three types of reset, defined as system reset, power reset and RTC domain reset.

7.1.1 Power reset

A power reset is generated when one of the following events occurs:

1. Power-on/power-down reset (POR/PDR reset)
2. When exiting Standby mode

A power reset sets all registers to their reset values.

7.1.2 System reset

A system reset sets all registers to their reset values except the reset flags in the clock controller CSR register.

A system reset is generated when one of the following events occurs:

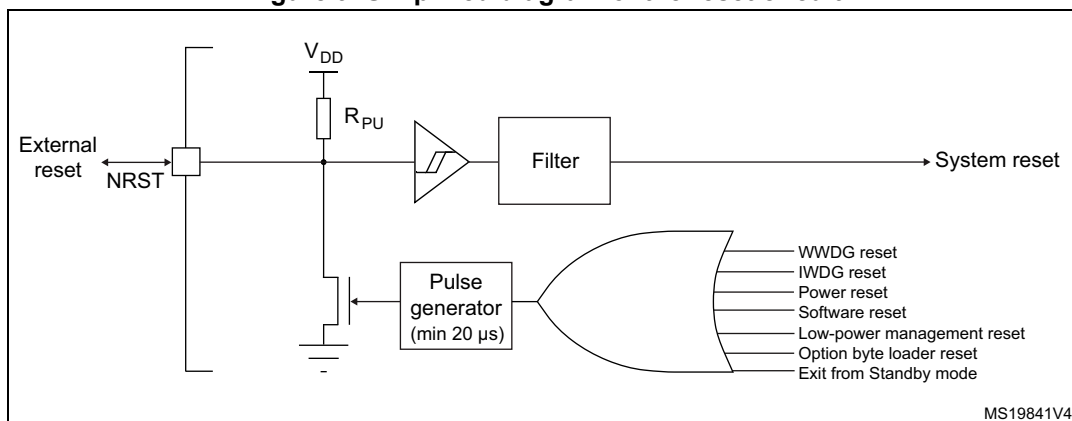
1. A low level on the NRST pin (external reset)
2. Window watchdog event (WWDG reset)
3. Independent watchdog event (IWDG reset)
4. A software reset (SW reset) (see [Software reset](#))
5. Low-power management reset (see [Low-power management reset](#))
6. Option byte loader reset (see [Option byte loader reset](#))
7. A power reset

The reset source can be identified by checking the reset flags in the Control/Status register, RCC_CSR (see [Section 7.4.10: Control/status register \(RCC_CSR\)](#)).

These sources act on the NRST pin and it is always kept low during the delay phase. The RESET service routine vector is fixed at address 0x0000_0004 in the memory map.

The system reset signal provided to the device is output on the NRST pin. The pulse generator guarantees a minimum reset pulse duration of 20 μ s for each internal reset source. In case of an external reset, the reset pulse is generated while the NRST pin is asserted low.

Figure 9. Simplified diagram of the reset circuit



Software reset

The SYSRESETREQ bit in ARM® Cortex®-M0 Application Interrupt and Reset Control Register must be set to force a software reset on the device. Refer to the *Cortex™-M0 technical reference manual* for more details.

Low-power management reset

There are two ways to generate a low-power management reset:

1. Reset generated when entering Standby mode:
This type of reset is enabled by resetting nRST_STDBY bit in User Option Bytes. In this case, whenever a Standby mode entry sequence is successfully executed, the device is reset instead of entering Standby mode.
2. Reset when entering Stop mode:
This type of reset is enabled by resetting nRST_STOP bit in User Option Bytes. In this case, whenever a Stop mode entry sequence is successfully executed, the device is reset instead of entering Stop mode.

For further information on the User Option Bytes, refer to [Section 4: Option bytes](#).

Option byte loader reset

The option byte loader reset is generated when the OBL_LAUNCH bit (bit 13) is set in the FLASH_CR register. This bit is used to launch the option byte loading by software.

7.1.3 RTC domain reset

An RTC domain reset only affects the LSE oscillator, the RTC and the RCC [RTC domain control register \(RCC_BDCR\)](#). It is generated when one of the following events occurs.

1. Software reset, triggered by setting the BDRST bit in the [RTC domain control register \(RCC_BDCR\)](#).
2. A POR reset.

7.2 Clocks

Various clock sources can be used to drive the system clock (SYSCLK):

- HSI 8 MHz RC oscillator clock
- HSE oscillator clock
- PLL clock

The devices have the following additional clock sources:

- 40 kHz low speed internal RC (LSI RC) which drives the independent watchdog and optionally the RTC used for Auto-wakeup from Stop/Standby mode.
- 32.768 kHz low speed external crystal (LSE crystal) which optionally drives the real-time clock (RTCCLK)
- 14 MHz high speed internal RC (HSI14) dedicated for ADC.

Each clock source can be switched on or off independently when it is not used, to optimize power consumption.

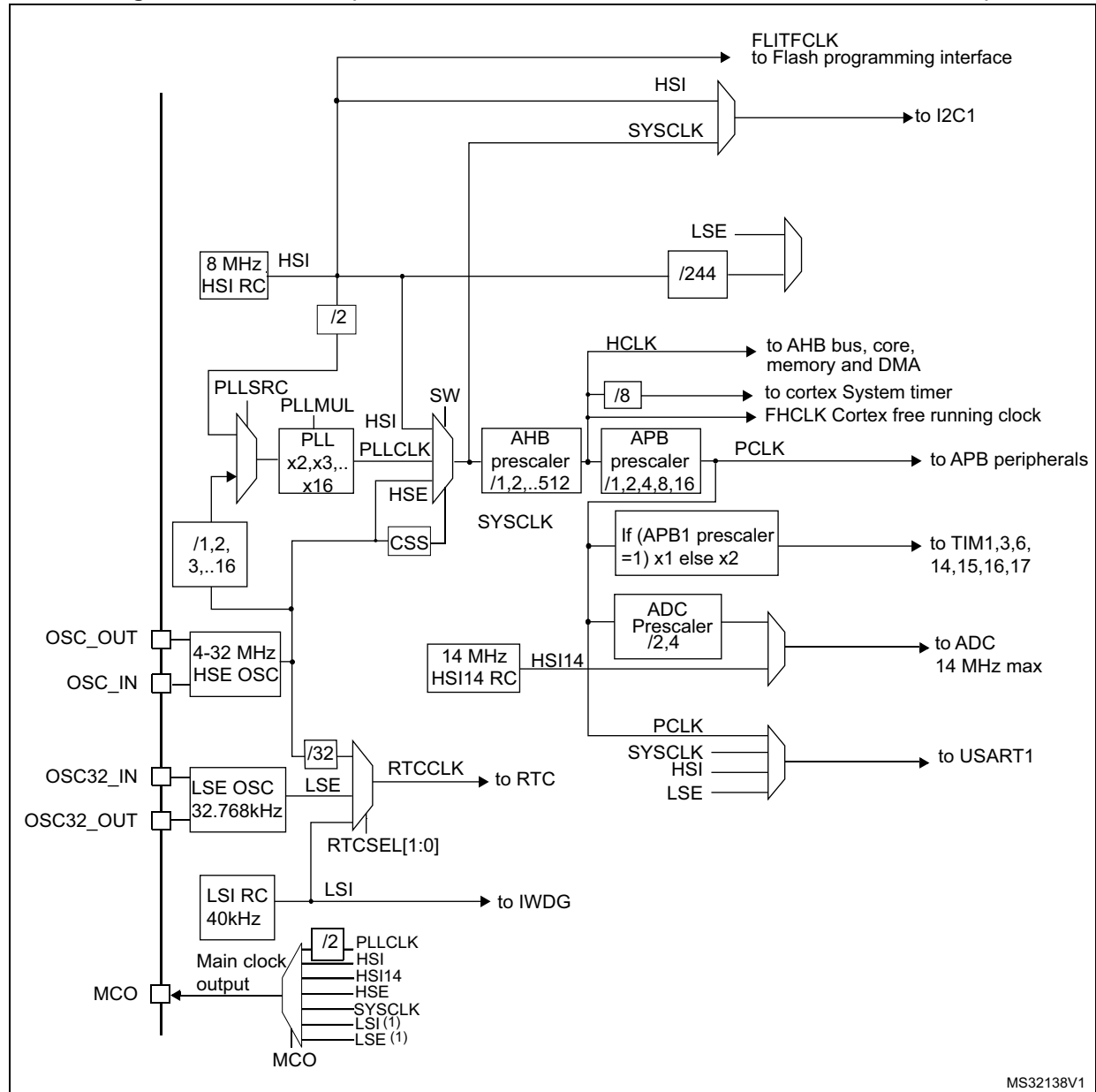
Several prescalers can be used to configure the frequency of the AHB and the APB domains. The AHB and the APB domains maximum frequency is 48 MHz.

All the peripheral clocks are derived from their bus clock (HCLK for AHB or PCLK for APB) except:

- The Flash memory programming interface clock (FLITFCLK) which is always the HSI clock.
- The option byte loader clock which is always the HSI clock
- The ADC clock which is derived (selected by software) from one of the two following sources:
 - dedicated HSI14 clock, to run always at the maximum sampling rate
 - APB clock (PCLK) divided by 2 or 4
- The USART1 clock which is derived (selected by software) from one of the four following sources:
 - system clock
 - HSI clock
 - LSE clock
 - APB clock (PCLK)
- The I2C1 clock which is derived (selected by software) from one of the two following sources:
 - system clock
 - HSI clock
- The USB clock which is derived (selected by software) from the following source:
 - PLL clock
- The RTC clock which is derived from the LSE, LSI or from the HSE clock divided by 32.
- The timer clock frequencies are automatically fixed by hardware. There are two cases:
 - if the APB prescaler is 1, the timer clock frequencies are set to the same frequency as that of the APB domain;
 - otherwise, they are set to twice (x2) the frequency of the APB domain.
- The IWDG clock which is always the LSI clock.

The RCC feeds the Cortex System Timer (SysTick) external clock with the AHB clock (HCLK) divided by 8. The SysTick can work either with this clock or directly with the Cortex clock (HCLK), configurable in the SysTick Control and Status Register.

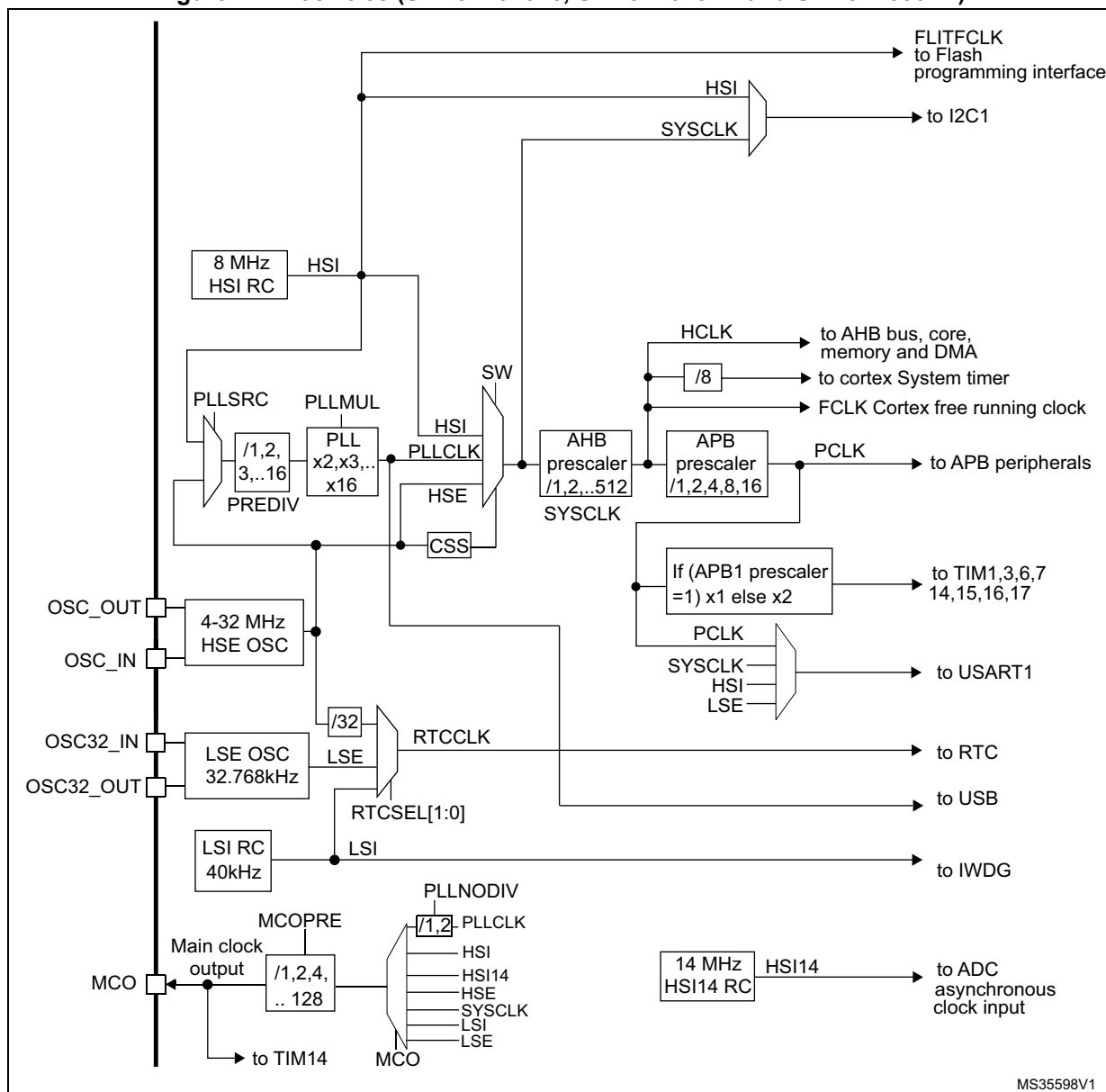
Figure 10. Clock tree (STM32F030x4, STM32F030x6 and STM32F030x8 devices)



MS32138V1

1. LSI/LSE is not available on STM32F030x8 devices.

Figure 11. Clock tree (STM32F070x6, STM32F070xB and STM32F030xC)



MS35598V1

FCLK acts as ARM® Cortex®-M0's free-running clock. For more details refer to the *ARM Cortex™-M0 r0p0 technical reference manual (TRM)*.

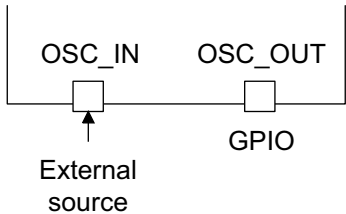
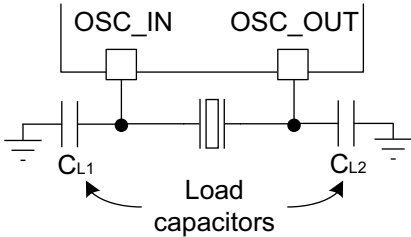
7.2.1 HSE clock

The high speed external clock signal (HSE) can be generated from two possible clock sources:

- HSE external crystal/ceramic resonator
- HSE user external clock

The resonator and the load capacitors have to be placed as close as possible to the oscillator pins in order to minimize output distortion and startup stabilization time. The loading capacitance values must be adjusted according to the selected oscillator.

Figure 12. HSE/ LSE clock sources

Clock source	Hardware configuration
External clock	 MSv31915V1
Crystal/Ceramic resonators	 MSv31916V1

External crystal/ceramic resonator (HSE crystal)

The 4 to 32 MHz external oscillator has the advantage of producing a very accurate rate on the main clock.

The associated hardware configuration is shown in [Figure 12](#). Refer to the electrical characteristics section of the *datasheet* for more details.

The HSERDY flag in the [Clock control register \(RCC_CR\)](#) indicates if the HSE oscillator is stable or not. At startup, the clock is not released until this bit is set by hardware. An interrupt can be generated if enabled in the [Clock interrupt register \(RCC_CIR\)](#).

The HSE Crystal can be switched on and off using the HSEON bit in the [Clock control register \(RCC_CR\)](#).

For code example refer to the Appendix section [A.3.1: HSE start sequence code example](#).

Caution: To switch ON the HSE oscillator, 512 HSE clock pulses need to be seen by an internal stabilization counter after the HSEON bit is set. Even in the case that no crystal or resonator is connected to the device, excessive external noise on the OSC_IN pin may still lead the oscillator to start. Once the oscillator is started, it needs another 6 HSE clock pulses to complete a switching OFF sequence. If for any reason the oscillations are no more present on the OSC_IN pin, the oscillator cannot be switched OFF, locking the OSC pins from any other use and introducing unwanted power consumption. To avoid such situation, it is strongly recommended to always enable the Clock Security System (CSS) which is able to switch OFF the oscillator even in this case.

External source (HSE bypass)

In this mode, an external clock source must be provided. It can have a frequency of up to 32 MHz. You select this mode by setting the HSEBYP and HSEON bits in the [Clock control register \(RCC_CR\)](#). The external clock signal (square, sinus or triangle) with ~40-60% duty cycle depending on the frequency (refer to the *datasheet*) has to drive the OSC_IN pin while the OSC_OUT pin can be used a GPIO. See [Figure 12](#).

7.2.2 HSI clock

The HSI clock signal is generated from an internal 8 MHz RC oscillator and can be used directly as a system clock or for PLL input

The HSI RC oscillator has the advantage of providing a clock source at low cost (no external components). It also has a faster startup time than the HSE crystal oscillator however, even with calibration the frequency is less accurate than an external crystal oscillator or ceramic resonator.

Calibration

RC oscillator frequencies can vary from one chip to another due to manufacturing process variations, this is why each device is factory calibrated by ST for 1% accuracy at $T_A=25^{\circ}\text{C}$.

After reset, the factory calibration value is loaded in the HSICAL[7:0] bits in the [Clock control register \(RCC_CR\)](#).

If the application is subject to voltage or temperature variations this may affect the RC oscillator speed. You can trim the HSI frequency in the application using the HSITRIM[4:0] bits in the [Clock control register \(RCC_CR\)](#).

For more details on how to measure the HSI frequency variation please refer to [Section 7.2.12: Internal/external clock measurement with TIM14 on page 97](#).

The HSIRDY flag in the [Clock control register \(RCC_CR\)](#) indicates if the HSI RC is stable or not. At startup, the HSI RC output clock is not released until this bit is set by hardware.

The HSI RC can be switched on and off using the HSION bit in the [Clock control register \(RCC_CR\)](#).

The HSI signal can also be used as a backup source (Auxiliary clock) if the HSE crystal oscillator fails. Refer to [Section 7.2.7: Clock security system \(CSS\) on page 95](#).

Furthermore it is possible to drive the HSI clock to the MCO multiplexer. Then the clock could be driven to the Timer 14 giving the ability to the user to calibrate the oscillator.

7.2.3 PLL

The internal PLL can be used to multiply the HSI and the HSE output clock frequency. Refer to [Figure 9: Simplified diagram of the reset circuit](#), [Figure 12: HSE/ LSE clock sources](#) and [Clock control register \(RCC_CR\)](#).

The PLL configuration (selection of the input clock, predivider and multiplication factor) must be done before enabling the PLL. Once the PLL is enabled, these parameters cannot be changed.

To modify the PLL configuration, proceed as follows:

1. Disable the PLL by setting PLLON to 0.
2. Wait until PLLRDY is cleared. The PLL is now fully stopped.
3. Change the desired parameter.
4. Enable the PLL again by setting PLLON to 1.
5. Wait until PLLRDY is set.

An interrupt can be generated when the PLL is ready, if enabled in the [Clock interrupt register \(RCC_CIR\)](#).

The PLL output frequency must be set in the range 16-48 MHz.

For code example refer to the Appendix section [A.3.2: PLL configuration modification code example](#).

7.2.4 LSE clock

The LSE crystal is a 32.768 kHz Low Speed External crystal or ceramic resonator. It has the advantage of providing a low-power but highly accurate clock source to the real-time clock peripheral (RTC) for clock/calendar or other timing functions.

The LSE crystal is switched on and off using the LSEON bit in [RTC domain control register \(RCC_BDCR\)](#). The crystal oscillator driving strength can be changed at runtime using the LSEDRV[1:0] bits in the [RTC domain control register \(RCC_BDCR\)](#) to obtain the best compromise between robustness and short start-up time on one side and low-power consumption on the other.

The LSERDY flag in the [RTC domain control register \(RCC_BDCR\)](#) indicates whether the LSE crystal is stable or not. At startup, the LSE crystal output clock signal is not released until this bit is set by hardware. An interrupt can be generated if enabled in the [Clock interrupt register \(RCC_CIR\)](#).

Caution: To switch ON the LSE oscillator, 4096 LSE clock pulses need to be seen by an internal stabilization counter after the LSEON bit is set. Even in the case that no crystal or resonator is connected to the device, excessive external noise on the OSC32_IN pin may still lead the oscillator to start. Once the oscillator is started, it needs another 6 LSE clock pulses to complete a switching OFF sequence. If for any reason the oscillations are no more present on the OSC_IN pin, the oscillator cannot be switched OFF, locking the OSC32 pins from any other use and introducing unwanted power consumption. The only way to recover such situation is to perform the RTC domain reset by software.

External source (LSE bypass)

In this mode, an external clock source must be provided. It can have a frequency of up to 1 MHz. You select this mode by setting the LSEBYP and LSEON bits in the [RTC domain control register \(RCC_BDCR\)](#). The external clock signal (square, sinus or triangle) with ~50% duty cycle has to drive the OSC32_IN pin while the OSC32_OUT pin can be used as GPIO. See [Figure 12](#).

7.2.5 LSI clock

The LSI RC acts as a low-power clock source that can be kept running in Stop and Standby mode for the independent watchdog (IWDG) and RTC. The clock frequency is around 40 kHz. For more details, refer to the electrical characteristics section of the datasheets.

The LSI RC can be switched on and off using the LSION bit in the [Control/status register \(RCC_CSR\)](#).

The LSIRDY flag in the [Control/status register \(RCC_CSR\)](#) indicates if the LSI oscillator is stable or not. At startup, the clock is not released until this bit is set by hardware. An interrupt can be generated if enabled in the [Clock interrupt register \(RCC_CIR\)](#).

7.2.6 System clock (SYSCLK) selection

Various clock sources can be used to drive the system clock (SYSCLK):

- HSI oscillator
- HSE oscillator
- PLL

After a system reset, the HSI oscillator is selected as system clock. When a clock source is used directly or through the PLL as a system clock, it is not possible to stop it.

A switch from one clock source to another occurs only if the target clock source is ready (clock stable after startup delay or PLL locked). If a clock source which is not yet ready is selected, the switch will occur when the clock source becomes ready. Status bits in the [Clock control register \(RCC_CR\)](#) indicate which clock(s) is (are) ready and which clock is currently used as a system clock.

7.2.7 Clock security system (CSS)

Clock Security System can be activated by software. In this case, the clock detector is enabled after the HSE oscillator startup delay, and disabled when this oscillator is stopped.

If a failure is detected on the HSE clock, the HSE oscillator is automatically disabled, a clock failure event is sent to the break input of the advanced-control timers (TIM1) and general-purpose timers (TIM15, TIM16 and TIM17) and an interrupt is generated to inform the software about the failure (Clock Security System Interrupt CSSI), allowing the MCU to

perform rescue operations. The CSSI is linked to the ARM® Cortex®-M0 NMI (Non-Maskable Interrupt) exception vector.

Note: Once the CSS is enabled and if the HSE clock fails, the CSS interrupt occurs and an NMI is automatically generated. The NMI will be executed indefinitely unless the CSS interrupt pending bit is cleared. As a consequence, in the NMI ISR user must clear the CSS interrupt by setting the CSSC bit in the [Clock interrupt register \(RCC_CIR\)](#).

If the HSE oscillator is used directly or indirectly as the system clock (indirectly means: it is used as PLL input clock, and the PLL clock is used as system clock), a detected failure causes a switch of the system clock to the HSI oscillator and the disabling of the HSE oscillator. If the HSE clock (divided or not) is the clock entry of the PLL used as system clock when the failure occurs, the PLL is disabled too.

7.2.8 ADC clock

The ADC clock selection is done inside the ADC_CFGR2 (refer to [Section 12.11.5: ADC configuration register 2 \(ADC_CFGR2\) on page 216](#)). It can be either the dedicated 14 MHz RC oscillator (HSI14) or PCLK divided by 2 or 4. The 14 MHz RC oscillator can be configured by software either to be turned on/off (“auto-off mode”) by the ADC interface or to be always enabled. The HSI 14 MHz RC oscillator cannot be turned on by ADC interface when the APB clock is selected as an ADC kernel clock.

7.2.9 RTC clock

The RTCCLK clock source can be either the HSE/32, LSE or LSI clocks. This is selected by programming the RTCSEL[1:0] bits in the [RTC domain control register \(RCC_BDCR\)](#). This selection cannot be modified without resetting the RTC domain. The system must be always configured in a way that the PCLK frequency is greater then or equal to the RTCCLK frequency for proper operation of the RTC.

7.2.10 Independent watchdog clock

If the Independent watchdog (IWDG) is started by either hardware option or software access, the LSI oscillator is forced ON and cannot be disabled. After the LSI oscillator temporization, the clock is provided to the IWDG.

7.2.11 Clock-out capability

The microcontroller clock output (MCO) capability allows the clock to be output onto the external MCO pin. The configuration registers of the corresponding GPIO port must be programmed in alternate function mode. One of the following clock signals can be selected as the MCO clock:

- HSI14
- SYSCCLK
- HSI
- HSE
- PLL clock divided by 2 or direct (direct connection is not available on STM32F030x8 devices)
- LSE
- LSI

The selection is controlled by the MCO[3:0] bits of the *Clock configuration register (RCC_CFGR)*.

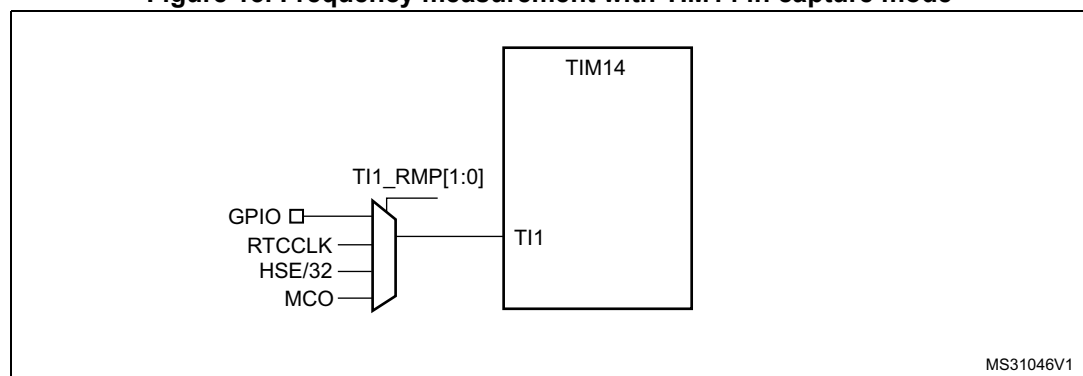
For code example refer to the Appendix section *A.3.3: MCO selection code example*.

On STM32F030x4, STM32F030x6, STM32F070x6, STM32F070xB and STM32F030xC devices, the additional bit PLLNODIV of this register controls the divider bypass for a PLL clock input to MCO. The MCO frequency can be reduced by a configurable binary divider, controlled by the MCOPRE[2..0] bits of the *Clock configuration register (RCC_CFGR)*.

7.2.12 Internal/external clock measurement with TIM14

It is possible to indirectly measure the frequency of all on-board clock sources by mean of the TIM14 channel 1 input capture. As represented on *Figure 13*.

Figure 13. Frequency measurement with TIM14 in capture mode



The input capture channel of the Timer 14 can be a GPIO line or an internal clock of the MCU. This selection is performed through the TI1_RMP [1:0] bits in the TIM14_OR register. The possibilities available are the following ones.

- TIM14 Channel1 is connected to the GPIO. Refer to the alternate function mapping in the device datasheets.
- TIM14 Channel1 is connected to the RTCCLK.
- TIM14 Channel1 is connected to the HSE/32 Clock.
- TIM14 Channel1 is connected to the microcontroller clock output (MCO). Refer to *Section 7.2.11: Clock-out capability* for MCO clock configuration.

For code example refer to the Appendix section *A.3.4: Clock measurement configuration with TIM14 code example*.

Calibration of the HSI

The primary purpose of connecting the LSE, through the MCO multiplexer, to the channel 1 input capture is to be able to precisely measure the HSI system clocks (for this, the HSI should be used as the system clock source). The number of HSI clock counts between consecutive edges of the LSE signal provides a measure of the internal clock period. Taking advantage of the high precision of LSE crystals (typically a few tens of ppm), it is possible to determine the internal clock frequency with the same resolution, and trim the source to compensate for manufacturing-process- and/or temperature- and voltage-related frequency deviations.

The HSI oscillator has dedicated user-accessible calibration bits for this purpose.

The basic concept consists in providing a relative measurement (e.g. the HSI/LSE ratio): the precision is therefore closely related to the ratio between the two clock sources. The higher the ratio is, the better the measurement will be.

If LSE is not available, HSE/32 will be the better option in order to reach the most precise calibration possible.

Calibration of the LSI

The calibration of the LSI will follow the same pattern that for the HSI, but changing the reference clock. It will be necessary to connect LSI clock to the channel 1 input capture of the TIM14. Then define the HSE as system clock source, the number of its clock counts between consecutive edges of the LSI signal provides a measure of the internal low speed clock period.

The basic concept consists in providing a relative measurement (e.g. the HSE/LSI ratio): the precision is therefore closely related to the ratio between the two clock sources. The higher the ratio is, the better the measurement will be.

Calibration of the HSI14

For the HSI14, because of its high frequency, it is not possible to have a precise resolution. However a solution could be to clock Timer 14 with HSE through PLL to reach 48 MHz, and to use the input capture line with the HSI14 and the capture prescaler defined to the higher value. In that configuration, we got a ratio of 27 events. It is still a bit low to have an accurate calibration. In order to increase the measure accuracy, it is advised to count the HSI periods after multiple cycles of Timer 14. Using polling to treat the capture event will be necessary in this case.

7.3 Low-power modes

APB peripheral clocks and DMA clock can be disabled by software.

Sleep mode stops the CPU clock. The memory interface clocks (Flash and RAM interfaces) can be stopped by software during sleep mode. The AHB to APB bridge clocks are disabled by hardware during Sleep mode when all the clocks of the peripherals connected to them are disabled.

Stop mode stops all the clocks in the core supply domain and disables the PLL and the HSI, HSI14 and HSE oscillators.

Standby mode stops all the clocks in the core supply domain and disables the PLL and the HSI, HSI14 and HSE oscillators.

The CPU's deepsleep mode can be overridden for debugging by setting the DBG_STOP or DBG_STANDBY bits in the DBGMCU_CR register.

When waking up from deepsleep after an interrupt (Stop mode) or reset (Standby mode), the HSI oscillator is selected as system clock.

If a Flash programming operation is on going, deepsleep mode entry is delayed until the Flash interface access is finished. If an access to the APB domain is ongoing, deepsleep mode entry is delayed until the APB access is finished.

7.4 RCC registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

7.4.1 Clock control register (RCC_CR)

Address offset: 0x00

Reset value: 0x0000 XX83 where X is undefined.

Access: no wait state, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	PLL RDY	PLLON	Res.	Res.	Res.	Res.	CSS ON	HSE BYP	HSE RDY	HSE ON
						r	rw					rw	rw	r	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
HSICAL[7:0]								HSITRIM[4:0]					Res.	HSI RDY	HSION
r	r	r	r	r	r	r	r	rw	rw	rw	rw	rw		r	rw

Bits 31:26 Reserved, must be kept at reset value.

Bit 25 **PLL RDY**: PLL clock ready flag

Set by hardware to indicate that the PLL is locked.

0: PLL unlocked

1: PLL locked

Bit 24 **PLLON**: PLL enable

Set and cleared by software to enable PLL.

Cleared by hardware when entering Stop or Standby mode. This bit can not be reset if the PLL clock is used as system clock or is selected to become the system clock.

0: PLL OFF

1: PLL ON

Bits 23:20 Reserved, must be kept at reset value.

Bit 19 **CSSON**: Clock security system enable

Set and cleared by software to enable the clock security system. When CSSON is set, the clock detector is enabled by hardware when the HSE oscillator is ready, and disabled by hardware if a HSE clock failure is detected.

0: Clock security system disabled (clock detector OFF).

1: Clock security system enabled (clock detector ON if the HSE is ready, OFF if not).

Bit 18 **HSEBYP**: HSE crystal oscillator bypass

Set and cleared by software to bypass the oscillator with an external clock. The external clock must be enabled with the HSEON bit set, to be used by the device. The HSEBYP bit can be written only if the HSE oscillator is disabled.

0: HSE crystal oscillator not bypassed

1: HSE crystal oscillator bypassed with external clock

Bit 17 **HSERDY**: HSE clock ready flag

Set by hardware to indicate that the HSE oscillator is stable. This bit needs 6 cycles of the HSE oscillator clock to fall down after HSEON reset.

- 0: HSE oscillator not ready
- 1: HSE oscillator ready

Bit 16 **HSEON**: HSE clock enable

Set and cleared by software.

Cleared by hardware to stop the HSE oscillator when entering Stop or Standby mode. This bit cannot be reset if the HSE oscillator is used directly or indirectly as the system clock.

- 0: HSE oscillator OFF
- 1: HSE oscillator ON

Bits 15:8 **HSICAL[7:0]**: HSI clock calibration

These bits are initialized automatically at startup. They are adjusted by SW through the HSITRIM setting.

Bits 7:3 **HSITRIM[4:0]**: HSI clock trimming

These bits provide an additional user-programmable trimming value that is added to the HSICAL[7:0] bits. It can be programmed to adjust to variations in voltage and temperature that influence the frequency of the HSI.

The default value is 16, which, when added to the HSICAL value, should trim the HSI to 8 MHz $\pm$ 1%. The trimming step is around 40 kHz between two consecutive HSICAL steps.

Note: Increased value in the register results to higher clock frequency.

Bit 2 Reserved, must be kept at reset value.

Bit 1 **HSIRDY**: HSI clock ready flag

Set by hardware to indicate that HSI oscillator is stable. After the HSION bit is cleared, HSIRDY goes low after 6 HSI oscillator clock cycles.

- 0: HSI oscillator not ready
- 1: HSI oscillator ready

Bit 0 **HSION**: HSI clock enable

Set and cleared by software.

Set by hardware to force the HSI oscillator ON when leaving Stop or Standby mode or in case of failure of the HSE crystal oscillator used directly or indirectly as system clock. This bit cannot be reset if the HSI is used directly or indirectly as system clock or is selected to become the system clock.

- 0: HSI oscillator OFF
- 1: HSI oscillator ON

7.4.2 Clock configuration register (RCC_CFGR)

Address offset: 0x04

Reset value: 0x0000 0000

Access: 0 ≤ wait state ≤ 2, word, half-word and byte access

1 or 2 wait states inserted only if the access occurs during clock source switch.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PLL NODIV	MCOPRE[2:0]			MCO[3:0]				Res.	Res.	PLLMUL[3:0]				PLL XTPRE	PLL SRC
rw	rw	rw	rw	rw	rw	rw	rw			rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	ADC PRE	Res.	Res.	Res.	PPRE[2:0]			HPRE[3:0]			SWS[1:0]		SW[1:0]		
	rw				rw	rw	rw	rw	rw	rw	rw	r	r	rw	rw

Bit 31 **PLLNODIV**: PLL clock not divided for MCO (not available on STM32F030x8 devices)

This bit is set and cleared by software. It switches off divider by 2 for PLL connection to MCO.

0: PLL is divided by 2 for MCO

1: PLL is not divided for MCO

Bits 30:28 **MCOPRE[2:0]**: Microcontroller Clock Output Prescaler (not available on STM32F030x8 devices)

These bits are set and cleared by software to select the MCO prescaler division factor. To avoid glitches, it is highly recommended to change this prescaler only when the MCO output is disabled.

000: MCO is divided by 1

001: MCO is divided by 2

010: MCO is divided by 4

.....

111: MCO is divided by 128

Bits 27:24 **MCO[3:0]**: Microcontroller clock output

Set and cleared by software.

0000: MCO output disabled, no clock on MCO

0001: Internal RC 14 MHz (HSI14) oscillator clock selected

0010: Internal low speed (LSI) oscillator clock selected

0011: External low speed (LSE) oscillator clock selected

0100: System clock selected

0101: Internal RC 8 MHz (HSI) oscillator clock selected

0110: External 4-32 MHz (HSE) oscillator clock selected

0111: PLL clock selected (divided by 1 or 2, depending on PLLNODIV)

1xxx: Reserved, must be kept at reset value.

Note: This clock output may have some truncated cycles at startup or during MCO clock source switching.

Bits 23:22 Reserved, must be kept at reset value.

Bits 21:18 **PLLMUL[3:0]**: PLL multiplication factor

These bits are written by software to define the PLL multiplication factor. These bits can be written only when PLL is disabled.

Caution: The PLL output frequency must not exceed 48 MHz.

0000: PLL input clock x 2
 0001: PLL input clock x 3
 0010: PLL input clock x 4
 0011: PLL input clock x 5
 0100: PLL input clock x 6
 0101: PLL input clock x 7
 0110: PLL input clock x 8
 0111: PLL input clock x 9
 1000: PLL input clock x 10
 1001: PLL input clock x 11
 1010: PLL input clock x 12
 1011: PLL input clock x 13
 1100: PLL input clock x 14
 1101: PLL input clock x 15
 1110: PLL input clock x 16
 1111: PLL input clock x 16

Bit 17 **PLLXTPRE**: HSE divider for PLL input clock

This bit is the same bit as bit PREDIV[0] from RCC_CFGR2. Refer to RCC_CFGR2 PREDIV bits description for its meaning.

Bit 16 **PLLSRC**: PLL entry clock source

Set and cleared by software to select PLL clock source. This bit can be written only when PLL is disabled.

0: HSI/2 selected as PLL input clock
 1: HSE/PREDIV selected as PLL input clock (refer to [Section 7.4.12: Clock configuration register 2 \(RCC_CFGR2\) on page 122](#))

Bit 15 Reserved, must be kept at reset value.

Bit 14 **ADCPRE**: ADC prescaler

Obsolete setting. Proper ADC clock selection is done inside the ADC_CFGR2 (refer to [Section 12.11.5: ADC configuration register 2 \(ADC_CFGR2\) on page 216](#)).

Bits 13:11 Reserved, must be kept at reset value.

Bits 10:8 **PPRE[2:0]**: PCLK prescaler

Set and cleared by software to control the division factor of the APB clock (PCLK).

0xx: HCLK not divided
 100: HCLK divided by 2
 101: HCLK divided by 4
 110: HCLK divided by 8
 111: HCLK divided by 16

Bits 7:4 **HPRE[3:0]**: HCLK prescaler

Set and cleared by software to control the division factor of the AHB clock.

- 0xxx: SYSCLK not divided
- 1000: SYSCLK divided by 2
- 1001: SYSCLK divided by 4
- 1010: SYSCLK divided by 8
- 1011: SYSCLK divided by 16
- 1100: SYSCLK divided by 64
- 1101: SYSCLK divided by 128
- 1110: SYSCLK divided by 256
- 1111: SYSCLK divided by 512

Bits 3:2 **SWS[1:0]**: System clock switch status

Set and cleared by hardware to indicate which clock source is used as system clock.

- 00: HSI oscillator used as system clock
- 01: HSE oscillator used as system clock
- 10: PLL used as system clock
- 11: Reserved, must be kept at reset value.

Bits 1:0 **SW[1:0]**: System clock switch

Set and cleared by software to select SYSCLK source.

Cleared by hardware to force HSI selection when leaving Stop and Standby mode or in case of failure of the HSE oscillator used directly or indirectly as system clock (if the Clock Security System is enabled).

- 00: HSI selected as system clock
- 01: HSE selected as system clock
- 10: PLL selected as system clock
- 11: Reserved, must be kept at reset value.

7.4.3 Clock interrupt register (RCC_CIR)

Address offset: 0x08

Reset value: 0x0000 0000

Access: no wait state, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CSSC	Res.	HSI14 RDYC	PLL RDYC	HSE RDYC	HSI RDYC	LSE RDYC	LSI RDYC
								w		w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	HSI14 RDYIE	PLL RDYIE	HSE RDYIE	HSI RDYIE	LSE RDYIE	LSI RDYIE	CSSF	Res.	HSI14 RDYF	PLL RDYF	HSE RDYF	HSI RDYF	LSE RDYF	LSI RDYF
		rw	rw	rw	rw	rw	rw	r		r	r	r	r	r	r

Bits 31:24 Reserved, must be kept at reset value.

Bit 23 **CSSC**: Clock security system interrupt clear

This bit is set by software to clear the CSSF flag.

0: No effect

1: Clear CSSF flag

Bit 22

Reserved, must be kept at reset value.

Bit 21 **HSI14RDYC**: HSI14 ready interrupt clear

This bit is set by software to clear the HSI14RDYF flag.

0: No effect

1: Clear HSI14RDYF flag

Bit 20 **PLLRDYC**: PLL ready interrupt clear

This bit is set by software to clear the PLLRDYF flag.

0: No effect

1: Clear PLLRDYF flag

Bit 19 **HSE RDYC**: HSE ready interrupt clear

This bit is set by software to clear the HSE RDYF flag.

0: No effect

1: Clear HSE RDYF flag

Bit 18 **HSIRDYC**: HSI ready interrupt clear

This bit is set software to clear the HSIRDYF flag.

0: No effect

1: Clear HSIRDYF flag

Bit 17 **LSERDYC**: LSE ready interrupt clear

This bit is set by software to clear the LSERDYF flag.

0: No effect

1: LSERDYF cleared

Bit 16 **LSIRDYC**: LSI ready interrupt clear
This bit is set by software to clear the LSIRDYF flag.
0: No effect
1: LSIRDYF cleared

Bits 15:14 Reserved, must be kept at reset value.

Bit 13 **HSI14RDYIE**: HSI14 ready interrupt enable
Set and cleared by software to enable/disable interrupt caused by the HSI14 oscillator stabilization.
0: HSI14 ready interrupt disabled
1: HSI14 ready interrupt enabled

Bit 12 **PLLRDYIE**: PLL ready interrupt enable
Set and cleared by software to enable/disable interrupt caused by PLL lock.
0: PLL lock interrupt disabled
1: PLL lock interrupt enabled

Bit 11 **HSE RDYIE**: HSE ready interrupt enable
Set and cleared by software to enable/disable interrupt caused by the HSE oscillator stabilization.
0: HSE ready interrupt disabled
1: HSE ready interrupt enabled

Bit 10 **HSIRDYIE**: HSI ready interrupt enable
Set and cleared by software to enable/disable interrupt caused by the HSI oscillator stabilization.
0: HSI ready interrupt disabled
1: HSI ready interrupt enabled

Bit 9 **LSE RDYIE**: LSE ready interrupt enable
Set and cleared by software to enable/disable interrupt caused by the LSE oscillator stabilization.
0: LSE ready interrupt disabled
1: LSE ready interrupt enabled

Bit 8 **LSIRDYIE**: LSI ready interrupt enable
Set and cleared by software to enable/disable interrupt caused by the LSI oscillator stabilization.
0: LSI ready interrupt disabled
1: LSI ready interrupt enabled

Bit 7 **CSSF**: Clock security system interrupt flag
Set by hardware when a failure is detected in the HSE oscillator.
Cleared by software setting the CSSC bit.
0: No clock security interrupt caused by HSE clock failure
1: Clock security interrupt caused by HSE clock failure

Bit 6 Reserved, must be kept at reset value.

Bit 5 HSI14RDYF: HSI14 ready interrupt flag

Set by hardware when the HSI14 becomes stable and HSI14RDYDIE is set in a response to setting the HSI14ON bit in [Clock control register 2 \(RCC_CR2\)](#). When HSI14ON is not set but the HSI14 oscillator is enabled by the peripheral through a clock request, this bit is not set and no interrupt is generated.

Cleared by software setting the HSI14RDYC bit.

0: No clock ready interrupt caused by the HSI14 oscillator

1: Clock ready interrupt caused by the HSI14 oscillator

Bit 4 PLLRDYF: PLL ready interrupt flag

Set by hardware when the PLL locks and PLLRDYDIE is set.

Cleared by software setting the PLLRDYC bit.

0: No clock ready interrupt caused by PLL lock

1: Clock ready interrupt caused by PLL lock

Bit 3 HSERDYF: HSE ready interrupt flag

Set by hardware when the HSE clock becomes stable and HSERDYDIE is set.

Cleared by software setting the HSERDYC bit.

0: No clock ready interrupt caused by the HSE oscillator

1: Clock ready interrupt caused by the HSE oscillator

Bit 2 HSIRDYF: HSI ready interrupt flag

Set by hardware when the HSI clock becomes stable and HSIRDYDIE is set in a response to setting the HSION (refer to [Clock control register \(RCC_CR\)](#)). When HSION is not set but the HSI oscillator is enabled by the peripheral through a clock request, this bit is not set and no interrupt is generated.

Cleared by software setting the HSIRDYC bit.

0: No clock ready interrupt caused by the HSI oscillator

1: Clock ready interrupt caused by the HSI oscillator

Bit 1 LSERDYF: LSE ready interrupt flag

Set by hardware when the LSE clock becomes stable and LSERDYDIE is set.

Cleared by software setting the LSERDYC bit.

0: No clock ready interrupt caused by the LSE oscillator

1: Clock ready interrupt caused by the LSE oscillator

Bit 0 LSIRDYF: LSI ready interrupt flag

Set by hardware when the LSI clock becomes stable and LSIRDYDIE is set.

Cleared by software setting the LSIRDYC bit.

0: No clock ready interrupt caused by the LSI oscillator

1: Clock ready interrupt caused by the LSI oscillator

7.4.4 APB peripheral reset register 2 (RCC_APB2RSTR)

Address offset: 0x0C

Reset value: 0x00000 0000

Access: no wait state, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBGMCU RST	Res.	Res.	Res.	TIM17 RST	TIM16 RST	TIM15 RST
									rw				rw	rw	rw

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	USART1 RST	Res.	SPI1 RST	TIM1 RST	Res.	ADC RST	Res.	Res.	Res.	USART6 RST	Res.	Res.	Res.	Res.	SYSCFG RST
	rw		rw	rw		rw				rw					rw

Bits 31:23 Reserved, must be kept at reset value.

Bits 22 **DBGMCURST**: Debug MCU reset

Set and cleared by software.

0: No effect

1: Reset Debug MCU

Bits 21:19 Reserved, must be kept at reset value.

Bit 18 **TIM17RST**: TIM17 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM17 timer

Bit 17 **TIM16RST**: TIM16 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM16 timer

Bit 16 **TIM15RST**: TIM15 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM15 timer

Bit 15 Reserved, must be kept at reset value.

Bit 14 **USART1RST**: USART1 reset

Set and cleared by software.

0: No effect

1: Reset USART1

Bit 13 Reserved, must be kept at reset value.

Bit 12 **SPI1RST**: SPI1 reset

Set and cleared by software.

0: No effect

1: Reset SPI1

Bit 11 **TIM1RST**: TIM1 timer reset

Set and cleared by software.

0: No effect

1: Reset TIM1 timer

Bit 10 Reserved, must be kept at reset value.

Bit 9 **ADCRST**: ADC interface reset

Set and cleared by software.

0: No effect

1: Reset ADC interface

Bits 8:6 Reserved, must be kept at reset value.

Bit 5 **USART6RST**: USART6 reset

Set and cleared by software

0: No effect

1: Reset USART6

Bits 4:1 Reserved, must be kept at reset value.

Bit 0 **SYSCFGRST**: SYSCFG reset

Set and cleared by software.

0: No effect

1: Reset SYSCFG

7.4.5 APB peripheral reset register 1 (RCC_APB1RSTR)

Address offset: 0x10

Reset value: 0x0000 0000

Access: no wait state, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	PWR RST	Res.	Res.	Res.	Res.	USB RST	I2C2 RST	I2C1 RST	USART5 RST	USART4 RST	USART3 RST	USART2 RST	Res.
			rw					rw	rw	rw	rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SPI2 RST	Res.	Res.	WWDG RST	Res.	Res.	TIM14 RST	Res.	Res.	TIM7 RST	TIM6 RST	Res.	Res.	TIM3 RST	Res.
	rw			rw			rw			rw	rw			rw	

Bit 31:29 Reserved, must be kept at reset value.

Bit 28 **PWRRST**: Power interface reset

Set and cleared by software.

0: No effect

1: Reset power interface

Bit 27:24 Reserved, must be kept at reset value.

Bit 23 **USBRST**: USB interface reset

Set and cleared by software.

0: No effect

1: Reset USB interface

Bit 22 **I2C2RST**: I2C2 reset

Set and cleared by software.

0: No effect

1: Reset I2C2

Bit 21 **I2C1RST**: I2C1 reset

Set and cleared by software.

0: No effect

1: Reset I2C1

- Bit 20 **USART5RST**: USART5 reset
Set and cleared by software.
0: No effect
1: Reset USART4
- Bit 19 **USART4RST**: USART4 reset
Set and cleared by software.
0: No effect
1: Reset USART4
- Bit 18 **USART3RST**: USART3 reset
Set and cleared by software.
0: No effect
1: Reset USART3
- Bit 17 **USART2RST**: USART2 reset
Set and cleared by software.
0: No effect
1: Reset USART2
- Bits 16:15 Reserved, must be kept at reset value.
- Bit 14 **SPI2RST**: SPI2 reset
Set and cleared by software.
0: No effect
1: Reset SPI2
- Bits 13:12 Reserved, must be kept at reset value.
- Bit 11 **WWDGRST**: Window watchdog reset
Set and cleared by software.
0: No effect
1: Reset window watchdog
- Bits 10:9 Reserved, must be kept at reset value.
- Bit 8 **TIM14RST**: TIM14 timer reset
Set and cleared by software.
0: No effect
1: Reset TIM14
- Bits 7:6 Reserved, must be kept at reset value.
- Bit 5 **TIM7RST**: TIM7 timer reset
Set and cleared by software.
0: No effect
1: Reset TIM7
- Bit 4 **TIM6RST**: TIM6 timer reset
Set and cleared by software.
0: No effect
1: Reset TIM6

Bit 3:2 Reserved, must be kept at reset value.

Bit 1 **TIM3RST**: TIM3 timer reset
Set and cleared by software.
0: No effect
1: Reset TIM3

Bit 0 Reserved, must be kept at reset value.

7.4.6 AHB peripheral clock enable register (RCC_AHBENR)

Address offset: 0x14

Reset value: 0x0000 0014

Access: no wait state, word, half-word and byte access

Note: *When the peripheral clock is not active, the peripheral register values may not be readable by software and the returned value is always 0x0.*

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IOPF EN	Res.	IOPD EN	IOPC EN	IOPB EN	IOPA EN	Res.
									rw		rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CRC EN	Res.	FLITF EN	Res.	SRAM EN	Res.	DMA EN
									rw		rw		rw		rw

Bits 31:23 Reserved, must be kept at reset value.

Bit 22 **IOPFEN**: I/O port F clock enable

Set and cleared by software.

0: I/O port F clock disabled

1: I/O port F clock enabled

Bit 21 Reserved, must be kept at reset value.

Bit 20 **IOPDEN**: I/O port D clock enable

Set and cleared by software.

0: I/O port D clock disabled

1: I/O port D clock enabled

Bit 19 **IOPCEN**: I/O port C clock enable

Set and cleared by software.

0: I/O port C clock disabled

1: I/O port C clock enabled

Bit 18 **IOPBEN**: I/O port B clock enable

Set and cleared by software.

0: I/O port B clock disabled

1: I/O port B clock enabled

Bit 17 **IOPAEN**: I/O port A clock enable

Set and cleared by software.

0: I/O port A clock disabled

1: I/O port A clock enabled

Bits 16:7 Reserved, must be kept at reset value.

Bit 6 **CRCEN**: CRC clock enable

Set and cleared by software.

0: CRC clock disabled

1: CRC clock enabled

Bit 5 Reserved, must be kept at reset value.

Bit 4 **FLITFEN**: FLITF clock enable

Set and cleared by software to disable/enable FLITF clock during Sleep mode.

0: FLITF clock disabled during Sleep mode

1: FLITF clock enabled during Sleep mode

Bit 3 Reserved, must be kept at reset value.

Bit 2 **SRAMEN**: SRAM interface clock enable

Set and cleared by software to disable/enable SRAM interface clock during Sleep mode.

0: SRAM interface clock disabled during Sleep mode.

1: SRAM interface clock enabled during Sleep mode

Bit 1 Reserved, must be kept at reset value.

Bit 0 **DMAEN**: DMA clock enable

Set and cleared by software.

0: DMA clock disabled

1: DMA clock enabled

7.4.7 APB peripheral clock enable register 2 (RCC_APB2ENR)

Address: 0x18

Reset value: 0x0000 0000

Access: word, half-word and byte access

No wait states, except if the access occurs while an access to a peripheral in the APB domain is on going. In this case, wait states are inserted until the access to APB peripheral is finished.

Note: When the peripheral clock is not active, the peripheral register values may not be readable by software and the returned value is always 0x0.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG MCUEN	Res.	Res.	Res.	TIM17 EN	TIM16 EN	TIM15EN
									rw				rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	USART1 EN	Res.	SPI1EN	TIM1EN	Res.	ADCEN	Res.	Res.	Res.	USART6 EN	Res.	Res.	Res.	Res.	SYSCFG COMPEN
	rw		rw	rw		rw				rw					rw

Bits 31:23 Reserved, must be kept at reset value.

Bit 22 **DBGMCUEN** MCU debug module clock enable

Set and reset by software.

0: MCU debug module clock disabled

1: MCU debug module enabled

Bits 21:19 Reserved, must be kept at reset value.

Bit 18 **TIM17EN**: TIM17 timer clock enable

Set and cleared by software.

0: TIM17 timer clock disabled

1: TIM17 timer clock enabled

Bit 17 **TIM16EN**: TIM16 timer clock enable

Set and cleared by software.

0: TIM16 timer clock disabled

1: TIM16 timer clock enabled

Bit 16 **TIM15EN**: TIM15 timer clock enable

Set and cleared by software.

0: TIM15 timer clock disabled

1: TIM15 timer clock enabled

Bit 15 Reserved, must be kept at reset value.

Bit 14 **USART1EN**: USART1 clock enable

Set and cleared by software.

0: USART1clock disabled

1: USART1clock enabled

Bit 13 Reserved, must be kept at reset value.

Bit 12 **SPI1EN**: SPI1 clock enable

Set and cleared by software.

0: SPI1 clock disabled

1: SPI1 clock enabled

Bit 11 **TIM1EN**: TIM1 timer clock enable

Set and cleared by software.

0: TIM1 timer clock disabled

1: TIM1P timer clock enabled

Bit 10 Reserved, must be kept at reset value.

Bit 9 **ADCEN**: ADC interface clock enable

Set and cleared by software.

0: ADC interface disabled

1: ADC interface clock enabled

Bits 8:6 Reserved, must be kept at reset value.

Bit 5 **USART6EN**: USART6 clock enable

Set and cleared by software.

0: USART6clock disabled

1: USART6clock enabled

Bits 4:1 Reserved, must be kept at reset value.

Bit 0 **SYSCFGEN**: SYSCFG clock enable

Set and cleared by software.

0: SYSCFG clock disabled

1: SYSCFG clock enabled

7.4.8 APB peripheral clock enable register 1 (RCC_APB1ENR)

Address: 0x1C

Reset value: 0x0000 0000

Access: word, half-word and byte access

No wait state, except if the access occurs while an access to a peripheral on APB domain is on going. In this case, wait states are inserted until this access to APB peripheral is finished.

Note: When the peripheral clock is not active, the peripheral register values may not be readable by software and the returned value is always 0x0.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	PWR EN	Res.	Res.	Res.	Res.	USB EN	I2C2 EN	I2C1 EN	USART5 EN	USART4 EN	USART3 EN	USART2 EN	Res.
			rw					rw	rw	rw	rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SPI2 EN	Res.	Res.	WWDG EN	Res.	Res.	TIM14 EN	Res.	Res.	TIM7 EN	TIM6 EN	Res.	Res.	TIM3 EN	Res.
	rw			rw			rw			rw	rw			rw	

Bit 31:29 Reserved, must be kept at reset value.

Bit 28 **PWREN**: Power interface clock enable

Set and cleared by software.

0: Power interface clock disabled

1: Power interface clock enabled

Bit 27:24 Reserved, must be kept at reset value.

Bit 23 **USBEN**: USB interface clock enable

Set and cleared by software.

0: USB interface clock disabled

1: USB interface clock enabled

- Bit 22 **I2C2EN**: I2C2 clock enable
Set and cleared by software.
0: I2C2 clock disabled
1: I2C2 clock enabled
- Bit 21 **I2C1EN**: I2C1 clock enable
Set and cleared by software.
0: I2C1 clock disabled
1: I2C1 clock enabled
- Bit 20 **USART5EN**: USART5 clock enable
Set and cleared by software.
0: USART5 clock disabled
1: USART5 clock enabled
- Bit 19 **USART4EN**: USART4 clock enable
Set and cleared by software.
0: USART4 clock disabled
1: USART4 clock enabled
- Bit 18 **USART3EN**: USART3 clock enable
Set and cleared by software.
0: USART3 clock disabled
1: USART3 clock enabled
- Bit 17 **USART2EN**: USART2 clock enable
Set and cleared by software.
0: USART2 clock disabled
1: USART2 clock enabled
- Bits 16:15 Reserved, must be kept at reset value.
- Bit 14 **SPI2EN**: SPI2 clock enable
Set and cleared by software.
0: SPI2 clock disabled
1: SPI2 clock enabled
- Bits 13:12 Reserved, must be kept at reset value.
- Bit 11 **WWDGEN**: Window watchdog clock enable
Set and cleared by software.
0: Window watchdog clock disabled
1: Window watchdog clock enabled
- Bits 10:9 Reserved, must be kept at reset value.
- Bit 8 **TIM14EN**: TIM14 timer clock enable
Set and cleared by software.
0: TIM14 clock disabled
1: TIM14 clock enabled
- Bits 7:6 Reserved, must be kept at reset value.
- Bit 5 **TIM7EN**: TIM7 timer clock enable (not available on STM32F070x6, nor STM32F030x4/6/8/C devices.)
Set and cleared by software.
0: TIM7 clock disabled
1: TIM7 clock enabled

Bit 4 **TIM6EN**: TIM6 timer clock enable

Set and cleared by software.

0: TIM6 clock disabled

1: TIM6 clock enabled

Bits 3:2 Reserved, must be kept at reset value.

Bit 1 **TIM3EN**: TIM3 timer clock enable

Set and cleared by software.

0: TIM3 clock disabled

1: TIM3 clock enabled

Bit 0 Reserved, must be kept at reset value.

7.4.9 RTC domain control register (RCC_BDCR)

Address offset: 0x20

Reset value: 0x0000 0018, reset by RTC domain reset.

Access: $0 \leq \text{wait state} \leq 3$, word, half-word and byte access

Wait states are inserted in case of successive accesses to this register.

Note: The LSEON, LSEBYP, RTCSEL and RTCEN bits of the [RTC domain control register \(RCC_BDCR\)](#) are in the RTC domain. As a result, after Reset, these bits are write-protected and the DBP bit in the [Power control register \(PWR_CR\)](#) has to be set before these can be modified. Refer to [Section 6.1.2: Voltage regulator](#) for further information. These bits are only reset after a RTC domain reset (see [Section 7.1.3: RTC domain reset](#)). Any internal or external Reset will not have any effect on these bits.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BDRST
															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RTC EN	Res.	Res.	Res.	Res.	Res.	RTCSEL[1:0]		Res.	Res.	Res.	LSEDRV[1:0]		LSE BYP	LSE RDY	LSEON
rw						rw	rw				rw	rw	rw	r	rw

Bits 31:17 Reserved, must be kept at reset value.

Bit 16 **BDRST**: RTC domain software reset

Set and cleared by software.

0: Reset not activated

1: Resets the entire RTC domain

Bit 15 **RTCEN**: RTC clock enable

Set and cleared by software.

0: RTC clock disabled

1: RTC clock enabled

Bits 14:10 Reserved, must be kept at reset value.

Bits 9:8 **RTCSEL[1:0]**: RTC clock source selection

Set by software to select the clock source for the RTC. Once the RTC clock source has been selected, it cannot be changed anymore unless the RTC domain is reset. The BDRST bit can be used to reset them.

00: No clock

01: LSE oscillator clock used as RTC clock

10: LSI oscillator clock used as RTC clock

11: HSE oscillator clock divided by 32 used as RTC clock

Bits 7:5 Reserved, must be kept at reset value.

Bits 4:3 **LSEDRV** LSE oscillator drive capability

Set and reset by software to modulate the LSE oscillator's drive capability. A reset of the RTC domain restores the default value.

00: 'Xtal mode' lower driving capability

01: 'Xtal mode' medium high driving capability

10: 'Xtal mode' medium low driving capability

11: 'Xtal mode' higher driving capability (reset value)

Note: The oscillator is in Xtal mode when it is not in bypass mode.

Bit 2 **LSEBYP**: LSE oscillator bypass

Set and cleared by software to bypass oscillator in debug mode. This bit can be written only when the external 32 kHz oscillator is disabled.

0: LSE oscillator not bypassed

1: LSE oscillator bypassed

Bit 1 **LSERDY**: LSE oscillator ready

Set and cleared by hardware to indicate when the external 32 kHz oscillator is stable. After the LSEON bit is cleared, LSERDY goes low after 6 external low-speed oscillator clock cycles.

0: LSE oscillator not ready

1: LSE oscillator ready

Bit 0 **LSEON**: LSE oscillator enable

Set and cleared by software.

0: LSE oscillator OFF

1: LSE oscillator ON

7.4.10 Control/status register (RCC_CSR)

Address: 0x24

Reset value: 0xFFFF 0000, reset by system Reset, except reset flags by power Reset only.

Access: $0 \leq \text{wait state} \leq 3$, word, half-word and byte access

Wait states are inserted in case of successive accesses to this register.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
LPWR RSTF	WWDG RSTF	IWDG RSTF	SFT RSTF	POR RSTF	PIN RSTF	OB LRSTF	RMVF	V18PWR RSTF	Res.	Res.	Res.	Res.	Res.	Res.	Res.
r	r	r	r	r	r	r	rt_w	r							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	LSI RDY	LSION
														r	rw

Bit 31 **LPWRRSTF**: Low-power reset flag

Set by hardware when a Low-power management reset occurs.

Cleared by writing to the RMVF bit.

0: No Low-power management reset occurred

1: Low-power management reset occurred

For further information on Low-power management reset, refer to [Low-power management reset](#).

Bit 30 **WWDGRSTF**: Window watchdog reset flag

Set by hardware when a window watchdog reset occurs.

Cleared by writing to the RMVF bit.

0: No window watchdog reset occurred

1: Window watchdog reset occurred

Bit 29 **IWDGRSTF**: Independent watchdog reset flag

Set by hardware when an independent watchdog reset from V_{DD} domain occurs.

Cleared by writing to the RMVF bit.

0: No watchdog reset occurred

1: Watchdog reset occurred

Bit 28 **SFTRSTF**: Software reset flag

Set by hardware when a software reset occurs.

Cleared by writing to the RMVF bit.

0: No software reset occurred

1: Software reset occurred

Bit 27 **PORRSTF**: POR/PDR reset flag

Set by hardware when a POR/PDR reset occurs.

Cleared by writing to the RMVF bit.

0: No POR/PDR reset occurred

1: POR/PDR reset occurred

Bit 26 PINRSTF: PIN reset flag

Set by hardware when a reset from the NRST pin occurs.

Cleared by writing to the RMVF bit.

0: No reset from NRST pin occurred

1: Reset from NRST pin occurred

Bit 25 OBLRSTF: Option byte loader reset flag

Set by hardware when a reset from the OBL occurs.

Cleared by writing to the RMVF bit.

0: No reset from OBL occurred

1: Reset from OBL occurred

Bit 24 RMVF: Remove reset flag

Set by software to clear the reset flags including RMVF.

0: No effect

1: Clear the reset flags

Bit 23 V18PWRSTF: Reset flag of the 1.8 V domain.

Set by hardware when a POR/PDR of the 1.8 V domain occurred.

Cleared by writing to the RMVF bit.

0: No POR/PDR reset of the 1.8 V domain occurred

1: POR/PDR reset of the 1.8 V domain occurred

Bits 22:2 Reserved, must be kept at reset value.

Bit 1 LSIRDY: LSI oscillator ready

Set and cleared by hardware to indicate when the LSI oscillator is stable. After the LSION bit is cleared, LSIRDY goes low after 3 LSI oscillator clock cycles.

0: LSI oscillator not ready

1: LSI oscillator ready

Bit 0 LSION: LSI oscillator enable

Set and cleared by software.

0: LSI oscillator OFF

1: LSI oscillator ON

7.4.11 AHB peripheral reset register (RCC_AHBRSTR)

Address: 0x28

Reset value: 0x0000 0000

Access: no wait states, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IOPF RST	Res.	IOPD RST	IOPC RST	IOPB RST	IOPA RST	Res.
									rw		rw	rw	rw	rw	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.

Bits 31:23 Reserved, must be kept at reset value.

Bit 22 **IOPFRST**: I/O port F reset
Set and cleared by software.
0: No effect
1: Reset I/O port F

Bit 21 Reserved, must be kept at reset value.

Bit 20 **IOPDRST**: I/O port D reset
Set and cleared by software.
0: No effect
1: Reset I/O port D

Bit 19 **IOPCRST**: I/O port C reset
Set and cleared by software.
0: No effect
1: Reset I/O port C

Bit 18 **IOPBRST**: I/O port B reset
Set and cleared by software.
0: No effect
1: Reset I/O port B

Bit 17 **IOPARST**: I/O port A reset
Set and cleared by software.
0: No effect
1: Reset I/O port A

Bits 16:0 Reserved, must be kept at reset value.

7.4.13 Clock configuration register 3 (RCC_CFGR3)

Address: 0x30

Reset value: 0x0000 0000

Access: no wait states, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	ADC SW	USB SW	Res.	Res.	I2C1 SW	Res.	Res.	USART1SW[1:0]	
							rw	rw			rw			rw	rw

Bits 31:9 Reserved, must be kept at reset value.

Bit 8 **ADCSW**: ADC clock source selection

Obsolete setting. To be kept at reset value, connecting the HSI14 clock to the ADC asynchronous clock input. Proper ADC clock selection is done inside the ADC_CFGR2 (refer to [Section 12.11.5: ADC configuration register 2 \(ADC_CFGR2\) on page 216](#)).

Bit 7 **USBSW**: USB clock source selection

This bit is set and cleared by software to select the USB clock source.

0: USB clock disabled (default)

1: PLL clock (PLLCLK) selected as USB clock

Bits 6:5 Reserved, must be kept at reset value.

Bit 4 **I2C1SW**: I2C1 clock source selection

This bit is set and cleared by software to select the I2C1 clock source.

0: HSI clock selected as I2C1 clock source (default)

1: System clock (SYSCLK) selected as I2C1 clock

Bits 3:2 Reserved, must be kept at reset value.

Bits 1:0 **USART1SW[1:0]**: USART1 clock source selection

This bit is set and cleared by software to select the USART1 clock source.

00: PCLK selected as USART1 clock source (default)

01: System clock (SYSCLK) selected as USART1 clock

10: LSE clock selected as USART1 clock

11: HSI clock selected as USART1 clock

7.4.14 Clock control register 2 (RCC_CR2)

Address: 0x34

Reset value: 0xXX00 XX80, where X is undefined.

Access: no wait states, word, half-word and byte access

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
HSI14CAL[7:0]								HSI14TRIM[4:0]					HSI14 DIS	HSI14 RDY	HSI14 ON
r	r	r	r	r	r	r	r	rw	rw	rw	rw	rw	rw	r	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:8 **HSI14CAL[7:0]**: HSI14 clock calibration

These bits are initialized automatically at startup.

Bits 7:3 **HSI14TRIM[4:0]**: HSI14 clock trimming

These bits provide an additional user-programmable trimming value that is added to the HSI14CAL[7:0] bits. It can be programmed to adjust to variations in voltage and temperature that influence the frequency of the HSI14.

The default value is 16, which, when added to the HSI14CAL value, should trim the HSI14 to 14 MHz $\pm$ 1%. The trimming step is around 50 kHz between two consecutive HSI14CAL steps.

Bit 2 **HSI14DIS** HSI14 clock request from ADC disable

Set and cleared by software.

When set this bit prevents the ADC interface from enabling the HSI14 oscillator.

0: ADC interface can turn on the HSI14 oscillator

1: ADC interface can not turn on the HSI14 oscillator

Bit 1 **HSI14RDY**: HSI14 clock ready flag

Set by hardware to indicate that HSI14 oscillator is stable. After the HSI14ON bit is cleared, HSI14RDY goes low after 6 HSI14 oscillator clock cycles.

0: HSI14 oscillator not ready

1: HSI14 oscillator ready

Bit 0 **HSI14ON**: HSI14 clock enable

Set and cleared by software.

0: HSI14 oscillator OFF

1: HSI14 oscillator ON

7.4.15 RCC register map

The following table gives the RCC register map and the reset values.

Table 21. RCC register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	RCC_CR	Res.	Res.	Res.	Res.	Res.	Res.	PLL RDY	PLL ON	Res.	Res.	Res.	Res.	CSSON	HSEBYP	HSERDY	HSEON	HSICAL[7:0]							HSITRIM[4:0]				Res.	HSIRDY	HSION		
	Reset value							0	0					0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0		1	1
0x04	RCC_CFGR	PLL NODIV	MCOPRE [2:0]			MCO [3:0]				Res.	Res.	PLLMUL[3:0]				PLLXTPRE	PLLSRC	Res.	ADC PRE	Res.	Res.	PPRE [2:0]				HPRE[3:0]			SWS [1:0]		SW [1:0]		
	Reset value	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0			0	0	0	0	0	0	0	0	0	0	0
0x08	RCC_CIR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CSSC	Res.	HSI14 RDYC	PLLRDYC	HSERDYC	HSIRDYC	LSERDYC	LSIRDYC	Res.	Res.	HSI14 RDYIE	PLLRDYIE	HSERDYIE	HSIRDYIE	LSERDYIE	LSIRDYIE	CSSF	Res.	HSI14 RDYF	PLLRDYF	HSERDYF	HSIRDYF	LSERDYF	
	Reset value									0		0	0	0	0	0	0	0			0	0	0	0	0	0		0	0	0	0	0	0
0x0C	RCC_APB2RSTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBGMCURST	Res.	Res.	Res.	TIM17RST	TIM16RST	TIM15RST	Res.	USART1RST	Res.	Res.	SPI1RST	TIM1RST	Res.	ADCRST	Res.	Res.	USART6RST	Res.	Res.	Res.	SYSCFGRST	
	Reset value										0				0	0	0		0			0	0	0	0		0				0		0
0x010	RCC_APB1RSTR	Res.	Res.	Res.	PWRST	CRSRST	Res.	Res.	Res.	USBRST	I2C2RST	I2C1RST	USART5RST	USART4RST	USART3RST	USART2RST	Res.	Res.	SPI2RST	Res.	Res.	Res.	Res.	Res.	TIM14RST	Res.	Res.	Res.	Res.	Res.	Res.	TIM3RST	Res.
	Reset value				0	0				0	0	0	0	0	0	0	0		0			0	0	0	0	0		0	0	0	0	0	0
0x14	RCC_AHBENR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IOPEEN	USART4RST	IOPCEN	IOBPEN	IOPAEN	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DMAEN	
	Reset value												0	0	0	0											0						
0x18	RCC_APB2ENR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBGMCUEN	Res.	Res.	Res.	TIM17 EN	TIM16 EN	TIM15 EN	Res.	USART1EN	Res.	Res.	SPI1EN	TIM1EN	Res.	ADCEN	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value										0				0	0	0		0			0	0	0	0			0				0	0
0x1C	RCC_APB1ENR	Res.	Res.	Res.	PWREN	CRSEN	Res.	Res.	Res.	USBEN	I2C2EN	I2C1EN	USART5EN	USART4EN	USART3EN	USART2EN	Res.	Res.	SPI2EN	Res.	Res.	Res.	Res.	Res.	TIM14EN	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value				0	0				0	0	0	0	0	0	0	0		0			0	0		0								
0x20	RCC_BDCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BDRST	RTCEN	Res.	Res.	Res.	Res.	Res.	Res.	RTCSEL [1:0]	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value																0	0							0	0							
0x24	RCC_CSR	LPWRSTF	WWDGRSTF	IWDGRSTF	SFTRSTF	PORRSTF	PINRSTF	OBLRSTF	RMVF	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value	X	X	X	X	X	X	X	X								0	0							0	0						0	0

Table 21. RCC register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x28	RCC_AHBRSTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value										0	Res.	0	Res.	0	Res.	0	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.				
0x2C	RCC_CFGR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PREDIV[3:0]				
	Reset value																													0	0	0	0	
0x30	RCC_CFGR3	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	USART1SW[1:0]	
	Reset value																															0	0	
0x34	RCC_CR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	HSI14CAL[7:0]						HSI14TRIM[14:0]						HSI14DIS	HSI14RDY	HSI14ON		
	Reset value																	X	X	X	X	X	X	X	X	1	0	0	0	0	0	0	0	

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

8 General-purpose I/Os (GPIO)

8.1 Introduction

Each general-purpose I/O port has four 32-bit configuration registers (GPIOx_MODER, GPIOx_OTYPER, GPIOx_OSPEEDR and GPIOx_PUPDR), two 32-bit data registers (GPIOx_IDR and GPIOx_ODR) and a 32-bit set/reset register (GPIOx_BSRR). Ports A and B also have a 32-bit locking register (GPIOx_LCKR) and two 32-bit alternate function selection registers (GPIOx_AFRH and GPIOx_AFRL).

On STM32F030xB and STM32F030xC devices, also ports C and D have two 32-bit alternate function selection registers (GPIOx_AFRH and GPIOx_AFRL).

8.2 GPIO main features

- Output states: push-pull or open drain + pull-up/down
- Output data from output data register (GPIOx_ODR) or peripheral (alternate function output)
- Speed selection for each I/O
- Input states: floating, pull-up/down, analog
- Input data to input data register (GPIOx_IDR) or peripheral (alternate function input)
- Bit set and reset register (GPIOx_BSRR) for bitwise write access to GPIOx_ODR
- Locking mechanism (GPIOx_LCKR) provided to freeze the port A or B I/O port configuration.
- Analog function
- Alternate function selection registers(at most 16 AFs possible per I/O)
- Fast toggle capable of changing every two clock cycles
- Highly flexible pin multiplexing allows the use of I/O pins as GPIOs or as one of several peripheral functions

8.3 GPIO functional description

Subject to the specific hardware characteristics of each I/O port listed in the datasheet, each port bit of the general-purpose I/O (GPIO) ports can be individually configured by software in several modes:

- Input floating
- Input pull-up
- Input-pull-down
- Analog
- Output open-drain with pull-up or pull-down capability
- Output push-pull with pull-up or pull-down capability
- Alternate function push-pull with pull-up or pull-down capability
- Alternate function open-drain with pull-up or pull-down capability

Each I/O port bit is freely programmable, however the I/O port registers have to be accessed as 32-bit words, half-words or bytes. The purpose of the GPIOx_BSRR and

GPIOx_BRR registers is to allow atomic read/modify accesses to any of the GPIOx_ODR registers. In this way, there is no risk of an IRQ occurring between the read and the modify access.

Figure 14 shows the basic structures of a standard I/O port bit. Table 22 gives the possible port bit configurations.

Figure 14. Basic structure of an I/O port bit

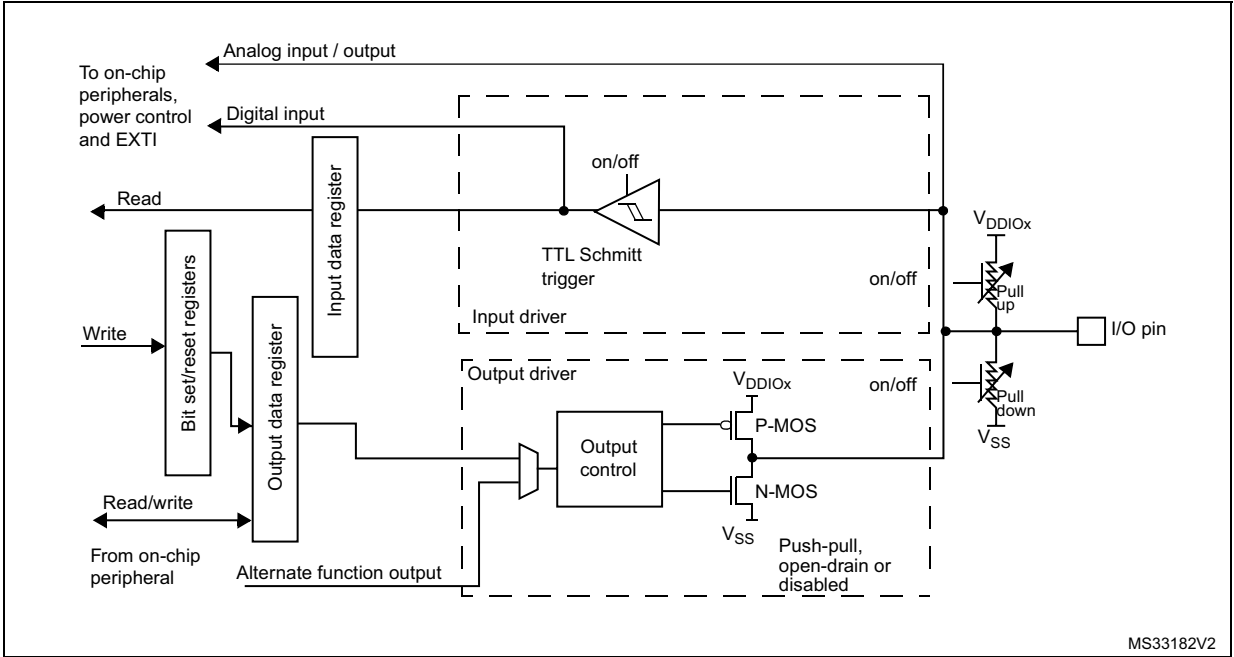


Table 22. Port bit configuration table⁽¹⁾

MODER(i) [1:0]	OTYPER(i)	OSPEEDR(i) [1:0]	PUPDR(i) [1:0]		I/O configuration	
01	0	SPEED [1:0]	0	0	GP output	PP
	0		0	1	GP output	PP + PU
	0		1	0	GP output	PP + PD
	0		1	1	Reserved	
	1		0	0	GP output	OD
	1		0	1	GP output	OD + PU
	1		1	0	GP output	OD + PD
	1		1	1	Reserved (GP output OD)	

Table 22. Port bit configuration table⁽¹⁾ (continued)

MODER(i) [1:0]	OTYPER(i)	OSPEEDR(i) [1:0]		PUPDR(i) [1:0]		I/O configuration	
10	0	SPEED [1:0]		0	0	AF	PP
	0			0	1	AF	PP + PU
	0			1	0	AF	PP + PD
	0			1	1	Reserved	
	1			0	0	AF	OD
	1			0	1	AF	OD + PU
	1			1	0	AF	OD + PD
	1			1	1	Reserved	
00	x	x	x	0	0	Input	Floating
	x	x	x	0	1	Input	PU
	x	x	x	1	0	Input	PD
	x	x	x	1	1	Reserved (input floating)	
11	x	x	x	0	0	Input/output	Analog
	x	x	x	0	1	Reserved	
	x	x	x	1	0		
	x	x	x	1	1		

1. GP = general-purpose, PP = push-pull, PU = pull-up, PD = pull-down, OD = open-drain, AF = alternate function.

8.3.1 General-purpose I/O (GPIO)

During and just after reset, the alternate functions are not active and most of the I/O ports are configured in input floating mode.

The debug pins are in AF pull-up/pull-down after reset:

- PA14: SWCLK in pull-down
- PA13: SWDIO in pull-up

When the pin is configured as output, the value written to the output data register (GPIOx_ODR) is output on the I/O pin. It is possible to use the output driver in push-pull mode or open-drain mode (only the low level is driven, high level is HI-Z).

The input data register (GPIOx_IDR) captures the data present on the I/O pin at every AHB clock cycle.

All GPIO pins have weak internal pull-up and pull-down resistors, which can be activated or not depending on the value in the GPIOx_PUPDR register.

8.3.2 I/O pin alternate function multiplexer and mapping

The device I/O pins are connected to on-board peripherals/modules through a multiplexer that allows only one peripheral alternate function (AF) connected to an I/O pin at a time. In this way, there can be no conflict between peripherals available on the same I/O pin.

Each I/O pin has a multiplexer with up to sixteen alternate function inputs (AF0 to AF15) that can be configured through the GPIOx_AFRL (for pin 0 to 7) and GPIOx_AFRH (for pin 8 to 15) registers:

- After reset the multiplexer selection is alternate function 0 (AF0). The I/Os are configured in alternate function mode through GPIOx_MODER register.
- The specific alternate function assignments for each pin are detailed in the device datasheet.

In addition to this flexible I/O multiplexing architecture, each peripheral has alternate functions mapped onto different I/O pins to optimize the number of peripherals available in smaller packages.

To use an I/O in a given configuration, the user has to proceed as follows:

- **Debug function:** after each device reset these pins are assigned as alternate function pins immediately usable by the debugger host
- **GPIO:** configure the desired I/O as output, input or analog in the GPIOx_MODER register.
- **Peripheral alternate function:**
 - Connect the I/O to the desired AFx in one of the GPIOx_AFRL or GPIOx_AFRH register.
 - Select the type, pull-up/pull-down and output speed via the GPIOx_OTYPER, GPIOx_PUPDR and GPIOx_OSPEEDER registers, respectively.
 - Configure the desired I/O as an alternate function in the GPIOx_MODER register.
- **Additional functions:**
 - For the ADC, configure the desired I/O in analog mode in the GPIOx_MODER register and configure the required function in the ADC registers.
 - For the additional functions like RTC, WKUPx and oscillators, configure the required function in the related RTC, PWR and RCC registers. These functions have priority over the configuration in the standard GPIO registers.

Please refer to the “Alternate function mapping” table in the device datasheet for the detailed mapping of the alternate function I/O pins.

8.3.3 I/O port control registers

Each of the GPIO ports has four 32-bit memory-mapped control registers (GPIOx_MODER, GPIOx_OTYPER, GPIOx_OSPEEDR, GPIOx_PUPDR) to configure up to 16 I/Os. The GPIOx_MODER register is used to select the I/O mode (input, output, AF, analog). The GPIOx_OTYPER and GPIOx_OSPEEDR registers are used to select the output type (push-pull or open-drain) and speed. The GPIOx_PUPDR register is used to select the pull-up/pull-down whatever the I/O direction.

8.3.4 I/O port data registers

Each GPIO has two 16-bit memory-mapped data registers: input and output data registers (GPIOx_IDR and GPIOx_ODR). GPIOx_ODR stores the data to be output, it is read/write accessible. The data input through the I/O are stored into the input data register (GPIOx_IDR), a read-only register.

See [Section 8.4.5: GPIO port input data register \(GPIOx_IDR\) \(x = A..D, F\)](#) and [Section 8.4.6: GPIO port output data register \(GPIOx_ODR\) \(x = A..D, F\)](#) for the register descriptions.

8.3.5 I/O data bitwise handling

The bit set reset register (GPIOx_BSRR) is a 32-bit register which allows the application to set and reset each individual bit in the output data register (GPIOx_ODR). The bit set reset register has twice the size of GPIOx_ODR.

To each bit in GPIOx_ODR, correspond two control bits in GPIOx_BSRR: BS(i) and BR(i). When written to 1, bit BS(i) **sets** the corresponding ODR(i) bit. When written to 1, bit BR(i) **resets** the ODR(i) corresponding bit.

Writing any bit to 0 in GPIOx_BSRR does not have any effect on the corresponding bit in GPIOx_ODR. If there is an attempt to both set and reset a bit in GPIOx_BSRR, the set action takes priority.

Using the GPIOx_BSRR register to change the values of individual bits in GPIOx_ODR is a “one-shot” effect that does not lock the GPIOx_ODR bits. The GPIOx_ODR bits can always be accessed directly. The GPIOx_BSRR register provides a way of performing atomic bitwise handling.

There is no need for the software to disable interrupts when programming the GPIOx_ODR at bit level: it is possible to modify one or more bits in a single atomic AHB write access.

8.3.6 GPIO locking mechanism

It is possible to freeze the port A and B GPIO control registers by applying a specific write sequence to the GPIOx_LCKR register. The frozen registers are GPIOx_MODER, GPIOx_OTYPER, GPIOx_OSPEEDR, GPIOx_PUPDR, GPIOx_AFRL and GPIOx_AFRH.

To write the GPIOx_LCKR register, a specific write / read sequence has to be applied. When the right LOCK sequence is applied to bit 16 in this register, the value of LCKR[15:0] is used to lock the configuration of the I/Os (during the write sequence the LCKR[15:0] value must be the same). When the LOCK sequence has been applied to a port bit, the value of the port bit can no longer be modified until the next MCU reset or peripheral reset. Each GPIOx_LCKR bit freezes the corresponding bit in the control registers (GPIOx_MODER, GPIOx_OTYPER, GPIOx_OSPEEDR, GPIOx_PUPDR, GPIOx_AFRL and GPIOx_AFRH).

The LOCK sequence (refer to [Section 8.4.8: GPIO port configuration lock register \(GPIOx_LCKR\)](#) ($x = A..B$)) can only be performed using a word (32-bit long) access to the GPIOx_LCKR register due to the fact that GPIOx_LCKR bit 16 has to be set at the same time as the [15:0] bits.

For more details please refer to LCKR register description in [Section 8.4.8: GPIO port configuration lock register \(GPIOx_LCKR\)](#) ($x = A..B$).

8.3.7 I/O alternate function input/output

Two registers are provided to select one of the alternate function inputs/outputs available for each I/O. With these registers, the user can connect an alternate function to some other pin as required by the application.

This means that a number of possible peripheral functions are multiplexed on each GPIO using the GPIOx_AFRL and GPIOx_AFRH alternate function registers. The application can thus select any one of the possible functions for each I/O. The AF selection signal being common to the alternate function input and alternate function output, a single channel is selected for the alternate function input/output of a given I/O.

For code example refer to the Appendix section [A.4.2: Alternate function selection sequence code example](#).

To know which functions are multiplexed on each GPIO pin, refer to the device datasheet.

8.3.8 External interrupt/wakeup lines

All ports have external interrupt capability. To use external interrupt lines, the given pin must not be configured in analog mode or being used as oscillator pin, so the input trigger is kept enabled. Refer to [Section 11.2: Extended interrupts and events controller \(EXTI\)](#) and to [Section 11.2.3: Event management](#).

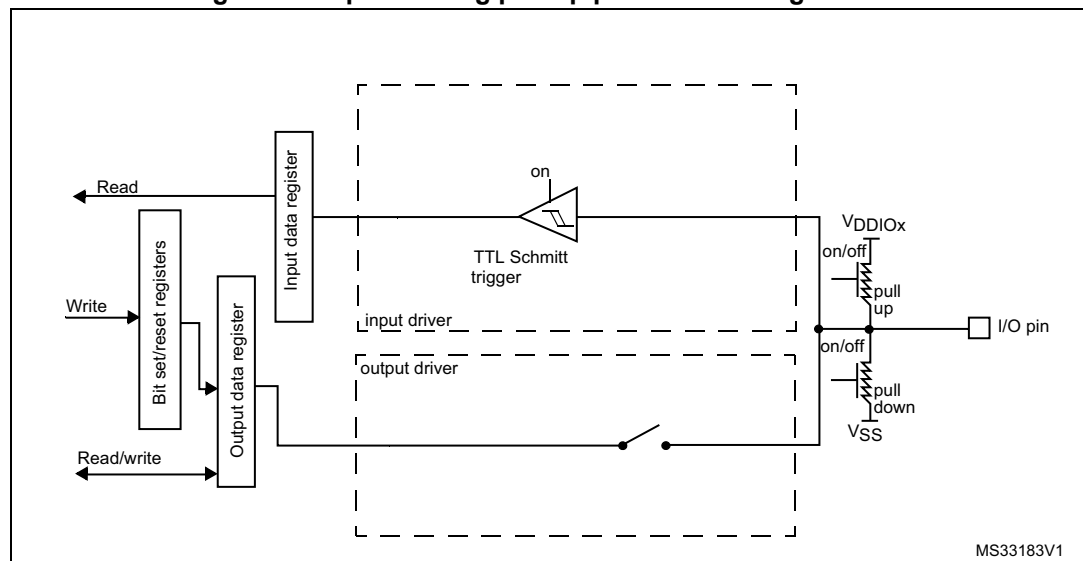
8.3.9 Input configuration

When the I/O port is programmed as input:

- The output buffer is disabled
- The Schmitt trigger input is activated
- The pull-up and pull-down resistors are activated depending on the value in the GPIOx_PUPDR register
- The data present on the I/O pin are sampled into the input data register every AHB clock cycle
- A read access to the input data register provides the I/O state

[Figure 15](#) shows the input configuration of the I/O port bit.

Figure 15. Input floating/pull up/pull down configurations



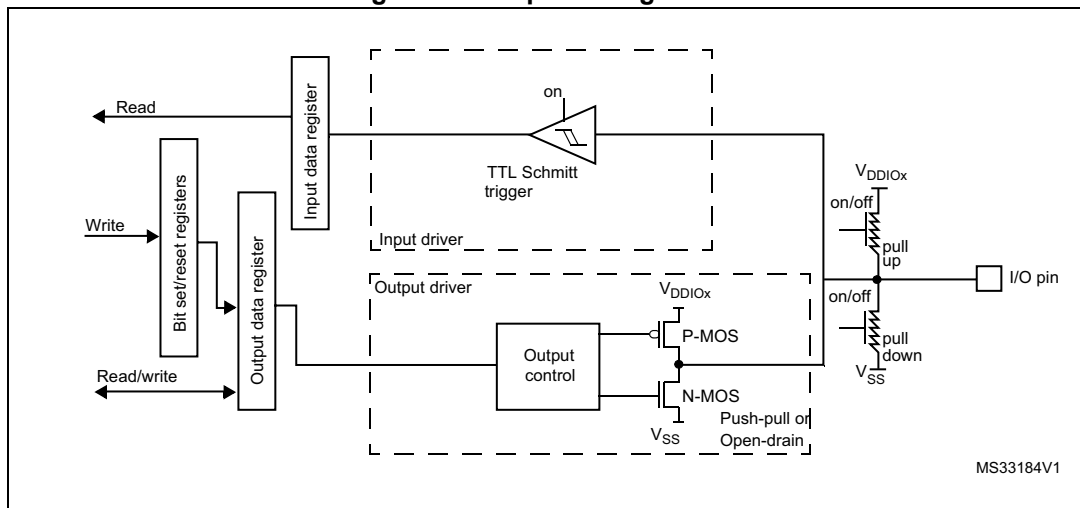
8.3.10 Output configuration

When the I/O port is programmed as output:

- The output buffer is enabled:
 - Open drain mode: A “0” in the Output register activates the N-MOS whereas a “1” in the Output register leaves the port in Hi-Z (the P-MOS is never activated)
 - Push-pull mode: A “0” in the Output register activates the N-MOS whereas a “1” in the Output register activates the P-MOS
- The Schmitt trigger input is activated
- The pull-up and pull-down resistors are activated depending on the value in the GPIOx_PUPDR register
- The data present on the I/O pin are sampled into the input data register every AHB clock cycle
- A read access to the input data register gets the I/O state
- A read access to the output data register gets the last written value

Figure 16 shows the output configuration of the I/O port bit.

Figure 16. Output configuration



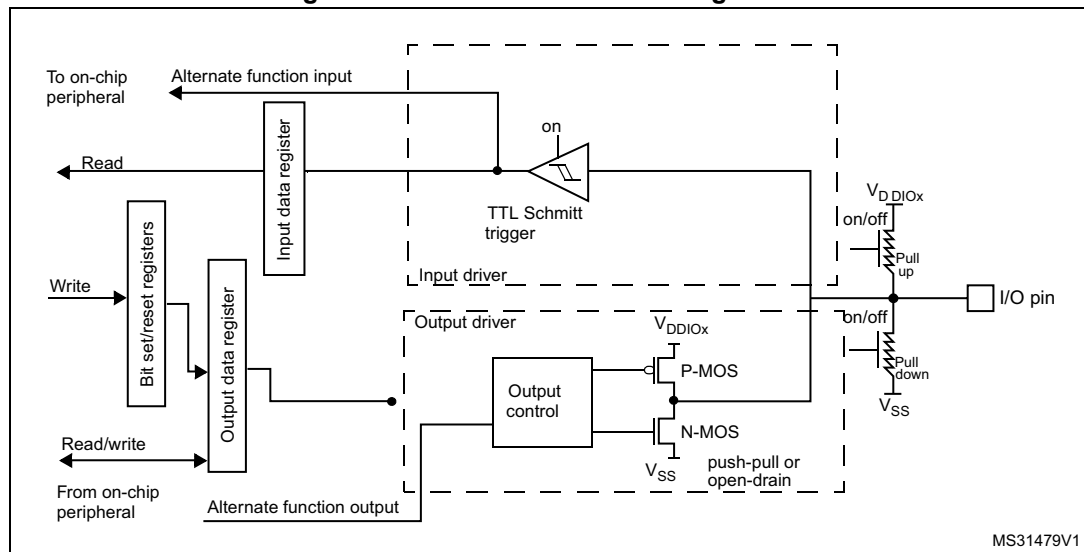
8.3.11 Alternate function configuration

When the I/O port is programmed as alternate function:

- The output buffer can be configured in open-drain or push-pull mode
- The output buffer is driven by the signals coming from the peripheral (transmitter enable and data)
- The Schmitt trigger input is activated
- The weak pull-up and pull-down resistors are activated or not depending on the value in the GPIOx_PUPDR register
- The data present on the I/O pin are sampled into the input data register every AHB clock cycle
- A read access to the input data register gets the I/O state

Figure 17 shows the Alternate function configuration of the I/O port bit.

Figure 17. Alternate function configuration



8.3.12 Analog configuration

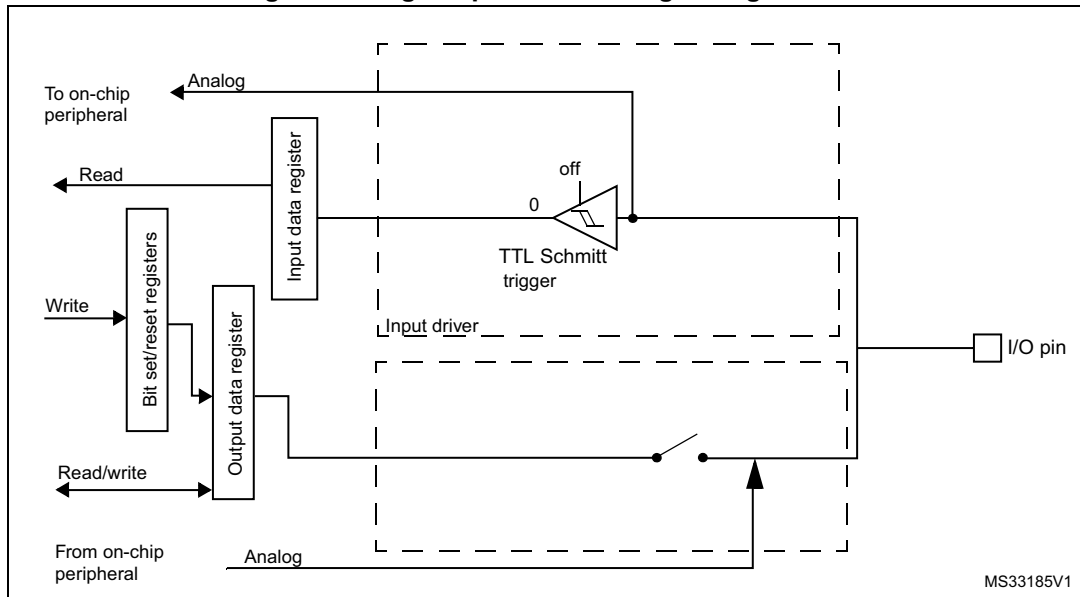
When the I/O port is programmed as analog configuration:

- The output buffer is disabled
- The Schmitt trigger input is deactivated, providing zero consumption for every analog value of the I/O pin. The output of the Schmitt trigger is forced to a constant value (0).
- The weak pull-up and pull-down resistors are disabled by hardware
- Read access to the input data register gets the value "0"

For code example refer to the Appendix section [A.4.3: Analog GPIO configuration code example](#).

[Figure 18](#) shows the high-impedance, analog-input configuration of the I/O port bit.

Figure 18. High impedance-analog configuration



8.3.13 Using the HSE or LSE oscillator pins as GPIOs

When the HSE or LSE oscillator is switched OFF (default state after reset), the related oscillator pins can be used as normal GPIOs.

When the HSE or LSE oscillator is switched ON (by setting the HSEON or LSEON bit in the RCC_CSR register) the oscillator takes control of its associated pins and the GPIO configuration of these pins has no effect.

When the oscillator is configured in a user external clock mode, only the pin is reserved for clock input and the OSC_OUT or OSC32_OUT pin can still be used as normal GPIO.

8.3.14 Using the GPIO pins in the RTC supply domain

The PC13/PC14/PC15 GPIO functionality is lost when the core supply domain is powered off (when the device enters Standby mode). In this case, if their GPIO configuration is not bypassed by the RTC configuration, these pins are set in an analog input mode.

For details about I/O control by the RTC, refer to [Section 21.4: RTC functional description on page 488](#).

8.4 GPIO registers

This section gives a detailed description of the GPIO registers.

For a summary of register bits, register address offsets and reset values, refer to [Table 23](#).

The peripheral registers can be written in word, half word or byte mode.

8.4.1 GPIO port mode register (GPIOx_MODER) (x = A..D, F)

Address offset: 0x00

Reset values:

- 0x2800 0000 for port A
- 0x0000 0000 for other ports

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MODER15[1:0]		MODER14[1:0]		MODER13[1:0]		MODER12[1:0]		MODER11[1:0]		MODER10[1:0]		MODER9[1:0]		MODER8[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MODER7[1:0]		MODER6[1:0]		MODER5[1:0]		MODER4[1:0]		MODER3[1:0]		MODER2[1:0]		MODER1[1:0]		MODER0[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 2y+1:2y **MODERy[1:0]**: Port x configuration bits (y = 0..15)

These bits are written by software to configure the I/O mode.

00: Input mode (reset state)

01: General purpose output mode

10: Alternate function mode

11: Analog mode

8.4.2 GPIO port output type register (GPIOx_OTYPER) (x = A..D, F)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OT15	OT14	OT13	OT12	OT11	OT10	OT9	OT8	OT7	OT6	OT5	OT4	OT3	OT2	OT1	OT0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **OTy**: Port x configuration bits (y = 0..15)

These bits are written by software to configure the I/O output type.

0: Output push-pull (reset state)

1: Output open-drain

8.4.3 GPIO port output speed register (GPIOx_OSPEEDR) (x = A..D, F)

Address offset: 0x08

Reset value:

- 0x0C00 0000 for port A
- 0x0000 0000 for other ports

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
OSPEEDR15 [1:0]		OSPEEDR14 [1:0]		OSPEEDR13 [1:0]		OSPEEDR12 [1:0]		OSPEEDR11 [1:0]		OSPEEDR10 [1:0]		OSPEEDR9 [1:0]		OSPEEDR8 [1:0]	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OSPEEDR7 [1:0]		OSPEEDR6 [1:0]		OSPEEDR5 [1:0]		OSPEEDR4 [1:0]		OSPEEDR3 [1:0]		OSPEEDR2 [1:0]		OSPEEDR1 [1:0]		OSPEEDR0 [1:0]	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 2y+1:2y **OSPEEDRy[1:0]**: Port x configuration bits (y = 0..15)

These bits are written by software to configure the I/O output speed.

x0: Low speed

01: Medium speed

11: High speed

Note: Refer to the device datasheet for the frequency specifications and the power supply and load conditions for each speed.

8.4.4 GPIO port pull-up/pull-down register (GPIOx_PUPDR) (x = A..D, F)

Address offset: 0x0C

Reset values:

- 0x2400 0000 for port A
- 0x0000 0000 for other ports

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PUPDR15[1:0]		PUPDR14[1:0]		PUPDR13[1:0]		PUPDR12[1:0]		PUPDR11[1:0]		PUPDR10[1:0]		PUPDR9[1:0]		PUPDR8[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PUPDR7[1:0]		PUPDR6[1:0]		PUPDR5[1:0]		PUPDR4[1:0]		PUPDR3[1:0]		PUPDR2[1:0]		PUPDR1[1:0]		PUPDR0[1:0]	
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 2y+1:2y **PUPDRy[1:0]**: Port x configuration bits (y = 0..15)

These bits are written by software to configure the I/O pull-up or pull-down

00: No pull-up, pull-down

01: Pull-up

10: Pull-down

11: Reserved

8.4.5 GPIO port input data register (GPIOx_IDR) (x = A..D, F)

Address offset: 0x10

Reset value: 0x0000 XXXX (where X means undefined)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IDR15	IDR14	IDR13	IDR12	IDR11	IDR10	IDR9	IDR8	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **IDRy**: Port input data bit (y = 0..15)

These bits are read-only. They contain the input value of the corresponding I/O port.

8.4.6 GPIO port output data register (GPIOx_ODR) (x = A..D, F)

Address offset: 0x14

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ODR15	ODR14	ODR13	ODR12	ODR11	ODR10	ODR9	ODR8	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **ODRy**: Port output data bit (y = 0..15)

These bits can be read and written by software.

Note: For atomic bit set/reset, the ODR bits can be individually set and/or reset by writing to the GPIOx_BSRR or GPIOx_BRR registers (x = A..D, F).

8.4.7 GPIO port bit set/reset register (GPIOx_BSRR) (x = A..D, F)

Address offset: 0x18

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
BR15	BR14	BR13	BR12	BR11	BR10	BR9	BR8	BR7	BR6	BR5	BR4	BR3	BR2	BR1	BR0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BS15	BS14	BS13	BS12	BS11	BS10	BS9	BS8	BS7	BS6	BS5	BS4	BS3	BS2	BS1	BS0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:16 **BRy**: Port x reset bit y (y = 0..15)

These bits are write-only. A read to these bits returns the value 0x0000.

0: No action on the corresponding ODRx bit

1: Resets the corresponding ODRx bit

Note: If both BSx and BRx are set, BSx has priority.

Bits 15:0 **BSy**: Port x set bit y (y= 0..15)

These bits are write-only. A read to these bits returns the value 0x0000.

0: No action on the corresponding ODRx bit

1: Sets the corresponding ODRx bit

8.4.8 GPIO port configuration lock register (GPIOx_LCKR) (x = A..B)

This register is used to lock the configuration of the port bits when a correct write sequence is applied to bit 16 (LCKK). The value of bits [15:0] is used to lock the configuration of the GPIO. During the write sequence, the value of LCKR[15:0] must not change. When the LOCK sequence has been applied on a port bit, the value of this port bit can no longer be modified until the next MCU reset or peripheral reset.

Note: A specific write sequence is used to write to the GPIOx_LCKR register. Only word access (32-bit long) is allowed during this locking sequence.

Each lock bit freezes a specific configuration register (control and alternate function registers).

Address offset: 0x1C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	LCKK
															rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
LCK15	LCK14	LCK13	LCK12	LCK11	LCK10	LCK9	LCK8	LCK7	LCK6	LCK5	LCK4	LCK3	LCK2	LCK1	LCK0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:17 Reserved, must be kept at reset value.

Bit 16 **LCKK**: Lock key

This bit can be read any time. It can only be modified using the lock key write sequence.

0: Port configuration lock key not active

1: Port configuration lock key active. The GPIOx_LCKR register is locked until the next MCU reset or peripheral reset.

LOCK key write sequence:

WR LCKR[16] = '1' + LCKR[15:0]

WR LCKR[16] = '0' + LCKR[15:0]

WR LCKR[16] = '1' + LCKR[15:0]

RD LCKR

RD LCKR[16] = '1' (this read operation is optional but it confirms that the lock is active)

Note: During the LOCK key write sequence, the value of LCK[15:0] must not change.

Any error in the lock sequence aborts the lock.

After the first lock sequence on any bit of the port, any read access on the LCKK bit will return '1' until the next MCU reset or peripheral reset.

For code example refer to the Appendix section [A.4.1: Lock sequence code example](#).

Bits 15:0 **LCKy**: Port x lock bit y (y = 0..15)

These bits are read/write but can only be written when the LCKK bit is '0'.

0: Port configuration not locked

1: Port configuration locked

8.4.9 GPIO alternate function low register (GPIOx_AFRL) (x = A..D,)

Address offset: 0x20

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AFSEL7[3:0]				AFSEL6[3:0]				AFSEL5[3:0]				AFSEL4[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AFSEL3[3:0]				AFSEL2[3:0]				AFSEL1[3:0]				AFSEL0[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:0 **AFSELy[3:0]**: Alternate function selection for port x pin y (y = 0..7)

These bits are written by software to configure alternate function I/Os

AFSELy selection:

0000: AF0	1000: Reserved
0001: AF1	1001: Reserved
0010: AF2	1010: Reserved
0011: AF3	1011: Reserved
0100: AF4	1100: Reserved
0101: AF5	1101: Reserved
0110: AF6	1110: Reserved
0111: AF7	1111: Reserved

8.4.10 GPIO alternate function high register (GPIOx_AFRH) (x = A..D, F)

Address offset: 0x24

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AFSEL15[3:0]				AFSEL14[3:0]				AFSEL13[3:0]				AFSEL12[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AFSEL11[3:0]				AFSEL10[3:0]				AFSEL9[3:0]				AFSEL8[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:0 **AFSELY[3:0]**: Alternate function selection for port x pin y (y = 8..15)

These bits are written by software to configure alternate function I/Os

AFSELY selection:

0000: AF0	1000: Reserved
0001: AF1	1001: Reserved
0010: AF2	1010: Reserved
0011: AF3	1011: Reserved
0100: AF4	1100: Reserved
0101: AF5	1101: Reserved
0110: AF6	1110: Reserved
0111: AF7	1111: Reserved

8.4.11 GPIO port bit reset register (GPIOx_BRR) (x = A..D, F)

Address offset: 0x28

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BR15	BR14	BR13	BR12	BR11	BR10	BR9	BR8	BR7	BR6	BR5	BR4	BR3	BR2	BR1	BR0
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:16 Reserved

Bits 15:0 **BRy**: Port x Reset bit y (y = 0..15)

These bits are write-only. A read to these bits returns the value 0x0000

- 0: No action on the corresponding ODx bit
- 1: Reset the corresponding ODx bit

8.4.12 GPIO register map

The following table gives the GPIO register map and reset values.

Table 23. GPIO register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x00	GPIOA_MODER	MODER15[1:0]		MODER14[1:0]		MODER13[1:0]		MODER12[1:0]		MODER11[1:0]		MODER10[1:0]		MODER9[1:0]		MODER8[1:0]		MODER7[1:0]		MODER6[1:0]		MODER5[1:0]		MODER4[1:0]		MODER3[1:0]		MODER2[1:0]		MODER1[1:0]		MODER0[1:0]		
	Reset value	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x00	GPIOx_MODER (where x = B..F)	MODER15[1:0]		MODER14[1:0]		MODER13[1:0]		MODER12[1:0]		MODER11[1:0]		MODER10[1:0]		MODER9[1:0]		MODER8[1:0]		MODER7[1:0]		MODER6[1:0]		MODER5[1:0]		MODER4[1:0]		MODER3[1:0]		MODER2[1:0]		MODER1[1:0]		MODER0[1:0]		
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x04	GPIOx_OTYPER (where x = A..F)	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OT15	OT14	OT13	OT12	OT11	OT10	OT9	OT8	OT7	OT6	OT5	OT4	OT3	OT2	OT1	OT0	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x08	GPIOx_OSPEEDR (where x = B..F)	OSPEEDR15[1:0]		OSPEEDR14[1:0]		OSPEEDR13[1:0]		OSPEEDR12[1:0]		OSPEEDR11[1:0]		OSPEEDR10[1:0]		OSPEEDR9[1:0]		OSPEEDR8[1:0]		OSPEEDR7[1:0]		OSPEEDR6[1:0]		OSPEEDR5[1:0]		OSPEEDR4[1:0]		OSPEEDR3[1:0]		OSPEEDR2[1:0]		OSPEEDR1[1:0]		OSPEEDR0[1:0]		
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x0C	GPIOA_PUPDR	PUPDR15[1:0]		PUPDR14[1:0]		PUPDR13[1:0]		PUPDR12[1:0]		PUPDR11[1:0]		PUPDR10[1:0]		PUPDR9[1:0]		PUPDR8[1:0]		PUPDR7[1:0]		PUPDR6[1:0]		PUPDR5[1:0]		PUPDR4[1:0]		PUPDR3[1:0]		PUPDR2[1:0]		PUPDR1[1:0]		PUPDR0[1:0]		
	Reset value	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x0C	GPIOx_PUPDR (where x = B..D,F)	PUPDR15[1:0]		PUPDR14[1:0]		PUPDR13[1:0]		PUPDR12[1:0]		PUPDR11[1:0]		PUPDR10[1:0]		PUPDR9[1:0]		PUPDR8[1:0]		PUPDR7[1:0]		PUPDR6[1:0]		PUPDR5[1:0]		PUPDR4[1:0]		PUPDR3[1:0]		PUPDR2[1:0]		PUPDR1[1:0]		PUPDR0[1:0]		
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x10	GPIOx_IDR (where x = A..F)	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IDR15	IDR14	IDR13	IDR12	IDR11	IDR10	IDR9	IDR8	IDR7	IDR6	IDR5	IDR4	IDR3	IDR2	IDR1	IDR0	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x14	GPIOx_ODR (where x = A..F)	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ODR15	ODR14	ODR13	ODR12	ODR11	ODR10	ODR9	ODR8	ODR7	ODR6	ODR5	ODR4	ODR3	ODR2	ODR1	ODR0	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x18	GPIOx_BSRR (where x = A..F)	BR15	BR14	BR13	BR12	BR11	BR10	BR9	BR8	BR7	BR6	BR5	BR4	BR3	BR2	BR1	BR0	BS15	BS14	BS13	BS12	BS11	BS10	BS9	BS8	BS7	BS6	BS5	BS4	BS3	BS2	BS1	BS0	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x1C	GPIOx_LCKR (where x = A..B)	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	LCKK	LCK15	LCK14	LCK13	LCK12	LCK11	LCK10	LCK9	LCK8	LCK7	LCK6	LCK5	LCK4	LCK3	LCK2	LCK1	LCK0	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x20	GPIOx_AFRL (where x = A.., B)	AFSEL7 [3:0]			AFSEL6 [3:0]			AFSEL5 [3:0]			AFSEL4 [3:0]			AFSEL3 [3:0]			AFSEL2 [3:0]			AFSEL1 [3:0]			AFSEL0 [3:0]			AFSEL0 [3:0]			AFSEL0 [3:0]			AFSEL0 [3:0]		
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Table 23. GPIO register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x24	GPIOx_AFRH (where x = A..B)	AFSEL15 [3:0]				AFSEL14 [3:0]				AFSEL13 [3:0]				AFSEL12 [3:0]				AFSEL11 [3:0]				AFSEL10 [3:0]				AFSEL9 [3:0]				AFSEL8 [3:0]			
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x28	GPIOx_BRR (where x = A..F)	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BR15	BR14	BR13	BR12	BR11	BR10	BR9	BR8	BR7	BR6	BR5	BR4	BR3	BR2	BR1	BR0
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

9 System configuration controller (SYSCFG)

The devices feature a set of configuration registers. The main purposes of the system configuration controller are the following:

- Enabling/disabling I²C Fast Mode Plus on some IO ports
- Remapping some DMA trigger sources to different DMA channels
- Remapping the memory located at the beginning of the code area
- Managing the external interrupt line connection to the GPIOs
- Managing robustness feature

9.1 SYSCFG registers

9.1.1 SYSCFG configuration register 1 (SYSCFG_CFGR1)

This register is used for specific configurations of memory and DMA requests remap and to control special I/O features.

Two bits are used to configure the type of memory accessible at address 0x0000 0000. These bits are used to select the physical remap by software and so, bypass the hardware BOOT selection.

After reset these bits take the value selected by the actual boot mode configuration.

Address offset: 0x00

Reset value: 0x0000 000X (X is the memory mode selected by the actual boot mode configuration)

Note: For STM32F030xC devices, DMA remapping bits are replaced by more flexible mapping configured through DMA_CSELR register. Refer to [Section 10.4.7: DMA channel selection register \(DMA_CSELR\)](#) for more details.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	USART3_DMA_RMP	Res.	Res.	I2C_PA10_FMP	I2C_PA9_FMP	Res.	I2C1_FMP	I2C_PB9_FMP	I2C_PB8_FMP	I2C_PB7_FMP	I2C_PB6_FMP
					rw			rw	rw		rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res	Res	TIM17_DMA_RMP	TIM16_DMA_RMP	USART1_RX_DMA_RMP	USART1_TX_DMA_RMP	ADC_DMA_RMP	Res.	Res.	PA11_PA12_RMP	Res.	Res.	MEM_MODE [1:0]		
			rw	rw	rw	rw	rw			rw			rw	rw	

Bits 31:27 Reserved, must be kept at reset value.

Bit 26 **USART3_DMA_RMP**: USART3 DMA request remapping bit. Available on STM32F070xB devices only.

This bit is set and cleared by software. It controls the remapping of USART3 DMA requests.

0: Disabled, need to enable remap before use.

1: Remap (USART3_RX and USART3_TX DMA requests mapped on DMA channel 3 and 2 respectively)

Bits 25:24 Reserved, must be kept at reset value.

Bits 23:22 **I2C_PAx_FMP**: Fast Mode Plus (FM+) driving capability activation bits. Available on STM32F030x4, STM32F030x6, STM32F070x6 and STM32F030xC devices only.

These bits are set and cleared by software. Each bit enables I²C FM+ mode for PA10 and PA9 I/Os.

0: PAX pin operates in standard mode.

1: I²C FM+ mode enabled on PAX pin and the Speed control is bypassed.

Bit 21 Reserved, must be kept at reset value.

Bit 20 **I2C1_FMP**: FM+ driving capability activation for I2C1. Not available on STM32F030x8 devices.

This bit is set and cleared by software. This bit is OR-ed with I2C_Pxx_FM+ bits.

0: FM+ mode is controlled by I2C_Pxx_FM+ bits only.

1: FM+ mode is enabled on all I2C1 pins selected through selection bits in GPIOx_AFR registers. This is the only way to enable the FM+ mode for pads without a dedicated I2C_Pxx_FM+ control bit.

Bits 19:16 **I2C_PBx_FMP**: Fast Mode Plus (FM+) driving capability activation bits.

These bits are set and cleared by software. Each bit enables I²C FM+ mode for PB6, PB7, PB8, and PB9 I/Os.

0: PBx pin operates in standard mode.

1: I²C FM+ mode enabled on PBx pin and the Speed control is bypassed.

Bits 15:13 Reserved, must be kept at reset value.

Bit 12 **TIM17_DMA_RMP**: TIM17 DMA request remapping bit. Available on STM32F030x4, STM32F030x6, STM32F070x6, STM32F030x8 and STM32F070xB devices only.

This bit is set and cleared by software. It controls the remapping of TIM17 DMA requests.

0: No remap (TIM17_CH1 and TIM17_UP DMA requests mapped on DMA channel 1)

1: Remap (TIM17_CH1 and TIM17_UP DMA requests mapped on DMA channel 2)

Bit 11 **TIM16_DMA_RMP**: TIM16 DMA request remapping bit. Available on STM32F030x4, STM32F030x6, STM32F070x6, STM32F030x8 and STM32F070xB devices only.

This bit is set and cleared by software. It controls the remapping of TIM16 DMA requests.

0: No remap (TIM16_CH1 and TIM16_UP DMA requests mapped on DMA channel 3)

1: Remap (TIM16_CH1 and TIM16_UP DMA requests mapped on DMA channel 4)

Bit 10 **USART1_RX_DMA_RMP**: USART1_RX DMA request remapping bit. Available on STM32F030x4, STM32F030x6, STM32F070x6, STM32F030x8 and STM32F070xB devices only.

This bit is set and cleared by software. It controls the remapping of USART1_RX DMA requests.

0: No remap (USART1_RX DMA request mapped on DMA channel 3)

1: Remap (USART1_RX DMA request mapped on DMA channel 5)

Bit 9 **USART1_TX_DMA_RMP**: USART1_TX DMA request remapping bit. . Available on STM32F030x4, STM32F030x6, STM32F070x6, STM32F030x8 and STM32F070xB devices only.

This bit is set and cleared by software. It bit controls the remapping of USART1_TX DMA requests.

- 0: No remap (USART1_TX DMA request mapped on DMA channel 2)
- 1: Remap (USART1_TX DMA request mapped on DMA channel 4)

Bit 8 **ADC_DMA_RMP**: ADC DMA request remapping bit. Available on STM32F030x4, STM32F030x6, STM32F070x6, STM32F030x8 and STM32F070xB devices only.

This bit is set and cleared by software. It controls the remapping of ADC DMA requests.

- 0: No remap (ADC DMA request mapped on DMA channel 1)
- 1: Remap (ADC DMA request mapped on DMA channel 2)

Bits 7:5 Reserved, must be kept at reset value.

Bit 4 **PA11_PA12_RMP**: PA11 and PA12 remapping bit for small packages (28 and 20 pins). Available on STM32F070x6 devices only.

This bit is set and cleared by software. It controls the mapping of either PA9/10 or PA11/12 pin pair on small pin-count packages.

- 0: No remap (pin pair PA9/10 mapped on the pins)
- 1: Remap (pin pair PA11/12 mapped instead of PA9/10)

Bits 3:2 Reserved, must be kept at reset value.

Bits 1:0 **MEM_MODE[1:0]**: Memory mapping selection bits

These bits are set and cleared by software. They control the memory internal mapping at address 0x0000 0000. After reset these bits take on the value selected by the actual boot mode configuration. Refer to [Chapter 2.5: Boot configuration](#) for more details.

- x0: Main Flash memory mapped at 0x0000 0000
- 01: System Flash memory mapped at 0x0000 0000
- 11: Embedded SRAM mapped at 0x0000 0000

9.1.2 SYSCFG external interrupt configuration register 1 (SYSCFG_EXTICR1)

Address offset: 0x08

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EXTI3[3:0]				EXTI2[3:0]				EXTI1[3:0]				EXTI0[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **EXTIx[3:0]**: EXTI x configuration bits (x = 0 to 3)

These bits are written by software to select the source input for the EXTIx external interrupt.

x000: PA[x] pin

x001: PB[x] pin

x010: PC[x] pin

x011: PD[x] pin

x100: Reserved

x101: PF[x] pin

other configurations: reserved

Note: Some of the I/O pins mentioned in the above register may not be available on small packages.

9.1.3 SYSCFG external interrupt configuration register 2 (SYSCFG_EXTICR2)

Address offset: 0x0C

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EXTI7[3:0]				EXTI6[3:0]				EXTI5[3:0]				EXTI4[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **EXTIx[3:0]**: EXTI x configuration bits (x = 4 to 7)

These bits are written by software to select the source input for the EXTIx external interrupt.

x000: PA[x] pin
 x001: PB[x] pin
 x010: PC[x] pin
 x011: PD[x] pin
 x100: Reserved
 x101: PF[x] pin
 other configurations: reserved

Note: Some of the I/O pins mentioned in the above register may not be available on small packages.

9.1.4 SYSCFG external interrupt configuration register 3 (SYSCFG_EXTICR3)

Address offset: 0x10

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EXTI11[3:0]				EXTI10[3:0]				EXTI9[3:0]				EXTI8[3:0]			
r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **EXTIx[3:0]**: EXTI x configuration bits (x = 8 to 11)

These bits are written by software to select the source input for the EXTIx external interrupt.

x000: PA[x] pin
 x001: PB[x] pin
 x010: PC[x] pin
 x011: PD[x] pin
 x100: Reserved
 x101: PF[x] pin
 other configurations: reserved

Note: Some of the I/O pins mentioned in the above register may not be available on small packages.

9.1.5 SYSCFG external interrupt configuration register 4 (SYSCFG_EXTICR4)

Address offset: 0x14

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EXTI15[3:0]				EXTI14[3:0]				EXTI13[3:0]				EXTI12[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **EXTIx[3:0]**: EXTI x configuration bits (x = 12 to 15)

These bits are written by software to select the source input for the EXTIx external interrupt.

x000: PA[x] pin

x001: PB[x] pin

x010: PC[x] pin

x011: PD[x] pin

x100: Reserved

x101: PF[x] pin

other configurations: reserved

Note: Some of the I/O pins mentioned in the above register may not be available on small packages.

9.1.6 SYSCFG configuration register 2 (SYSCFG_CFGR2)

Address offset: 0x18

System reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	SRAM_PEF	Res.	Res.	Res.	Res.	Res.	Res.	SRAM_PARITY_LOCK	LOCKUP_LOCK
							rc_w1							rw	rw

Bits 31:9 Reserved, must be kept at reset value

Bit 8 **SRAM_PEF**: SRAM parity error flag

This bit is set by hardware when an SRAM parity error is detected. It is cleared by software by writing '1'.

0: No SRAM parity error detected

1: SRAM parity error detected

Bits 7:2 Reserved, must be kept at reset value

Bit 1 **SRAM_PARITY_LOCK**: SRAM parity lock bit

This bit is set by software and cleared by a system reset. It can be used to enable and lock the SRAM parity error signal connection to TIM1/15/16/17 Break input.

0: SRAM parity error disconnected from TIM1/15/16/17 Break input

1: SRAM parity error connected to TIM1/15/16/17 Break input

Bit 0 **LOCKUP_LOCK**: Cortex-M0 LOCKUP bit enable bit

This bit is set by software and cleared by a system reset. It can be use to enable and lock the connection of Cortex-M0 LOCKUP (Hardfault) output to TIM1/15/16/17 Break input.

0: Cortex-M0 LOCKUP output disconnected from TIM1/15/16/17 Break input

1: Cortex-M0 LOCKUP output connected to TIM1/15/16/17 Break input

9.1.7 SYSCFG register maps

The following table gives the SYSCFG register map and the reset values.

Table 24. SYSCFG register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	SYSCFG_CFGR1	Res.	Res.	Res.	Res.	Res.	USART3_DMA_RMP	Res.	Res.	I2C_PA10_FMP	I2C_PA9_FMP	Res.	I2C1_FMP	I2C_PB9_FMP	I2C_PB8_FMP	I2C_PB7_FMP	I2C_PB6_FMP	Res.	Res.	Res.	TIM17_DMA_RMP	TIM16_DMA_RMP	USART1_RX_DMA_RMP	USART1_TX_DMA_RMP	ADC_DMA_RMP	Res.	Res.	Res.	PA11_PA12_RMP	Res.	Res.	MEM_MODE[1:0]	
	Reset value						0			0	0		0	0	0	0	0				0	0	0	0	0				0			X	X
0x08	SYSCFG_EXTICR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI3[3:0]			EXTI2[3:0]			EXTI1[3:0]			EXTI0[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x0C	SYSCFG_EXTICR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI7[3:0]			EXTI6[3:0]			EXTI5[3:0]			EXTI4[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x10	SYSCFG_EXTICR3	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI11[3:0]			EXTI10[3:0]			EXTI9[3:0]			EXTI8[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x14	SYSCFG_EXTICR4	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EXTI15[3:0]			EXTI14[3:0]			EXTI13[3:0]			EXTI12[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x18	SYSCFG_CFGR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SRAM_PEF	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SRAM_PARITY_LOCK	LOCUP_LOCK
	Reset value																							0								0	0

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

10 Direct memory access controller (DMA)

10.1 Introduction

Direct memory access (DMA) is used in order to provide high-speed data transfer between peripherals and memory as well as memory to memory. Data can be quickly moved by DMA without any CPU actions. This keeps CPU resources free for other operations.

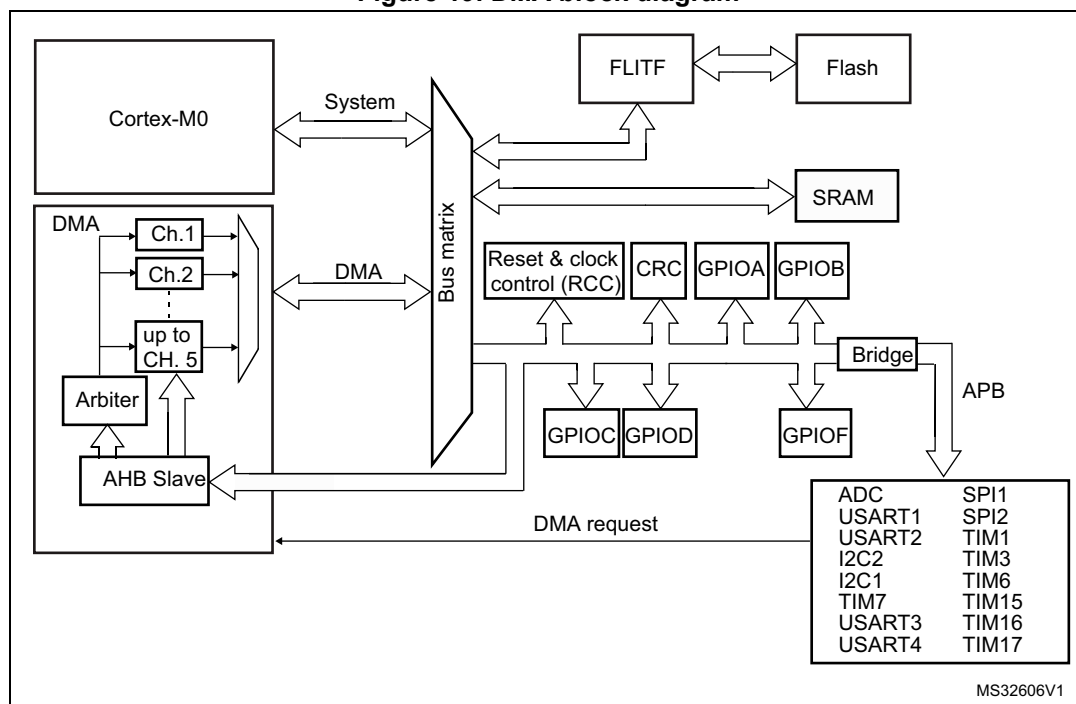
The DMA controller has 5 channels, each dedicated to managing memory access requests from one or more peripherals. It has an arbiter for handling the priority between DMA requests.

10.2 DMA main features

- 5 independently configurable channels (requests) on DMA
- Each channel is connected to dedicated hardware DMA requests, software trigger is also supported on each channel. This configuration is done by software.
- Priorities between requests from the DMA channels are software programmable (4 levels consisting of very high, high, medium, low) or hardware in case of equality (request 1 has priority over request 2, etc.)
- Independent source and destination transfer size (byte, half word, word), emulating packing and unpacking. Source/destination addresses must be aligned on the data size.
- Support for circular buffer management
- 3 event flags (DMA Half Transfer, DMA Transfer complete and DMA Transfer Error) logically ORed together in a single interrupt request for each channel
- Memory-to-memory transfer
- Peripheral-to-memory and memory-to-peripheral, and peripheral-to-peripheral transfers
- Access to peripherals as source and destination
- Programmable number of data to be transferred: up to 65535

10.3 DMA functional description

Figure 19. DMA block diagram



The DMA controller performs direct memory transfer by sharing the system bus with the ARM® Cortex®-M0 core. The DMA request may stop the CPU access to the system bus for some bus cycles, when the CPU and DMA are targeting the same destination (memory or peripheral). The bus matrix implements round-robin scheduling, thus ensuring at least half of the system bus bandwidth (both to memory and peripheral) for the CPU.

10.3.1 DMA transactions

After an event, the peripheral sends a request signal to the DMA Controller. The DMA controller serves the request depending on the channel priorities. As soon as the DMA Controller accesses the peripheral, an Acknowledge is sent to the peripheral by the DMA Controller. The peripheral releases its request as soon as it gets the Acknowledge from the DMA Controller. Once the request is de-asserted by the peripheral, the DMA Controller release the Acknowledge. If there are more requests, the peripheral can initiate the next transaction.

In summary, each DMA transfer consists of three operations:

- The loading of data from the peripheral data register or a location in memory addressed through an internal current peripheral/memory address register. The start address used for the first transfer is the base peripheral/memory address programmed in the DMA_CPARx or DMA_CMARx register.

- The storage of the data loaded to the peripheral data register or a location in memory addressed through an internal current peripheral/memory address register. The start address used for the first transfer is the base peripheral/memory address programmed in the DMA_CPARx or DMA_CMARx register.
- The post-decrementing of the DMA_CNDTRx register, which contains the number of transactions that have still to be performed.

10.3.2 Arbiter

The arbiter manages the channel requests based on their priority and launches the peripheral/memory access sequences.

The priorities are managed in two stages:

- Software: each channel priority can be configured in the DMA_CCRx register. There are four levels:
 - Very high priority
 - High priority
 - Medium priority
 - Low priority
- Hardware: if 2 requests have the same software priority level, the channel with the lowest number will get priority versus the channel with the highest number. For example, channel 2 gets priority over channel 4.

10.3.3 DMA channels

Each channel can handle DMA transfer between a peripheral register located at a fixed address and a memory address. The amount of data to be transferred (up to 65535) is programmable. The register which contains the amount of data items to be transferred is decremented after each transaction.

Programmable data sizes

Transfer data sizes of the peripheral and memory are fully programmable through the PSIZE and MSIZE bits in the DMA_CCRx register.

Pointer incrementation

Peripheral and memory pointers can optionally be automatically post-incremented after each transaction depending on the PINC and MINC bits in the DMA_CCRx register. If incremented mode is enabled, the address of the next transfer will be the address of the previous one incremented by 1, 2 or 4 depending on the chosen data size. The first transfer address is the one programmed in the DMA_CPARx/DMA_CMARx registers. During transfer operations, these registers keep the initially programmed value. The current transfer addresses (in the current internal peripheral/memory address register) are not accessible by software.

If the channel is configured in non-circular mode, no DMA request is served after the last transfer (that is once the number of data items to be transferred has reached zero). In order to reload a new number of data items to be transferred into the DMA_CNDTRx register, the DMA channel must be disabled.

Note: *If a DMA channel is disabled, the DMA registers are not reset. The DMA channel registers (DMA_CCRx, DMA_CPARx and DMA_CMARx) retain the initial values programmed during the channel configuration phase.*

In circular mode, after the last transfer, the DMA_CNDTRx register is automatically reloaded with the initially programmed value. The current internal address registers are reloaded with the base address values from the DMA_CPARx/DMA_CMARx registers.

Channel configuration procedure

The following sequence should be followed to configure a DMA channel x (where x is the channel number).

1. Set the peripheral register address in the DMA_CPARx register. The data will be moved from/ to this address to/ from the memory after the peripheral event.
2. Set the memory address in the DMA_CMARx register. The data will be written to or read from this memory after the peripheral event.
3. Configure the total number of data to be transferred in the DMA_CNDTRx register. After each peripheral event, this value will be decremented.
4. Configure the channel priority using the PL[1:0] bits in the DMA_CCRx register
5. Configure data transfer direction, circular mode, peripheral & memory incremented mode, peripheral & memory data size, and interrupt after half and/or full transfer in the DMA_CCRx register
6. Activate the channel by setting the ENABLE bit in the DMA_CCRx register.

For code example refer to the Appendix section [A.5.1: DMA Channel Configuration sequence code example](#).

As soon as the channel is enabled, it can serve any DMA request from the peripheral connected on the channel.

Once half of the bytes are transferred, the half-transfer flag (HTIF) is set and an interrupt is generated if the Half-Transfer Interrupt Enable bit (HTIE) is set. At the end of the transfer, the Transfer Complete Flag (TCIF) is set and an interrupt is generated if the Transfer Complete Interrupt Enable bit (TCIE) is set.

Circular mode

Circular mode is available to handle circular buffers and continuous data flows (e.g. ADC scan mode). This feature can be enabled using the CIRC bit in the DMA_CCRx register. When circular mode is activated, the number of data to be transferred is automatically reloaded with the initial value programmed during the channel configuration phase, and the DMA requests continue to be served.

Memory-to-memory mode

The DMA channels can also work without being triggered by a request from a peripheral. This mode is called Memory to Memory mode.

If the MEM2MEM bit in the DMA_CCRx register is set, then the channel initiates transfers as soon as it is enabled by software by setting the Enable bit (EN) in the DMA_CCRx register. The transfer stops once the DMA_CNDTRx register reaches zero. Memory to Memory mode may not be used at the same time as Circular mode.

10.3.4 Programmable data width, data alignment and endians

When PSIZE and MSIZE are not equal, the DMA performs some data alignments as described in [Table 25: Programmable data width & endian behavior \(when bits PINC = MINC = 1\)](#).

Table 25. Programmable data width & endian behavior (when bits PINC = MINC = 1)

Source port width	Destination port width	Number of data items to transfer (NDT)	Source content: address / data	Transfer operations	Destination content: address / data
8	8	4	@0x0 / B0 @0x1 / B1 @0x2 / B2 @0x3 / B3	1: READ B0[7:0] @0x0 then WRITE B0[7:0] @0x0 2: READ B1[7:0] @0x1 then WRITE B1[7:0] @0x1 3: READ B2[7:0] @0x2 then WRITE B2[7:0] @0x2 4: READ B3[7:0] @0x3 then WRITE B3[7:0] @0x3	@0x0 / B0 @0x1 / B1 @0x2 / B2 @0x3 / B3
8	16	4	@0x0 / B0 @0x1 / B1 @0x2 / B2 @0x3 / B3	1: READ B0[7:0] @0x0 then WRITE 00B0[15:0] @0x0 2: READ B1[7:0] @0x1 then WRITE 00B1[15:0] @0x2 3: READ B2[7:0] @0x2 then WRITE 00B2[15:0] @0x4 4: READ B3[7:0] @0x3 then WRITE 00B3[15:0] @0x6	@0x0 / 00B0 @0x2 / 00B1 @0x4 / 00B2 @0x6 / 00B3
8	32	4	@0x0 / B0 @0x1 / B1 @0x2 / B2 @0x3 / B3	1: READ B0[7:0] @0x0 then WRITE 000000B0[31:0] @0x0 2: READ B1[7:0] @0x1 then WRITE 000000B1[31:0] @0x4 3: READ B2[7:0] @0x2 then WRITE 000000B2[31:0] @0x8 4: READ B3[7:0] @0x3 then WRITE 000000B3[31:0] @0xC	@0x0 / 000000B0 @0x4 / 000000B1 @0x8 / 000000B2 @0xC / 000000B3
16	8	4	@0x0 / B1B0 @0x2 / B3B2 @0x4 / B5B4 @0x6 / B7B6	1: READ B1B0[15:0] @0x0 then WRITE B0[7:0] @0x0 2: READ B3B2[15:0] @0x2 then WRITE B2[7:0] @0x1 3: READ B5B4[15:0] @0x4 then WRITE B4[7:0] @0x2 4: READ B7B6[15:0] @0x6 then WRITE B6[7:0] @0x3	@0x0 / B0 @0x1 / B2 @0x2 / B4 @0x3 / B6
16	16	4	@0x0 / B1B0 @0x2 / B3B2 @0x4 / B5B4 @0x6 / B7B6	1: READ B1B0[15:0] @0x0 then WRITE B1B0[15:0] @0x0 2: READ B3B2[15:0] @0x2 then WRITE B3B2[15:0] @0x2 3: READ B5B4[15:0] @0x4 then WRITE B5B4[15:0] @0x4 4: READ B7B6[15:0] @0x6 then WRITE B7B6[15:0] @0x6	@0x0 / B1B0 @0x2 / B3B2 @0x4 / B5B4 @0x6 / B7B6
16	32	4	@0x0 / B1B0 @0x2 / B3B2 @0x4 / B5B4 @0x6 / B7B6	1: READ B1B0[15:0] @0x0 then WRITE 0000B1B0[31:0] @0x0 2: READ B3B2[15:0] @0x2 then WRITE 0000B3B2[31:0] @0x4 3: READ B5B4[15:0] @0x4 then WRITE 0000B5B4[31:0] @0x8 4: READ B7B6[15:0] @0x6 then WRITE 0000B7B6[31:0] @0xC	@0x0 / 0000B1B0 @0x4 / 0000B3B2 @0x8 / 0000B5B4 @0xC / 0000B7B6
32	8	4	@0x0 / B3B2B1B0 @0x4 / B7B6B5B4 @0x8 / BBBAB9B8 @0xC / BFBEBDBC	1: READ B3B2B1B0[31:0] @0x0 then WRITE B0[7:0] @0x0 2: READ B7B6B5B4[31:0] @0x4 then WRITE B4[7:0] @0x1 3: READ BBBAB9B8[31:0] @0x8 then WRITE B8[7:0] @0x2 4: READ BFBEBDBC[31:0] @0xC then WRITE BC[7:0] @0x3	@0x0 / B0 @0x1 / B4 @0x2 / B8 @0x3 / BC
32	16	4	@0x0 / B3B2B1B0 @0x4 / B7B6B5B4 @0x8 / BBBAB9B8 @0xC / BFBEBDBC	1: READ B3B2B1B0[31:0] @0x0 then WRITE B1B0[15:0] @0x0 2: READ B7B6B5B4[31:0] @0x4 then WRITE B5B4[15:0] @0x2 3: READ BBBAB9B8[31:0] @0x8 then WRITE B9B8[15:0] @0x4 4: READ BFBEBDBC[31:0] @0xC then WRITE BDBC[15:0] @0x6	@0x0 / B1B0 @0x2 / B5B4 @0x4 / B9B8 @0x6 / BDBC
32	32	4	@0x0 / B3B2B1B0 @0x4 / B7B6B5B4 @0x8 / BBBAB9B8 @0xC / BFBEBDBC	1: READ B3B2B1B0[31:0] @0x0 then WRITE B3B2B1B0[31:0] @0x0 2: READ B7B6B5B4[31:0] @0x4 then WRITE B7B6B5B4[31:0] @0x4 3: READ BBBAB9B8[31:0] @0x8 then WRITE BBBAB9B8[31:0] @0x8 4: READ BFBEBDBC[31:0] @0xC then WRITE BFBEBDBC[31:0] @0xC	@0x0 / B3B2B1B0 @0x4 / B7B6B5B4 @0x8 / BBBAB9B8 @0xC / BFBEBDBC

Addressing an AHB peripheral that does not support byte or halfword write operations

When the DMA initiates an AHB byte or halfword write operation, the data are duplicated on the unused lanes of the HWDATA[31:0] bus. So when the used AHB slave peripheral does not support byte or halfword write operations (when HSIZE is not used by the peripheral) *and* does not generate any error, the DMA writes the 32 HWDATA bits as shown in the two examples below:

- To write the halfword “0xABCD”, the DMA sets the HWDATA bus to “0xABCDABCD” with HSIZE = HalfWord
- To write the byte “0xAB”, the DMA sets the HWDATA bus to “0xABABABAB” with HSIZE = Byte

Assuming that the AHB/APB bridge is an AHB 32-bit slave peripheral that does not take the HSIZE data into account, it will transform any AHB byte or halfword operation into a 32-bit APB operation in the following manner:

- An AHB byte write operation of the data “0xB0” to 0x0 (or to 0x1, 0x2 or 0x3) will be converted to an APB word write operation of the data “0xB0B0B0B0” to 0x0
- An AHB halfword write operation of the data “0xB1B0” to 0x0 (or to 0x2) will be converted to an APB word write operation of the data “0xB1B0B1B0” to 0x0

For instance, to write the APB backup registers (16-bit registers aligned to a 32-bit address boundary), the software must configure the memory source size (MSIZE) to “16-bit” and the peripheral destination size (PSIZE) to “32-bit”.

10.3.5 Error management

A DMA transfer error can be generated by reading from or writing to a reserved address space. When a DMA transfer error occurs during a DMA read or a write access, the faulty channel is automatically disabled through a hardware clear of its EN bit in the corresponding Channel configuration register (DMA_CCRx). The channel's transfer error interrupt flag (TEIF) in the DMA_IFR register is set and an interrupt is generated if the transfer error interrupt enable bit (TEIE) in the DMA_CCRx register is set.

10.3.6 DMA interrupts

An interrupt can be produced on a Half-transfer, Transfer complete or Transfer error for each DMA channel. Separate interrupt enable bits are available for flexibility.

Table 26. DMA interrupt requests

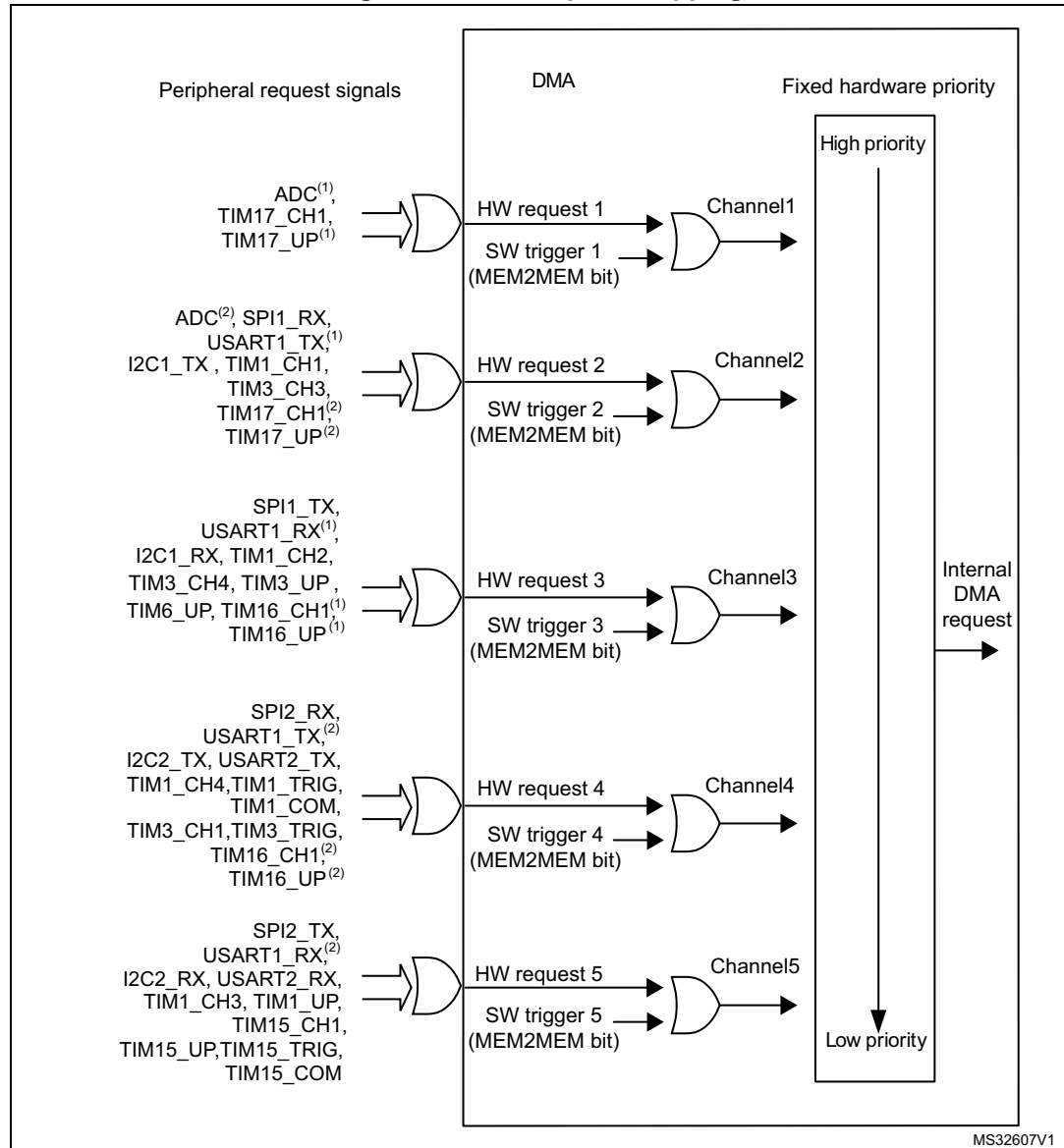
Interrupt event	Event flag	Enable control bit
Half-transfer	HTIF	HTIE
Transfer complete	TCIF	TCIE
Transfer error	TEIF	TEIE

DMA controller

The hardware requests from the peripherals (TIMx, ADC, SPI, I2C, and USARTx) are simply logically ORed before entering the DMA. This means that on one channel, only one request must be enabled at a time.

The peripheral DMA requests can be independently activated/de-activated by programming the DMA control bit in the registers of the corresponding peripheral.

Figure 20. DMA request mapping



1. DMA request mapped on this DMA channel only if the corresponding remapping bit is cleared in the SYSCFG_CFGR1 register. For more details, please refer to [Section 9.1.1: SYSCFG configuration register 1 \(SYSCFG_CFGR1\) on page 144](#).
2. DMA request mapped on this DMA channel only if the corresponding remapping bit is set in the SYSCFG_CFGR1 register. For more details, please refer to [Section 9.1.1: SYSCFG configuration register 1 \(SYSCFG_CFGR1\) on page 144](#).

[Table 27](#) lists the DMA requests for each channel.

**Table 27. Summary of the DMA requests for each channel
on STM32F030x4/6, STM32F070x6, STM32F070xB and STM32F030x8 devices**

Peripherals	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5
ADC	ADC ⁽¹⁾	ADC ⁽²⁾	-	-	-
SPI	-	SPI1_RX	SPI1_TX	SPI2_RX	SPI2_TX
USART	-	USART1_TX ⁽¹⁾ USART3_TX ⁽²⁾	USART1_RX ⁽¹⁾ USART3_RX ⁽²⁾	USART1_TX ⁽²⁾ USART2_TX	USART1_RX ⁽²⁾ USART2_RX
I2C	-	I2C1_TX	I2C1_RX	I2C2_TX	I2C2_RX
TIM1	-	TIM1_CH1	TIM1_CH2	TIM1_CH4 TIM1_TRIG TIM1_COM	TIM1_CH3 TIM1_UP
TIM3	-	TIM3_CH3	TIM3_CH4 TIM3_UP	TIM3_CH1 TIM3_TRIG	-
TIM6	-	-	TIM6_UP	-	-
TIM7	-	-	-	TIM7_UP	-
TIM15	-	-	-	-	TIM15_CH1 TIM15_UP TIM15_TRIG TIM15_COM
TIM16	-	-	TIM16_CH1 ⁽¹⁾ TIM16_UP ⁽¹⁾	TIM16_CH1 ⁽²⁾ TIM16_UP ⁽²⁾	-
TIM17	TIM17_CH1 ⁽¹⁾ TIM17_UP ⁽¹⁾	TIM17_CH1 ⁽²⁾ TIM17_UP ⁽²⁾	-	-	-

1. DMA request mapped on this DMA channel only if the corresponding remapping bit is cleared in the SYSCFG_CFGR1 register. For more details, please refer to [Section 9.1.1: SYSCFG configuration register 1 \(SYSCFG_CFGR1\) on page 144](#).
2. DMA request mapped on this DMA channel only if the corresponding remapping bit is set in the SYSCFG_CFGR1 register. For more details, please refer to [Section 9.1.1: SYSCFG configuration register 1 \(SYSCFG_CFGR1\) on page 144](#).

Table 28. Summary of the DMA requests for each channel on STM32F030xC devices

CxS [3:0]	Channel 1	Channel 2	Channel 3	Channel 4	Channel 5
0000	-	TIM3_CH3	TIM3_CH4 TIM3_UP	TIM1_CH4 TIM1_TRIG TIM1_COM	TIM1_UP
	-	-	-		TIM15_CH1 TIM15_UP TIM15_TRIG TIM15_COM
	ADC	-	TIM6_UP	TIM7_UP	
	-	USART1_TX	USART1_RX	USART2_TX	USART2_RX
	-	-	-	-	-
	-	SPI1_RX	SPI1_TX	SPI2_RX	SPI2_TX
	-	I2C1_TX	I2C1_RX	I2C2_TX	I2C2_RX
	-	TIM1_CH1	TIM1_CH2	-	TIM1_CH3
	TIM17_CH1 TIM17_UP	-	TIM16_CH1 TIM16_UP	TIM3_CH1 TIM3_TRIG	-
0001	ADC	ADC	TIM6_UP	TIM7_UP	-
0010	-	I2C1_TX	I2C1_RX	I2C2_TX	I2C2_RX
0011	-	SPI1_RX	SPI1_TX	SPI2_RX	SPI2_TX
0100	-	TIM1_CH1	TIM1_CH2	-	TIM1_CH3
0101	-	-	-	-	-
0110	-	-	-	TIM3_CH1 TIM3_TRIG	-
0111	TIM17_CH1 TIM17_UP	TIM17_CH1 TIM17_UP	TIM16_CH1 TIM16_UP	TIM16_CH1 TIM16_UP	-
1000	USART1_RX	USART1_TX	USART1_RX	USART1_TX	USART1_RX
1001	USART2_RX	USART2_TX	USART2_RX	USART2_TX	USART2_RX
1010	USART3_RX	USART3_TX	USART3_RX	USART3_TX	USART3_RX
1011	USART4_RX	USART4_TX	USART4_RX	USART4_TX	USART4_RX
1100	USART5_RX	USART5_TX	USART5_RX	USART5_TX	USART5_RX
1101	USART6_RX	USART6_TX	USART6_RX	USART6_TX	USART6_RX

10.4 DMA registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by bytes (8-bit), half-words (16-bit) or words (32-bit).

10.4.1 DMA interrupt status register (DMA_ISR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
				Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TEIF5	HTIF5	TCIF5	GIF5
												r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TEIF4	HTIF4	TCIF4	GIF4	TEIF3	HTIF3	TCIF3	GIF3	TEIF2	HTIF2	TCIF2	GIF2	TEIF1	HTIF1	TCIF1	GIF1
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 19, 15, 11, 7, 3 **TEIFx**: Channel x transfer error flag (x = 1..5)

This bit is set by hardware. It is cleared by software writing 1 to the corresponding bit in the DMA_IFCR register.

0: No transfer error (TE) on channel x

1: A transfer error (TE) occurred on channel x

Bits 18, 14, 10, 6, 2 **HTIFx**: Channel x half transfer flag (x = 1..5)

This bit is set by hardware. It is cleared by software writing 1 to the corresponding bit in the DMA_IFCR register.

0: No half transfer (HT) event on channel x

1: A half transfer (HT) event occurred on channel x

Bits 17, 13, 9, 5, 1 **TCIFx**: Channel x transfer complete flag (x = 1..5)

This bit is set by hardware. It is cleared by software writing 1 to the corresponding bit in the DMA_IFCR register.

0: No transfer complete (TC) event on channel x

1: A transfer complete (TC) event occurred on channel x

Bits 16, 12, 8, 4, 0 **GIFx**: Channel x global interrupt flag (x = 1..5)

This bit is set by hardware. It is cleared by software writing 1 to the corresponding bit in the DMA_IFCR register.

0: No TE, HT or TC event on channel x

1: A TE, HT or TC event occurred on channel x

10.4.2 DMA interrupt flag clear register (DMA_IFCR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
				Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTEIF5	CHTIF5	CTCIF5	CGIF5
												w	w	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CTEIF4	CHTIF4	CTCIF4	CGIF4	CTEIF3	CHTIF3	CTCIF3	CGIF3	CTEIF2	CHTIF2	CTCIF2	CGIF2	CTEIF1	CHTIF1	CTCIF1	CGIF1
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 19, 15, 11, 7, 3 **CTEIFx**: Channel x transfer error clear (x = 1..5)

This bit is set by software.

0: No effect

1: Clears the corresponding TEIF flag in the DMA_ISR register

Bits 18, 14, 10, 6, 2 **CHTIFx**: Channel x half transfer clear (x = 1..5)

This bit is set by software.

0: No effect

1: Clears the corresponding HTIF flag in the DMA_ISR register

Bits 17, 13, 9, 5, 1 **CTCIFx**: Channel x transfer complete clear (x = 1..5)

This bit is set by software.

0: No effect

1: Clears the corresponding TCIF flag in the DMA_ISR register

Bits 16, 12, 8, 4, 0 **CGIFx**: Channel x global interrupt clear (x = 1..5)

This bit is set by software.

0: No effect

1: Clears the GIF, TEIF, HTIF and TCIF flags in the DMA_ISR register

10.4.3 DMA channel x configuration register (DMA_CCRx) (x = 1..5, where x = channel number)

Address offset: 0x08 + 0d20 × (channel number – 1)

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
	MEM2 MEM	PL[1:0]		MSIZE[1:0]		PSIZE[1:0]		MINC	PINC	CIRC	DIR	TEIE	HTIE	TCIE	EN
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:1 Reserved, must be kept at reset value.

Bit 14 **MEM2MEM**: Memory to memory mode

This bit is set and cleared by software.

0: Memory to memory mode disabled

1: Memory to memory mode enabled

Bits 13:12 **PL[1:0]**: Channel priority level

These bits are set and cleared by software.

00: Low

01: Medium

10: High

11: Very high

Bits 11:10 **MSIZE[1:0]**: Memory size

These bits are set and cleared by software.

00: 8-bits

01: 16-bits

10: 32-bits

11: Reserved

Bits 9:8 **PSIZE[1:0]**: Peripheral size

These bits are set and cleared by software.

00: 8-bits

01: 16-bits

10: 32-bits

11: Reserved

Bit 7 **MINC**: Memory increment mode

This bit is set and cleared by software.

0: Memory increment mode disabled

1: Memory increment mode enabled

Bit 6 **PINC**: Peripheral increment mode

This bit is set and cleared by software.

0: Peripheral increment mode disabled

1: Peripheral increment mode enabled

- Bit 5 **CIRC**: Circular mode
This bit is set and cleared by software.
0: Circular mode disabled
1: Circular mode enabled
- Bit 4 **DIR**: Data transfer direction
This bit is set and cleared by software.
0: Read from peripheral
1: Read from memory
- Bit 3 **TEIE**: Transfer error interrupt enable
This bit is set and cleared by software.
0: TE interrupt disabled
1: TE interrupt enabled
- Bit 2 **HTIE**: Half transfer interrupt enable
This bit is set and cleared by software.
0: HT interrupt disabled
1: HT interrupt enabled
- Bit 1 **TCIE**: Transfer complete interrupt enable
This bit is set and cleared by software.
0: TC interrupt disabled
1: TC interrupt enabled
- Bit 0 **EN**: Channel enable
This bit is set and cleared by software.
0: Channel disabled
1: Channel enabled

10.4.4 DMA channel x number of data register (DMA_CNDTRx) (x = 1..5, where x = channel number)

Address offset: $0x0C + 0d20 \times (\text{channel number} - 1)$

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NDT[15:0]															
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **NDT[15:0]**: Number of data to transfer

Number of data to be transferred (0 up to 65535). This register can only be written when the channel is disabled. Once the channel is enabled, this register is read-only, indicating the remaining bytes to be transmitted. This register decrements after each DMA transfer.

Once the transfer is completed, this register can either stay at zero or be reloaded automatically by the value previously programmed if the channel is configured in circular mode.

If this register is zero, no transaction can be served whether the channel is enabled or not.

10.4.5 DMA channel x peripheral address register (DMA_CPARx) (x = 1..5, where x = channel number)

Address offset: $0x10 + 0d20 \times (\text{channel number} - 1)$

Reset value: 0x0000 0000

This register must *not* be written when the channel is enabled.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PA [31:16]															
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PA [15:0]															
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 31:0 **PA[31:0]**: Peripheral address

Base address of the peripheral data register from/to which the data will be read/written.

When PSIZE is 01 (16-bit), the PA[0] bit is ignored. Access is automatically aligned to a half-word address.

When PSIZE is 10 (32-bit), PA[1:0] are ignored. Access is automatically aligned to a word address.

10.4.6 DMA channel x memory address register (DMA_CMARx) (x = 1..5, where x = channel number)

Address offset: 0x14 + 0d20 × (channel number – 1)

Reset value: 0x0000 0000

This register must *not* be written when the channel is enabled.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MA [31:16]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MA [15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:0 **MA[31:0]**: Memory address

Base address of the memory area from/to which the data will be read/written.

When MSIZE is 01 (16-bit), the MA[0] bit is ignored. Access is automatically aligned to a half-word address.

When MSIZE is 10 (32-bit), MA[1:0] are ignored. Access is automatically aligned to a word address.

10.4.7 DMA channel selection register (DMA_CSELR)

This register is present only on STM32F030xC devices.

Address offset: 0xA8

Reset value: 0x0000 0000

This register is used to manage the remapping of DMA channels.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	C5S [3:0]			
												rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
C4S [3:0]				C3S [3:0]				C2S [3:0]				C1S [3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:20 Reserved, must be kept at reset value.

Bits 19:16 **C5S[3:0]**: DMA channel 5 selection
DMA request mapping for channel 5 ⁽¹⁾

Bits 15:12 **C4S[3:0]**: DMA channel 4 selection
DMA request mapping for channel 4 ⁽¹⁾

Bits 11:8 **C3S[3:0]**: DMA channel 3 selection
DMA request mapping for channel 3 ⁽¹⁾

Bits 7:4 **C2S[3:0]**: DMA channel 2 selection
DMA request mapping for channel 2 ⁽¹⁾

Bits 3:0 **C1S[3:0]**: DMA channel 1 selection
DMA request mapping for channel 1 ⁽¹⁾

1. For concrete DMA requests mapping, refer to [Table 28: Summary of the DMA requests for each channel on STM32F030xC devices](#).

10.4.8 DMA register map

The following table gives the DMA register map and the reset values.

Table 29. DMA register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	DMA_ISR					Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TEIF5	HTIF5	TCIF5	GIF5	TEIF4	HTIF4	TCIF4	GIF4	TEIF3	HTIF3	TCIF3	GIF3	TEIF2	HTIF2	TCIF2	GIF2	TEIF1	HTIF1	TCIF1	GIF1
	Reset value													0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x04	DMA_IFCR					Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTEIF5	CHTIF5	CTCIF5	CGIF5	CTEIF4	CHTIF4	CTCIF4	CGIF4	CTEIF3	CHTIF3	CTCIF3	CGIF3	CTEIF2	CHTIF2	CTCIF2	CGIF2	CTEIF1	CHTIF1	CTCIF1	CGIF1
	Reset value													0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x08	DMA_CCR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.			MEM2MEM	PL [1:0]		MSIZE [1:0]		PSIZE [1:0]		MINC	PINC	CIRC	DIR	TEIE	HTIE	TCIE	EN
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x0C	DMA_CNDTR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	NDT[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x10	DMA_CPAR1	PA[31:0]																															
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x14	DMA_CMAR1	MA[31:0]																															
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x1C	DMA_CCR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.			MEM2MEM	PL [1:0]		MSIZE [1:0]		PSIZE [1:0]		MINC	PINC	CIRC	DIR	TEIE	HTIE	TCIE	EN
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x20	DMA_CNDTR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	NDT[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x24	DMA_CPAR2	PA[31:0]																															
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x28	DMA_CMAR2	MA[31:0]																															
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x30	DMA_CCR3	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.			MEM2MEM	PL [1:0]		MSIZE [1:0]		PSIZE [1:0]		MINC	PINC	CIRC	DIR	TEIE	HTIE	TCIE	EN
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x34	DMA_CNDTR3	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	NDT[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x38	DMA_CPAR3	PA[31:0]																															
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x3C	DMA_CMAR3	MA[31:0]																															
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 29. DMA register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
0x44	DMA_CCR4	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res			MEM2MEM	PL [1:0]		MSIZE [1:0]		PSIZE [1:0]		MINC	PINC	CIRC	DIR	TEIE	HTIE	TCIE	EN		
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x48	DMA_CNDTR4	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	NDT[15:0]																	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x4C	DMA_CPAR4	PA[31:0]																																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x50	DMA_CMAR4	MA[31:0]																																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x58	DMA_CCR5	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res			MEM2MEM	PL [1:0]		MSIZE [1:0]		PSIZE [1:0]		MINC	PINC	CIRC	DIR	TEIE	HTIE	TCIE	EN		
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x5C	DMA_CNDTR5	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	NDT[15:0]																	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x60	DMA_CPAR5	PA[31:0]																																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x64	DMA_CMAR5	MA[31:0]																																	
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Table 31. DMA register map and reset values(register available on STM32F030xC devices only)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0xA8	DMA_CSELR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	C5S[3:0]				C4S[3:0]				C3S[3:0]				C2S[3:0]				C1S[3:0]			
	Reset value													0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

11 Interrupts and events

11.1 Nested vectored interrupt controller (NVIC)

11.1.1 NVIC main features

- 32 maskable interrupt channels (not including the sixteen ARM® Cortex®-M0 interrupt lines)
- 4 programmable priority levels (2 bits of interrupt priority are used)
- Low-latency exception and interrupt handling
- Power management control
- Implementation of System Control Registers

The NVIC and the processor core interface are closely coupled, which enables low latency interrupt processing and efficient processing of late arriving interrupts.

All interrupts including the core exceptions are managed by the NVIC. For more information on exceptions and NVIC programming, refer to the PM0215 programming manual.

For code example refer to the Appendix section [A.6.1: NVIC initialization example](#).

11.1.2 SysTick calibration value register

The SysTick calibration value is set to 6000, which gives a reference time base of 1 ms with the SysTick clock set to 6 MHz (max $f_{HCLK}/8$).

11.1.3 Interrupt and exception vectors

[Table 32](#) is the vector table for STM32F0x0 devices. Please consider peripheral availability on given device.

Table 32. Vector table

Position	Priority	Type of priority	Acronym	Description	Address
-	-	-	-	Reserved	0x0000 0000
-	-3	fixed	Reset	Reset	0x0000 0004
-	-2	fixed	NMI	Non maskable interrupt. The RCC Clock Security System (CSS) is linked to the NMI vector.	0x0000 0008
-	-1	fixed	HardFault	All class of fault	0x0000 000C
-	3	settable	SVCall	System service call via SWI instruction	0x0000 002C
-	5	settable	PendSV	Pendable request for system service	0x0000 0038
-	6	settable	SysTick	System tick timer	0x0000 003C
0	7	settable	WWDG	Window watchdog interrupt	0x0000 0040
1			Reserved		0x0000 0044
2	9	settable	RTC	RTC interrupts (combined EXTI lines 17, 19 and 20)	0x0000 0048

Table 32. Vector table (continued)

Position	Priority	Type of priority	Acronym	Description	Address
3	10	settable	FLASH	Flash global interrupt	0x0000 004C
4	11	settable	RCC	RCC global interrupts	0x0000 0050
5	12	settable	EXTI0_1	EXTI Line[1:0] interrupts	0x0000 0054
6	13	settable	EXTI2_3	EXTI Line[3:2] interrupts	0x0000 0058
7	14	settable	EXTI4_15	EXTI Line[15:4] interrupts	0x0000 005C
8			Reserved		0x0000 0060
9	16	settable	DMA_CH1	DMA channel 1 interrupt	0x0000 0064
10	17	settable	DMA_CH2_3	DMA channel 2 and 3 interrupts	0x0000 0068
11	18	settable	DMA_CH4_5	DMA channel 4 and 5 interrupts	0x0000 006C
12	19	settable	ADC	ADC interrupts	0x0000 0070
13	20	settable	TIM1_BRK_UP_TRG_COM	TIM1 break, update, trigger and commutation interrupt	0x0000 0074
14	21	settable	TIM1_CC	TIM1 capture compare interrupt	0x0000 0078
15			Reserved		0x0000 007C
16	23	settable	TIM3	TIM3 global interrupt	0x0000 0080
17	24	settable	TIM6	TIM6 global interrupt	0x0000 0084
18			Reserved		0x0000 0084
19			Reserved		0x0000 0088
19	26	settable	TIM14	TIM14 global interrupt	0x0000 008C
20	27	settable	TIM15	TIM15 global interrupt	0x0000 0090
21	28	settable	TIM16	TIM16 global interrupt	0x0000 0094
22	29	settable	TIM17	TIM17 global interrupt	0x0000 0098
23	30	settable	I2C1	I ² C1 global interrupt	0x0000 009C
24	31	settable	I2C2	I ² C2 global interrupt	0x0000 00A0
25	32	settable	SPI1	SPI1 global interrupt	0x0000 00A4
26	33	settable	SPI2	SPI2 global interrupt	0x0000 00A8
27	34	settable	USART1	USART1 global interrupt	0x0000 00AC
28	35	settable	USART2	USART2 global interrupt	0x0000 00B0
29	36	settable	USART3_4_5_6	USART3, USART4, USART5, USART6 global interrupts	0x0000 00B4
30			Reserved		0x0000 00B8
31	38	settable	USB	USB global interrupt (combined with EXTI line 18)	0x0000 00BC

11.2 Extended interrupts and events controller (EXTI)

The extended interrupts and events controller (EXTI) manages the external and internal asynchronous events/interrupts and generates the event request to the CPU/Interrupt Controller and a wake-up request to the Power Manager.

The EXTI allows the management of up to 28 external/internal event line (21 external event lines and 7 internal event lines).

The active edge of each external interrupt line can be chosen independently, whilst for internal interrupt the active edge is always the rising one. An interrupt could be left pending: in case of an external one, a status register is instantiated and indicates the source of the interrupt; an event is always a simple pulse and it's used for triggering the core Wake-up (e.g. Cortex-M0 RXEV pin). For internal interrupts, the pending status is assured by the generating IP, so no need for a specific flag. Each input line can be masked independently for interrupt or event generation, in addition the internal lines are sampled only in STOP mode. This controller allows also to emulate the (only) external events by software, multiplexed with the corresponding hardware event line, by writing to a dedicated register.

11.2.1 Main features

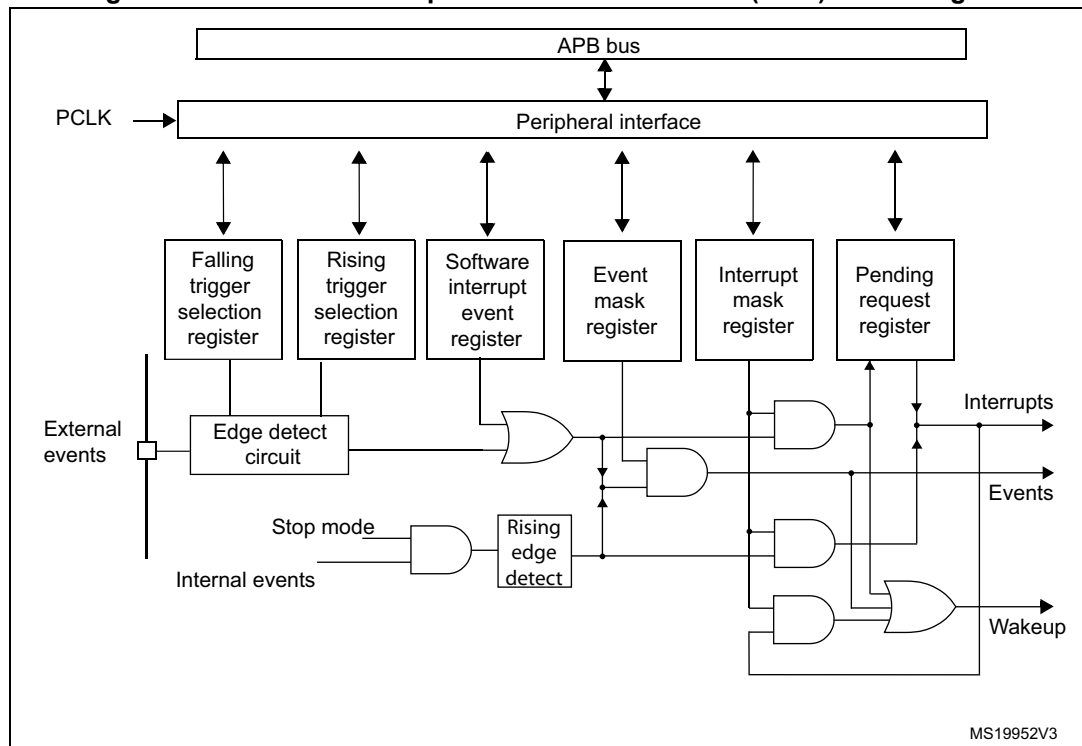
The EXTI main features are the following:

- Supports generation of up to 32 event/interrupt requests
- Independent mask on each event/interrupt line
- Automatic disable of internal lines when system is not in STOP mode
- Independent trigger for external event/interrupt line
- Dedicated status bit for external interrupt line
- Emulation for all the external event requests

11.2.2 Block diagram

The extended interrupt/event block diagram is shown in [Figure 21](#).

Figure 21. Extended interrupts and events controller (EXTI) block diagram



11.2.3 Event management

The STM32F0x0 is able to handle external or internal events in order to wake up the core (WFE). The wakeup event can be generated either by:

- enabling an interrupt in the peripheral control register but not in the NVIC, and enabling the SEVONPEND bit in the Cortex-M0 System Control register. When the MCU resumes from WFE, the EXTI peripheral interrupt pending bit and the peripheral NVIC IRQ channel pending bit (in the NVIC interrupt clear pending register) have to be cleared.
- or by configuring an external or internal EXTI line in event mode. When the CPU resumes from WFE, it is not necessary to clear the peripheral interrupt pending bit or the NVIC IRQ channel pending bit as the pending bit corresponding to the event line is not set.

11.2.4 Functional description

For the external interrupt lines, to generate the interrupt, the interrupt line should be configured and enabled. This is done by programming the two trigger registers with the desired edge detection and by enabling the interrupt request by writing a '1' to the corresponding bit in the interrupt mask register. When the selected edge occurs on the external interrupt line, an interrupt request is generated. The pending bit corresponding to the interrupt line is also set. This request is reset by writing a '1' in the pending register.

For the internal interrupt lines, the active edge is always the rising edge, the interrupt is enabled by default in the interrupt mask register and there is no corresponding pending bit in the pending register.

To generate the event, the event line should be configured and enabled. This is done by programming the two trigger registers with the desired edge detection and by enabling the event request by writing a '1' to the corresponding bit in the event mask register. When the selected edge occurs on the event line, an event pulse is generated. The pending bit corresponding to the event line is not set.

For the external lines, an interrupt/event request can also be generated by software by writing a '1' in the software interrupt/event register.

Note: The interrupts or events associated to the internal lines can be triggered only when the system is in STOP mode. If the system is still running, no interrupt/event is generated.

For code example refer to the Appendix section [A.6.2: External interrupt selection code example](#).

Hardware interrupt selection

To configure a line as interrupt source, use the following procedure:

- Configure the corresponding mask bit in the EXTI_IMR register.
- Configure the Trigger Selection bits of the Interrupt line (EXTI_RTISR and EXTI_FTISR)
- Configure the enable and mask bits that control the NVIC IRQ channel mapped to the EXTI so that an interrupt coming from one of the EXTI line can be correctly acknowledged.

Hardware event selection

To configure a line as event source, use the following procedure:

- Configure the corresponding mask bit in the EXTI_EMR register.
- Configure the Trigger Selection bits of the Event line (EXTI_RTISR and EXTI_FTISR)

Software interrupt/event selection

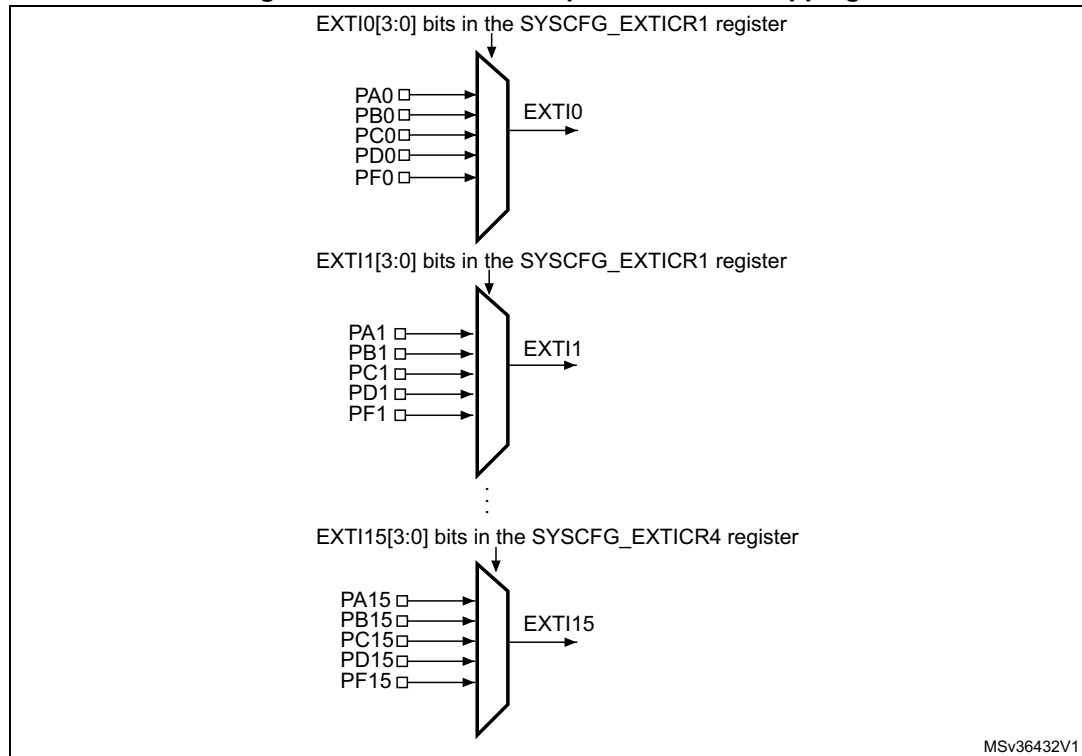
Any of the external lines can be configured as software interrupt/event lines. The following is the procedure to generate a software interrupt.

- Configure the corresponding mask bit (EXTI_IMR, EXTI_EMR)
- Set the required bit of the software interrupt register (EXTI_SWIER)

11.2.5 External and internal interrupt/event line mapping

The GPIOs are connected to the 16 external interrupt/event lines in the following manner:

Figure 22. External interrupt/event GPIO mapping



The remaining lines are connected as follow:

- EXTI line 16 is reserved (internally held low)
- EXTI line 17 is connected to the RTC Alarm event
- EXTI line 18 is connected to the internal USB wakeup event
- EXTI line 19 is connected to the RTC Tamper and TimeStamp events
- EXTI line 20 is connected to the RTC Wakeup event (available only on STM32F070xB and STM32F030xC devices)
- EXTI line 21 is reserved (internally held low)
- EXTI line 22 is reserved (internally held low)
- EXTI line 23 is reserved (internally held low)
- EXTI line 24 is reserved (internally held low)
- EXTI line 25 is reserved (internally held low)
- EXTI line 26 is reserved (internally held low)
- EXTI line 27 is reserved (internally held low)
- EXTI line 28 is reserved (internally held low)
- EXTI line 29 is reserved (internally held low)
- EXTI line 30 is reserved (internally held low)
- EXTI line 31 is reserved (internally held low)

Note: EXTI lines which are reserved or not used on some devices are considered as internal.

11.3 EXTI registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

The peripheral registers have to be accessed by words (32-bit).

11.3.1 Interrupt mask register (EXTI_IMR)

Address offset: 0x00

Reset value: 0x0FF4 0000 (STM32F030x4, STM32F030x6 devices)
 0x7FF4 0000 (STM32F070x6 devices)
 0x0F94 0000 (STM32F030x8 devices)
 0x7F84 0000 (STM32F070xB and STM32F030xC devices)

Note: The reset value for the internal lines is set to '1' in order to enable the interrupt by default.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
IM31	IM30	IM29	IM28	IM27	IM26	IM25	IM24	IM23	IM22	IM21	IM20	IM19	IM18	IM17	IM16
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
IM15	IM14	IM13	IM12	IM11	IM10	IM9	IM8	IM7	IM6	IM5	IM4	IM3	IM2	IM1	IM0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:0 **IMx**: Interrupt Mask on line x (x = 31 to 0)

0: Interrupt request from Line x is masked

1: Interrupt request from Line x is not masked

11.3.2 Event mask register (EXTI_EMR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
EM31	EM30	EM29	EM28	EM27	EM26	EM25	EM24	EM23	EM22	EM21	EM20	EM19	EM18	EM17	EM16
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
EM15	EM14	EM13	EM12	EM11	EM10	EM9	EM8	EM7	EM6	EM5	EM4	EM3	EM2	EM1	EM0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:0 **EMx**: Event mask on line x (x = 31 to 0)

0: Event request from Line x is masked

1: Event request from Line x is not masked

11.3.3 Rising trigger selection register (EXTI_RTSR)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
RT31	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RT22	RT21	RT20	RT19	Res.	RT17	RT16
rw									rw	rw	rw	rw		rw	rw

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RT15	RT14	RT13	RT12	RT11	RT10	RT9	RT8	RT7	RT6	RT5	RT4	RT3	RT2	RT1	RT0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 31 **RT31**: Rising trigger event configuration bit of line 31

- 0: Rising trigger disabled (for Event and Interrupt) for input line
1: Rising trigger enabled (for Event and Interrupt) for input line.

Bits 30:23 Reserved, must be kept at reset value.

Bits 22:19 **RTx**: Rising trigger event configuration bit of line x (x = 22 to 19)

- 0: Rising trigger disabled (for Event and Interrupt) for input line
1: Rising trigger enabled (for Event and Interrupt) for input line.

Bits 18 Reserved, must be kept at reset value.

Bits 17:0 **RTx**: Rising trigger event configuration bit of line x (x = 17 to 0)

- 0: Rising trigger disabled (for Event and Interrupt) for input line
1: Rising trigger enabled (for Event and Interrupt) for input line.

Note: *The external wakeup lines are edge triggered. No glitches must be generated on these lines. If a rising edge on an external interrupt line occurs during a write operation to the EXTI_RTSR register, the pending bit is not set.*

Rising and falling edge triggers can be set for the same interrupt line. In this case, both generate a trigger condition.

11.3.4 Falling trigger selection register (EXTI_FTSR)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
FT31	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	FT22	FT21	FT20	FT19	Res.	FT17	FT16
rw									rw	rw	rw	rw		rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FT15	FT14	FT13	FT12	FT11	FT10	FT9	FT8	FT7	FT6	FT5	FT4	FT3	FT2	FT1	FT1
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 31 **FT31**: Falling trigger event configuration bit of line 31

- 0: Falling trigger disabled (for Event and Interrupt) for input line
1: Falling trigger enabled (for Event and Interrupt) for input line.

Bits 30:23 Reserved, must be kept at reset value.

Bits 22:19 **FTx**: Falling trigger event configuration bit of line x (x = 22 to 19)

- 0: Falling trigger disabled (for Event and Interrupt) for input line.
1: Falling trigger enabled (for Event and Interrupt) for input line.

Bits 18 Reserved, must be kept at reset value.

Bits 17:0 **FTx**: Falling trigger event configuration bit of line x (x = 17 to 0)

- 0: Falling trigger disabled (for Event and Interrupt) for input line.
1: Falling trigger enabled (for Event and Interrupt) for input line.

Note: The external wakeup lines are edge triggered. No glitches must be generated on these lines. If a falling edge on an external interrupt line occurs during a write operation to the EXTI_FTSR register, the pending bit is not set.

Rising and falling edge triggers can be set for the same interrupt line. In this case, both generate a trigger condition.

11.3.5 Software interrupt event register (EXTI_SWIER)

Address offset: 0x10

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
SWI31	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SWI22	SWI21	SWI20	SWI19	Res.	SWI17	SWI16
rw									rw	rw	rw	rw		rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SWI15	SWI14	SWI13	SWI12	SWI11	SWI10	SWI9	SWI8	SWI7	SWI6	SWI5	SWI4	SWI3	SWI2	SWI1	SWI0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 31 **SWI31**: Software interrupt on line 31

If the interrupt is enabled on this line in the EXTI_IMR, writing a '1' to this bit when it is at '0' sets the corresponding pending bit in EXTI_PR resulting in an interrupt request generation. This bit is cleared by clearing the corresponding bit of EXTI_PR (by writing a '1' to the bit)

Bits 30:23 Reserved, must be kept at reset value.

Bits 22:19 **SWIx**: Software interrupt on line x (x = 22 to 19)

If the interrupt is enabled on this line in the EXTI_IMR, writing a '1' to this bit when it is at '0' sets the corresponding pending bit in EXTI_PR resulting in an interrupt request generation. This bit is cleared by clearing the corresponding bit of EXTI_PR (by writing a '1' to the bit)

Bits 18 Reserved, must be kept at reset value.

Bits 17:0 **SWIx**: Software interrupt on line x (x = 17 to 0)

If the interrupt is enabled on this line in the EXTI_IMR, writing a '1' to this bit when it is at '0' sets the corresponding pending bit in EXTI_PR resulting in an interrupt request generation. This bit is cleared by clearing the corresponding bit of EXTI_PR (by writing a '1' to the bit).

11.3.6 Pending register (EXTI_PR)

Address offset: 0x14

Reset value: undefined

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PIF31	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PIF22	PIF21	PIF20	PIF19	Res.	PIF17	PIF16
rc_w1									rc_w1	rc_w1	rc_w1	rc_w1		rc_w1	rc_w1
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PIF15	PIF14	PIF13	PIF12	PIF11	PIF10	PIF9	PIF8	PIF7	PIF6	PIF5	PIF4	PIF3	PIF2	PIF1	PIF0
rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1	rc_w1

Bit 31 **PIF31**: Pending bit on line 31

0: no trigger request occurred

1: selected trigger request occurred

This bit is set when the selected edge event arrives on the external interrupt line. This bit is cleared by writing a 1 to the bit.

Bits 30:23 Reserved, must be kept at reset value.

Bits 22:19 **PIF_x**: Pending bit on line x (x = 22 to 19)

0: no trigger request occurred

1: selected trigger request occurred

This bit is set when the selected edge event arrives on the external interrupt line. This bit is cleared by writing a 1 to the bit.

Bits 18 Reserved, must be kept at reset value.

Bits 17:0 **PIF_x**: Pending bit on line x (x = 17 to 0)

0: no trigger request occurred

1: selected trigger request occurred

This bit is set when the selected edge event arrives on the external interrupt line. This bit is cleared by writing a 1 to the bit.

11.3.7 EXTI register map

The following table gives the EXTI register map and the reset values.

Table 33. External interrupt/event controller register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	EXTI_IMR	IM[31:0]																															
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x04	EXTI_EMR	EM[31:0]																															
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x08	EXTI_RTSR	RT31	Res	Res	Res	Res	Res	Res	Res	Res	RT23	RT22	RT21	RT20	RT19	Res	RT[17:0]																
	Reset value	0									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x0C	EXTI_FTSR	FT31	Res	Res	Res	Res	Res	Res	Res	Res	FT23	FT22	FT21	FT20	FT19	Res	FT[17:0]																
	Reset value	0									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x10	EXTI_SWIER	SWI31	Res	Res	Res	Res	Res	Res	Res	Res	SWI23	SWI22	SWI21	SWI20	SWI19	Res	SWI[17:0]																
	Reset value	0									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x14	EXTI_PR	PIF31	Res	Res	Res	Res	Res	Res	Res	Res	PIF23	PIF22	PIF21	PIF20	PIF19	Res	PIF[17:0]																
	Reset value	0									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

12 **Analog-to-digital converter (ADC)**

12.1 **Introduction**

The 12-bit ADC is a successive approximation analog-to-digital converter. It has up to 19 multiplexed channels allowing it to measure signals from 16 external and 2 internal sources. A/D conversion of the various channels can be performed in single, continuous, scan or discontinuous mode. The result of the ADC is stored in a left-aligned or right-aligned 16-bit data register.

The analog watchdog feature allows the application to detect if the input voltage goes outside the user-defined higher or lower thresholds.

An efficient low-power mode is implemented to allow very low consumption at low frequency.

12.2 ADC main features

- High performance
 - 12-bit, 10-bit, 8-bit or 6-bit configurable resolution
 - ADC conversion time: 1.0 μ s for 12-bit resolution (1 MHz), 0.93 μ s conversion time for 10-bit resolution, faster conversion times can be obtained by lowering resolution.
 - Self-calibration
 - Programmable sampling time
 - Data alignment with built-in data coherency
 - DMA support
- Low-power
 - Application can reduce PCLK frequency for low-power operation while still keeping optimum ADC performance. For example, 1.0 μ s conversion time is kept, whatever the frequency of PCLK)
 - Wait mode: prevents ADC overrun in applications with low frequency PCLK
 - Auto off mode: ADC is automatically powered off except during the active conversion phase. This dramatically reduces the power consumption of the ADC.
- Analog input channels
 - 16 external analog inputs
 - 1 channel for internal temperature sensor (V_{SENSE})
 - 1 channel for internal reference voltage (V_{REFINT})
- Start-of-conversion can be initiated:
 - By software
 - By hardware triggers with configurable polarity (internal timer events from TIM1, TIM3 and TIM15)
- Conversion modes
 - Can convert a single channel or can scan a sequence of channels.
 - Single mode converts selected inputs once per trigger
 - Continuous mode converts selected inputs continuously
 - Discontinuous mode
- Interrupt generation at the end of sampling, end of conversion, end of sequence conversion, and in case of analog watchdog or overrun events
- Analog watchdog
- ADC supply requirements: 2.4 V to 3.6 V
- ADC input range: $V_{SSA} \leq V_{IN} \leq V_{DDA}$

Figure 23 shows the block diagram of the ADC.

12.3 ADC pins and internal signals

Table 34. ADC internal signals

Internal signal name	Signal type	Description
TRGx	Input	ADC conversion triggers
V _{SENSE}	Input	Internal temperature sensor output voltage
V _{REFINT}	Input	Internal voltage reference output voltage

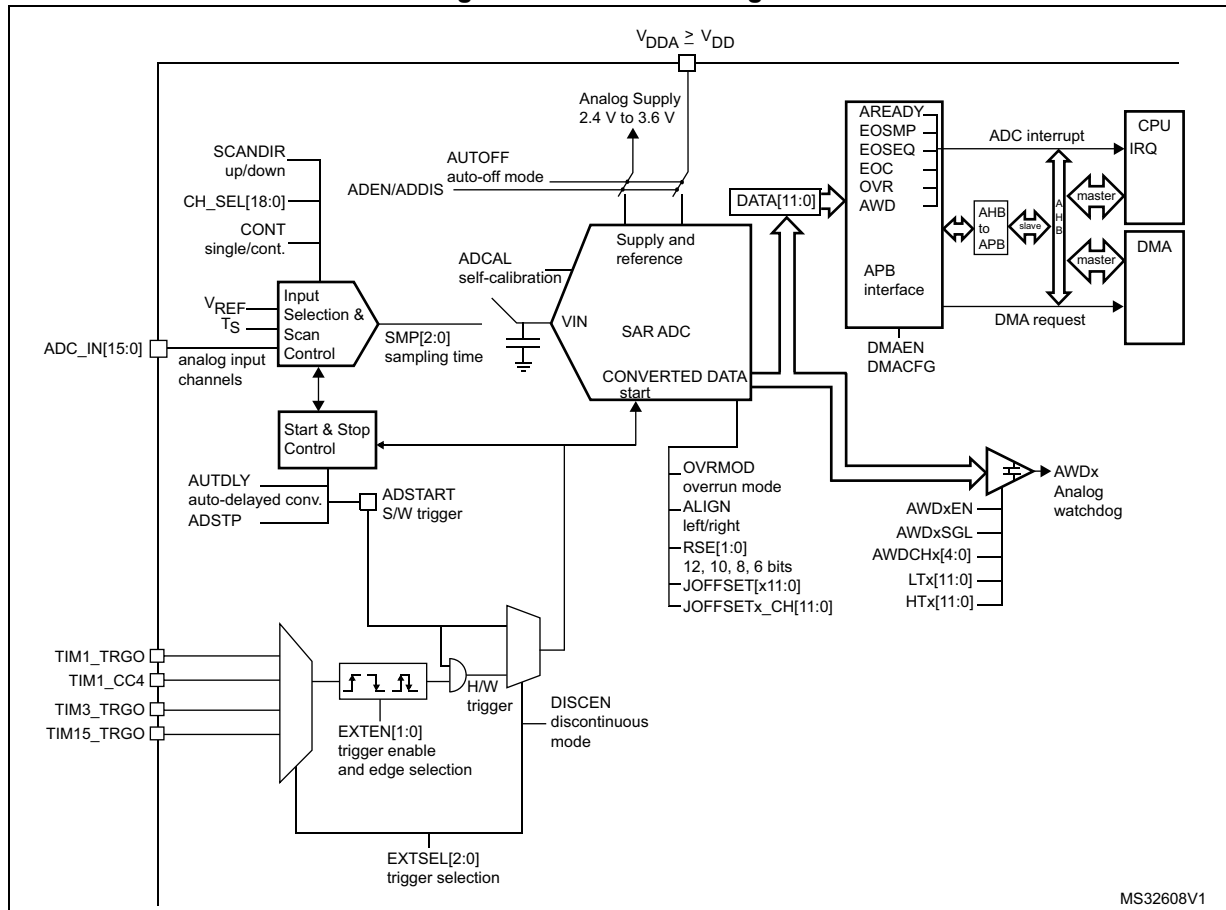
Table 35. ADC pins

Name	Signal type	Remarks
V _{DDA}	Input, analog power supply	Analog power supply and positive reference voltage for the ADC, $V_{DDA} \geq V_{DD}$
V _{SSA}	Input, analog supply ground	Ground for analog power supply. Must be at V _{SS} potential
ADC_IN[15:0]	Analog input signals	16 analog input channels

12.4 ADC functional description

Figure 23 shows the ADC block diagram and Table 35 gives the ADC pin description.

Figure 23. ADC block diagram



MS32608V1

12.4.1 Calibration (ADCAL)

The ADC has a calibration feature. During the procedure, the ADC calculates a calibration factor which is internally applied to the ADC until the next ADC power-off. The application must not use the ADC during calibration and must wait until it is complete.

Calibration should be performed before starting A/D conversion. It removes the offset error which may vary from chip to chip due to process variation.

The calibration is initiated by software by setting bit ADCAL=1. Calibration can only be initiated when the ADC is disabled (when ADEN=0). ADCAL bit stays at 1 during all the calibration sequence. It is then cleared by hardware as soon the calibration completes. After this, the calibration factor can be read from the ADC_DR register (from bits 6 to 0).

The internal analog calibration is kept if the ADC is disabled (ADEN=0). When the ADC operating conditions change (V_{DDA} changes are the main contributor to ADC offset variations and temperature change to a lesser extend), it is recommended to re-run a calibration cycle.

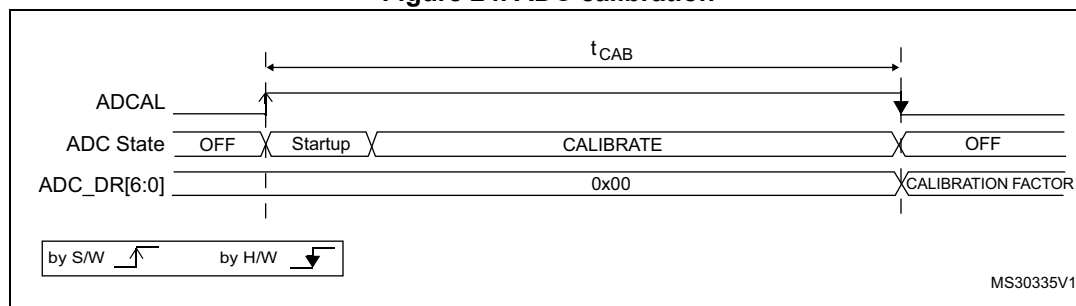
The calibration factor is lost each time power is removed from the ADC (for example when the product enters STANDBY mode).

Calibration software procedure

1. Ensure that ADEN=0 and DMAEN=0
2. Set ADCAL=1
3. Wait until ADCAL=0
4. The calibration factor can be read from bits 6:0 of ADC_DR.

For code example refer to the Appendix section [A.7.1: ADC Calibration code example](#).

Figure 24. ADC calibration



12.4.2 ADC on-off control (ADEN, ADDIS, ADRDY)

At MCU power-up, the ADC is disabled and put in power-down mode (ADEN=0).

As shown in [Figure 25](#), the ADC needs a stabilization time of t_{STAB} before it starts converting accurately.

Two control bits are used to enable or disable the ADC:

- Set ADEN=1 to enable the ADC. The ADRDY flag is set as soon as the ADC is ready for operation.
- Set ADDIS=1 to disable the ADC and put the ADC in power down mode. The ADEN and ADDIS bits are then automatically cleared by hardware as soon as the ADC is fully disabled.

Conversion can then start either by setting ADSTART=1 (refer to [Section 12.5: Conversion on external trigger and trigger polarity \(EXTSEL, EXTEN\) on page 192](#)) or when an external trigger event occurs if triggers are enabled.

Follow this procedure to enable the ADC:

1. Clear the ADRDY bit in ADC_ISR register by programming this bit to 1.
2. Set ADEN=1 in the ADC_CR register.
3. Wait until ADRDY=1 in the ADC_ISR register and continue to write ADEN=1 (ADRDY is set after the ADC startup time). This can be handled by interrupt if the interrupt is enabled by setting the ADRDYIE bit in the ADC_IER register.

For code example refer to the Appendix section [A.7.2: ADC enable sequence code example](#).

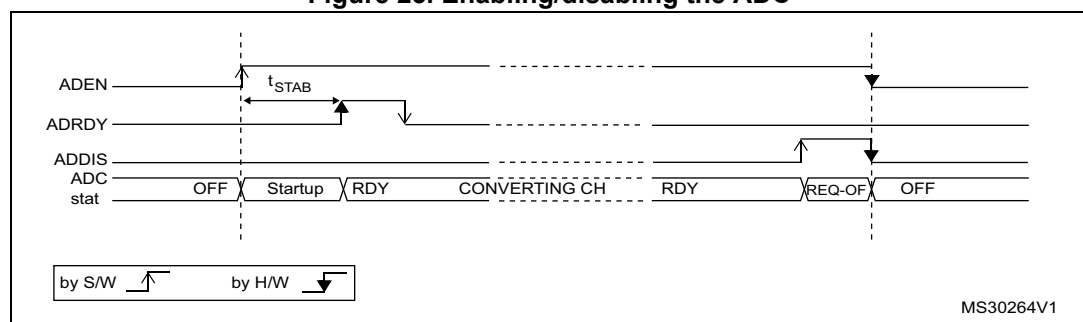
Follow this procedure to disable the ADC:

1. Check that ADSTART=0 in the ADC_CR register to ensure that no conversion is ongoing. If required, stop any ongoing conversion by writing 1 to the ADSTP bit in the ADC_CR register and waiting until this bit is read at 0.
2. Set ADDIS=1 in the ADC_CR register.
3. If required by the application, wait until ADEN=0 in the ADC_CR register, indicating that the ADC is fully disabled (ADDIS is automatically reset once ADEN=0).
4. Clear the ADRDY bit in ADC_ISR register by programming this bit to 1 (optional).

For code example refer to the Appendix section [A.7.3: ADC disable sequence code example](#).

Caution: ADEN bit cannot be set when ADCAL=1 and during four ADC clock cycles after the ADCAL bit is cleared by hardware (end of calibration).

Figure 25. Enabling/disabling the ADC



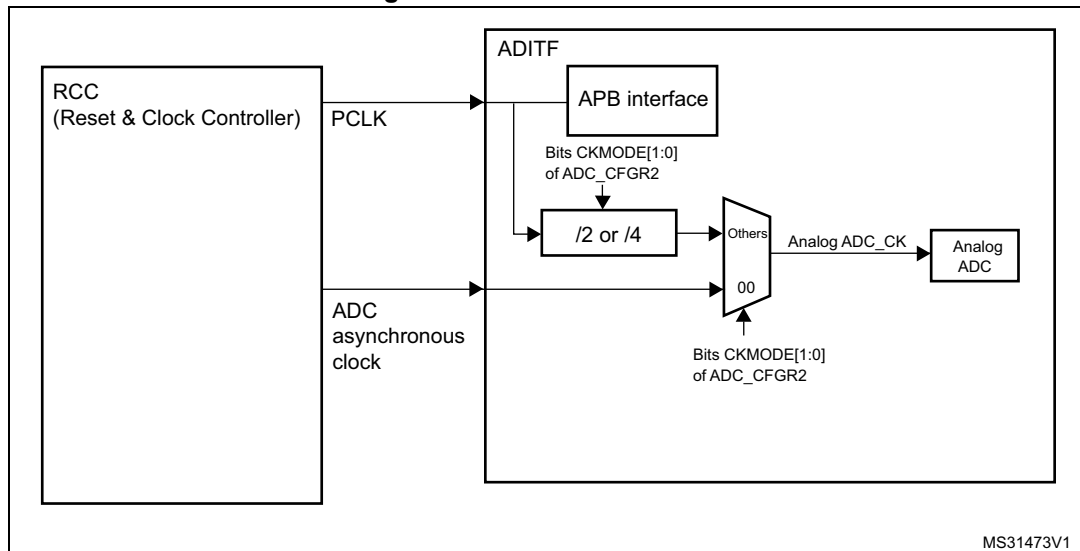
MS30264V1

Note: In auto-off mode (AUTOFF=1) the power-on/off phases are performed automatically, by hardware and the ADRDY flag is not set.

12.4.3 ADC clock (CKMODE)

The ADC has a dual clock-domain architecture, so that the ADC can be fed with a clock (ADC asynchronous clock) independent from the APB clock (PCLK).

Figure 26. ADC clock scheme



1. Refer to [Section 7: Reset and clock control \(RCC\) on page 87](#) to see how PCLK and ADC asynchronous clock are enabled.

The input clock of the analog ADC can be selected between two different clock sources (see [Figure 26: ADC clock scheme](#) to see how PCLK and the ADC asynchronous clock are enabled):

- a) The ADC clock can be a specific clock source, named “ADC asynchronous clock” which is independent and asynchronous with the APB clock.
Refer to RCC Section for more information on generating this clock source.
To select this scheme, bits CKMODE[1:0] of the ADC_CFGR2 register must be reset.
For code example refer to the Appendix section [A.7.4: ADC Clock selection code example](#).
- b) The ADC clock can be derived from the APB clock of the ADC bus interface, divided by a programmable factor (2 or 4) according to bits CKMODE[1:0].
To select this scheme, bits CKMODE[1:0] of the ADC_CFGR2 register must be different from “00”.

Option a) has the advantage of reaching the maximum ADC clock frequency whatever the APB clock scheme selected.

Option b) has the advantage of bypassing the clock domain resynchronizations. This can be useful when the ADC is triggered by a timer and if the application requires that the ADC is precisely triggered without any uncertainty (otherwise, an uncertainty of the trigger instant is added by the resynchronizations between the two clock domains).

Table 36. Latency between trigger and start of conversion

ADC clock source	CKMODE[1:0]	Latency between the trigger event and the start of conversion
Dedicated 14MHz clock	00	Latency is not deterministic (jitter)
PCLK divided by 2	01	Latency is deterministic (no jitter) and equal to 2.75 ADC clock cycles
PCLK divided by 4	10	Latency is deterministic (no jitter) and equal to 2.625 ADC clock cycles

12.4.4 Configuring the ADC

Software must write to the ADCAL and ADEN bits in the ADC_CR register if the ADC is disabled (ADEN must be 0).

Software must only write to the ADSTART and ADDIS bits in the ADC_CR register only if the ADC is enabled and there is no pending request to disable the ADC (ADEN = 1 and ADDIS = 0).

For all the other control bits in the ADC_IER, ADC_CFGRi, ADC_SMPR, ADC_TR, ADC_CHSELR and ADC_CCR registers, software must only write to the configuration control bits if the ADC is enabled (ADEN = 1) and if there is no conversion ongoing (ADSTART = 0).

Software must only write to the ADSTP bit in the ADC_CR register if the ADC is enabled (and possibly converting) and there is no pending request to disable the ADC (ADSTART = 1 and ADDIS = 0).

Note: There is no hardware protection preventing software from making write operations forbidden by the above rules. If such a forbidden write access occurs, the ADC may enter an

undefined state. To recover correct operation in this case, the ADC must be disabled (clear ADEN=0 and all the bits in the ADC_CR register).

12.4.5 Channel selection (CHSEL, SCANDIR)

There are up to 18 multiplexed channels:

- 16 analog inputs from GPIO pins (ADC_IN0...ADC_IN15)
- 2 internal analog inputs (Temperature Sensor, Internal Reference Voltage)

It is possible to convert a single channel or to automatically scan a sequence of channels.

The sequence of the channels to be converted must be programmed in the ADC_CHSELR channel selection register: each analog input channel has a dedicated selection bit (CHSEL0...CHSEL18).

The order in which the channels will be scanned can be configured by programming the bit SCANDIR bit in the ADC_CFGR1 register:

- SCANDIR=0: forward scan Channel 0 to Channel 18
- SCANDIR=1: backward scan Channel 18 to Channel 0

Temperature sensor, V_{REFINT} internal channels

The temperature sensor is connected to channel ADC_IN16. The internal voltage reference V_{REFINT} is connected to channel ADC_IN17.

12.4.6 Programmable sampling time (SMP)

Before starting a conversion, the ADC needs to establish a direct connection between the voltage source to be measured and the embedded sampling capacitor of the ADC. This sampling time must be enough for the input voltage source to charge the sample and hold capacitor to the input voltage level.

Having a programmable sampling time allows to trim the conversion speed according to the input resistance of the input voltage source.

The ADC samples the input voltage for a number of ADC clock cycles that can be modified using the SMP[2:0] bits in the ADC_SMPR register.

This programmable sampling time is common to all channels. If required by the application, the software can change and adapt this sampling time between each conversions.

The total conversion time is calculated as follows:

$$t_{CONV} = \text{Sampling time} + 12.5 \times \text{ADC clock cycles}$$

Example:

With ADC_CLK = 14 MHz and a sampling time of 1.5 ADC clock cycles:

$$t_{CONV} = 1.5 + 12.5 = 14 \text{ ADC clock cycles} = 1 \mu\text{s}$$

The ADC indicates the end of the sampling phase by setting the EOSMP flag.

12.4.7 Single conversion mode (CONT=0)

In Single conversion mode, the ADC performs a single sequence of conversions, converting all the channels once. This mode is selected when CONT=0 in the ADC_CFGR1 register. Conversion is started by either:

- Setting the ADSTART bit in the ADC_CR register
- Hardware trigger event

Inside the sequence, after each conversion is complete:

- The converted data are stored in the 16-bit ADC_DR register
- The EOC (end of conversion) flag is set
- An interrupt is generated if the EOCIE bit is set

After the sequence of conversions is complete:

- The EOSEQ (end of sequence) flag is set
- An interrupt is generated if the EOSEQIE bit is set

Then the ADC stops until a new external trigger event occurs or the ADSTART bit is set again.

Note: To convert a single channel, program a sequence with a length of 1.

12.4.8 Continuous conversion mode (CONT=1)

In continuous conversion mode, when a software or hardware trigger event occurs, the ADC performs a sequence of conversions, converting all the channels once and then automatically re-starts and continuously performs the same sequence of conversions. This mode is selected when CONT=1 in the ADC_CFGR1 register. Conversion is started by either:

- Setting the ADSTART bit in the ADC_CR register
- Hardware trigger event

Inside the sequence, after each conversion is complete:

- The converted data are stored in the 16-bit ADC_DR register
- The EOC (end of conversion) flag is set
- An interrupt is generated if the EOCIE bit is set

After the sequence of conversions is complete:

- The EOSEQ (end of sequence) flag is set
- An interrupt is generated if the EOSEQIE bit is set

Then, a new sequence restarts immediately and the ADC continuously repeats the conversion sequence.

Note: To convert a single channel, program a sequence with a length of 1.

It is not possible to have both discontinuous mode and continuous mode enabled: it is forbidden to set both bits DISCEN=1 and CONT=1.

12.4.9 Starting conversions (ADSTART)

Software starts ADC conversions by setting ADSTART=1.

When ADSTART is set, the conversion:

- Starts immediately if EXTEN = 00 (software trigger)
- At the next active edge of the selected hardware trigger if EXTEN ≠ 00

The ADSTART bit is also used to indicate whether an ADC operation is currently ongoing. It is possible to re-configure the ADC while ADSTART=0, indicating that the ADC is idle.

The ADSTART bit is cleared by hardware:

- In single mode with software trigger (CONT=0, EXTEN=00)
 - At any end of conversion sequence (EOSEQ=1)
- In discontinuous mode with software trigger (CONT=0, DISCEN=1, EXTEN=00)
 - At end of conversion (EOC=1)
- In all cases (CONT=x, EXTEN=XX)
 - After execution of the ADSTP procedure invoked by software (see [Section 12.4.11: Stopping an ongoing conversion \(ADSTP\) on page 192](#))

Note: In continuous mode (CONT=1), the ADSTART bit is not cleared by hardware when the EOSEQ flag is set because the sequence is automatically relaunched.

When hardware trigger is selected in single mode (CONT=0 and EXTEN = 01), ADSTART is not cleared by hardware when the EOSEQ flag is set. This avoids the need for software having to set the ADSTART bit again and ensures the next trigger event is not missed.

12.4.10 Timings

The elapsed time between the start of a conversion and the end of conversion is the sum of the configured sampling time plus the successive approximation time depending on data resolution:

$$t_{\text{ADC}} = t_{\text{SMPL}} + t_{\text{SAR}} = [1.5 \text{ }_{\text{min}} + 12.5 \text{ }_{12\text{bit}}] \times t_{\text{ADC\_CLK}}$$

$$t_{\text{ADC}} = t_{\text{SMPL}} + t_{\text{SAR}} = 107.1 \text{ ns }_{\text{min}} + 892.8 \text{ ns }_{12\text{bit}} = 1 \text{ }_{\text{min}} \mu\text{s} \text{ (for } f_{\text{ADC\_CLK}} = 14 \text{ MHz)}$$

Figure 27. Analog to digital conversion time

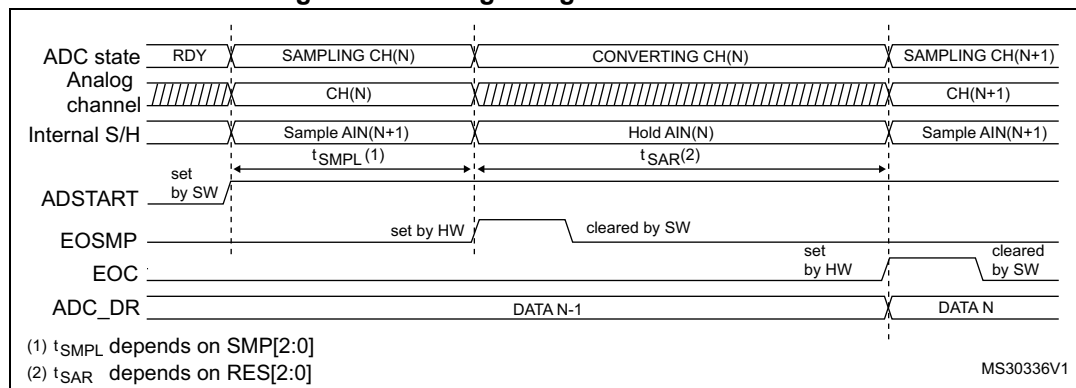
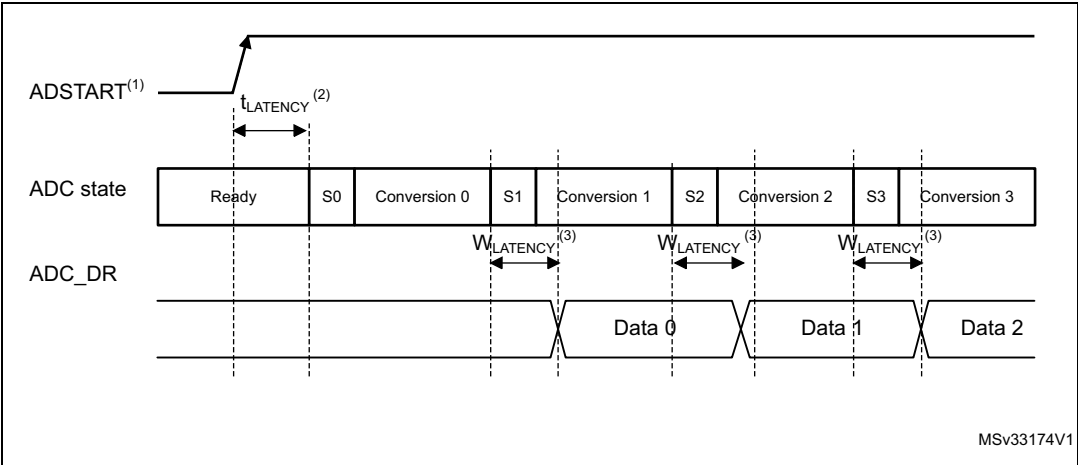


Figure 28. ADC conversion timings



1. EXTEN = 00 or EXTEN ≠ 00
2. Trigger latency (refer to datasheet for more details)
3. ADC_DR register write latency (refer to datasheet for more details)

12.4.11 Stopping an ongoing conversion (ADSTP)

The software can decide to stop any ongoing conversions by setting ADSTP=1 in the ADC_CR register.

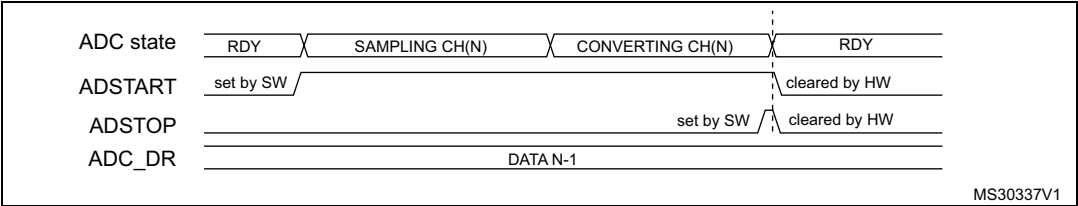
This will reset the ADC operation and the ADC will be idle, ready for a new operation.

When the ADSTP bit is set by software, any ongoing conversion is aborted and the result is discarded (ADC_DR register is not updated with the current conversion).

The scan sequence is also aborted and reset (meaning that restarting the ADC would restart a new sequence).

Once this procedure is complete, the ADSTP and ADSTART bits are both cleared by hardware and the software must wait until ADSTART=0 before starting new conversions.

Figure 29. Stopping an ongoing conversion



12.5 Conversion on external trigger and trigger polarity (EXTSEL, EXTEN)

A conversion or a sequence of conversion can be triggered either by software or by an external event (for example timer capture). If the EXTEN[1:0] control bits are not equal to "0b00", then external events are able to trigger a conversion with the selected polarity. The trigger selection is effective once software has set bit ADSTART=1.

Any hardware triggers which occur while a conversion is ongoing are ignored.

If bit ADSTART=0, any hardware triggers which occur are ignored.

[Table 37](#) provides the correspondence between the EXTEN[1:0] values and the trigger polarity.

Table 37. Configuring the trigger polarity

Source	EXTEN[1:0]
Trigger detection disabled	00
Detection on rising edge	01
Detection on falling edge	10
Detection on both rising and falling edges	11

Note: The polarity of the external trigger can be changed only when the ADC is not converting (ADSTART= 0).

The EXTSEL[2:0] control bits are used to select which of 8 possible events can trigger conversions.

[Table 38](#) gives the possible external trigger for regular conversion.

Software source trigger events can be generated by setting the ADSTART bit in the ADC_CR register.

Table 38. External triggers

Name	Source	EXTSEL[2:0]
TRG0	TIM1_TRGO	000
TRG1	TIM1_CC4	001
TRG2	Reserved	010
TRG3	TIM3_TRGO	011
TRG4	TIM15_TRGO	100
TRG5	Reserved	101
TRG6	Reserved	110
TRG7	Reserved	111

Note: The trigger selection can be changed only when the ADC is not converting (ADSTART= 0).

12.5.1 Discontinuous mode (DISCEN)

This mode is enabled by setting the DISCEN bit in the ADC_CFGR1 register.

In this mode (DISCEN=1), a hardware or software trigger event is required to start each conversion defined in the sequence. On the contrary, if DISCEN=0, a single hardware or software trigger event successively starts all the conversions defined in the sequence.

Example:

- DISCEN=1, channels to be converted = 0, 3, 7, 10
 - 1st trigger: channel 0 is converted and an EOC event is generated
 - 2nd trigger: channel 3 is converted and an EOC event is generated
 - 3rd trigger: channel 7 is converted and an EOC event is generated
 - 4th trigger: channel 10 is converted and both EOC and EOSEQ events are generated.
 - 5th trigger: channel 0 is converted an EOC event is generated
 - 6th trigger: channel 3 is converted and an EOC event is generated
 - ...
- DISCEN=0, channels to be converted = 0, 3, 7, 10
 - 1st trigger: the complete sequence is converted: channel 0, then 3, 7 and 10. Each conversion generates an EOC event and the last one also generates an EOSEQ event.
 - Any subsequent trigger events will restart the complete sequence.

Note: *It is not possible to have both discontinuous mode and continuous mode enabled: it is forbidden to set both bits DISCEN=1 and CONT=1.*

12.5.2 Programmable resolution (RES) - fast conversion mode

It is possible to obtain faster conversion times (t_{SAR}) by reducing the ADC resolution.

The resolution can be configured to be either 12, 10, 8, or 6 bits by programming the RES[1:0] bits in the ADC_CFGR1 register. Lower resolution allows faster conversion times for applications where high data precision is not required.

Note: *The RES[1:0] bit must only be changed when the ADEN bit is reset.*

The result of the conversion is always 12 bits wide and any unused LSB bits are read as zeros.

Lower resolution reduces the conversion time needed for the successive approximation steps as shown in [Table 39](#).

Table 39. t_{SAR} timings depending on resolution

RES[1:0] bits	t_{SAR} (ADC clock cycles)	t_{SAR} (ns) at $f_{\text{ADC}} = 14 \text{ MHz}$	t_{SMPL} (min) (ADC clock cycles)	t_{CONV} (ADC clock cycles) (with min. t_{SMPL})	t_{CONV} at $f_{\text{ADC}} =$ 14 MHz
12	12.5	893 ns	1.5	14	1000 ns
10	11.5	821 ns	1.5	13	928 ns
8	9.5	678 ns	1.5	11	785 ns
6	7.5	535 ns	1.5	9	643 ns

12.5.3 End of conversion, end of sampling phase (EOC, EOSMP flags)

The ADC indicates each end of conversion (EOC) event.

The ADC sets the EOC flag in the ADC_ISR register as soon as a new conversion data result is available in the ADC_DR register. An interrupt can be generated if the EOCIE bit is set in the ADC_IER register. The EOC flag is cleared by software either by writing 1 to it, or by reading the ADC_DR register.

The ADC also indicates the end of sampling phase by setting the EOSMP flag in the ADC_ISR register. The EOSMP flag is cleared by software by writing 1 to it. An interrupt can be generated if the EOSMPIE bit is set in the ADC_IER register.

The aim of this interrupt is to allow the processing to be synchronized with the conversions. Typically, an analog multiplexer can be accessed in hidden time during the conversion phase, so that the multiplexer is positioned when the next sampling starts.

Note: As there is only a very short time left between the end of the sampling and the end of the conversion, it is recommended to use polling or a WFE instruction rather than an interrupt and a WFI instruction.

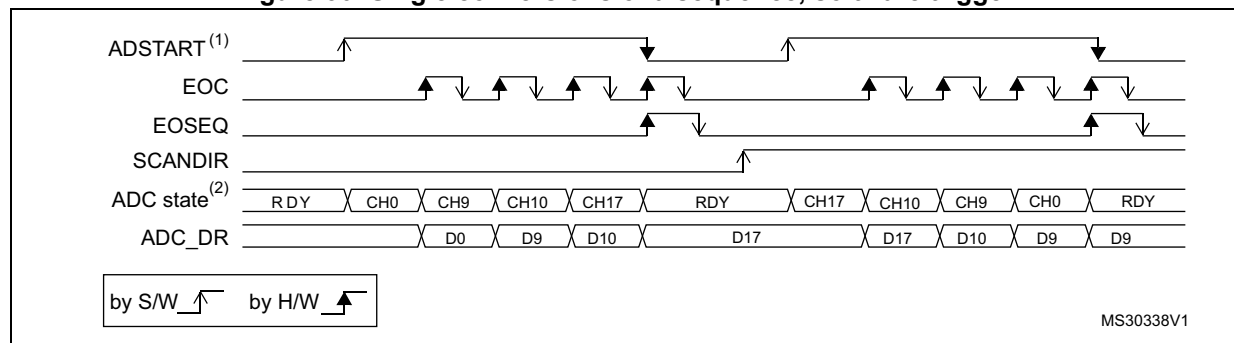
12.5.4 End of conversion sequence (EOSEQ flag)

The ADC notifies the application of each end of sequence (EOSEQ) event.

The ADC sets the EOSEQ flag in the ADC_ISR register as soon as the last data result of a conversion sequence is available in the ADC_DR register. An interrupt can be generated if the EOSEQIE bit is set in the ADC_IER register. The EOSEQ flag is cleared by software by writing 1 to it.

12.5.5 Example timing diagrams (single/continuous modes hardware/software triggers)

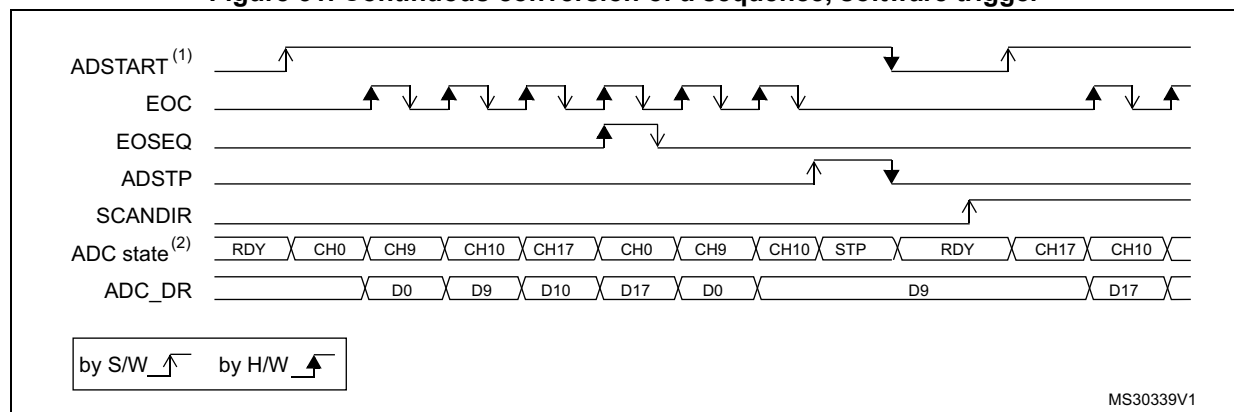
Figure 30. Single conversions of a sequence, software trigger



1. EXTEN=00, CONT=0
2. CHSEL=0x20601, WAIT=0, AUTOFF=0

For code example refer to the Appendix section [A.7.5: Single conversion sequence code example - Software trigger](#).

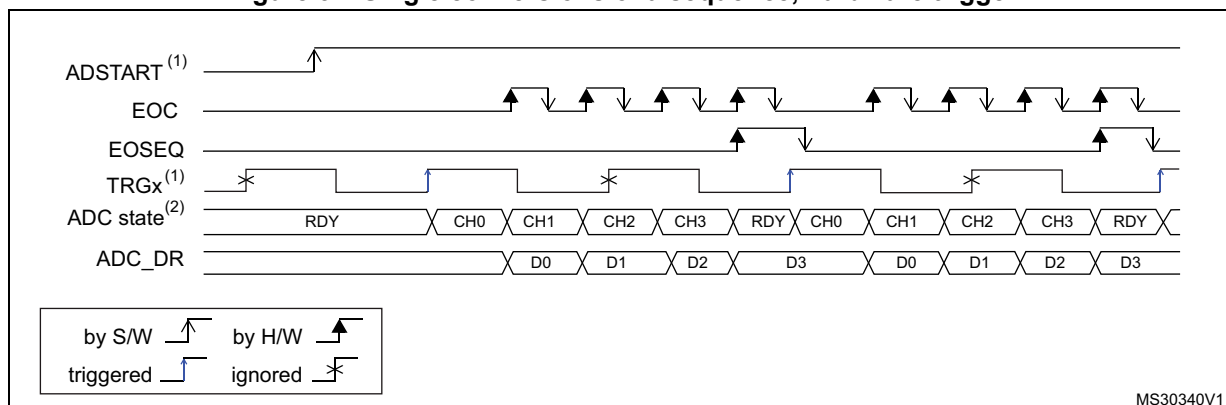
Figure 31. Continuous conversion of a sequence, software trigger



1. EXTEN=00, CONT=1,
2. CHSEL=0x20601, WAIT=0, AUTOFF=0

For code example refer to the Appendix section [A.7.6: Continuous conversion sequence code example - Software trigger](#).

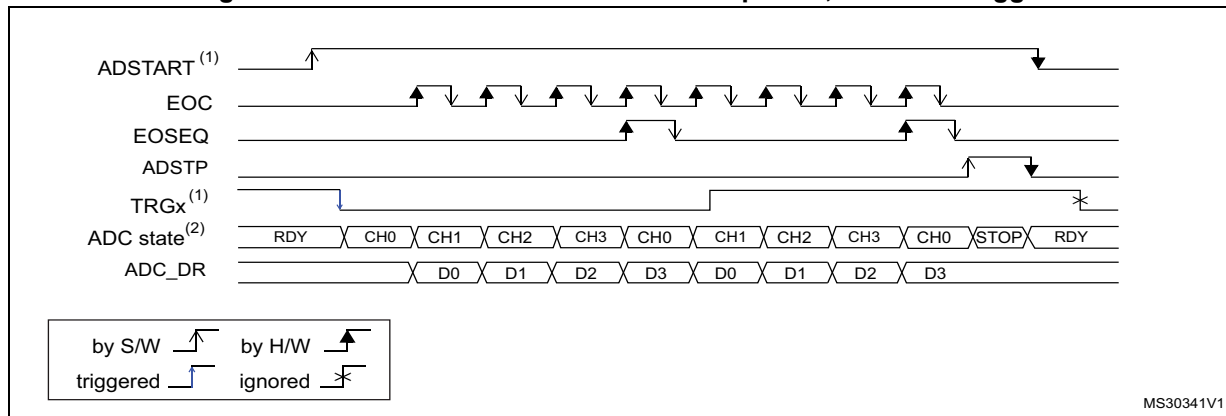
Figure 32. Single conversions of a sequence, hardware trigger



1. EXTSEL=TRGx (over-frequency), EXTEN=01 (rising edge), CONT=0
2. CHSEL=0xF, SCANDIR=0, WAIT=0, AUTOFF=0

For code example refer to the Appendix section [A.7.7: Single conversion sequence code example - Hardware trigger](#).

Figure 33. Continuous conversions of a sequence, hardware trigger



1. EXTSEL=TRGx, EXTEN=10 (falling edge), CONT=1
2. CHSEL=0xF, SCANDIR=0, WAIT=0, AUTOFF=0

For code example refer to the Appendix section [A.7.8: Continuous conversion sequence code example - Hardware trigger](#).

12.6 Data management

12.6.1 Data register and data alignment (ADC_DR, ALIGN)

At the end of each conversion (when an EOC event occurs), the result of the converted data is stored in the ADC_DR data register which is 16-bit wide.

The format of the ADC_DR depends on the configured data alignment and resolution.

The ALIGN bit in the ADC_CFGR1 register selects the alignment of the data stored after conversion. Data can be right-aligned (ALIGN=0) or left-aligned (ALIGN=1) as shown in [Figure 34](#).

Figure 34. Data alignment and resolution

ALIGN	RES	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0	0x0	0x0				DR[11:0]											
	0x1	0x00				DR[9:0]											
	0x2	0x00				DR[7:0]											
	0x3	0x00				DR[5:0]											
1	0x0	DR[11:0]												0x0			
	0x1	DR[9:0]												0x00			
	0x2	DR[7:0]												0x00			
	0x3	0x00												DR[5:0]			

MS30342V1

12.6.2 ADC overrun (OVR, OVRMOD)

The overrun flag (OVR) indicates a data overrun event, when the converted data was not read in time by the CPU or the DMA, before the data from a new conversion is available.

The OVR flag is set in the ADC_ISR register if the EOC flag is still at '1' at the time when a new conversion completes. An interrupt can be generated if the OVRIE bit is set in the ADC_IER register.

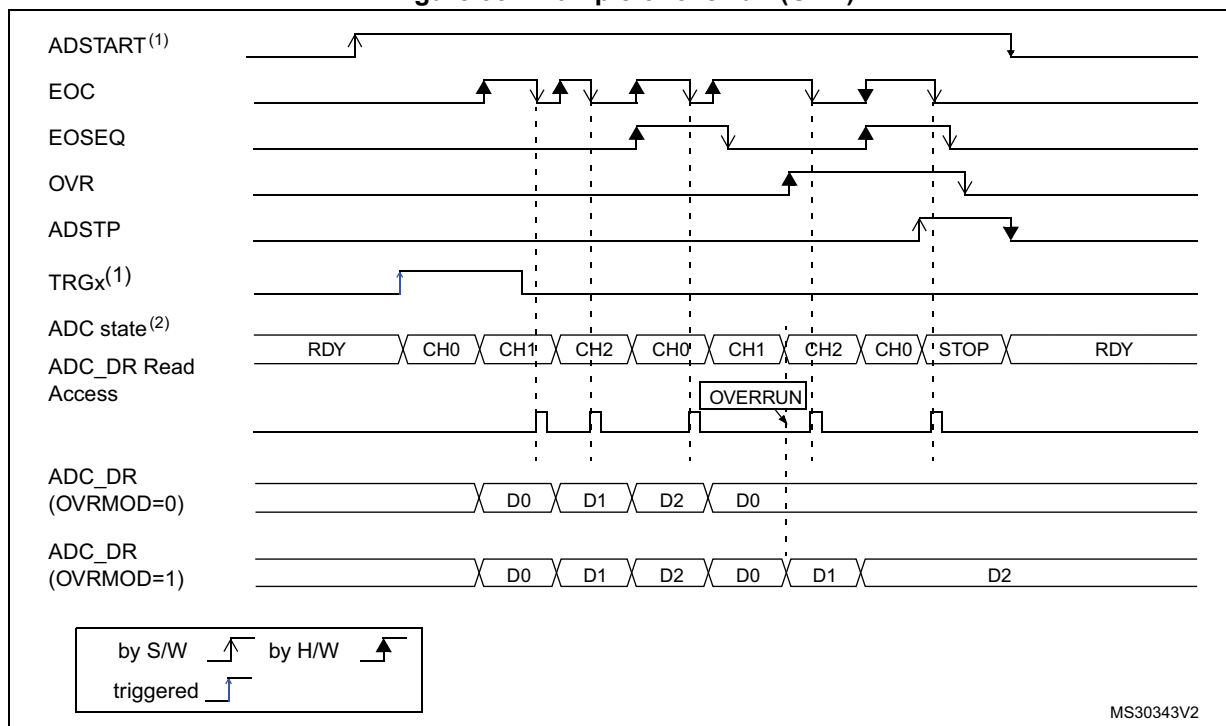
When an overrun condition occurs, the ADC keeps operating and can continue to convert unless the software decides to stop and reset the sequence by setting the ADSTP bit in the ADC_CR register.

The OVR flag is cleared by software by writing 1 to it.

It is possible to configure if the data is preserved or overwritten when an overrun event occurs by programming the OVRMOD bit in the ADC_CFGR1 register:

- OVRMOD=0
 - An overrun event preserves the data register from being overwritten: the old data is maintained and the new conversion is discarded. If OVR remains at 1, further conversions can be performed but the resulting data is discarded.
- OVRMOD=1
 - The data register is overwritten with the last conversion result and the previous unread data is lost. If OVR remains at 1, further conversions can be performed and the ADC_DR register always contains the data from the latest conversion.

Figure 35. Example of overrun (OVR)



12.6.3 Managing a sequence of data converted without using the DMA

If the conversions are slow enough, the conversion sequence can be handled by software. In this case the software must use the EOC flag and its associated interrupt to handle each data result. Each time a conversion is complete, the EOC bit is set in the ADC_ISR register and the ADC_DR register can be read. The OVRMOD bit in the ADC_CFGR1 register should be configured to 0 to manage overrun events as an error.

12.6.4 Managing converted data without using the DMA without overrun

It may be useful to let the ADC convert one or more channels without reading the data after each conversion. In this case, the OVRMOD bit must be configured at 1 and the OVR flag should be ignored by the software. When OVRMOD=1, an overrun event does not prevent the ADC from continuing to convert and the ADC_DR register always contains the latest conversion data.

12.6.5 Managing converted data using the DMA

Since all converted channel values are stored in a single data register, it is efficient to use DMA when converting more than one channel. This avoids losing the conversion data results stored in the ADC_DR register.

When DMA mode is enabled (DMAEN bit set to 1 in the ADC_CFGR1 register), a DMA request is generated after the conversion of each channel. This allows the transfer of the converted data from the ADC_DR register to the destination location selected by the software.

Note: The DMAEN bit in the ADC_CFGR1 register must be set after the ADC calibration phase.

Despite this, if an overrun occurs (OVR=1) because the DMA could not serve the DMA transfer request in time, the ADC stops generating DMA requests and the data corresponding to the new conversion is not transferred by the DMA. Which means that all the data transferred to the RAM can be considered as valid.

Depending on the configuration of OVRMOD bit, the data is either preserved or overwritten (refer to [Section 12.6.2: ADC overrun \(OVR, OVRMOD\) on page 198](#)).

The DMA transfer requests are blocked until the software clears the OVR bit.

Two different DMA modes are proposed depending on the application use and are configured with bit DMACFG in the ADC_CFGR1 register:

- DMA one shot mode (DMACFG=0).
This mode should be selected when the DMA is programmed to transfer a fixed number of data words.
- DMA circular mode (DMACFG=1)
This mode should be selected when programming the DMA in circular mode or double buffer mode.

DMA one shot mode (DMACFG=0)

In this mode, the ADC generates a DMA transfer request each time a new conversion data word is available and stops generating DMA requests once the DMA has reached the last DMA transfer (when a DMA_EOT interrupt occurs, see [Section 10: Direct memory access controller \(DMA\) on page 152](#)) even if a conversion has been started again.

For code example refer to the Appendix section [A.7.9: DMA one shot mode sequence code example](#).

When the DMA transfer is complete (all the transfers configured in the DMA controller have been done):

- The content of the ADC data register is frozen.
- Any ongoing conversion is aborted and its partial result discarded
- No new DMA request is issued to the DMA controller. This avoids generating an overrun error if there are still conversions which are started.
- The scan sequence is stopped and reset
- The DMA is stopped

DMA circular mode (DMACFG=1)

In this mode, the ADC generates a DMA transfer request each time a new conversion data word is available in the data register, even if the DMA has reached the last DMA transfer. This allows the DMA to be configured in circular mode to handle a continuous analog input data stream.

For code example refer to the Appendix section [A.7.10: DMA circular mode sequence code example](#).

12.7 Low-power features

12.7.1 Wait mode conversion

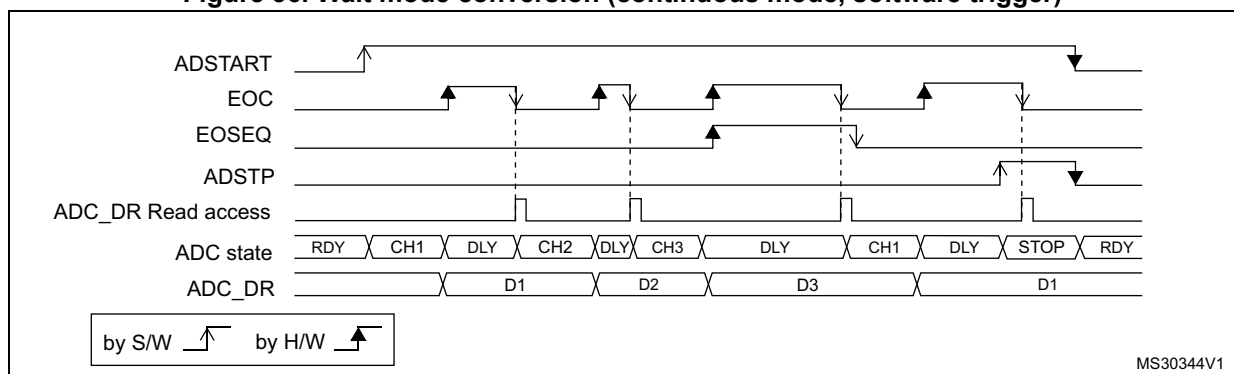
Wait mode conversion can be used to simplify the software as well as optimizing the performance of applications clocked at low frequency where there might be a risk of ADC overrun occurring.

When the WAIT bit is set to 1 in the ADC_CFGR1 register, a new conversion can start only if the previous data has been treated, once the ADC_DR register has been read or if the EOC bit has been cleared.

This is a way to automatically adapt the speed of the ADC to the speed of the system that reads the data.

Note: Any hardware triggers which occur while a conversion is ongoing or during the wait time preceding the read access are ignored.

Figure 36. Wait mode conversion (continuous mode, software trigger)



1. EXTEN=00, CONT=1
2. CHSEL=0x3, SCANDIR=0, WAIT=1, AUTOFF=0

For code example refer to the Appendix section [A.7.11: Wait mode sequence code example](#).

12.7.2 Auto-off mode (AUTOFF)

The ADC has an automatic power management feature which is called auto-off mode, and is enabled by setting AUTOFF=1 in the ADC_CFGR1 register.

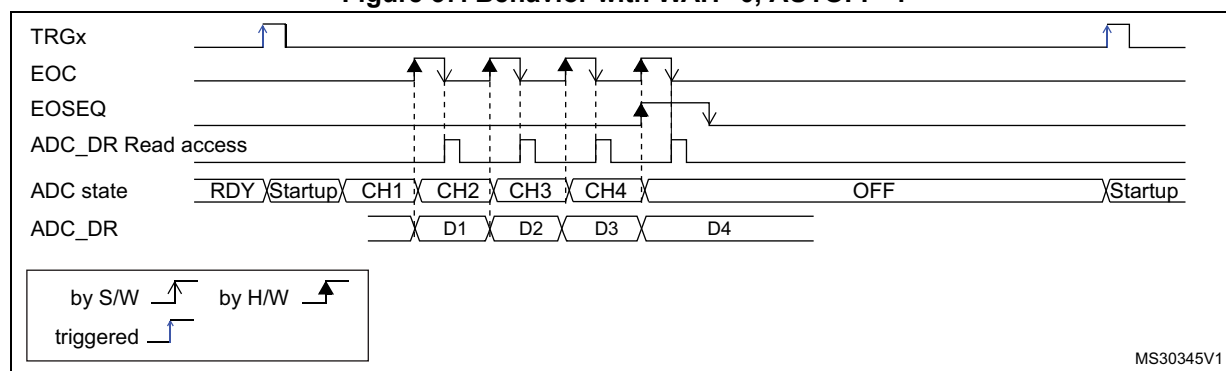
When AUTOFF=1, the ADC is always powered off when not converting and automatically wakes-up when a conversion is started (by software or hardware trigger). A startup-time is automatically inserted between the trigger event which starts the conversion and the sampling time of the ADC. The ADC is then automatically disabled once the sequence of conversions is complete.

Auto-off mode can cause a dramatic reduction in the power consumption of applications which need relatively few conversions or when conversion requests are timed far enough apart (for example with a low frequency hardware trigger) to justify the extra power and extra time used for switching the ADC on and off.

Auto-off mode can be combined with the wait mode conversion (WAIT=1) for applications clocked at low frequency. This combination can provide significant power savings if the ADC is automatically powered-off during the wait phase and restarted as soon as the ADC_DR register is read by the application (see [Figure 38: Behavior with WAIT=1, AUTOFF=1](#)).

Note: Please refer to the [Section 7: Reset and clock control \(RCC\)](#) on page 87 for the description of how to manage the dedicated 14 MHz internal oscillator. The ADC interface can automatically switch ON/OFF the 14 MHz internal oscillator to save power.

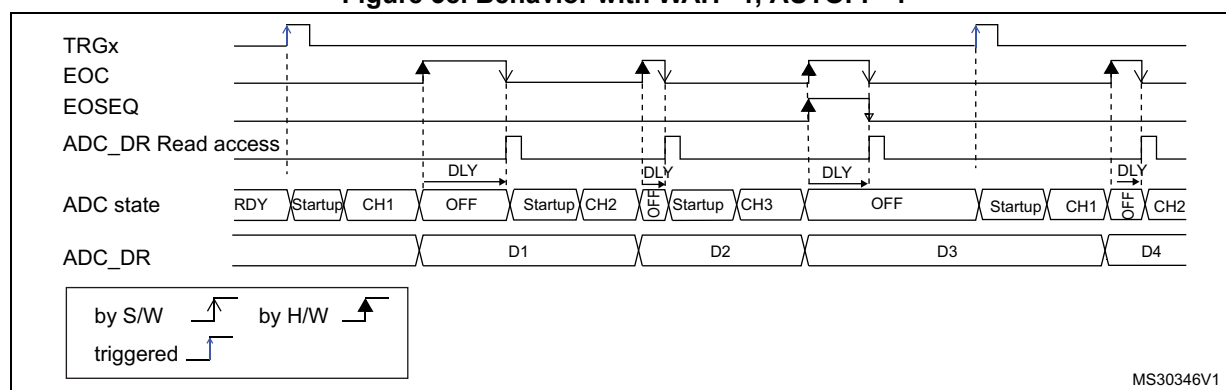
Figure 37. Behavior with WAIT=0, AUTOFF=1



1. EXTSEL=TRGx, EXTEN=01 (rising edge), CONT=x, ADSTART=1, CHSEL=0xF, SCANDIR=0, WAIT=1, AUTOFF=1

For code example refer to the Appendix section [A.7.12: Auto Off and no wait mode sequence code example](#).

Figure 38. Behavior with WAIT=1, AUTOFF=1



1. EXTSEL=TRGx, EXTEN=01 (rising edge), CONT=x, ADSTART=1, CHSEL=0xF, SCANDIR=0, WAIT=1, AUTOFF=1

For code example refer to the Appendix section [A.7.13: Auto Off and wait mode sequence code example](#).

12.8 Analog window watchdog (AWDEN, AWDSGL, AWDCH, AWD_HTR/LTR, AWD)

The AWD analog watchdog feature is enabled by setting the AWDEN bit in the ADC_CFGR1 register. It is used to monitor that either one selected channel or all enabled channels (see [Table 41: Analog watchdog channel selection](#)) remain within a configured voltage range (window) as shown in [Figure 39](#).

The AWD analog watchdog status bit is set if the analog voltage converted by the ADC is below a lower threshold or above a higher threshold. These thresholds are programmed in the 12 least significant bits of the ADC_HTR and ADC_LTR 16-bit registers. An interrupt can be enabled by setting the AWDIE bit in the ADC_IER register.

The AWD flag is cleared by software by writing 1 to it.

When converting a data with a resolution of less than 12-bit (according to bits DRES[1:0]), the LSB of the programmed thresholds must be kept cleared because the internal comparison is always performed on the full 12-bit raw converted data (left aligned).

For code example refer to the Appendix section [A.7.14: Analog watchdog code example](#).

[Table 40](#) describes how the comparison is performed for all the possible resolutions.

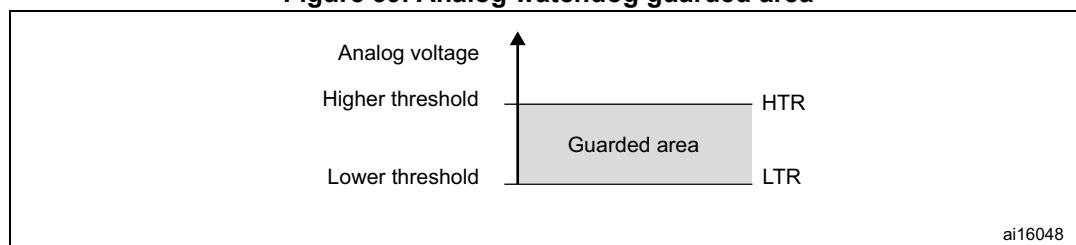
Table 40. Analog watchdog comparison

Resolution bits RES[1:0]	Analog Watchdog comparison between:		Comments
	Raw converted data, left aligned ⁽¹⁾	Thresholds	
00: 12-bit	DATA[11:0]	LT[11:0] and HT[11:0]	-
01: 10-bit	DATA[11:2],00	LT[11:0] and HT[11:0]	The user must configure LT1[1:0] and HT1[1:0] to "00"
10: 8-bit	DATA[11:4],0000	LT[11:0] and HT[11:0]	The user must configure LT1[3:0] and HT1[3:0] to "0000"
11: 6-bit	DATA[11:6],000000	LT[11:0] and HT[11:0]	The user must configure LT1[5:0] and HT1[5:0] to "000000"

1. The watchdog comparison is performed on the raw converted data before any alignment calculation.

[Table 41](#) shows how to configure the AWDSGL and AWDEN bits in the ADC_CFGR1 register to enable the analog watchdog on one or more channels.

Figure 39. Analog watchdog guarded area



ai16048

Table 41. Analog watchdog channel selection

Channels guarded by the analog watchdog	AWDSGL bit	AWDEN bit
None	x	0
All channels	0	1
Single ⁽¹⁾ channel	1	1

1. Selected by the AWDCH[4:0] bits

12.9 Temperature sensor and internal reference voltage

The temperature sensor can be used to measure the junction temperature (T_J) of the device. The temperature sensor is internally connected to the ADC_IN16 input channel which is used to convert the sensor's output voltage to a digital value. The sampling time for the temperature sensor analog pin must be greater than the minimum T_{S_temp} value specified in the datasheet. When not in use, the sensor can be put in power down mode.

The temperature sensor output voltage changes linearly with temperature, however its characteristics may vary significantly from chip to chip due to the process variations. To improve the accuracy of the temperature sensor (especially for absolute temperature measurement), calibration values are individually measured for each part by ST during production test and stored in the system memory area. Refer to the specific device datasheet for additional information.

The internal voltage reference (VREFINT) provides a stable (bandgap) voltage output for the ADC and Comparators. VREFINT is internally connected to the ADC_IN17 input channel. The precise voltage of VREFINT is individually measured for each part by ST during production test and stored in the system memory area. It is accessible in read-only mode.

Figure shows the block diagram of connections between the temperature sensor, the internal voltage reference and the ADC.

The TSEN bit must be set to enable the conversion of ADC_IN16 (temperature sensor) and the VREFEN bit must be set to enable the conversion of ADC_IN17 (VREFINT).

Main features

- Supported temperature range: -40 to 105 °C
- Linearity: ± 2 °C max., precision depending on calibration

Reading the temperature

1. Select the ADC_IN16 input channel
2. Select an appropriate sampling time specified in the device datasheet (T_{S_temp}).
3. Set the TSEN bit in the ADC_CCR register to wake up the temperature sensor from power down mode and wait for its stabilization time (t_{START})

For code example refer to the Appendix section [A.7.15: Temperature configuration code example](#).

4. Start the ADC conversion by setting the ADSTART bit in the ADC_CR register (or by external trigger)
5. Read the resulting_data in the ADC_DR register
6. Calculate the actual temperature using the following formula:

$$\text{Temperature (in } ^\circ\text{C)} = \frac{V_{30} - V_{\text{SENSE}}}{\text{Avg\_Slope}} + 30\text{ } ^\circ\text{C}$$

$$V_{\text{SENSE}} = \frac{\text{TS\_DATA}}{4095} \times V_{\text{DD}}$$

For code example refer to the [A.7.16: Temperature computation code example](#).

Note: The sensor has a startup time after waking from power down mode before it can output V_{SENSE} at the correct level. The ADC also has a startup time after power-on, so to minimize the delay, the ADEN and TSEN bits should be set at the same time.

Calculating the actual V_{DDA} voltage using the internal reference voltage

The V_{DDA} power supply voltage applied to the microcontroller may be subject to variation or not precisely known. The embedded internal voltage reference (VREFINT) and its calibration data acquired by the ADC during the manufacturing process at $V_{\text{DDA}} = 3.3\text{ V}$ can be used to evaluate the actual V_{DDA} voltage level.

The following formula gives the actual V_{DDA} voltage supplying the device:

$$V_{\text{DDA}} = .3\text{ V} \times \text{VREFINT\_CAL} / \text{VREFINT\_DATA}$$

Where:

- VREFINT_CAL is the VREFINT calibration value
- VREFINT_DATA is the actual VREFINT output value converted by ADC

Converting a supply-relative ADC measurement to an absolute voltage value

The ADC is designed to deliver a digital value corresponding to the ratio between the analog power supply and the voltage applied on the converted channel. For most application use cases, it is necessary to convert this ratio into a voltage independent of V_{DDA} . For applications where V_{DDA} is known and ADC converted values are right-aligned you can use the following formula to get this absolute value:

$$V_{\text{CHANNELx}} = \frac{V_{\text{DDA}}}{\text{FULL\_SCALE}} \times \text{ADC\_DATA}_x$$

For applications where V_{DDA} value is not known, you must use the internal voltage reference and V_{DDA} can be replaced by the expression provided in the section [Calculating the actual \$V_{\text{DDA}}\$ voltage using the internal reference voltage](#), resulting in the following formula:

$$V_{\text{CHANNELx}} = \frac{3.3\text{ V} \times \text{VREFINT\_CAL} \times \text{ADC\_DATA}_x}{\text{VREFINT\_DATA} \times \text{FULL\_SCALE}}$$

Where:

- VREFINT_CAL is the VREFINT calibration value
- ADC_DATA_x is the value measured by the ADC on channel x (right-aligned)
- VREFINT_DATA is the actual VREFINT output value converted by the ADC
- full_SCALE is the maximum digital value of the ADC output. For example with 12-bit resolution, it will be $2^{12} - 1 = 4095$ or with 8-bit resolution, $2^8 - 1 = 255$.

Note: If ADC measurements are done using an output format other than 12 bit right-aligned, all the parameters must first be converted to a compatible format before the calculation is done.

12.10 ADC interrupts

An interrupt can be generated by any of the following events:

- ADC power-up, when the ADC is ready (ADRDY flag)
- End of any conversion (EOC flag)
- End of a sequence of conversions (EOSEQ flag)
- When an analog watchdog detection occurs (AWD flag)
- When the end of sampling phase occurs (EOSMP flag)
- when a data overrun occurs (OVR flag)

Separate interrupt enable bits are available for flexibility.

Table 42. ADC interrupts

Interrupt event	Event flag	Enable control bit
ADC ready	ADRDY	ADRDYIE
End of conversion	EOC	EOCIE
End of sequence of conversions	EOSEQ	EOSEQIE
Analog watchdog status bit is set	AWD	AWDIE
End of sampling phase	EOSMP	EOSMPIE
Overrun	OVR	OVRIE

12.11 ADC registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

12.11.1 ADC interrupt and status register (ADC_ISR)

Address offset: 0x00

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	AWD	Res.	Res.	OVR	EOSEQ	EOC	EOSMP	ADRDY
								rc_w1			rc_w1	rc_w1	rc_w1	rc_w1	rc_w1

Bits 31:8 Reserved, must be kept at reset value.

Bit 7 **AWD**: Analog watchdog flag

This bit is set by hardware when the converted voltage crosses the values programmed in the ADC_LTR and ADC_HTR registers. It is cleared by software writing 1 to it.

0: No analog watchdog event occurred (or the flag event was already acknowledged and cleared by software)

1: Analog watchdog event occurred

Bit 6:5 Reserved, must be kept at reset value.

Bit 4 **OVR**: ADC overrun

This bit is set by hardware when an overrun occurs, meaning that a new conversion has complete while the EOC flag was already set. It is cleared by software writing 1 to it.

0: No overrun occurred (or the flag event was already acknowledged and cleared by software)

1: Overrun has occurred

Bit 3 **EOSEQ**: End of sequence flag

This bit is set by hardware at the end of the conversion of a sequence of channels selected by the CHSEL bits. It is cleared by software writing 1 to it.

0: Conversion sequence not complete (or the flag event was already acknowledged and cleared by software)

1: Conversion sequence complete

Bit 2 EOC: End of conversion flag

This bit is set by hardware at the end of each conversion of a channel when a new data result is available in the ADC_DR register. It is cleared by software writing 1 to it or by reading the ADC_DR register.

0: Channel conversion not complete (or the flag event was already acknowledged and cleared by software)

1: Channel conversion complete

Bit 1 EOSMP: End of sampling flag

This bit is set by hardware during the conversion, at the end of the sampling phase. It is cleared by software by programming it to '1'.

0: Not at the end of the sampling phase (or the flag event was already acknowledged and cleared by software)

1: End of sampling phase reached

Bit 0 ADRDY: ADC ready

This bit is set by hardware after the ADC has been enabled (bit ADEN=1) and when the ADC reaches a state where it is ready to accept conversion requests.

It is cleared by software writing 1 to it.

0: ADC not yet ready to start conversion (or the flag event was already acknowledged and cleared by software)

1: ADC is ready to start conversion

Note: In auto-off mode (AUTOFF=1) the power-on/off phases are performed automatically, by hardware and the ADRDY flag is not set.

12.11.2 ADC interrupt enable register (ADC_IER)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	AWD IE	Res.	Res.	OVRIE	EOSEQ IE	EOCIE	EOSMP IE	ADRDY IE
								rw			rw	rw	rw	rw	rw

Bits 31:8 Reserved, must be kept at reset value.

Bit 7 AWDIE: Analog watchdog interrupt enable

This bit is set and cleared by software to enable/disable the analog watchdog interrupt.

0: Analog watchdog interrupt disabled

1: Analog watchdog interrupt enabled

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 6:5 Reserved, must be kept at reset value.

Bit 4 OVRIE: Overrun interrupt enable

This bit is set and cleared by software to enable/disable the overrun interrupt.

0: Overrun interrupt disabled

1: Overrun interrupt enabled. An interrupt is generated when the OVR bit is set.

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 3 EOSEQIE: End of conversion sequence interrupt enable

This bit is set and cleared by software to enable/disable the end of sequence of conversions interrupt.

0: EOSEQ interrupt disabled

1: EOSEQ interrupt enabled. An interrupt is generated when the EOSEQ bit is set.

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 2 EOCIE: End of conversion interrupt enable

This bit is set and cleared by software to enable/disable the end of conversion interrupt.

0: EOC interrupt disabled

1: EOC interrupt enabled. An interrupt is generated when the EOC bit is set.

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 1 EOSMPIE: End of sampling flag interrupt enable

This bit is set and cleared by software to enable/disable the end of the sampling phase interrupt.

0: EOSMP interrupt disabled.

1: EOSMP interrupt enabled. An interrupt is generated when the EOSMP bit is set.

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bits 0 ADRDYIE: ADC ready interrupt enable

This bit is set and cleared by software to enable/disable the ADC Ready interrupt.

0: ADRDY interrupt disabled.

1: ADRDY interrupt enabled. An interrupt is generated when the ADRDY bit is set.

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

12.11.3 ADC control register (ADC_CR)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
AD CAL	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
rs															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ADSTP	Res.	ADSTAR	ADDIS	ADEN
											rs		rs	rs	rs

Bit 31 ADCAL: ADC calibration

This bit is set by software to start the calibration of the ADC.

It is cleared by hardware after calibration is complete.

0: Calibration complete

1: Write 1 to calibrate the ADC. Read at 1 means that a calibration is in progress.

Note: Software is allowed to set ADCAL only when the ADC is disabled (ADCAL=0, ADSTART=0, ADSTP=0, ADDIS=0 and ADEN=0).

Bits 30:5 Reserved, must be kept at reset value.

Bit 4 ADSTP: ADC stop conversion command

This bit is set by software to stop and discard an ongoing conversion (ADSTP Command).

It is cleared by hardware when the conversion is effectively discarded and the ADC is ready to accept a new start conversion command.

0: No ADC stop conversion command ongoing

1: Write 1 to stop the ADC. Read 1 means that an ADSTP command is in progress.

Note: Setting ADSTP to '1' is only effective when ADSTART=1 and ADDIS=0 (ADC is enabled and may be converting and there is no pending request to disable the ADC)

Bit 3 Reserved, must be kept at reset value.

Bit 2 ADSTART: ADC start conversion command

This bit is set by software to start ADC conversion. Depending on the EXTEN [1:0] configuration bits, a conversion either starts immediately (software trigger configuration) or once a hardware trigger event occurs (hardware trigger configuration).

It is cleared by hardware:

- In single conversion mode (CONT=0, DISCEN=0), when software trigger is selected (EXTEN=00): at the assertion of the end of Conversion Sequence (EOSEQ) flag.
- In discontinuous conversion mode (CONT=0, DISCEN=1), when the software trigger is selected (EXTEN=00): at the assertion of the end of Conversion (EOC) flag.
- In all other cases: after the execution of the ADSTP command, at the same time as the ADSTP bit is cleared by hardware.

0: No ADC conversion is ongoing.

1: Write 1 to start the ADC. Read 1 means that the ADC is operating and may be converting.

Note: Software is allowed to set ADSTART only when ADEN=1 and ADDIS=0 (ADC is enabled and there is no pending request to disable the ADC)

Bit 1 ADDIS: ADC disable command

This bit is set by software to disable the ADC (ADDIS command) and put it into power-down state (OFF state).

It is cleared by hardware once the ADC is effectively disabled (ADEN is also cleared by hardware at this time).

0: No ADDIS command ongoing

1: Write 1 to disable the ADC. Read 1 means that an ADDIS command is in progress.

Note: Setting ADDIS to '1' is only effective when ADEN=1 and ADSTART=0 (which ensures that no conversion is ongoing)

Bit 0 ADEN: ADC enable command

This bit is set by software to enable the ADC. The ADC will be effectively ready to operate once the ADRDY flag has been set.

It is cleared by hardware when the ADC is disabled, after the execution of the ADDIS command.

0: ADC is disabled (OFF state)

1: Write 1 to enable the ADC.

Note: Software is allowed to set ADEN only when all bits of ADC_CR registers are 0 (ADCAL=0, ADSTP=0, ADSTART=0, ADDIS=0 and ADEN=0)

12.11.4 ADC configuration register 1 (ADC_CFGR1)

Address offset: 0x0C

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	AWDCH[4:0]					Res.	Res.	AWDEN	AWDSGL	Res.	Res.	Res.	Res.	Res.	DISCEN
	rw	rw	rw	rw	rw			rw	rw						rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
AUTOFF	WAIT	CONT	OVRMOD	EXTEN[1:0]		Res.	EXTSEL[2:0]			ALIGN	RES[1:0]		SCAND IR	DMAC FG	DMAEN
rw	rw	rw	rw	rw			rw			rw	rw		rw	rw	rw

Bit 31 Reserved, must be kept at reset value.

Bits 30:26 **AWDCH[4:0]**: Analog watchdog channel selection

These bits are set and cleared by software. They select the input channel to be guarded by the analog watchdog.

00000: ADC analog input Channel 0 monitored by AWD

00001: ADC analog input Channel 1 monitored by AWD

.....

10010: ADC analog input Channel 18 monitored by AWD

other values: Reserved, must not be used

Note: The channel selected by the AWDCH[4:0] bits must be also set into the CHSELR register

Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

Bits 25:24 Reserved, must be kept at reset value.

Bit 23 **AWDEN**: Analog watchdog enable

This bit is set and cleared by software.

0: Analog watchdog disabled

1: Analog watchdog enabled

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 22 **AWDSGL**: Enable the watchdog on a single channel or on all channels

This bit is set and cleared by software to enable the analog watchdog on the channel identified by the AWDCH[4:0] bits or on all the channels

0: Analog watchdog enabled on all channels

1: Analog watchdog enabled on a single channel

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bits 21:17 Reserved, must be kept at reset value.

Bit 16 DISCEN: Discontinuous mode

This bit is set and cleared by software to enable/disable discontinuous mode.

- 0: Discontinuous mode disabled
- 1: Discontinuous mode enabled

Note: It is not possible to have both discontinuous mode and continuous mode enabled: it is forbidden to set both bits DISCEN=1 and CONT=1.

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 15 AUTOFF: Auto-off mode

This bit is set and cleared by software to enable/disable auto-off mode.

- 0: Auto-off mode disabled
- 1: Auto-off mode enabled

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 14 WAIT: Wait conversion mode

This bit is set and cleared by software to enable/disable wait conversion mode.

- 0: Wait conversion mode off
- 1: Wait conversion mode on

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 13 CONT: Single / continuous conversion mode

This bit is set and cleared by software. If it is set, conversion takes place continuously until it is cleared.

- 0: Single conversion mode
- 1: Continuous conversion mode

Note: It is not possible to have both discontinuous mode and continuous mode enabled: it is forbidden to set both bits DISCEN=1 and CONT=1.

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 12 OVRMOD: Overrun management mode

This bit is set and cleared by software and configure the way data overruns are managed.

- 0: ADC_DR register is preserved with the old data when an overrun is detected.
- 1: ADC_DR register is overwritten with the last conversion result when an overrun is detected.

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bits 11:10 EXTEN[1:0]: External trigger enable and polarity selection

These bits are set and cleared by software to select the external trigger polarity and enable the trigger.

- 00: Hardware trigger detection disabled (conversions can be started by software)
- 01: Hardware trigger detection on the rising edge
- 10: Hardware trigger detection on the falling edge
- 11: Hardware trigger detection on both the rising and falling edges

Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 9 Reserved, must be kept at reset value.

Bits 8:6 **EXTSEL[2:0]**: External trigger selection

These bits select the external event used to trigger the start of conversion (refer to [Table 38: External triggers](#) for details):

000: TRG0
001: TRG1
010: TRG2
011: TRG3
100: TRG4
101: TRG5
110: TRG6
111: TRG7

Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 5 **ALIGN**: Data alignment

This bit is set and cleared by software to select right or left alignment. Refer to [Figure 34: Data alignment and resolution on page 198](#)

0: Right alignment
1: Left alignment

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 4:3 **RES[1:0]**: Data resolution

These bits are written by software to select the resolution of the conversion.

00: 12 bits
01: 10 bits
10: 8 bits
11: 6 bits

Note: Software is allowed to write these bits only when ADEN=0.

Bit 2 SCANDIR: Scan sequence direction

This bit is set and cleared by software to select the direction in which the channels will be scanned in the sequence.

0: Upward scan (from CHSEL0 to CHSEL17)

1: Backward scan (from CHSEL17 to CHSEL0)

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 1 DMACFG: Direct memory access configuration

This bit is set and cleared by software to select between two DMA modes of operation and is effective only when DMAEN=1.

0: DMA one shot mode selected

1: DMA circular mode selected

For more details, refer to [Section 12.6.5: Managing converted data using the DMA on page 199](#)

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

Bit 0 DMAEN: Direct memory access enable

This bit is set and cleared by software to enable the generation of DMA requests. This allows to use the DMA controller to manage automatically the converted data. For more details, refer to [Section 12.6.5: Managing converted data using the DMA on page 199](#).

0: DMA disabled

1: DMA enabled

Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).

12.11.5 ADC configuration register 2 (ADC_CFGR2)

Address offset: 0x10

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
CKMODE[1:0]		Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
rw	rw														
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.

Bits 31:30 **CKMODE[1:0]**: ADC clock mode

These bits are set and cleared by software to define how the analog ADC is clocked:

00: ADCCLK (Asynchronous clock mode), generated at product level (refer to RCC section)

01: PCLK/2 (Synchronous clock mode)

10: PCLK/4 (Synchronous clock mode)

11: Reserved

In all synchronous clock modes, there is no jitter in the delay from a timer trigger to the start of a conversion.

Note: Software is allowed to write these bits only when the ADC is disabled (ADCAL=0, ADSTART=0, ADSTP=0, ADDIS=0 and ADEN=0).

Bits 29:0 Reserved, must be kept at reset value.

12.11.6 ADC sampling time register (ADC_SMPR)

Address offset: 0x14

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SMP[2:0]		
													rw		

Bits 31:3 Reserved, must be kept at reset value.

Bits 2:0 **SMP[2:0]**: *Sampling time selection*

These bits are written by software to select the sampling time that applies to all channels.

000: 1.5 ADC clock cycles
 001: 7.5 ADC clock cycles
 010: 13.5 ADC clock cycles
 011: 28.5 ADC clock cycles
 100: 41.5 ADC clock cycles
 101: 55.5 ADC clock cycles
 110: 71.5 ADC clock cycles
 111: 239.5 ADC clock cycles

Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

12.11.7 ADC watchdog threshold register (ADC_TR)

Address offset: 0x20

Reset value: 0x0FFF 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	HT[11:0]											
				r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	LT[11:0]											
				r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w

Bits 31:28 Reserved, must be kept at reset value.

Bit 27:16 **HT[11:0]**: *Analog watchdog higher threshold*

These bits are written by software to define the higher threshold for the analog watchdog. Refer to [Section 12.8: Analog window watchdog \(AWDEN, AWDSGL, AWDCH, AWD_HTR/LTR, AWD\) on page 203](#)

Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

Bits 15:12 Reserved, must be kept at reset value.

Bit 11:0 **LT[11:0]**: *Analog watchdog lower threshold*

These bits are written by software to define the lower threshold for the analog watchdog. Refer to [Section 12.8: Analog window watchdog \(AWDEN, AWDSGL, AWDCH, AWD_HTR/LTR, AWD\) on page 203](#)

Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

12.11.8 ADC channel selection register (ADC_CHSELR)

Address offset: 0x28

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CHSEL 17	CHSEL 16
														rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CHSEL 15	CHSEL 14	CHSEL 13	CHSEL 12	CHSEL 11	CHSEL 10	CHSEL 9	CHSEL 8	CHSEL 7	CHSEL 6	CHSEL 5	CHSEL 4	CHSEL 3	CHSEL 2	CHSEL 1	CHSEL 0
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:18 Reserved, must be kept at reset value.

Bits 17:0 **CHSELx**: Channel-x selection

These bits are written by software and define which channels are part of the sequence of channels to be converted.

0: Input Channel-x is not selected for conversion

1: Input Channel-x is selected for conversion

Note: Software is allowed to write these bits only when ADSTART=0 (which ensures that no conversion is ongoing).

12.11.9 ADC data register (ADC_DR)

Address offset: 0x40

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DATA[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **DATA[15:0]**: Converted data

These bits are read-only. They contain the conversion result from the last converted channel. The data are left- or right-aligned as shown in [Figure 34: Data alignment and resolution on page 198](#).

Just after a calibration is complete, DATA[6:0] contains the calibration factor.

12.11.10 ADC common configuration register (ADC_CCR)

Address offset: 0x308

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TS EN	VREF EN	Res.	Res.	Res.	Res.	Res.	Res.
								rw	rw						
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.

Bits 31:24 Reserved, must be kept at reset value.

Bit 23 **TSEN**: Temperature sensor enable

This bit is set and cleared by software to enable/disable the temperature sensor.

0: Temperature sensor disabled

1: Temperature sensor enabled

*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*Bit 22 **VREFEN**: V_{REFINT} enableThis bit is set and cleared by software to enable/disable the V_{REFINT}.0: V_{REFINT} disabled1: V_{REFINT} enabled*Note: Software is allowed to write this bit only when ADSTART=0 (which ensures that no conversion is ongoing).*

Bits 21:0 Reserved, must be kept at reset value.

12.11.11 ADC register map

The following table summarizes the ADC registers.

Table 43. ADC register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x00	ADC_ISR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	AWD	Res.	Res.	Res.	OVR	EOSEQ	EOC	EOSMP	ADRDY
	Reset value																									0			0	0	0	0	0	
0x04	ADC_IER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	AWDIE	Res.	Res.	Res.	OVRIE	EOSEQIE	EOCIE	EOSMPIE	ADRDYIE
	Reset value																									0			0	0	0	0	0	
0x08	ADC_CR	ADCAL	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ADSTP	Res.	ADSTART	ADDIS	ADEN	
	Reset value	0																											0		0	0	0	
0x0C	ADC_CFGR1	Res.	AWDCH[4:0]						Res.	Res.	AWDEN	AWDSGL	Res.	Res.	Res.	Res.	Res.	DISCEN	AUTOFF	WAIT	CONT	OVROMOD	EXTEN[1:0]			EXTSEL[2:0]		ALIGN	RES[1:0]		SCANDIR	DMACFG	DMAEN	
	Reset value		0	0	0	0	0	0			0	0						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x10	ADC_CFGR2	CKMODE[1:0]		Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value	0	0																															
0x14	ADC_SMPR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SMP[2:0]		
	Reset value																															0	0	0
0x18	Reserved	Reserved																																
0x1C	Reserved	Reserved																																
0x20	ADC_TR	Res.	Res.	Res.	Res.	HT[11:0]											Res.	Res.	Res.	Res.	LT[11:0]													
	Reset value					1	1	1	1	1	1	1	1	1	1	1	1					0	0	0	0	0	0	0	0	0	0	0	0	0
0x24	Reserved	Reserved																																
0x28	ADC_CHSELR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CHSEL17	CHSEL16	CHSEL15	CHSEL14	CHSEL13	CHSEL12	CHSEL11	CHSEL10	CHSEL9	CHSEL8	CHSEL7	CHSEL6	CHSEL5	CHSEL4	CHSEL3	CHSEL2	CHSEL1	CHSEL0	
	Reset value															0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x2C 0x30 0x34 0x38 0x3C	Reserved	Reserved																																
0x40	ADC_DR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DATA[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x308	ADC_CCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TSEN	VREFEN	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value									0	0																							

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

13 Advanced-control timers (TIM1)

13.1 TIM1 introduction

The advanced-control timers (TIM1) consist of a 16-bit auto-reload counter driven by a programmable prescaler.

It may be used for a variety of purposes, including measuring the pulse lengths of input signals (input capture) or generating output waveforms (output compare, PWM, complementary PWM with dead-time insertion).

Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the RCC clock controller prescalers.

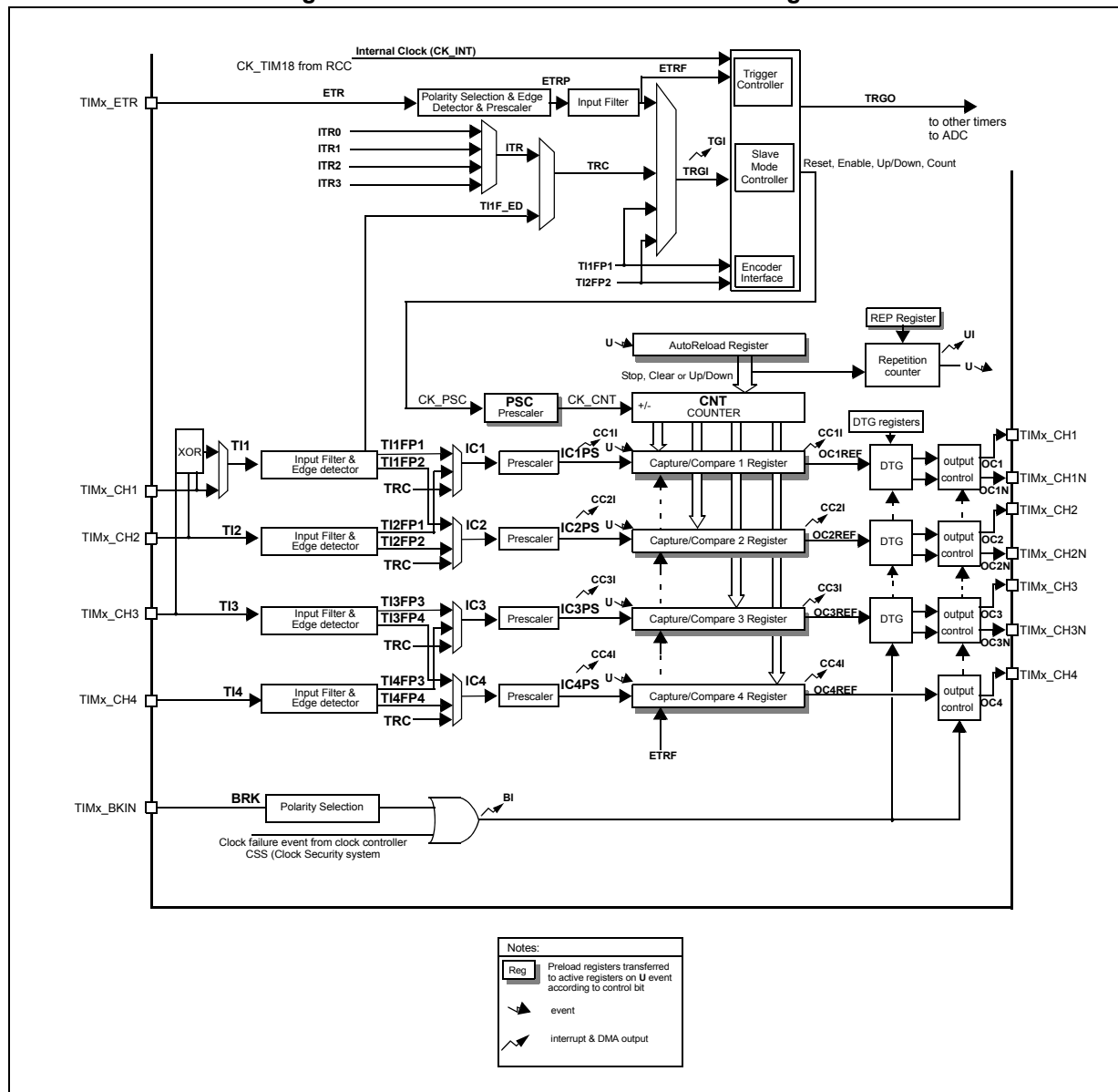
The advanced-control (TIM1) and general-purpose (TIMx) timers are completely independent, and do not share any resources. They can be synchronized together as described in [Section 13.3.20](#).

13.2 TIM1 main features

TIM1 timer features include:

- 16-bit up, down, up/down auto-reload counter.
- 16-bit programmable prescaler allowing dividing (also “on the fly”) the counter clock frequency either by any factor between 1 and 65535.
- Up to 4 independent channels for:
 - Input Capture
 - Output Compare
 - PWM generation (Edge- and Center-aligned modes)
 - One-pulse mode output
- Complementary outputs with programmable dead-time
- Synchronization circuit to control the timer with external signals and to interconnect several timers together.
- Repetition counter to update the timer registers only after a given number of cycles of the counter.
- Break input to put the timer’s output signals in reset state or in a known state.
- Interrupt/DMA generation on the following events:
 - Update: counter overflow/underflow, counter initialization (by software or internal/external trigger)
 - Trigger event (counter start, stop, initialization or count by internal/external trigger)
 - Input capture
 - Output compare
 - Break input
- Supports incremental (quadrature) encoder and hall-sensor circuitry for positioning purposes
- Trigger input for external clock or cycle-by-cycle current management

Figure 40. Advanced-control timer block diagram



13.3 TIM1 functional description

13.3.1 Time-base unit

The main block of the programmable advanced-control timer is a 16-bit counter with its related auto-reload register. The counter can count up, down or both up and down. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter register (TIMx_CNT)
- Prescaler register (TIMx_PSC)
- Auto-reload register (TIMx_ARR)
- Repetition counter register (TIMx_RCR)

The auto-reload register is preloaded. Writing to or reading from the auto-reload register accesses the preload register. The content of the preload register are transferred into the shadow register permanently or at each update event (UEV), depending on the auto-reload preload enable bit (ARPE) in TIMx_CR1 register. The update event is sent when the counter reaches the overflow (or underflow when downcounting) and if the UDIS bit equals 0 in the TIMx_CR1 register. It can also be generated by software. The generation of the update event is described in detailed for each configuration.

The counter is clocked by the prescaler output CK_CNT, which is enabled only when the counter enable bit (CEN) in TIMx_CR1 register is set (refer also to the slave mode controller description to get more details on counter enabling).

Note that the counter starts counting 1 clock cycle after setting the CEN bit in the TIMx_CR1 register.

Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit register (in the TIMx_PSC register). It can be changed on the fly as this control register is buffered. The new prescaler ratio is taken into account at the next update event.

Figure 42 and *Figure 43* give some examples of the counter behavior when the prescaler ratio is changed on the fly:

Figure 41. Counter timing diagram with prescaler division change from 1 to 2

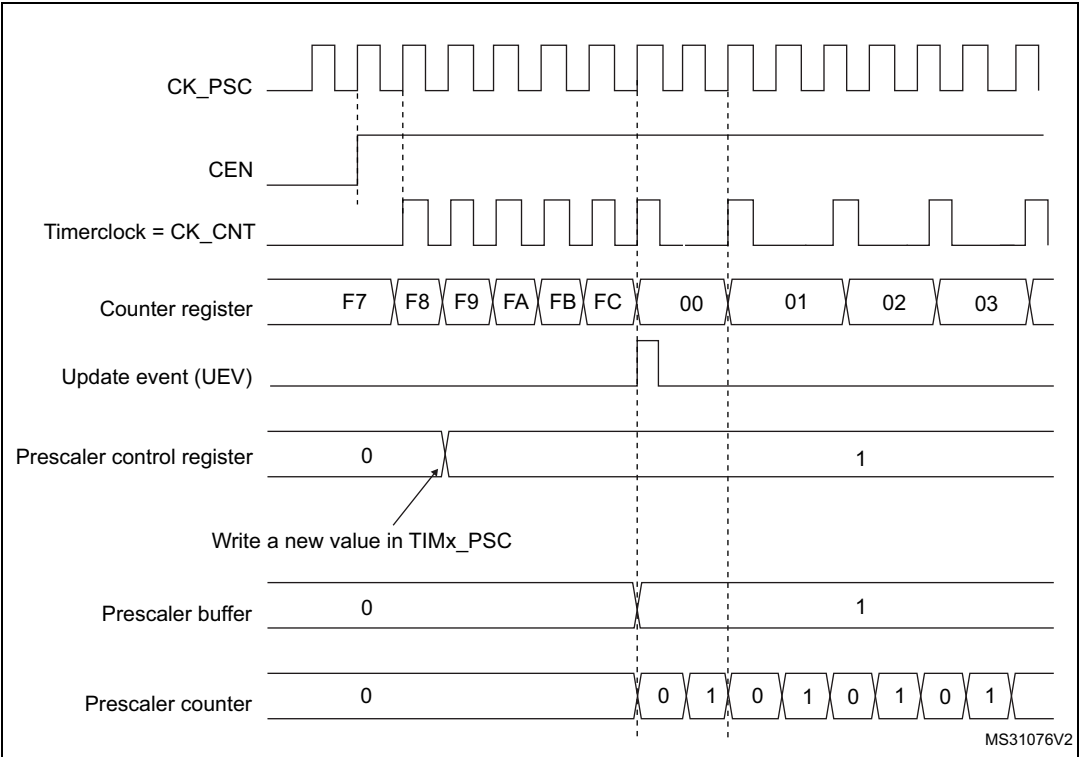
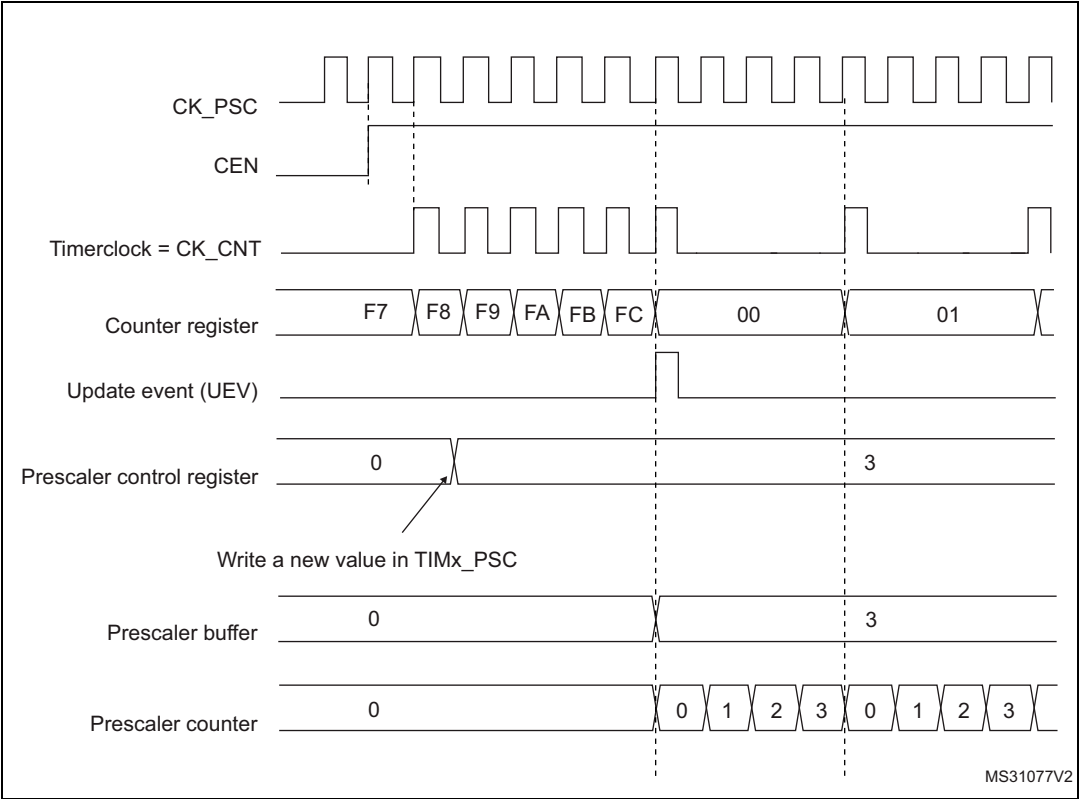


Figure 42. Counter timing diagram with prescaler division change from 1 to 4



13.3.2 Counter modes

Upcounting mode

In upcounting mode, the counter counts from 0 to the auto-reload value (content of the TIMx_ARR register), then restarts from 0 and generates a counter overflow event.

If the repetition counter is used, the update event (UEV) is generated after upcounting is repeated for the number of times programmed in the repetition counter register (TIMx_RCR). Else the update event is generated at each counter overflow.

Setting the UG bit in the TIMx_EGR register (by software or by using the slave mode controller) also generates an update event.

The UEV event can be disabled by software by setting the UDIS bit in the TIMx_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescale rate does not change). In addition, if the URS bit (update request selection) in TIMx_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx_SR register) is set (depending on the URS bit):

- The repetition counter is reloaded with the content of TIMx_RCR register,
- The auto-reload shadow register is updated with the preload value (TIMx_ARR),
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx_PSC register).

The following figures show some examples of the counter behavior for different clock frequencies when TIMx_ARR=0x36.

Figure 43. Counter timing diagram, internal clock divided by 1

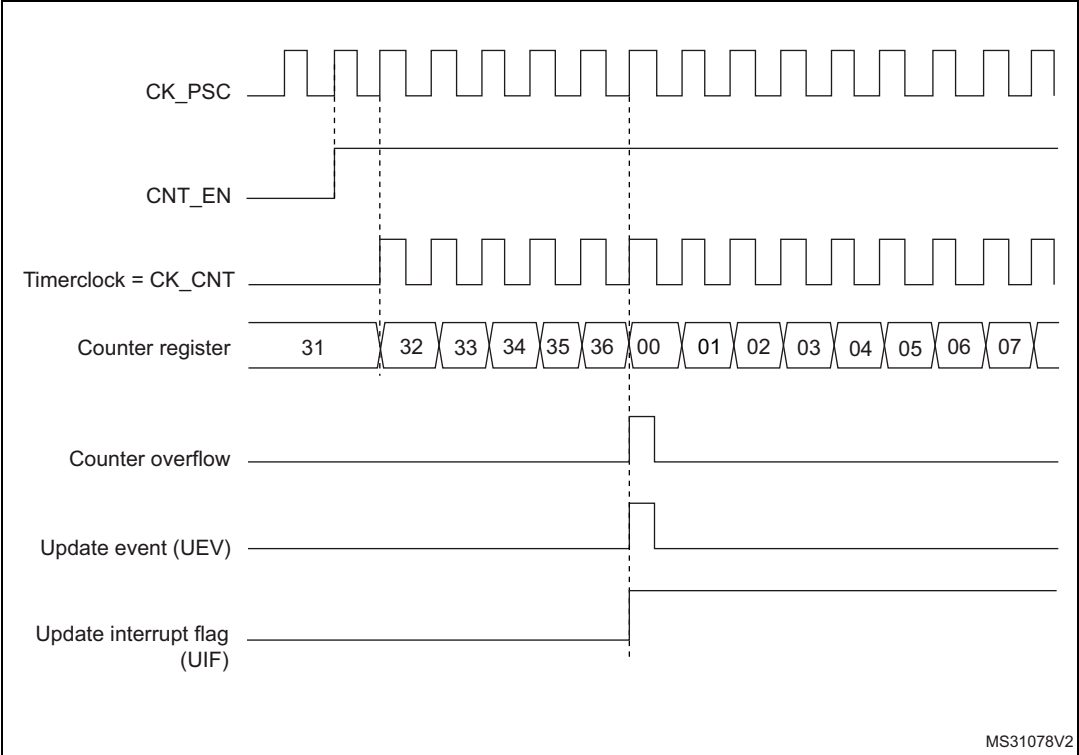


Figure 44. Counter timing diagram, internal clock divided by 2

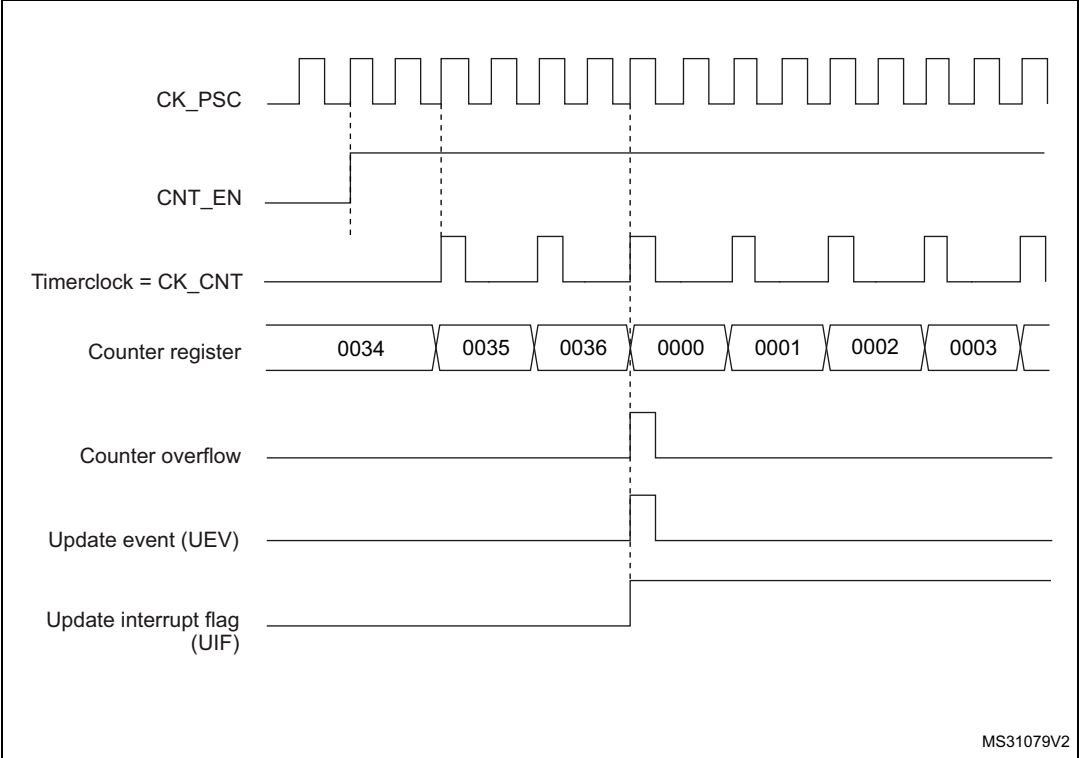


Figure 45. Counter timing diagram, internal clock divided by 4

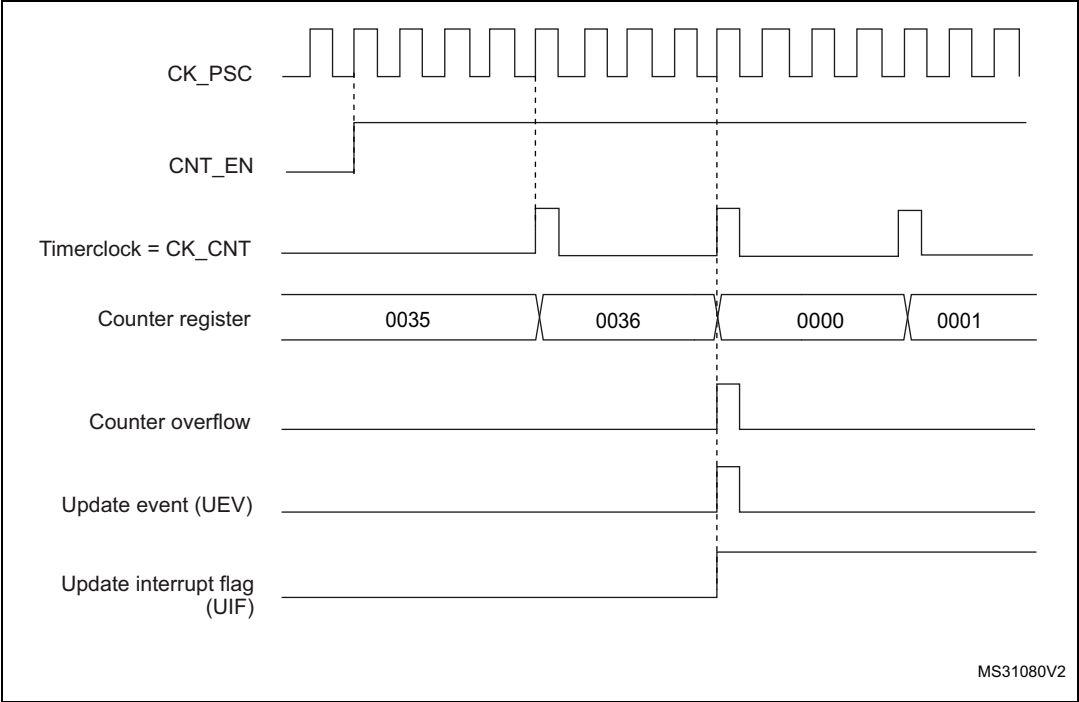


Figure 46. Counter timing diagram, internal clock divided by N

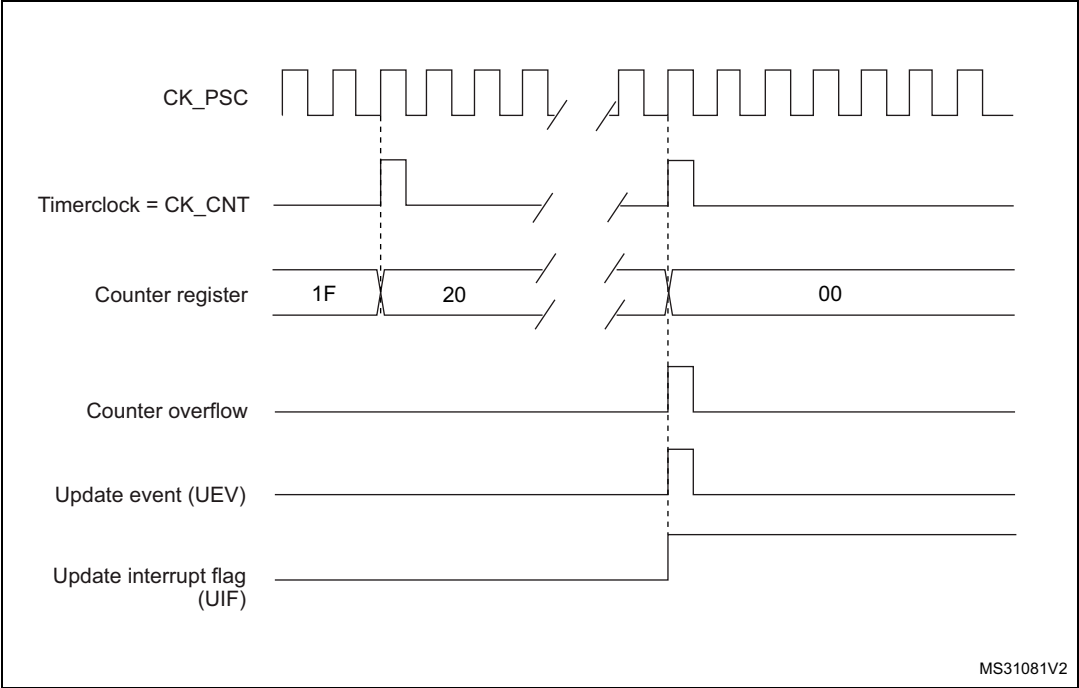


Figure 47. Counter timing diagram, update event when ARPE=0 (TIMx_ARR not preloaded)

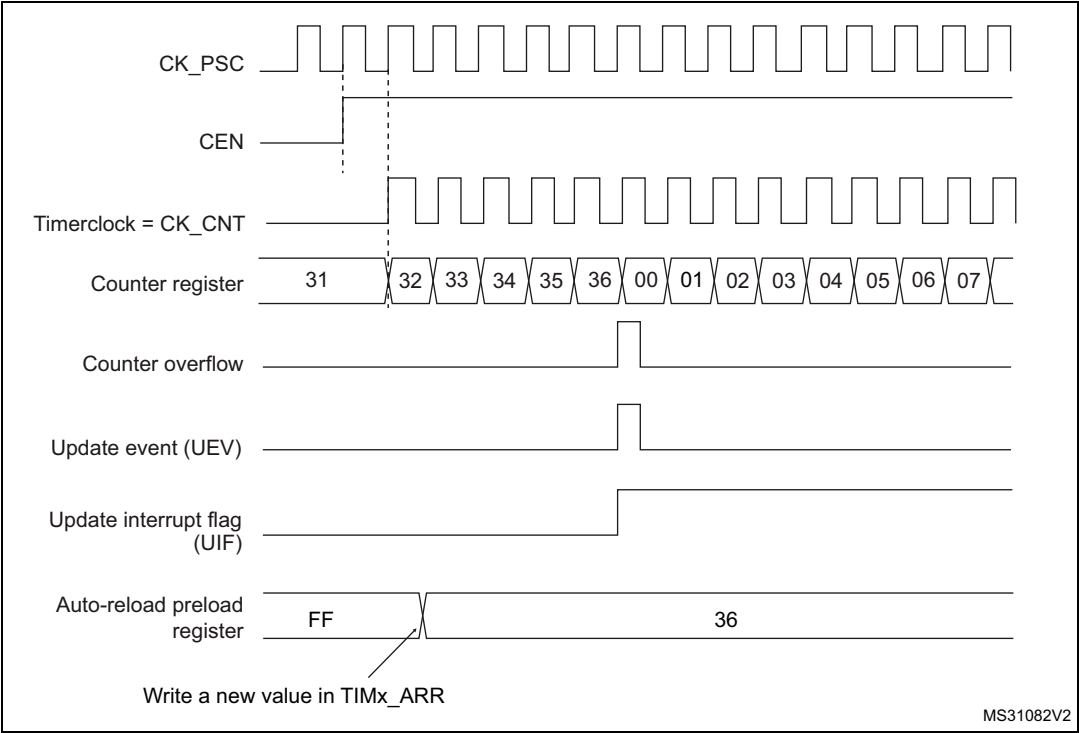
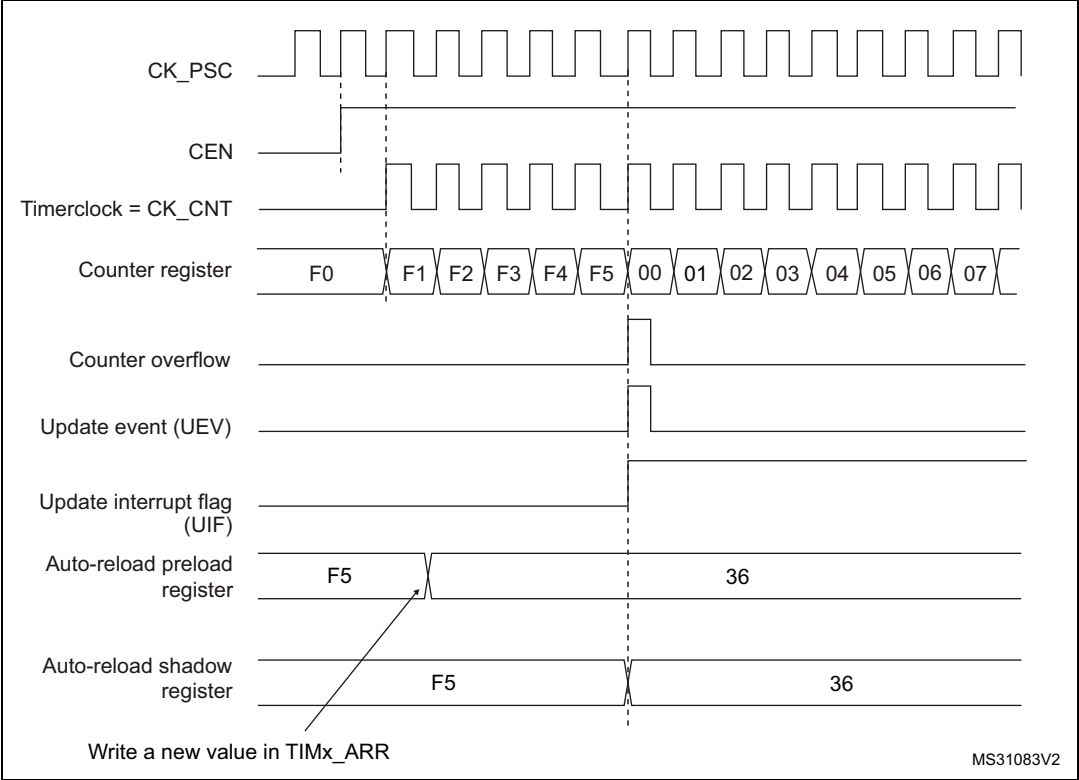


Figure 48. Counter timing diagram, update event when ARPE=1 (TIMx_ARR preloaded)



Downcounting mode

In downcounting mode, the counter counts from the auto-reload value (content of the TIMx_ARR register) down to 0, then restarts from the auto-reload value and generates a counter underflow event.

If the repetition counter is used, the update event (UEV) is generated after downcounting is repeated for the number of times programmed in the repetition counter register (TIMx_RCR). Else the update event is generated at each counter underflow.

Setting the UG bit in the TIMx_EGR register (by software or by using the slave mode controller) also generates an update event.

The UEV update event can be disabled by software by setting the UDIS bit in TIMx_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until UDIS bit has been written to 0. However, the counter restarts from the current auto-reload value, whereas the counter of the prescaler restarts from 0 (but the prescale rate doesn't change).

In addition, if the URS bit (update request selection) in TIMx_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx_SR register) is set (depending on the URS bit):

- The repetition counter is reloaded with the content of TIMx_RCR register
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx_PSC register)
- The auto-reload active register is updated with the preload value (content of the TIMx_ARR register). Note that the auto-reload is updated before the counter is reloaded, so that the next period is the expected one

The following figures show some examples of the counter behavior for different clock frequencies when TIMx_ARR=0x36.

Figure 49. Counter timing diagram, internal clock divided by 1

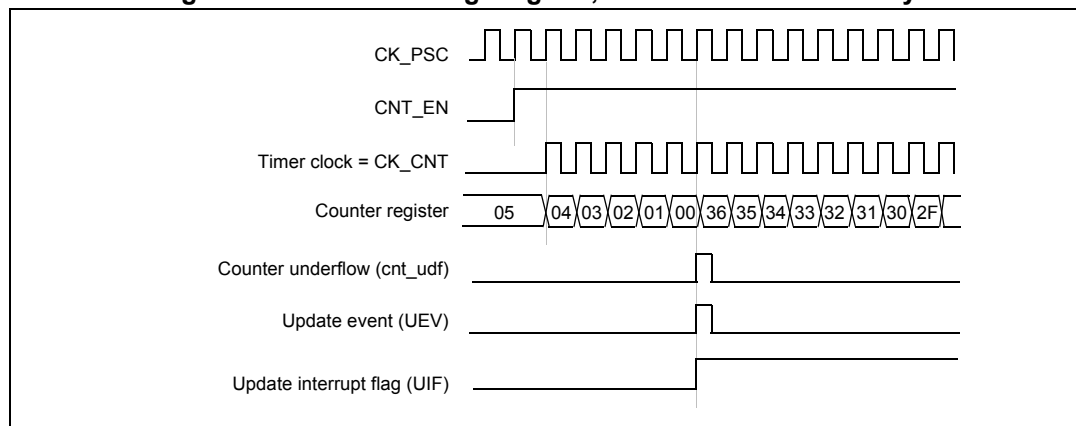


Figure 50. Counter timing diagram, internal clock divided by 2

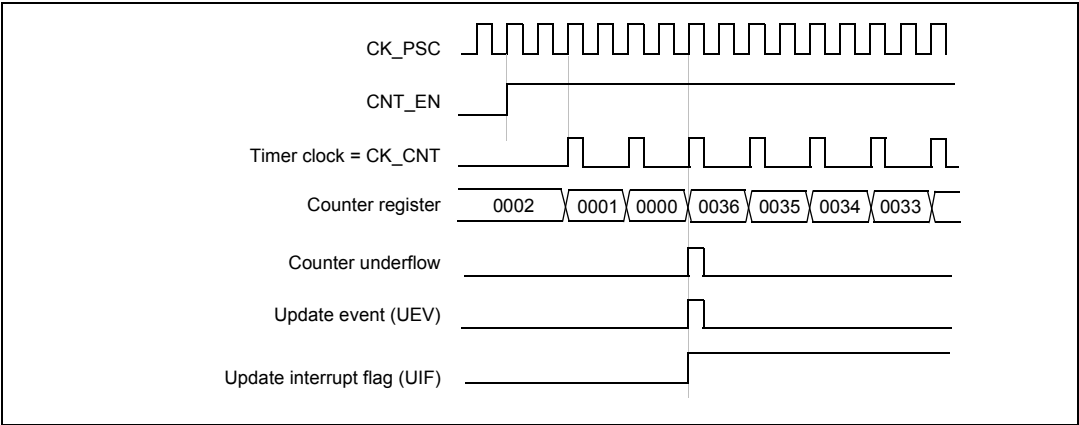


Figure 51. Counter timing diagram, internal clock divided by 4

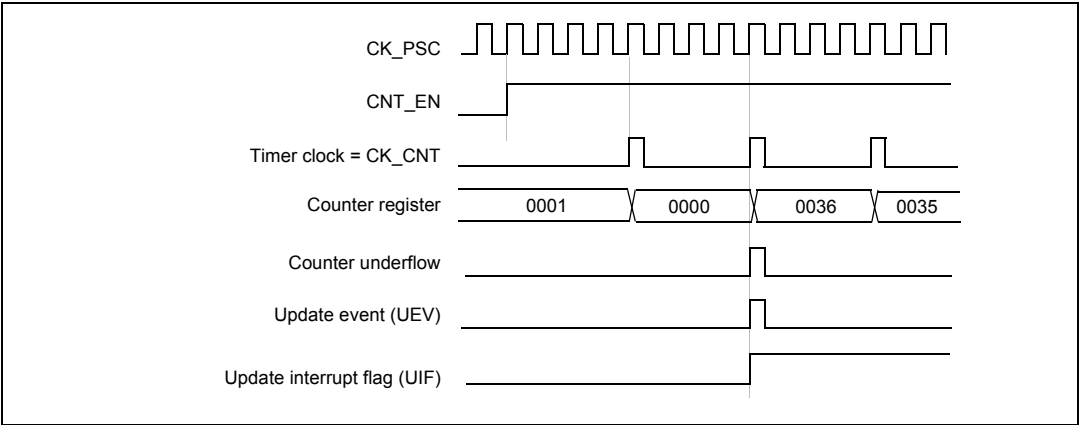


Figure 52. Counter timing diagram, internal clock divided by N

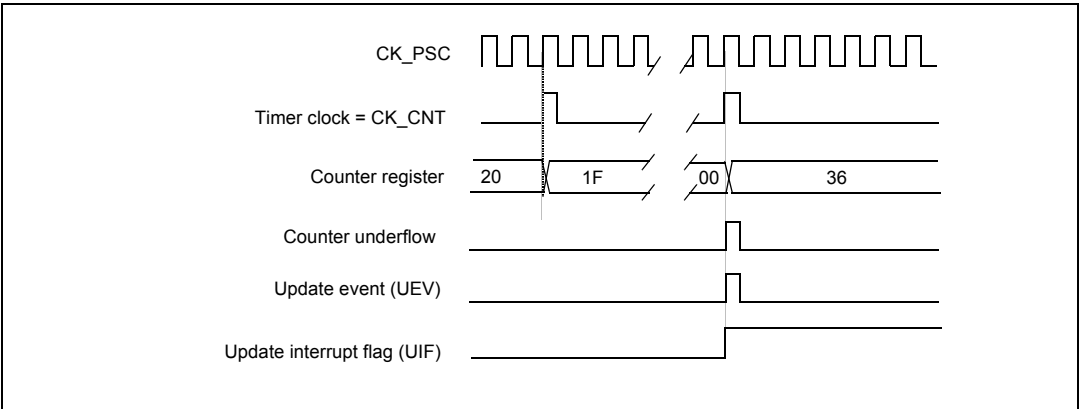
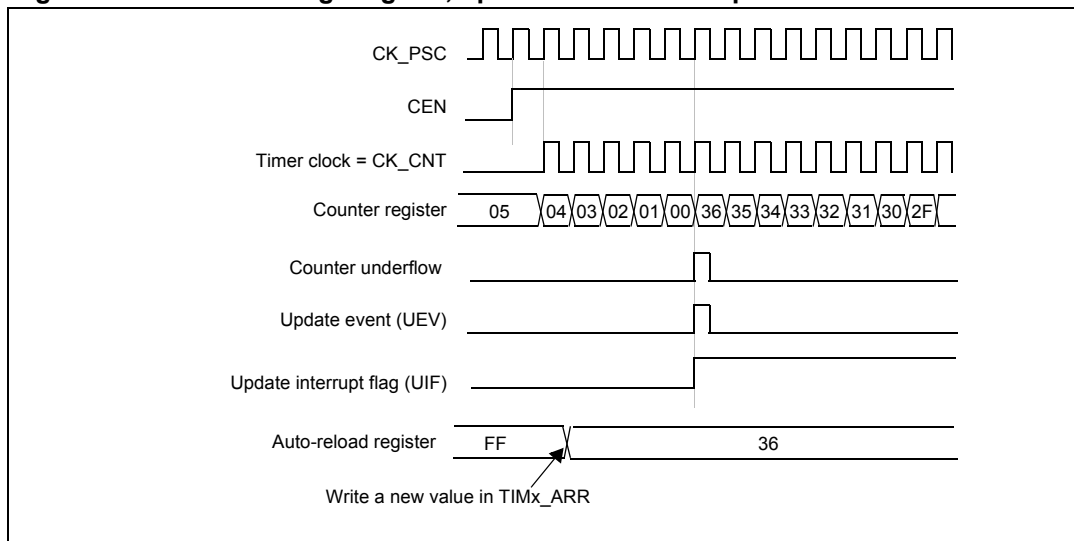


Figure 53. Counter timing diagram, update event when repetition counter is not used

Center-aligned mode (up/down counting)

In center-aligned mode, the counter counts from 0 to the auto-reload value (content of the TIMx_ARR register) – 1, generates a counter overflow event, then counts from the auto-reload value down to 1 and generates a counter underflow event. Then it restarts counting from 0.

Center-aligned mode is active when the CMS bits in TIMx_CR1 register are not equal to '00'. The Output compare interrupt flag of channels configured in output is set when: the counter counts down (Center aligned mode 1, CMS = "01"), the counter counts up (Center aligned mode 2, CMS = "10") the counter counts up and down (Center aligned mode 3, CMS = "11").

In this mode, the DIR direction bit in the TIMx_CR1 register cannot be written. It is updated by hardware and gives the current direction of the counter.

The update event can be generated at each counter overflow and at each counter underflow or by setting the UG bit in the TIMx_EGR register (by software or by using the slave mode controller) also generates an update event. In this case, the counter restarts counting from 0, as well as the counter of the prescaler.

The UEV update event can be disabled by software by setting the UDIS bit in the TIMx_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until UDIS bit has been written to 0. However, the counter continues counting up and down, based on the current auto-reload value.

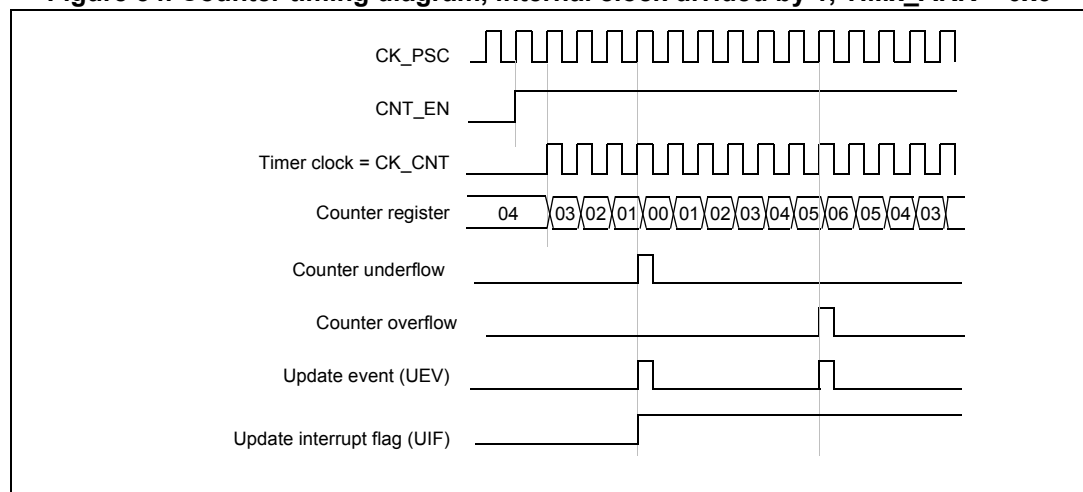
In addition, if the URS bit (update request selection) in TIMx_CR1 register is set, setting the UG bit generates an UEV update event but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx_SR register) is set (depending on the URS bit):

- The repetition counter is reloaded with the content of TIMx_RCR register
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx_PSC register)
- The auto-reload active register is updated with the preload value (content of the TIMx_ARR register). Note that if the update source is a counter overflow, the auto-reload is updated before the counter is reloaded, so that the next period is the expected one (the counter is loaded with the new value).

The following figures show some examples of the counter behavior for different clock frequencies.

Figure 54. Counter timing diagram, internal clock divided by 1, TIMx_ARR = 0x6



1. Here, center-aligned mode 1 is used (for more details refer to [Section 13.4: TIM1 registers on page 268](#)).

Figure 55. Counter timing diagram, internal clock divided by 2

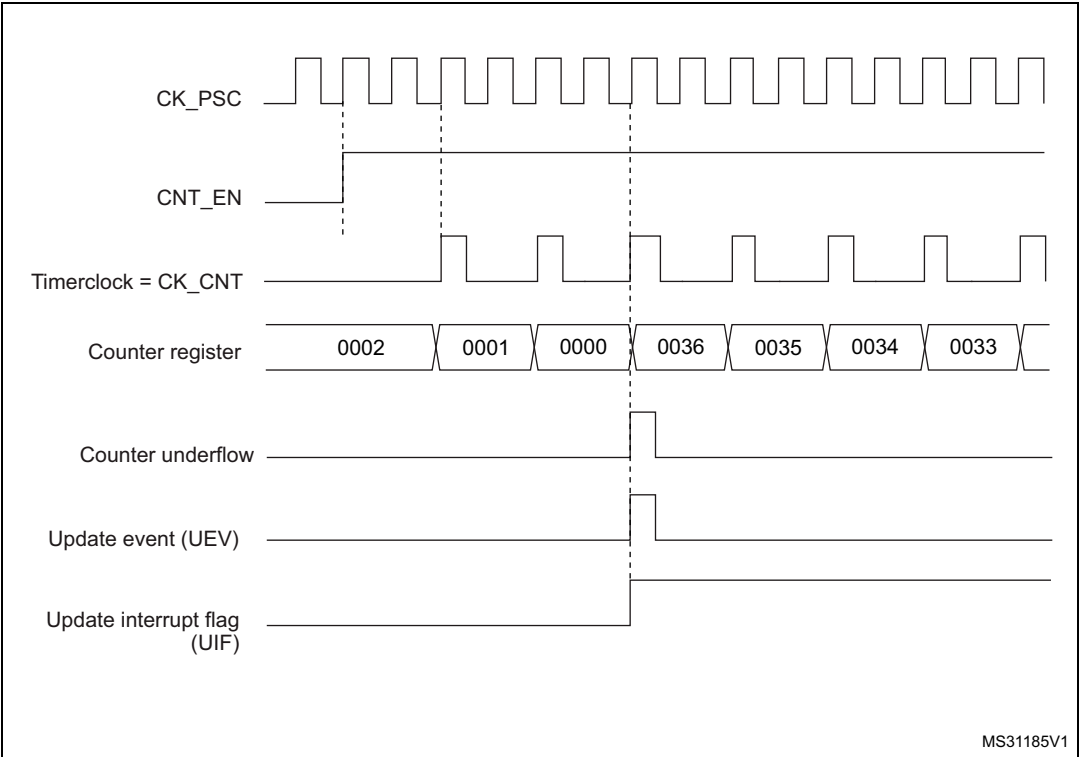
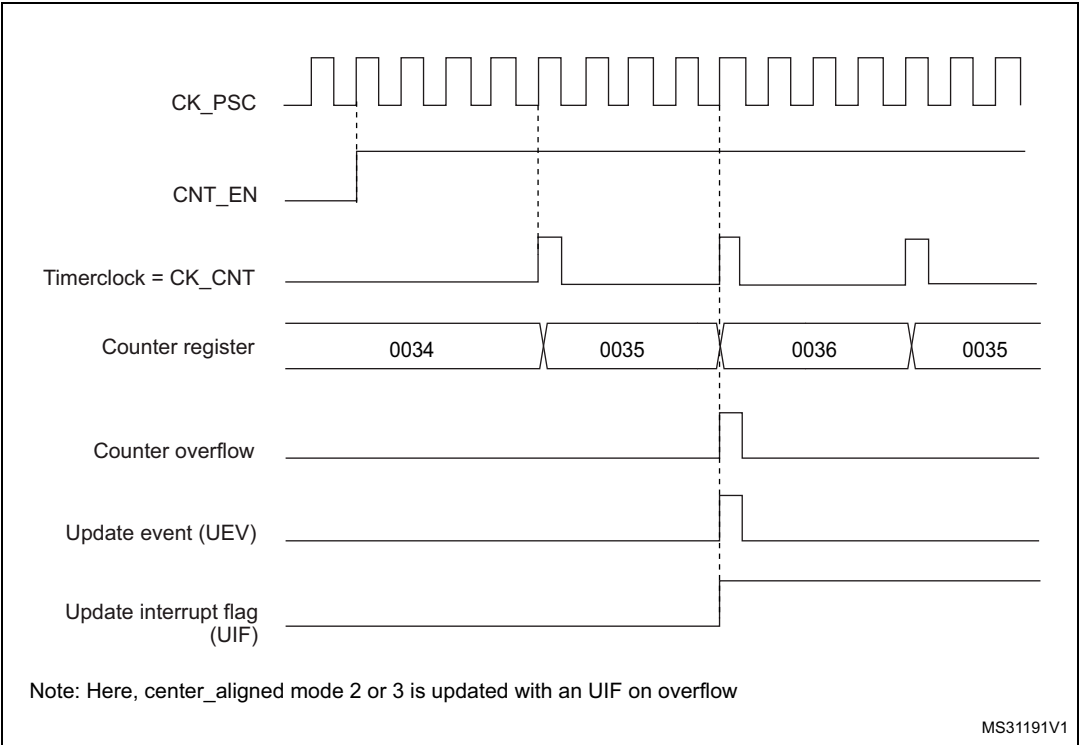


Figure 56. Counter timing diagram, internal clock divided by 4, TIMx_ARR=0x36



1. Center-aligned mode 2 or 3 is used with an UIF on overflow.

Figure 57. Counter timing diagram, internal clock divided by N

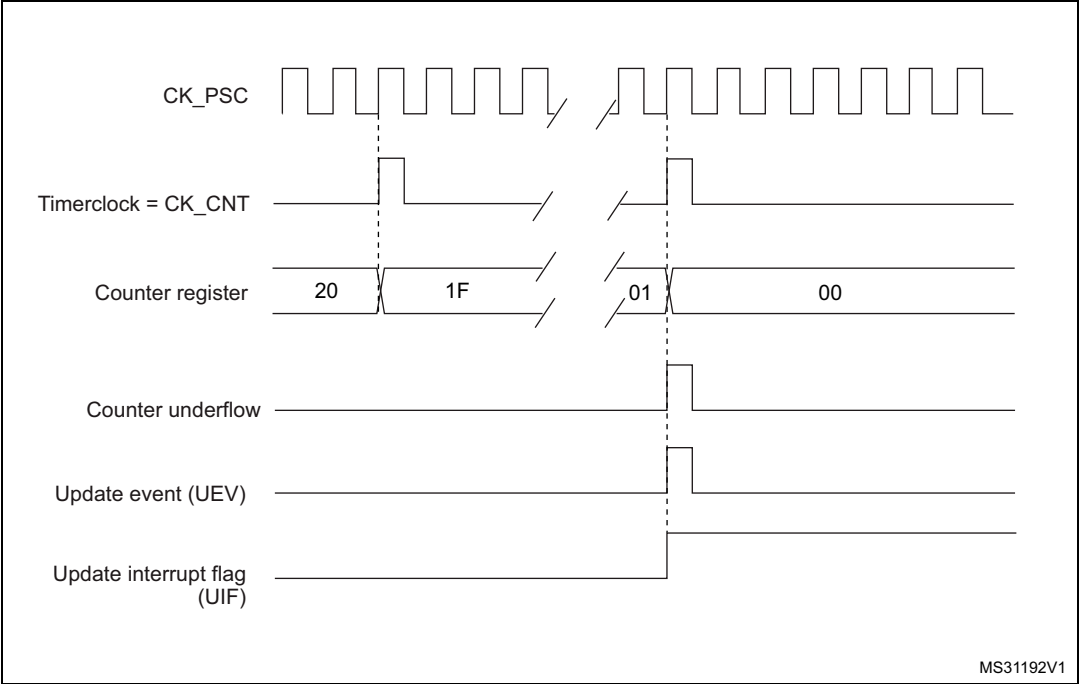


Figure 58. Counter timing diagram, update event with ARPE=1 (counter underflow)

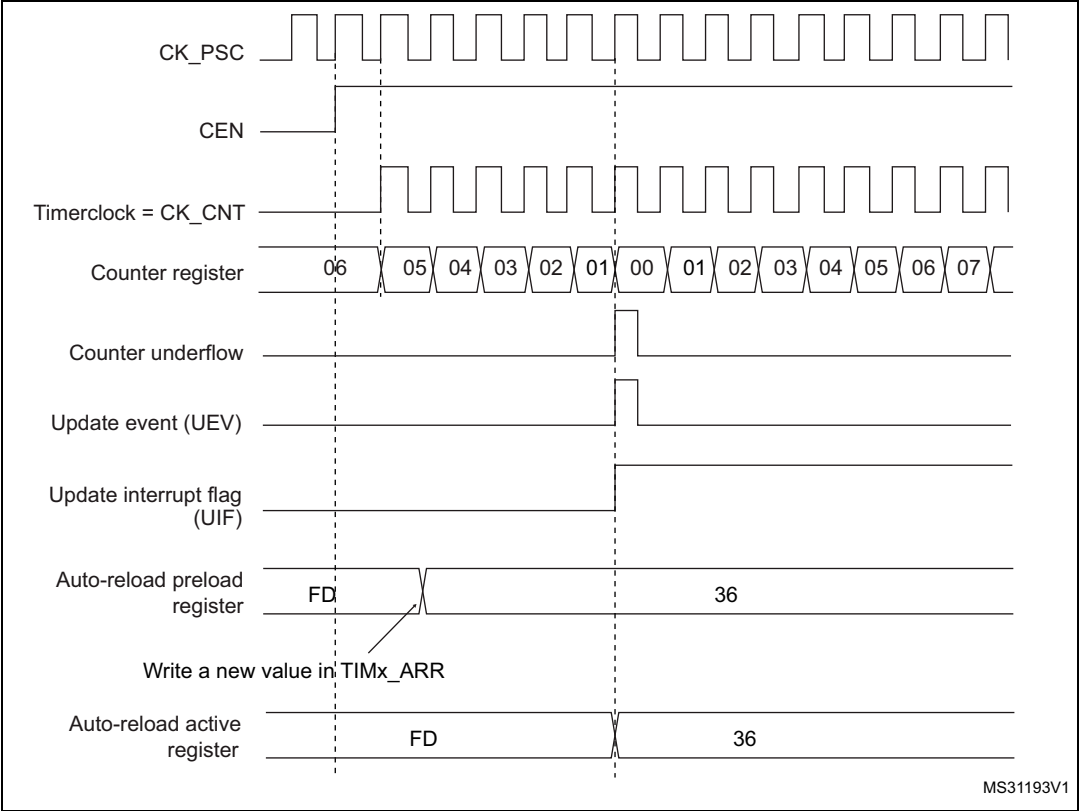
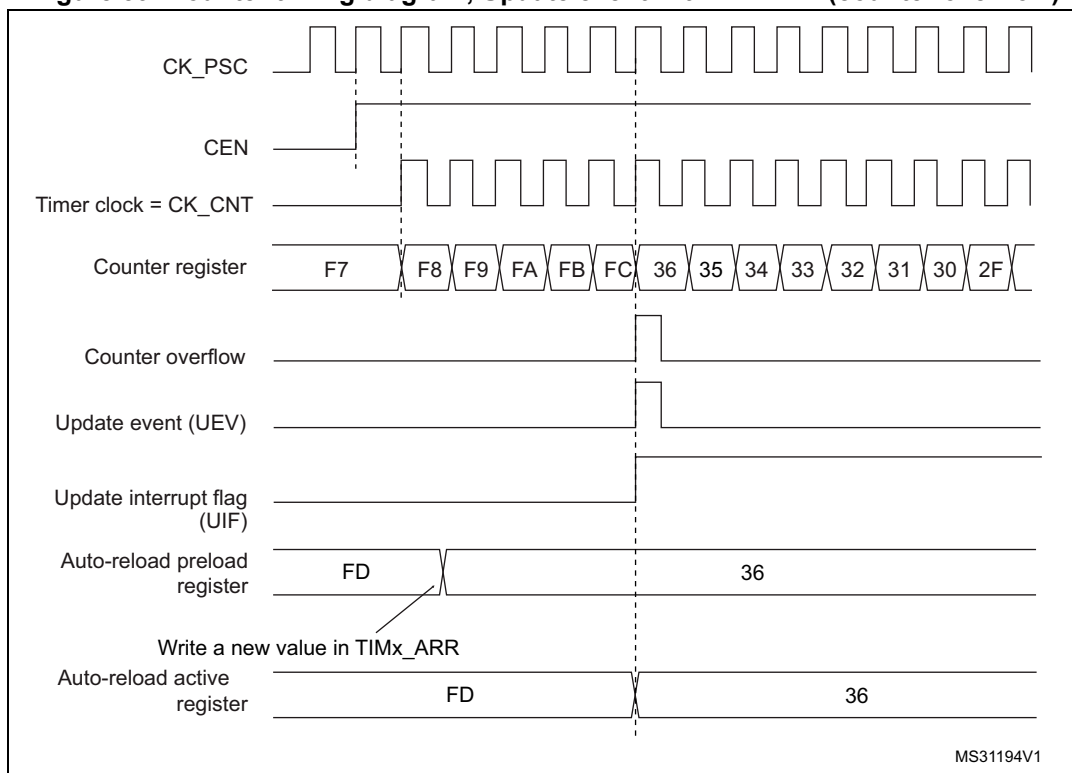


Figure 59. Counter timing diagram, Update event with ARPE=1 (counter overflow)

13.3.3 Repetition counter

[Section 13.3.1: Time-base unit](#) describes how the update event (UEV) is generated with respect to the counter overflows/underflows. It is actually generated only when the repetition counter has reached zero. This can be useful when generating PWM signals.

This means that data are transferred from the preload registers to the shadow registers (TIMx_ARR auto-reload register, TIMx_PSC prescaler register, but also TIMx_CCRx capture/compare registers in compare mode) every N counter overflows or underflows, where N is the value in the TIMx_RCR repetition counter register.

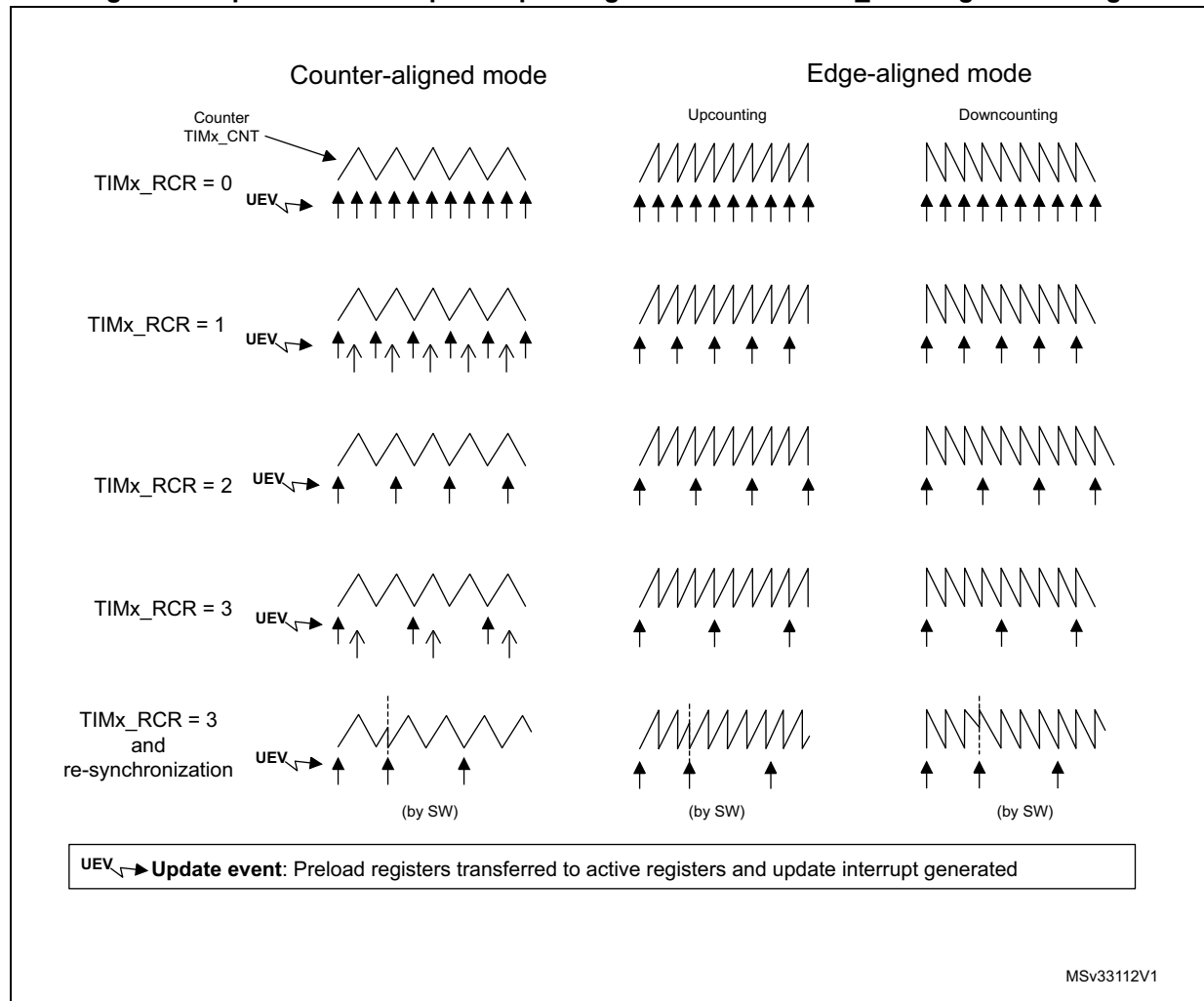
The repetition counter is decremented:

- At each counter overflow in upcounting mode,
 - At each counter underflow in downcounting mode,
 - At each counter overflow and at each counter underflow in center-aligned mode.
- Although this limits the maximum number of repetition to 128 PWM cycles, it makes it possible to update the duty cycle twice per PWM period. When refreshing compare registers only once per PWM period in center-aligned mode, maximum resolution is $2xT_{ck}$, due to the symmetry of the pattern.

The repetition counter is an auto-reload type; the repetition rate is maintained as defined by the TIMx_RCR register value (refer to [Figure 60](#)). When the update event is generated by software (by setting the UG bit in TIMx_EGR register) or by hardware through the slave mode controller, it occurs immediately whatever the value of the repetition counter is and the repetition counter is reloaded with the content of the TIMx_RCR register.

In center-aligned mode, for odd values of RCR, the update event occurs either on the overflow or on the underflow depending on when the RCR register was written and when the counter was started. If the RCR was written before starting the counter, the UEV occurs on the overflow. If the RCR was written after starting the counter, the UEV occurs on the underflow. For example for $RCR = 3$, the UEV is generated on each 4th overflow or underflow event depending on when RCR was written.

Figure 60. Update rate examples depending on mode and TIMx_RCR register settings



13.3.4 Clock sources

The counter clock can be provided by the following clock sources:

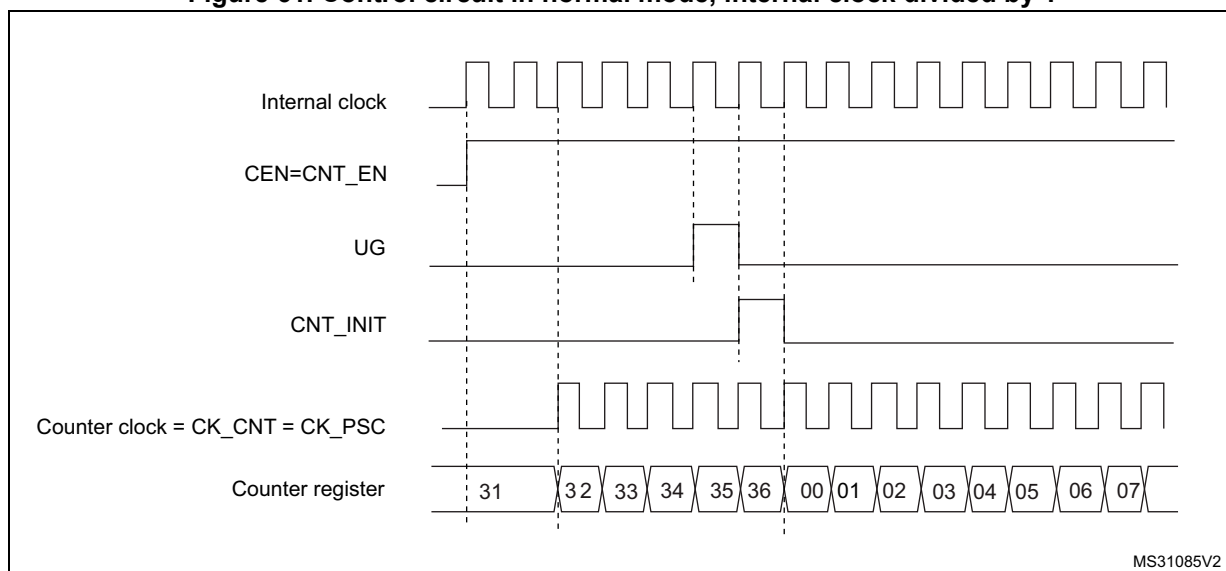
- Internal clock (CK_INT)
- External clock mode1: external input pin
- External clock mode2: external trigger input ETR
- Internal trigger inputs (ITRx): using one timer as prescaler for another timer, for example, you can configure Timer 1 to act as a prescaler for Timer 2. Refer to [Using one timer as prescaler for another on page 332](#) for more details.

Internal clock source (CK_INT)

If the slave mode controller is disabled (SMS=000), then the CEN, DIR (in the TIMx_CR1 register) and UG bits (in the TIMx_EGR register) are actual control bits and can be changed only by software (except UG which remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK_INT.

[Figure 61](#) shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

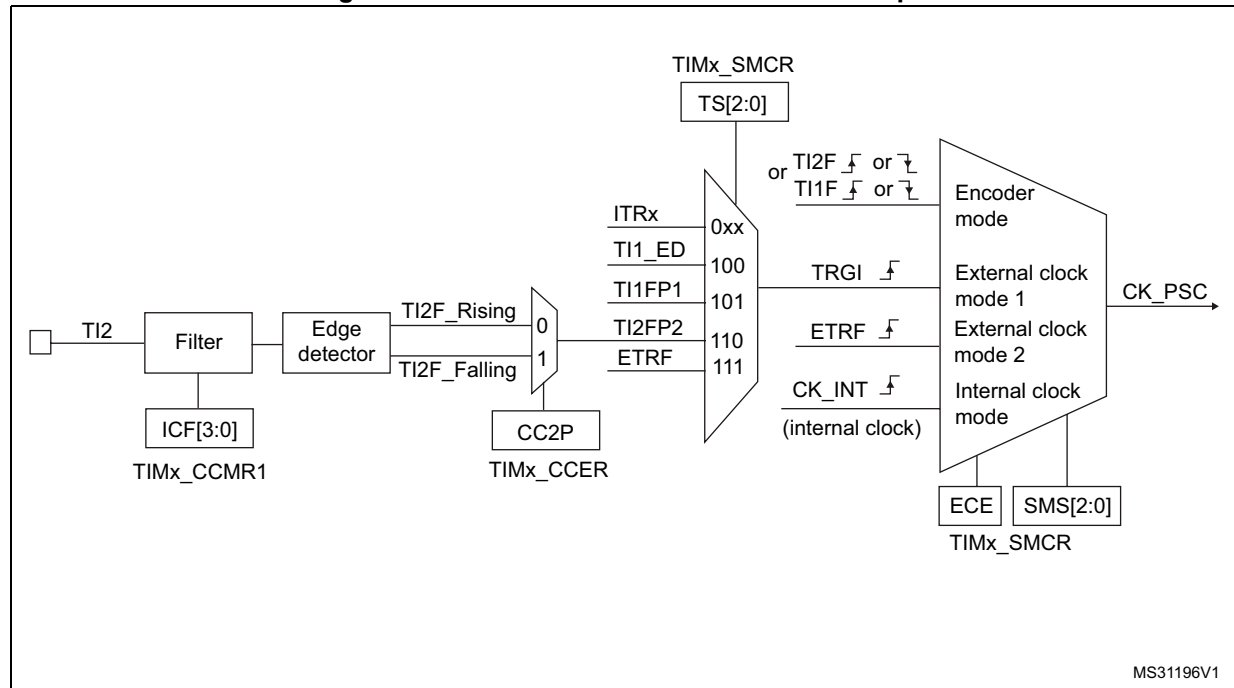
Figure 61. Control circuit in normal mode, internal clock divided by 1



External clock source mode 1

This mode is selected when SMS=111 in the TIMx_SMCR register. The counter can count at each rising or falling edge on a selected input.

Figure 62. TI2 external clock connection example



For example, to configure the upcounter to count in response to a rising edge on the TI2 input, use the following procedure:

1. Configure channel 2 to detect rising edges on the TI2 input by writing CC2S = '01' in the TIMx_CCMR1 register.
2. Configure the input filter duration by writing the IC2F[3:0] bits in the TIMx_CCMR1 register (if no filter is needed, keep IC2F=0000).
3. Select rising edge polarity by writing CC2P=0 in the TIMx_CCER register.
4. Configure the timer in external clock mode 1 by writing SMS=111 in the TIMx_SMCR register.
5. Select TI2 as the trigger input source by writing TS=110 in the TIMx_SMCR register.
6. Enable the counter by writing CEN=1 in the TIMx_CR1 register.

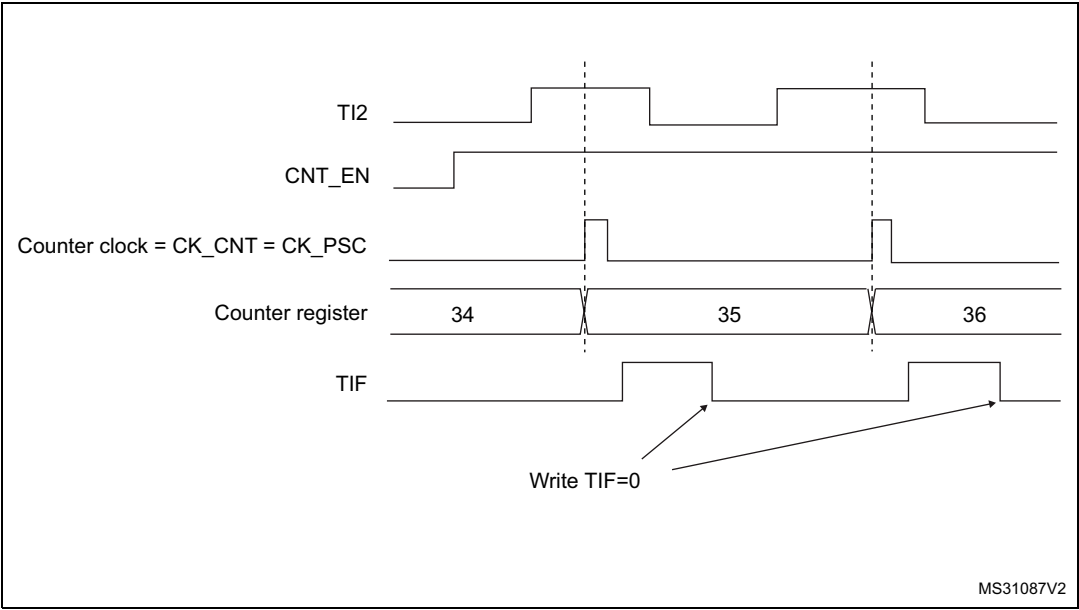
Note: The capture prescaler is not used for triggering, so you don't need to configure it.

For code examples refer to the Appendix section [A.8.1: Upcounter on TI2 rising edge code example](#).

When a rising edge occurs on TI2, the counter counts once and the TIF flag is set.

The delay between the rising edge on TI2 and the actual clock of the counter is due to the resynchronization circuit on TI2 input.

Figure 63. Control circuit in external clock mode 1

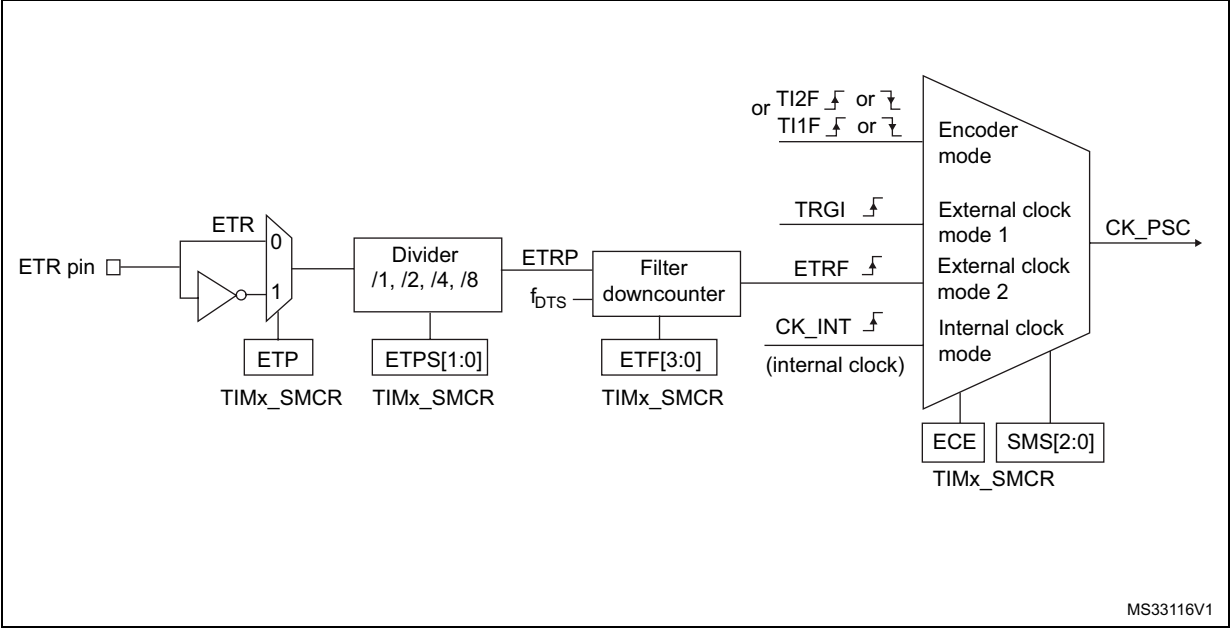


MS31087V2

External clock source mode 2

This mode is selected by writing ECE=1 in the TIMx_SMCR register. The counter can count at each rising or falling edge on the external trigger input ETR. The [Figure 64](#) gives an overview of the external trigger input block.

Figure 64. External trigger input block



MS33116V1

For example, to configure the upcounter to count each 2 rising edges on ETR, use the following procedure:

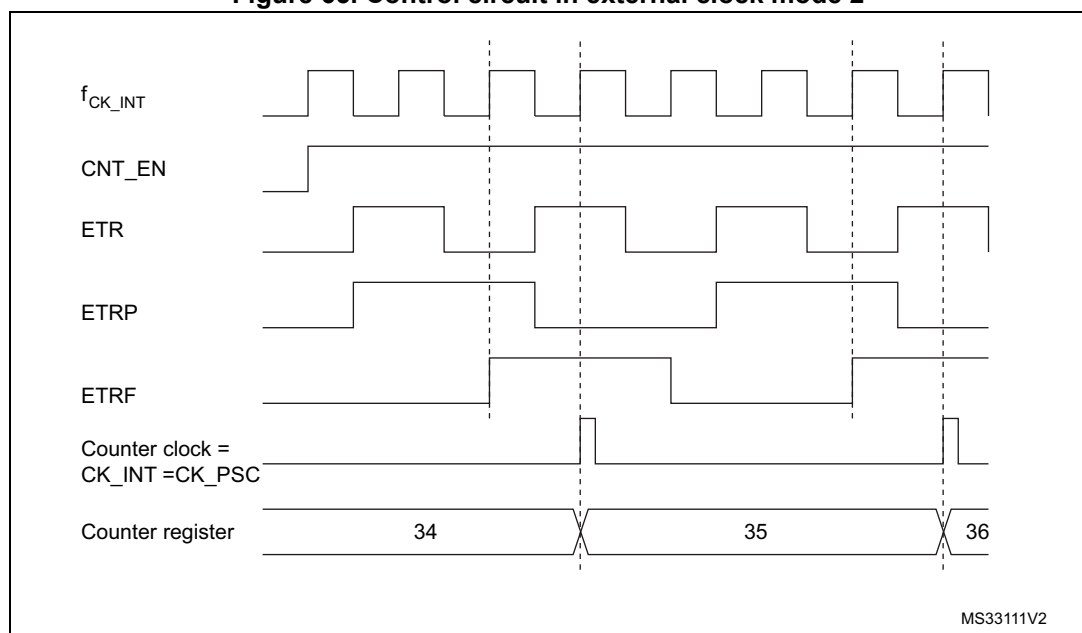
1. As no filter is needed in this example, write ETRF[3:0]=0000 in the TIMx_SMCR register.
2. Set the prescaler by writing ETPS[1:0]=01 in the TIMx_SMCR register
3. Select rising edge detection on the ETR pin by writing ETP=0 in the TIMx_SMCR register
4. Enable external clock mode 2 by writing ECE=1 in the TIMx_SMCR register.
5. Enable the counter by writing CEN=1 in the TIMx_CR1 register.

The counter counts once each 2 ETR rising edges.

For code example refer to the Appendix section [A.8.2: Up counter on each 2 ETR rising edges code example](#).

The delay between the rising edge on ETR and the actual clock of the counter is due to the resynchronization circuit on the ETRP signal.

Figure 65. Control circuit in external clock mode 2



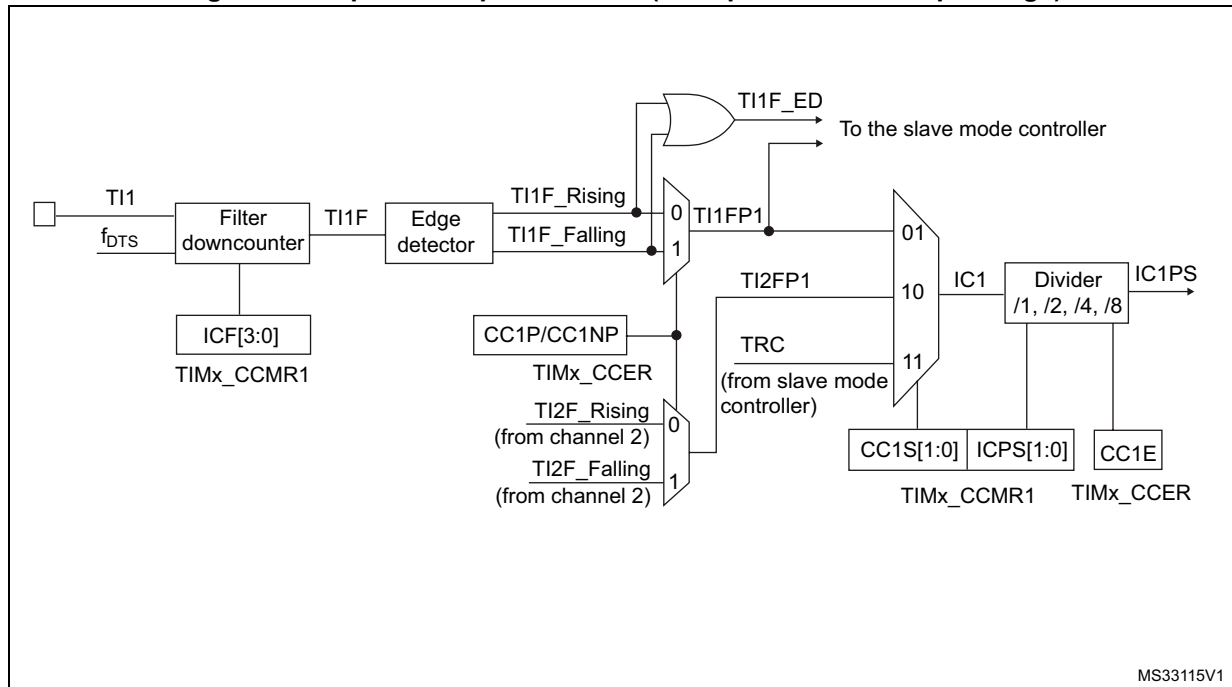
13.3.5 Capture/compare channels

Each Capture/Compare channel is built around a capture/compare register (including a shadow register), a input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

[Figure 66](#) to [Figure 69](#) give an overview of one Capture/Compare channel.

The input stage samples the corresponding TIx input to generate a filtered signal TIxF. Then, an edge detector with polarity selection generates a signal (TIxFPx) which can be used as trigger input by the slave mode controller or as the capture command. It is prescaled before the capture register (ICxPS).

Figure 66. Capture/compare channel (example: channel 1 input stage)



The output stage generates an intermediate waveform which is then used for reference: OCxRef (active high). The polarity acts at the end of the chain.

Figure 67. Capture/compare channel 1 main circuit

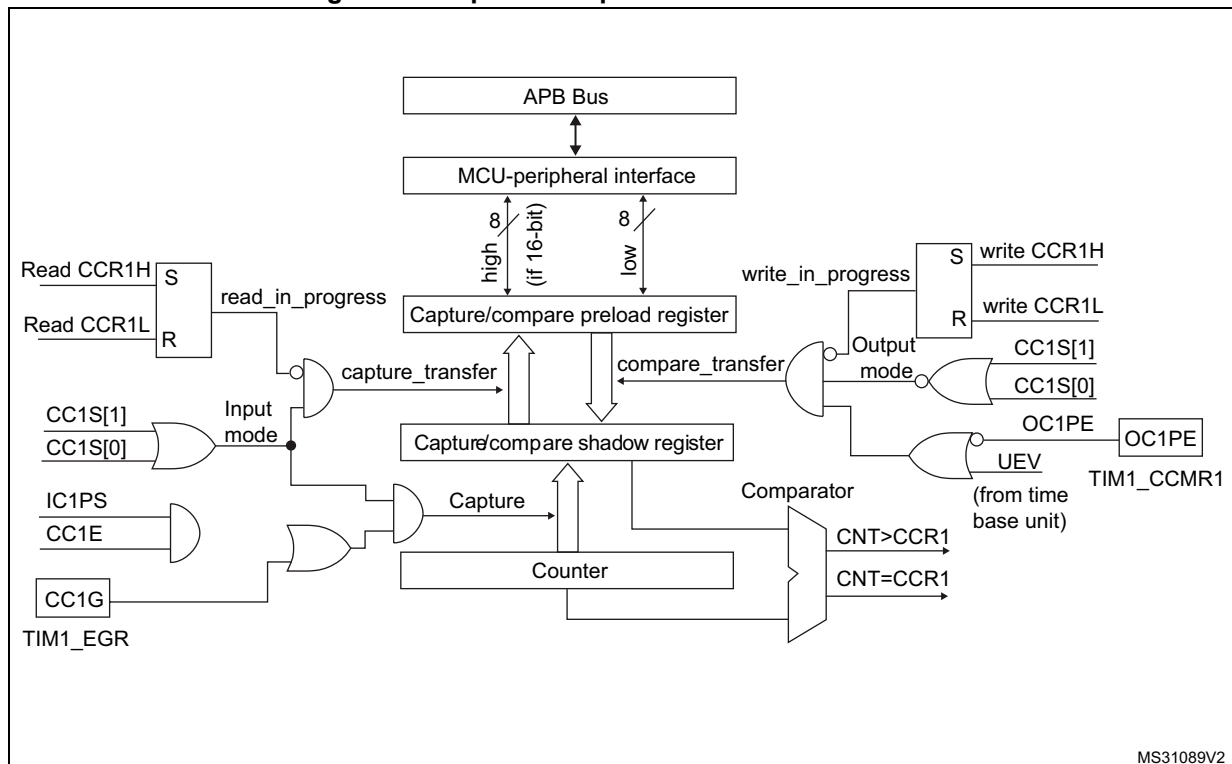


Figure 68. Output stage of capture/compare channel (channel 1 to 3)

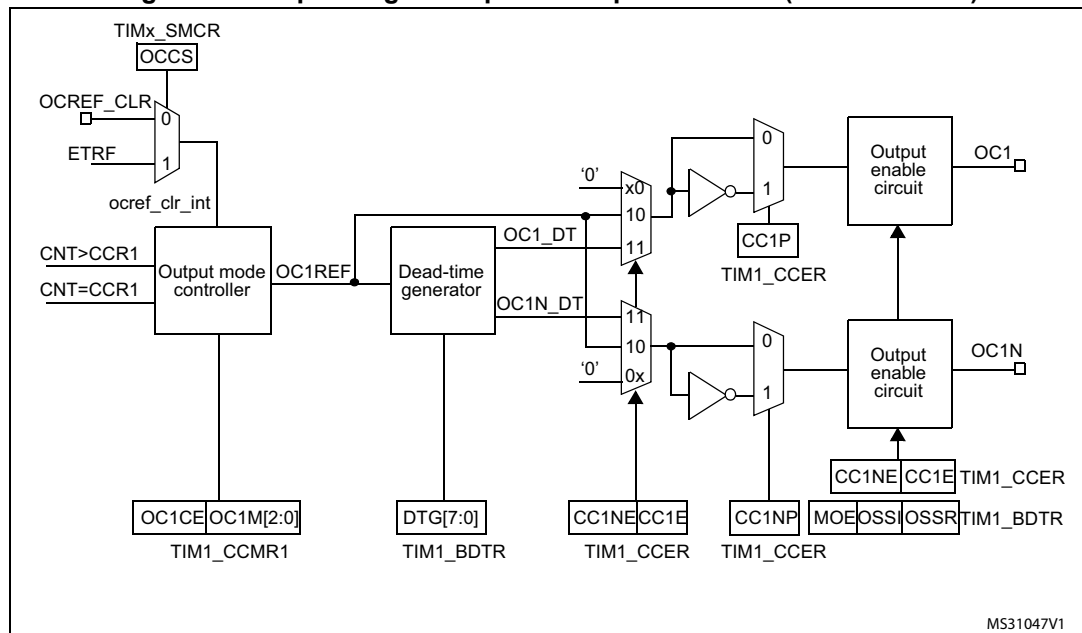
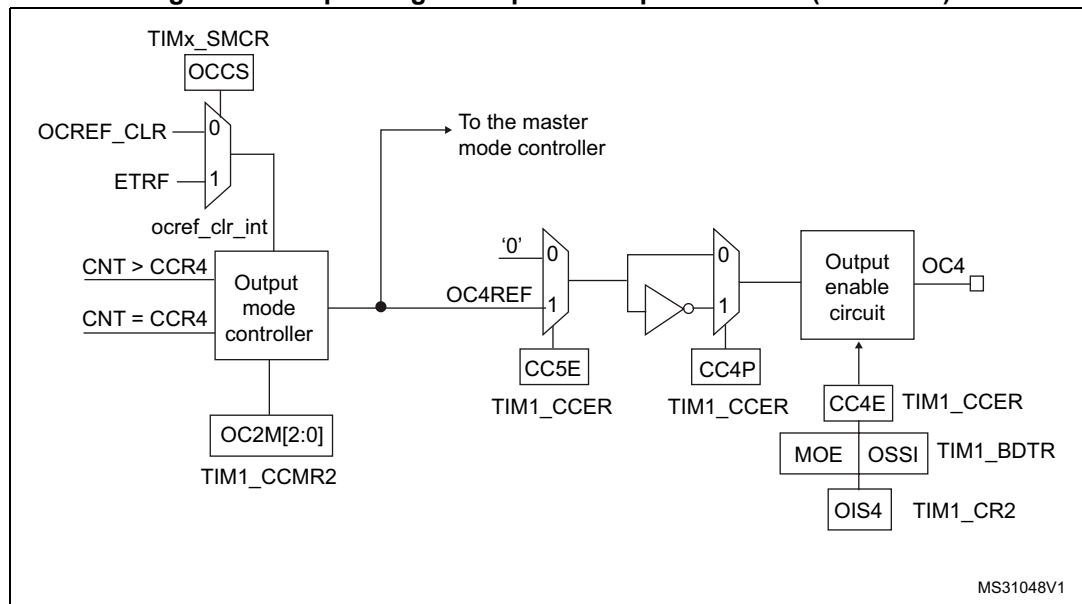


Figure 69. Output stage of capture/compare channel (channel 4)



The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register.

In capture mode, captures are actually done in the shadow register, which is copied into the preload register.

In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

13.3.6 Input capture mode

In Input capture mode, the Capture/Compare Registers (TIMx_CCRx) are used to latch the value of the counter after a transition detected by the corresponding ICx signal. When a capture occurs, the corresponding CCxIF flag (TIMx_SR register) is set and an interrupt or a DMA request can be sent if they are enabled. If a capture occurs while the CCxIF flag was already high, then the over-capture flag CCxOF (TIMx_SR register) is set. CCxIF can be cleared by software by writing it to '0' or by reading the captured data stored in the TIMx_CCRx register. CCxOF is cleared when you write it to '0'.

The following example shows how to capture the counter value in TIMx_CCR1 when TI1 input rises. To do this, use the following procedure:

- Select the active input: TIMx_CCR1 must be linked to the TI1 input, so write the CC1S bits to 01 in the TIMx_CCMR1 register. As soon as CC1S becomes different from 00, the channel is configured in input and the TIMx_CCR1 register becomes read-only.
- Program the input filter duration you need with respect to the signal you connect to the timer (when the input is one of the TIx (ICxF bits in the TIMx_CCMRx register). Let's imagine that, when toggling, the input signal is not stable during at most 5 internal clock cycles. We must program a filter duration longer than these 5 clock cycles. We can validate a transition on TI1 when 8 consecutive samples with the new level have been detected (sampled at f_{DTS} frequency). Then write IC1F bits to 0011 in the TIMx_CCMR1 register.
- Select the edge of the active transition on the TI1 channel by writing CC1P and CC1NP bits to 0 in the TIMx_CCER register (rising edge in this case).
- Program the input prescaler. In our example, we wish the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to '00' in the TIMx_CCMR1 register).
- Enable capture from the counter into the capture register by setting the CC1E bit in the TIMx_CCER register.
- If needed, enable the related interrupt request by setting the CC1IE bit in the TIMx_DIER register, and/or the DMA request by setting the CC1DE bit in the TIMx_DIER register.

For code example refer to the Appendix section [A.8.3: Input capture configuration code example](#).

When an input capture occurs:

- The TIMx_CCR1 register gets the value of the counter on the active transition.
- CC1IF flag is set (interrupt flag). CC1OF is also set if at least two consecutive captures occurred whereas the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.
- A DMA request is generated depending on the CC1DE bit.

For code example refer to the Appendix section [A.8.4: Input capture data management code example](#).

In order to handle the overcapture, it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

Note: *IC interrupt and/or DMA requests can be generated by software by setting the corresponding CCxG bit in the TIMx_EGR register.*

13.3.7 PWM input mode

This mode is a particular case of input capture mode. The procedure is the same except:

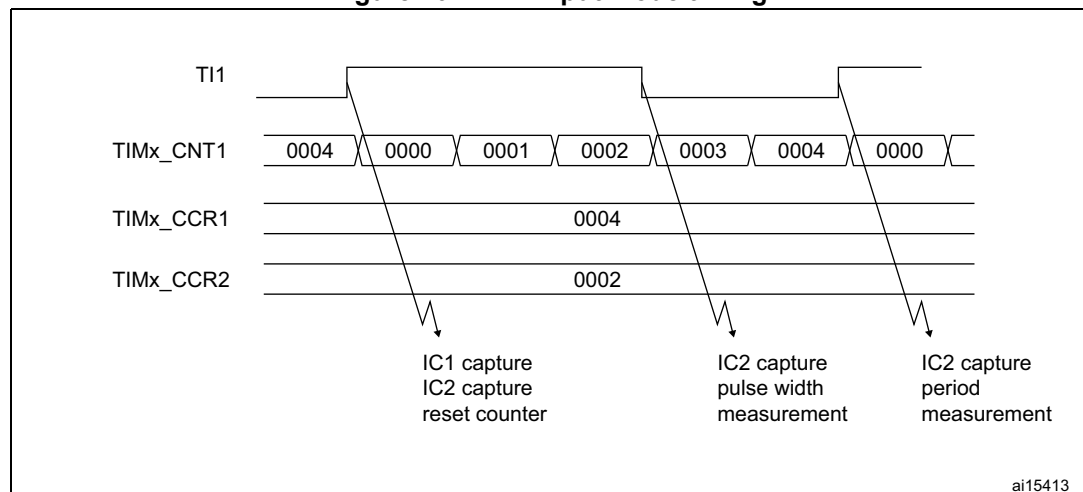
- Two ICx signals are mapped on the same TIx input.
- These 2 ICx signals are active on edges with opposite polarity.
- One of the two TIxFP signals is selected as trigger input and the slave mode controller is configured in reset mode.

For example, you can measure the period (in TIMx_CCR1 register) and the duty cycle (in TIMx_CCR2 register) of the PWM applied on TI1 using the following procedure (depending on CK_INT frequency and prescaler value):

- Select the active input for TIMx_CCR1: write the CC1S bits to 01 in the TIMx_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP1 (used both for capture in TIMx_CCR1 and counter clear): write the CC1P and CC1NP bits to '0' (active on rising edge).
- Select the active input for TIMx_CCR2: write the CC2S bits to 10 in the TIMx_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP2 (used for capture in TIMx_CCR2): write the CC2P bit to '1' (active on falling edge).
- Select the valid trigger input: write the TS bits to 101 in the TIMx_SMCR register (TI1FP1 selected).
- Configure the slave mode controller in reset mode: write the SMS bits to 100 in the TIMx_SMCR register.
- Enable the captures: write the CC1E and CC2E bits to '1' in the TIMx_CCER register.

For code example refer to the Appendix section [A.8.5: PWM input configuration code example](#).

Figure 70. PWM input mode timing



13.3.8 Forced output mode

In output mode (CCxS bits = 00 in the TIMx_CCMRx register), each output compare signal (OCxREF and then OCx/OCxN) can be forced to active or inactive level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal (OCXREF/OCx) to its active level, you just need to write 101 in the OCxM bits in the corresponding TIMx_CCMRx register. Thus OCXREF is forced high (OCxREF is always active high) and OCx get opposite value to CCxP polarity bit.

For example: CCxP=0 (OCx active high) => OCx is forced to high level.

The OCxREF signal can be forced low by writing the OCxM bits to 100 in the TIMx_CCMRx register.

Anyway, the comparison between the TIMx_CCRx shadow register and the counter is still performed and allows the flag to be set. Interrupt and DMA requests can be sent accordingly. This is described in the output compare mode section below.

13.3.9 Output compare mode

This function is used to control an output waveform or indicating when a period of time has elapsed.

When a match is found between the capture/compare register and the counter, the output compare function:

- Assigns the corresponding output pin to a programmable value defined by the output compare mode (OCxM bits in the TIMx_CCMRx register) and the output polarity (CCxP bit in the TIMx_CCER register). The output pin can keep its level (OCXM=000), be set active (OCXM=001), be set inactive (OCXM=010) or can toggle (OCXM=011) on match.
- Sets a flag in the interrupt status register (CCxIF bit in the TIMx_SR register).
- Generates an interrupt if the corresponding interrupt mask is set (CCXIE bit in the TIMx_DIER register).
- Sends a DMA request if the corresponding enable bit is set (CCxDE bit in the TIMx_DIER register, CCDS bit in the TIMx_CR2 register for the DMA request selection).

The TIMx_CCRx registers can be programmed with or without preload registers using the OCxPE bit in the TIMx_CCMRx register.

In output compare mode, the update event UEV has no effect on OCxREF and OCx output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse (in One Pulse mode).

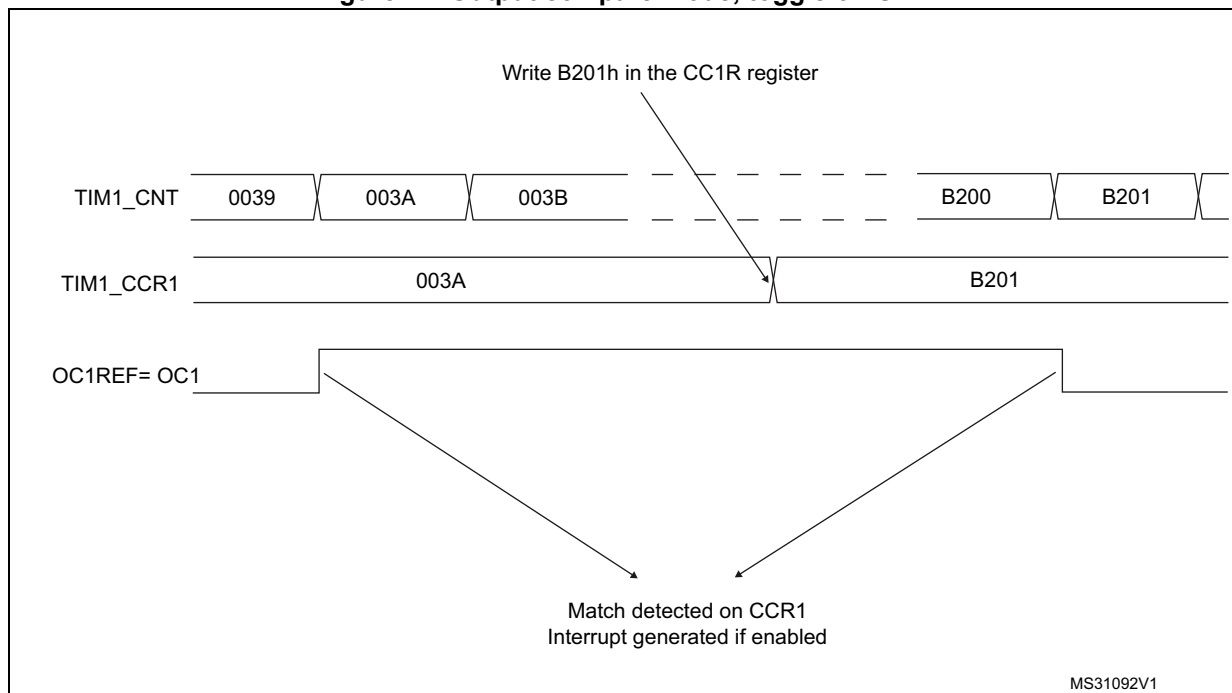
Procedure:

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the TIMx_ARR and TIMx_CCRx registers.
3. Set the CCxIE bit if an interrupt request is to be generated.
4. Select the output mode. For example:
 - Write OCxM = 011 to toggle OCx output pin when CNT matches CCRx
 - Write OCxPE = 0 to disable preload register
 - Write CCxP = 0 to select active high polarity
 - Write CCxE = 1 to enable the output
5. Enable the counter by setting the CEN bit in the TIMx_CR1 register.

For code example refer to the Appendix section [A.8.7: Output compare configuration code example](#).

The TIMx_CCRx register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled (OCxPE=0', else TIMx_CCRx shadow register is updated only at the next update event UEV). An example is given in [Figure 71](#).

Figure 71. Output compare mode, toggle on OC1



13.3.10 PWM mode

Pulse Width Modulation mode allows you to generate a signal with a frequency determined by the value of the TIMx_ARR register and a duty cycle determined by the value of the TIMx_CCRx register.

The PWM mode can be selected independently on each channel (one PWM per OCx output) by writing '110' (PWM mode 1) or '111' (PWM mode 2) in the OCxM bits in the TIMx_CCMRx register. You must enable the corresponding preload register by setting the

OCxPE bit in the TIMx_CCMRx register, and eventually the auto-reload preload register (in upcounting or center-aligned modes) by setting the ARPE bit in the TIMx_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIMx_EGR register.

OCx polarity is software programmable using the CCxP bit in the TIMx_CCER register. It can be programmed as active high or active low. OCx output is enabled by a combination of the CCxE, CCxNE, MOE, OSSI and OSSR bits (TIMx_CCER and TIMx_BDTR registers). Refer to the TIMx_CCER register description for more details.

In PWM mode (1 or 2), TIMx_CNT and TIMx_CCRx are always compared to determine whether $TIMx\_CCRx \leq TIMx\_CNT$ or $TIMx\_CNT \leq TIMx\_CCRx$ (depending on the direction of the counter).

The timer is able to generate PWM in edge-aligned mode or center-aligned mode depending on the CMS bits in the TIMx_CR1 register.

PWM edge-aligned mode

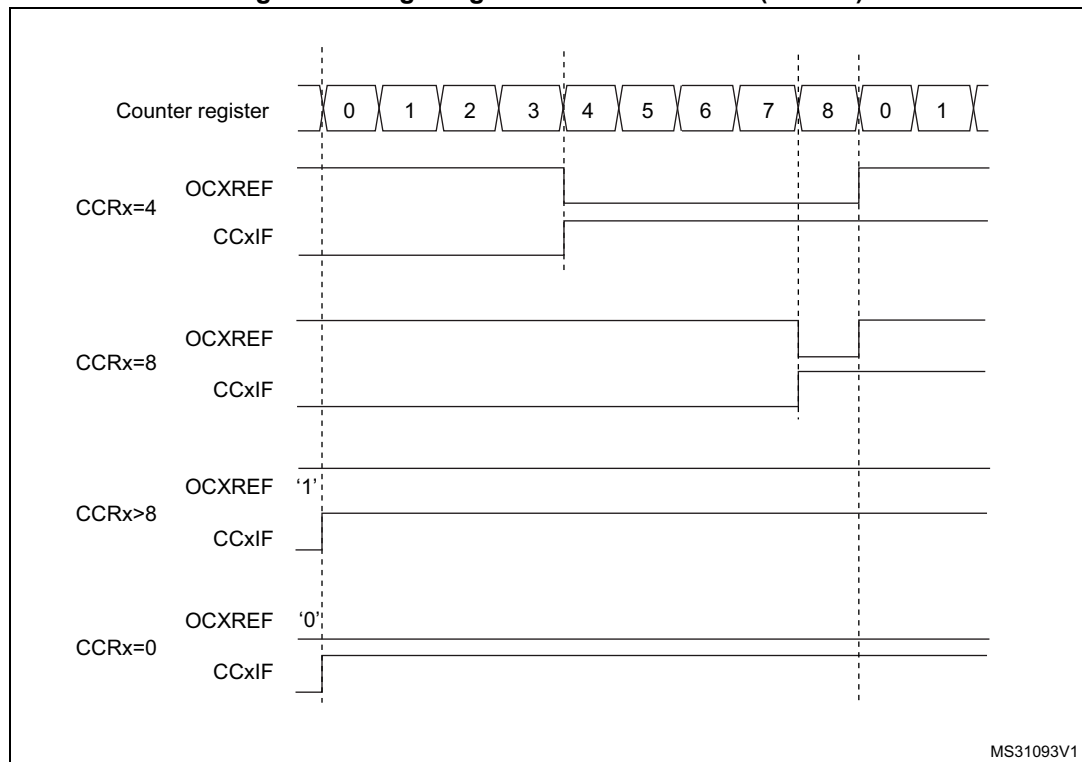
- Upcounting configuration

Upcounting is active when the DIR bit in the TIMx_CR1 register is low. Refer to the [Upcounting mode on page 225](#).

In the following example, we consider PWM mode 1. The reference PWM signal OCxREF is high as long as $TIMx\_CNT < TIMx\_CCRx$ else it becomes low. If the compare value in TIMx_CCRx is greater than the auto-reload value (in TIMx_ARR) then OCxREF is held at '1'. If the compare value is 0 then OCxRef is held at '0'.

[Figure 72](#) shows some edge-aligned PWM waveforms in an example where $TIMx\_ARR=8$.

Figure 72. Edge-aligned PWM waveforms (ARR=8)



For code example refer to the Appendix section [A.8.8: Edge-aligned PWM configuration example](#).

- Downcounting configuration

Downcounting is active when DIR bit in TIMx_CR1 register is high. Refer to the [Downcounting mode on page 229](#)

In PWM mode 1, the reference signal OCxRef is low as long as $TIMx\_CNT > TIMx\_CCRx$ else it becomes high. If the compare value in TIMx_CCRx is greater than the auto-reload value in TIMx_ARR, then OCxREF is held at '1'. 0% PWM is not possible in this mode.

PWM center-aligned mode

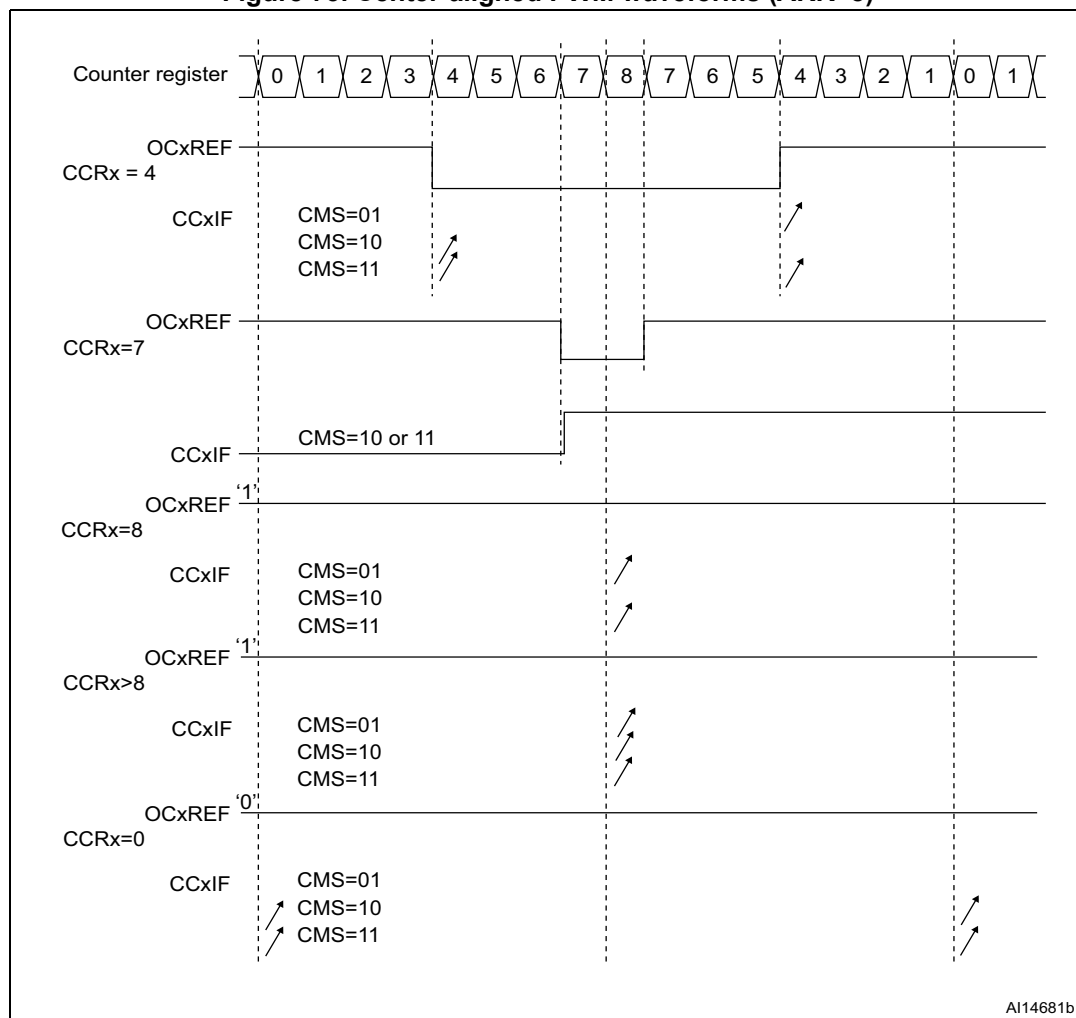
Center-aligned mode is active when the CMS bits in TIMx_CR1 register are different from '00' (all the remaining configurations having the same effect on the OCxRef/OCx signals). The compare flag is set when the counter counts up, when it counts down or both when it counts up and down depending on the CMS bits configuration. The direction bit (DIR) in the TIMx_CR1 register is updated by hardware and must not be changed by software. Refer to the [Center-aligned mode \(up/down counting\) on page 231](#).

Figure 73 shows some center-aligned PWM waveforms in an example where:

- TIMx_ARR=8,
- PWM mode is the PWM mode 1,
- The flag is set when the counter counts down corresponding to the center-aligned mode 1 selected for CMS=01 in TIMx_CR1 register.

For code example refer to the Appendix section [A.8.9: Center-aligned PWM configuration example](#).

Figure 73. Center-aligned PWM waveforms (ARR=8)



Hints on using center-aligned mode:

- When starting in center-aligned mode, the current up-down configuration is used. It means that the counter counts up or down depending on the value written in the DIR bit in the TIMx_CR1 register. Moreover, the DIR and CMS bits must not be changed at the same time by the software.
- Writing to the counter while running in center-aligned mode is not recommended as it can lead to unexpected results. In particular:
 - The direction is not updated if you write a value in the counter that is greater than the auto-reload value (TIMx_CNT > TIMx_ARR). For example, if the counter was counting up, it continues to count up.
 - The direction is updated if you write 0 or write the TIMx_ARR value in the counter but no Update Event UEV is generated.
- The safest way to use center-aligned mode is to generate an update by software (setting the UG bit in the TIMx_EGR register) just before starting the counter and not to write the counter while it is running.

13.3.11 Complementary outputs and dead-time insertion

The advanced-control timers (TIM1) can output two complementary signals and manage the switching-off and the switching-on instants of the outputs.

This time is generally known as dead-time and you have to adjust it depending on the devices you have connected to the outputs and their characteristics (intrinsic delays of level-shifters, delays due to power switches...)

You can select the polarity of the outputs (main output OCx or complementary OCxN) independently for each output. This is done by writing to the CCxP and CCxNP bits in the TIMx_CCER register.

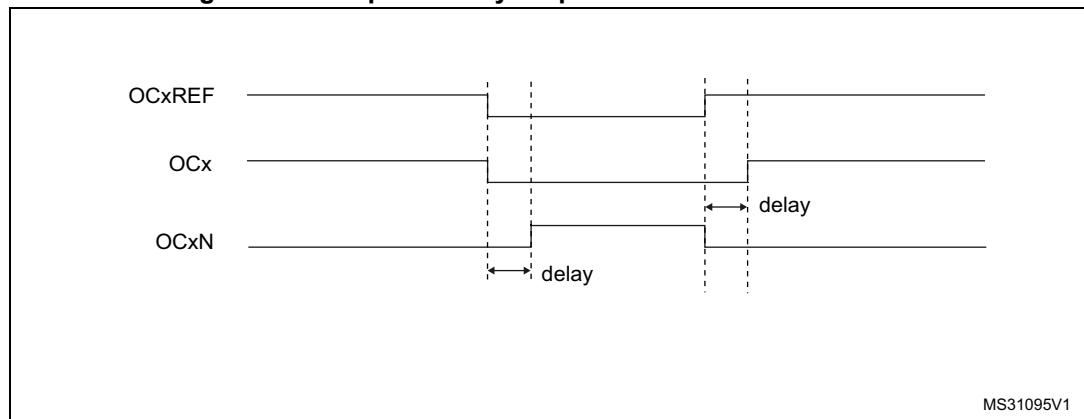
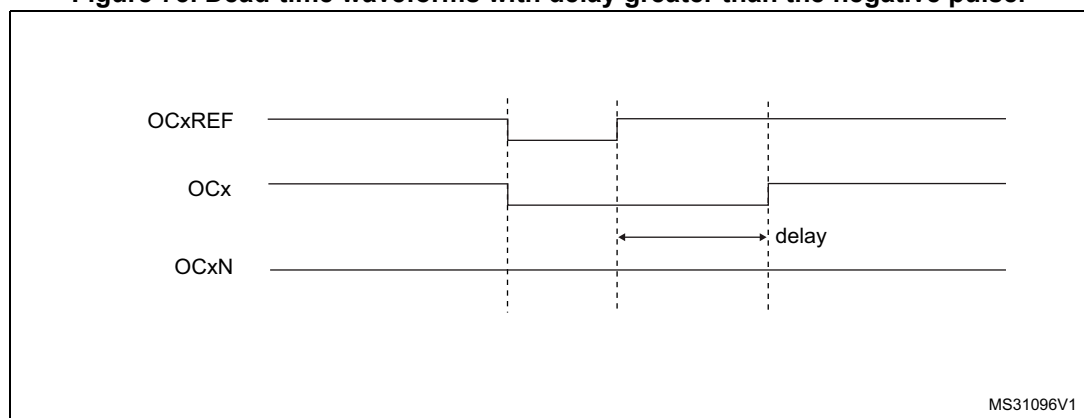
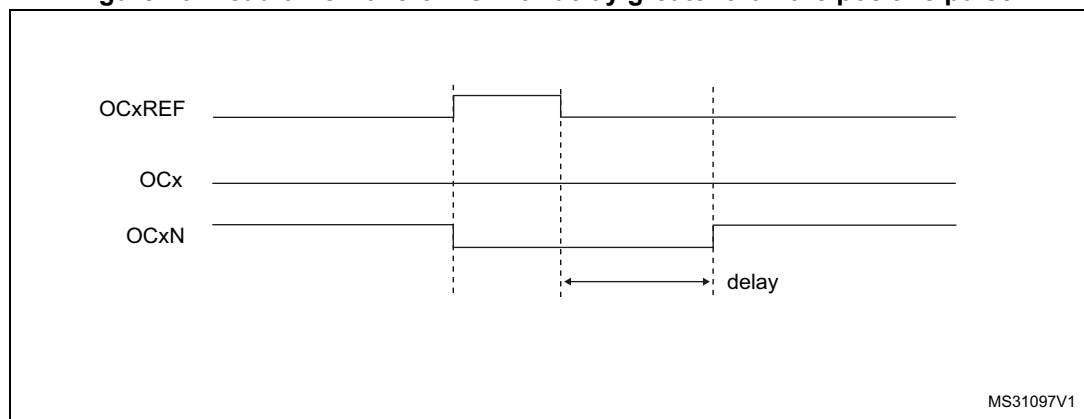
The complementary signals OCx and OCxN are activated by a combination of several control bits: the CCxE and CCxNE bits in the TIMx_CCER register and the MOE, OISx, OISxN, OSSI and OSSR bits in the TIMx_BDTR and TIMx_CR2 registers. Refer to [Table 46: Output control bits for complementary OCx and OCxN channels with break feature on page 286](#) for more details. In particular, the dead-time is activated when switching to the IDLE state (MOE falling down to 0).

Dead-time insertion is enabled by setting both CCxE and CCxNE bits, and the MOE bit if the break circuit is present. There is one 10-bit dead-time generator for each channel. From a reference waveform OCxREF, it generates 2 outputs OCx and OCxN. If OCx and OCxN are active high:

- The OCx output signal is the same as the reference signal except for the rising edge, which is delayed relative to the reference rising edge.
- The OCxN output signal is the opposite of the reference signal except for the rising edge, which is delayed relative to the reference falling edge.

If the delay is greater than the width of the active output (OCx or OCxN) then the corresponding pulse is not generated.

The following figures show the relationships between the output signals of the dead-time generator and the reference signal OCxREF. (we suppose CCxP=0, CCxNP=0, MOE=1, CCxE=1 and CCxNE=1 in these examples)

Figure 74. Complementary output with dead-time insertion.**Figure 75. Dead-time waveforms with delay greater than the negative pulse.****Figure 76. Dead-time waveforms with delay greater than the positive pulse.**

The dead-time delay is the same for each of the channels and is programmable with the DTG bits in the TIMx_BDTR register. Refer to [Section 13.4.18: TIM1 break and dead-time register \(TIM1_BDTR\) on page 290](#) for delay calculation.

Re-directing OCxREF to OCx or OCxN

In output mode (forced, output compare or PWM), OCxREF can be re-directed to the OCx output or to OCxN output by configuring the CCxE and CCxNE bits in the TIMx_CCER register.

This allows you to send a specific waveform (such as PWM or static active level) on one output while the complementary remains at its inactive level. Other alternative possibilities are to have both outputs at inactive level or both outputs active and complementary with dead-time.

Note: When only OCxN is enabled (CCxE=0, CCxNE=1), it is not complemented and becomes active as soon as OCxREF is high. For example, if CCxNP=0 then OCxN=OCxRef. On the other hand, when both OCx and OCxN are enabled (CCxE=CCxNE=1) OCx becomes active when OCxREF is high whereas OCxN is complemented and becomes active when OCxREF is low.

13.3.12 Using the break function

When using the break function, the output enable signals and inactive levels are modified according to additional control bits (MOE, OSSI and OSSR bits in the TIMx_BDTR register, OISx and OISxN bits in the TIMx_CR2 register). In any case, the OCx and OCxN outputs cannot be set both to active level at a given time. Refer to [Table 46: Output control bits for complementary OCx and OCxN channels with break feature on page 286](#) for more details.

The source for break (BRK) channel can be an external source connected to the BKIN pin or one of the following internal sources:

- the core LOCKUP output
- the PVD output
- the SRAM parity error signal
- a clock failure event generated by the CSS detector
- the output from a comparator

When exiting from reset, the break circuit is disabled and the MOE bit is low. You can enable the break function by setting the BKE bit in the TIMx_BDTR register. The break input polarity can be selected by configuring the BKP bit in the same register. BKE and BKP can be modified at the same time. When the BKE and BKP bits are written, a delay of 1 APB clock cycle is applied before the writing is effective. Consequently, it is necessary to wait 1 APB clock period to correctly read back the bit after the write operation.

Because MOE falling edge can be asynchronous, a resynchronization circuit has been inserted between the actual signal (acting on the outputs) and the synchronous control bit (accessed in the TIMx_BDTR register). It results in some delays between the asynchronous and the synchronous signals. In particular, if you write MOE to 1 whereas it was low, you must insert a delay (dummy instruction) before reading it correctly. This is because you write the asynchronous signal and read the synchronous signal.

When a break occurs (selected level on the break input):

- The MOE bit is cleared asynchronously, putting the outputs in inactive state, idle state or in reset state (selected by the OSS1 bit). This feature functions even if the MCU oscillator is off.
- Each output channel is driven with the level programmed in the OISx bit in the TIMx_CR2 register as soon as MOE=0. If OSS1=0 then the timer releases the enable output else the enable output remains high.
- When complementary outputs are used:
 - The outputs are first put in reset state inactive state (depending on the polarity). This is done asynchronously so that it works even if no clock is provided to the timer.
 - If the timer clock is still present, then the dead-time generator is reactivated in order to drive the outputs with the level programmed in the OISx and OISxN bits after a dead-time. Even in this case, OCx and OCxN cannot be driven to their active level together. Note that because of the resynchronization on MOE, the dead-time duration is a bit longer than usual (around 2 ck_tim clock cycles).
 - If OSS1=0 then the timer releases the enable outputs else the enable outputs remain or become high as soon as one of the CCxE or CCxNE bits is high.
- The break status flag (BIF bit in the TIMx_SR register) is set. An interrupt can be generated if the BIE bit in the TIMx_DIER register is set.
- If the AOE bit in the TIMx_BDTR register is set, the MOE bit is automatically set again at the next update event UEV. This can be used to perform a regulation, for instance. Else, MOE remains low until you write it to '1' again. In this case, it can be used for security and you can connect the break input to an alarm from power drivers, thermal sensors or any security components.

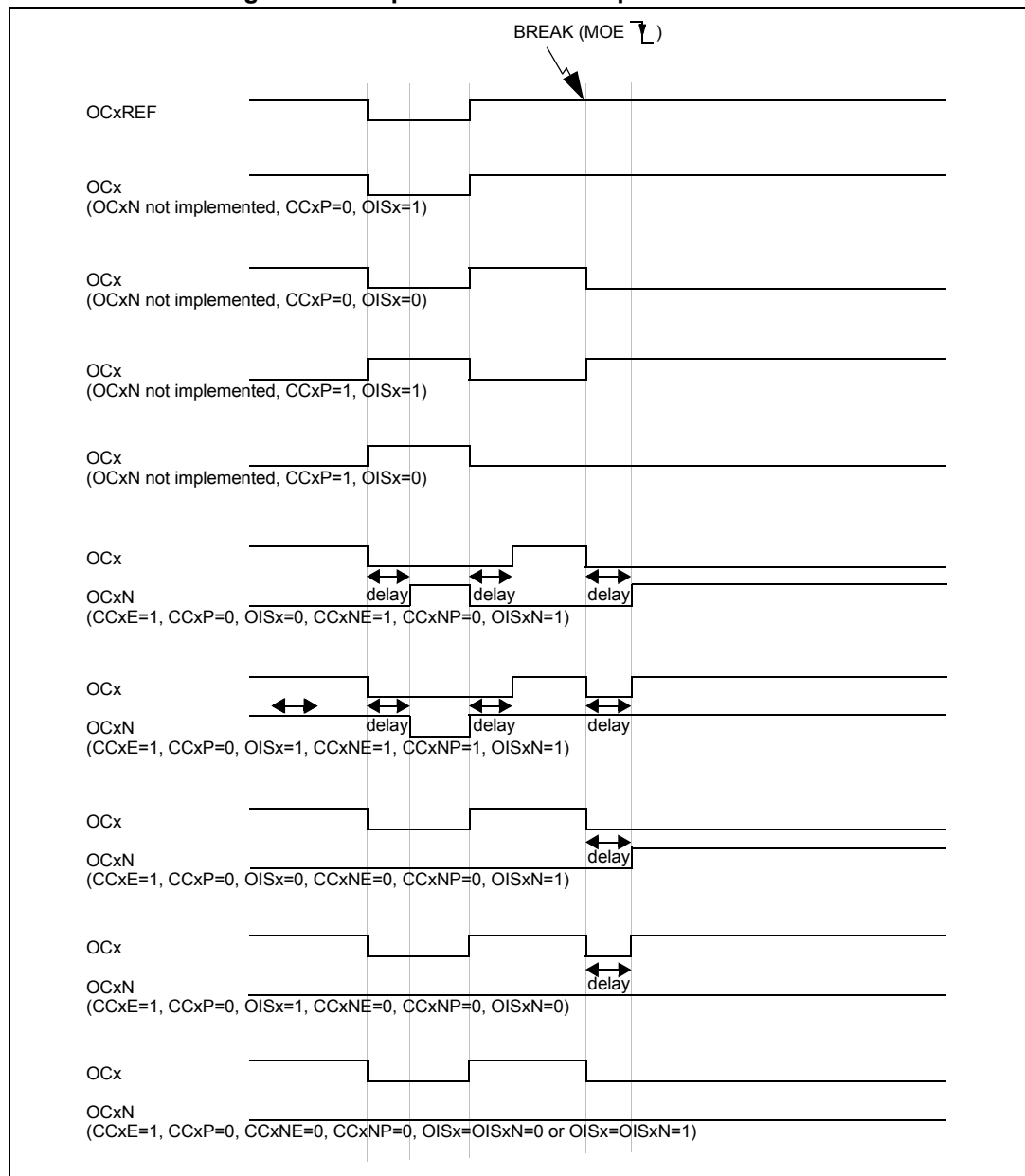
Note: The break inputs is acting on level. Thus, the MOE cannot be set while the break input is active (neither automatically nor by software). In the meantime, the status flag BIF cannot be cleared.

The break can be generated by the BRK input which has a programmable polarity and an enable bit BKE in the TIMx_BDTR Register.

In addition to the break input and the output management, a write protection has been implemented inside the break circuit to safeguard the application. It allows you to freeze the configuration of several parameters (dead-time duration, OCx/OCxN polarities and state when disabled, OCxM configurations, break enable and polarity). You can choose from 3 levels of protection selected by the LOCK bits in the TIMx_BDTR register. Refer to [Section 13.4.18: TIM1 break and dead-time register \(TIM1_BDTR\) on page 290](#). The LOCK bits can be written only once after an MCU reset.

The [Figure 77](#) shows an example of behavior of the outputs in response to a break.

Figure 77. Output behavior in response to a break



13.3.13 Clearing the OCxREF signal on an external event

The OCxREF signal of a given channel can be cleared when a high level is applied on the OCREF_CLR_INPUT (OCxCE enable bit in the corresponding TIMx_CCMRx register set to 1). OCxREF remains low until the next update event (UEV) occurs. This function can only be used in Output compare and PWM modes. It does not work in Forced mode.

OCREF_CLR_INPUT can be selected between the OCREF_CLR input and ETRF (ETR after the filter) by configuring the OCCS bit in the TIMx_SMCR register.

When ETRF is chosen, ETR must be configured as follows:

The OCxREF signal for a given channel can be driven Low by applying a High level to the ETRF input (OCxCE enable bit of the corresponding TIMx_CCMRx register set to '1'). The OCxREF signal remains Low until the next update event, UEV, occurs.

This function can only be used in output compare and PWM modes, and does not work in forced mode.

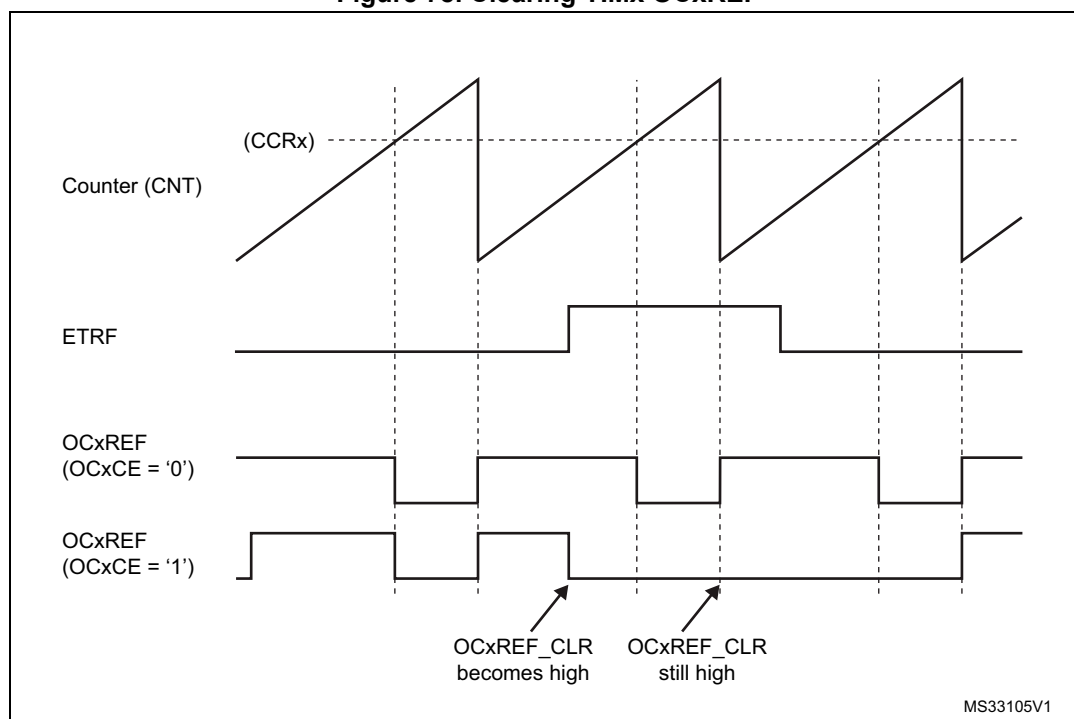
For example, the OCxREF signal can be connected to the output of a comparator to be used for current handling. In this case, the ETR must be configured as follow:

1. The External Trigger Prescaler should be kept off: bits ETPS[1:0] of the TIMx_SMCR register set to '00'.
2. The external clock mode 2 must be disabled: bit ECE of the TIMx_SMCR register set to '0'.
3. The External Trigger Polarity (ETP) and the External Trigger Filter (ETF) can be configured according to the user needs.

For code example refer to the Appendix section [A.8.10: ETR configuration to clear OCxREF code example](#).

[Figure 78](#) shows the behavior of the OCxREF signal when the ETRF Input becomes High, for both values of the enable bit OCxCE. In this example, the timer TIMx is programmed in PWM mode.

Figure 78. Clearing TIMx OCxREF



Note: In case of a PWM with a 100% duty cycle (if $CCR_x > ARR$), then OCxREF is enabled again at the next counter overflow.

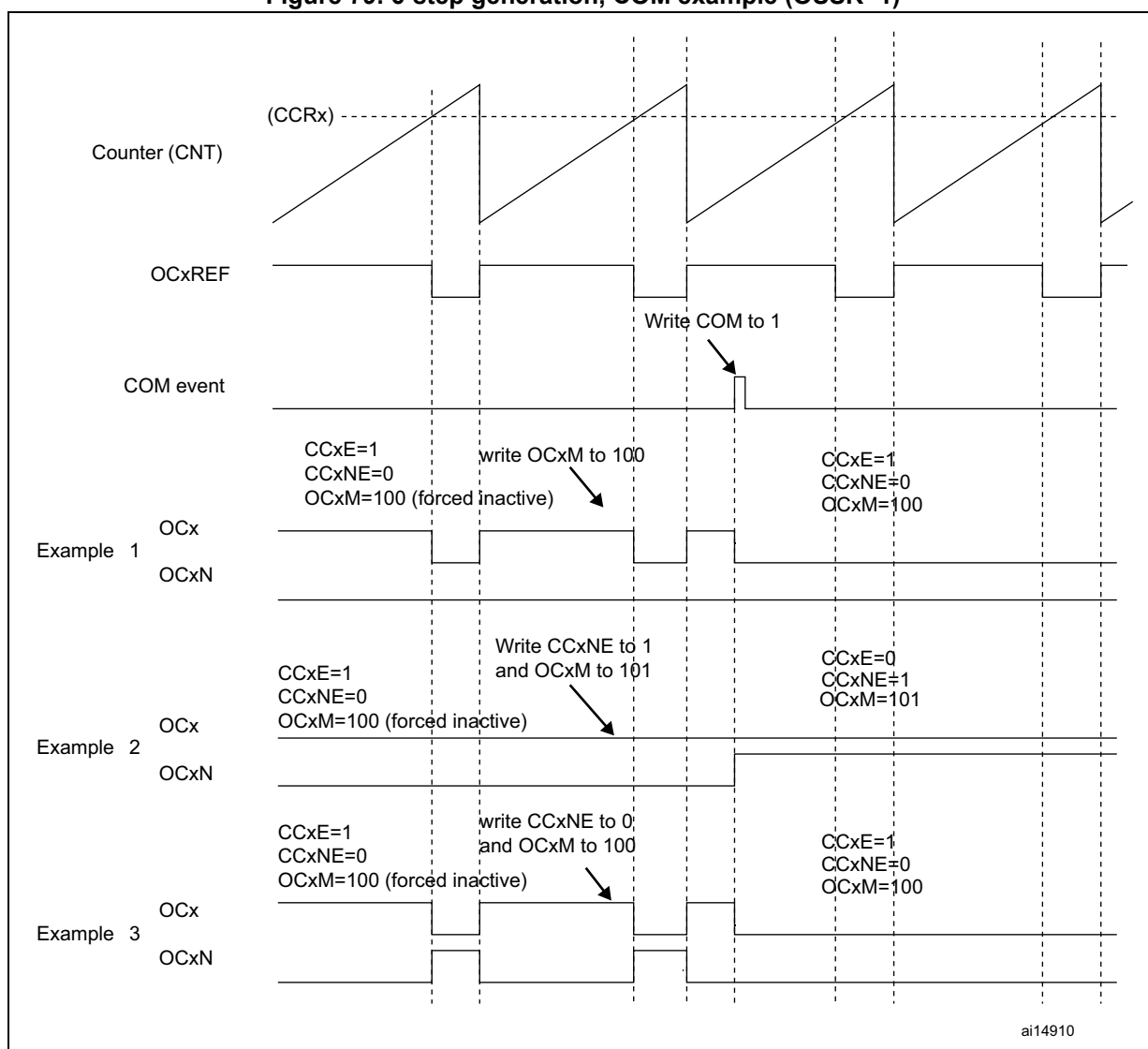
13.3.14 6-step PWM generation

When complementary outputs are used on a channel, preload bits are available on the OCxM, CCxE and CCxNE bits. The preload bits are transferred to the shadow bits at the COM commutation event. Thus you can program in advance the configuration for the next step and change the configuration of all the channels at the same time. COM can be generated by software by setting the COM bit in the TIMx_EGR register or by hardware (on TRGI rising edge).

A flag is set when the COM event occurs (COMIF bit in the TIMx_SR register), which can generate an interrupt (if the COMIE bit is set in the TIMx_DIER register) or a DMA request (if the COMDE bit is set in the TIMx_DIER register).

The [Figure 79](#) describes the behavior of the OCx and OCxN outputs when a COM event occurs, in 3 different examples of programmed configurations.

Figure 79. 6-step generation, COM example (OSSR=1)



13.3.15 One-pulse mode

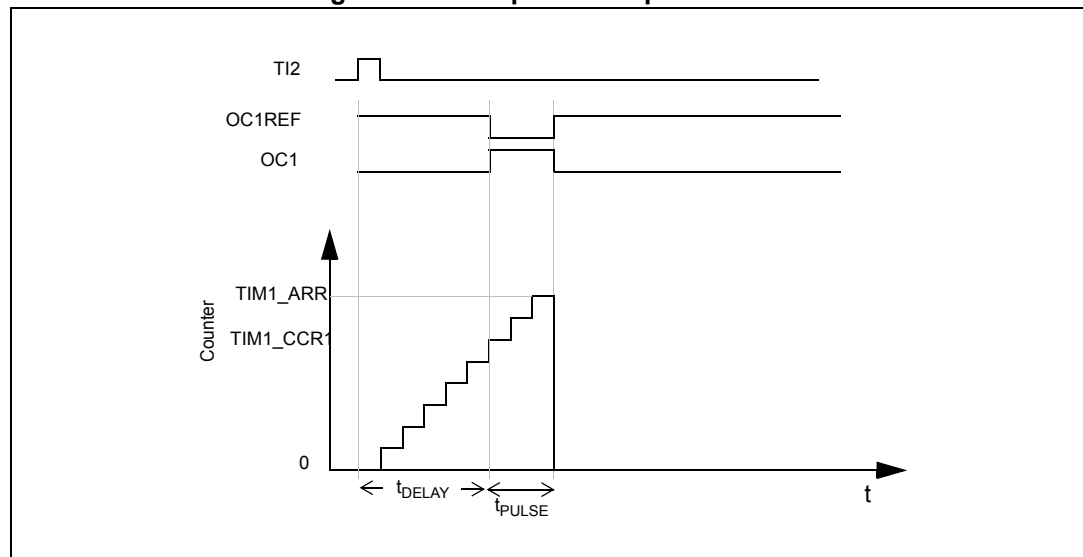
One-pulse mode (OPM) is a particular case of the previous modes. It allows the counter to be started in response to a stimulus and to generate a pulse with a programmable length after a programmable delay.

Starting the counter can be controlled through the slave mode controller. Generating the waveform can be done in output compare mode or PWM mode. You select One-pulse mode by setting the OPM bit in the TIMx_CR1 register. This makes the counter stop automatically at the next update event UEV.

A pulse can be correctly generated only if the compare value is different from the counter initial value. Before starting (when the timer is waiting for the trigger), the configuration must be:

- In upcounting: $CNT < CCRx \leq ARR$ (in particular, $0 < CCRx$)
- In downcounting: $CNT > CCRx$

Figure 80. Example of one pulse mode



For example you may want to generate a positive pulse on OC1 with a length of t_{PULSE} and after a delay of t_{DELAY} as soon as a positive edge is detected on the TI2 input pin.

Let's use TI2FP2 as trigger 1:

- Map TI2FP2 to TI2 by writing $CC2S='01'$ in the TIMx_CCMR1 register.
- TI2FP2 must detect a rising edge, write $CC2P='0'$ and $CC2NP='0'$ in the TIMx_CCER register.
- Configure TI2FP2 as trigger for the slave mode controller (TRGI) by writing $TS='110'$ in the TIMx_SMCR register.
- TI2FP2 is used to start the counter by writing SMS to '110' in the TIMx_SMCR register (trigger mode).

The OPM waveform is defined by writing the compare registers (taking into account the clock frequency and the counter prescaler).

- The t_{DELAY} is defined by the value written in the TIMx_CCR1 register.
- The t_{PULSE} is defined by the difference between the auto-reload value and the compare value (TIMx_ARR - TIMx_CCR1+1).
- Let's say you want to build a waveform with a transition from '0' to '1' when a compare match occurs and a transition from '1' to '0' when the counter reaches the auto-reload value. To do this you enable PWM mode 2 by writing OC1M=111 in the TIMx_CCMR1 register. You can optionally enable the preload registers by writing OC1PE='1' in the TIMx_CCMR1 register and ARPE in the TIMx_CR1 register. In this case you have to write the compare value in the TIMx_CCR1 register, the auto-reload value in the TIMx_ARR register, generate an update by setting the UG bit and wait for external trigger event on TI2. CC1P is written to '0' in this example.

In our example, the DIR and CMS bits in the TIMx_CR1 register should be low.

For code example refer to the Appendix section [A.8.16: One-Pulse mode code example](#).

You only want 1 pulse (Single mode), so you write '1' in the OPM bit in the TIMx_CR1 register to stop the counter at the next update event (when the counter rolls over from the auto-reload value back to 0). When OPM bit in the TIMx_CR1 register is set to '0', so the Repetitive Mode is selected.

Particular case: OCx fast enable

In One-pulse mode, the edge detection on Tix input set the CEN bit which enables the counter. Then the comparison between the counter and the compare value makes the output toggle. But several clock cycles are needed for these operations and it limits the minimum delay $t_{\text{DELAY min}}$ we can get.

If you want to output a waveform with the minimum delay, you can set the OCxFE bit in the TIMx_CCMRx register. Then OCxRef (and OCx) are forced in response to the stimulus, without taking in account the comparison. Its new level is the same as if a compare match had occurred. OCxFE acts only if the channel is configured in PWM1 or PWM2 mode.

For code example refer to the part of code, conditioned by PULSE_WITHOUT_DELAY > 0 in the Appendix section [A.8.16: One-Pulse mode code example](#).

13.3.16 Encoder interface mode

To select Encoder Interface mode write SMS='001' in the TIMx_SMCR register if the counter is counting on TI2 edges only, SMS='010' if it is counting on TI1 edges only and SMS='011' if it is counting on both TI1 and TI2 edges.

Select the TI1 and TI2 polarity by programming the CC1P and CC2P bits in the TIMx_CCER register. When needed, you can program the input filter as well. CC1NP and CC2NP must be kept low.

The two inputs TI1 and TI2 are used to interface to an incremental encoder. Refer to [Table 44](#). The counter is clocked by each valid transition on TI1FP1 or TI2FP2 (TI1 and TI2 after input filter and polarity selection, TI1FP1=TI1 if not filtered and not inverted, TI2FP2=TI2 if not filtered and not inverted) assuming that it is enabled (CEN bit in TIMx_CR1 register written to '1'). The sequence of transitions of the two inputs is evaluated and generates count pulses as well as the direction signal. Depending on the sequence the counter counts up or down, the DIR bit in the TIMx_CR1 register is modified by hardware

accordingly. The DIR bit is calculated at each transition on any input (TI1 or TI2), whatever the counter is counting on TI1 only, TI2 only or both TI1 and TI2.

Encoder interface mode acts simply as an external clock with direction selection. This means that the counter just counts continuously between 0 and the auto-reload value in the TIMx_ARR register (0 to ARR or ARR down to 0 depending on the direction). So you must configure TIMx_ARR before starting. In the same way, the capture, compare, prescaler, repetition counter, trigger output features continue to work as normal. Encoder mode and External clock mode 2 are not compatible and must not be selected together.

In this mode, the counter is modified automatically following the speed and the direction of the incremental encoder and its content, therefore, always represents the encoder's position. The count direction correspond to the rotation direction of the connected sensor. The table summarizes the possible combinations, assuming TI1 and TI2 don't switch at the same time.

Table 44. Counting direction versus encoder signals

Active edge	Level on opposite signal (TI1FP1 for TI2, TI2FP2 for TI1)	TI1FP1 signal		TI2FP2 signal	
		Rising	Falling	Rising	Falling
Counting on TI1 only	High	Down	Up	No Count	No Count
	Low	Up	Down	No Count	No Count
Counting on TI2 only	High	No Count	No Count	Up	Down
	Low	No Count	No Count	Down	Up
Counting on TI1 and TI2	High	Down	Up	Up	Down
	Low	Up	Down	Down	Up

An external incremental encoder can be connected directly to the MCU without external interface logic. However, comparators are normally be used to convert the encoder's differential outputs to digital signals. This greatly increases noise immunity. The third encoder output which indicate the mechanical zero position, may be connected to an external interrupt input and trigger a counter reset.

[Figure 81](#) gives an example of counter operation, showing count signal generation and direction control. It also shows how input jitter is compensated where both edges are selected. This might occur if the sensor is positioned near to one of the switching points. For this example we assume that the configuration is the following:

- CC1S='01' (TIMx_CCMR1 register, TI1FP1 mapped on TI1).
- CC2S='01' (TIMx_CCMR2 register, TI1FP2 mapped on TI2).
- CC1P='0' (TIMx_CCER register, TI1FP1 non-inverted, TI1FP1=TI1).
- CC2P='0' (TIMx_CCER register, TI1FP2 non-inverted, TI1FP2= TI2).
- SMS='011' (TIMx_SMCR register, both inputs are active on both rising and falling edges).
- CEN='1' (TIMx_CR1 register, Counter enabled).

For code example refer to the Appendix section [A.8.11: Encoder interface code example](#).

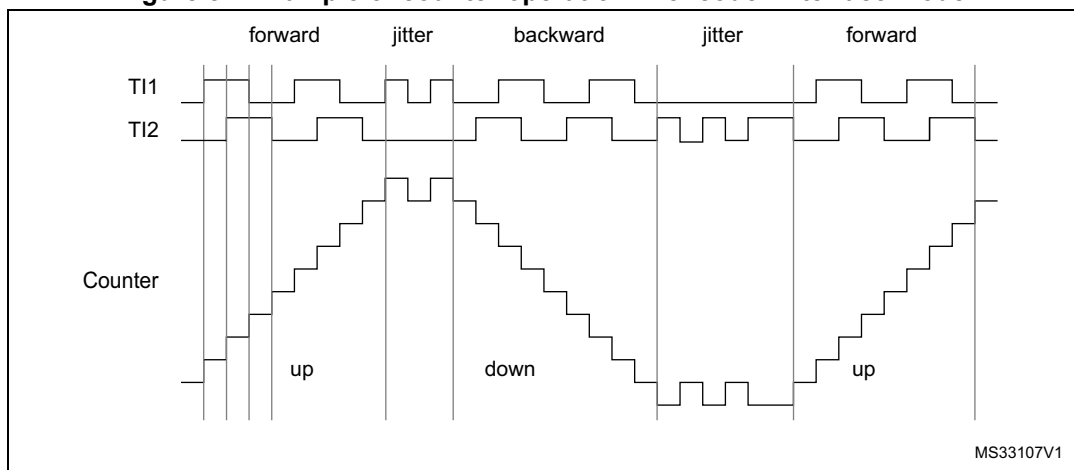
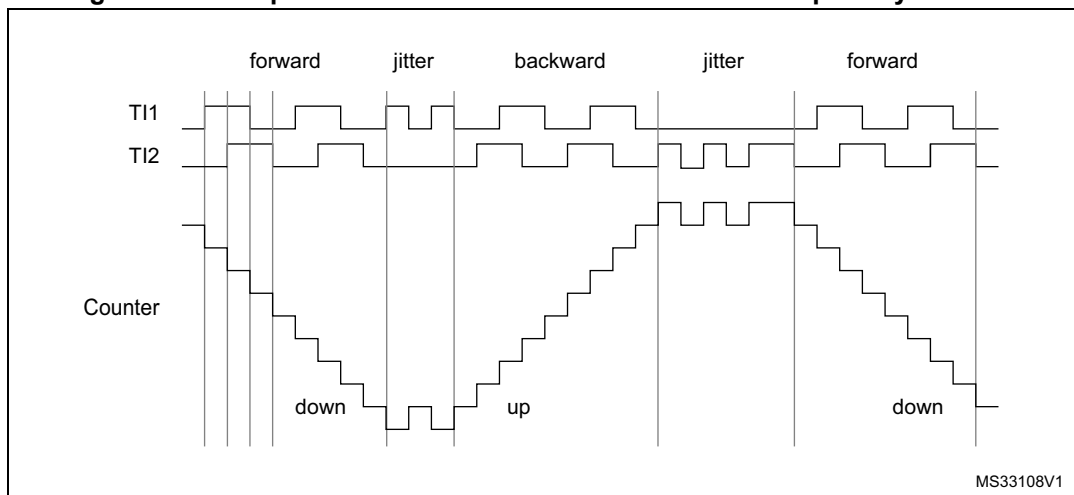
Figure 81. Example of counter operation in encoder interface mode.

Figure 82 gives an example of counter behavior when TI1FP1 polarity is inverted (same configuration as above except CC1P='1').

Figure 82. Example of encoder interface mode with TI1FP1 polarity inverted.

The timer, when configured in Encoder Interface mode provides information on the sensor's current position. You can obtain dynamic information (speed, acceleration, deceleration) by measuring the period between two encoder events using a second timer configured in capture mode. The output of the encoder which indicates the mechanical zero can be used for this purpose. Depending on the time between two events, the counter can also be read at regular times. You can do this by latching the counter value into a third input capture register if available (then the capture signal must be periodic and can be generated by another timer). when available, it is also possible to read its value through a DMA request generated by a real-time clock.

13.3.17 Timer input XOR function

The TI1S bit in the TIMx_CR2 register, allows the input filter of channel 1 to be connected to the output of a XOR gate, combining the three input pins TIMx_CH1, TIMx_CH2 and TIMx_CH3.

The XOR output can be used with all the timer input functions such as trigger or input capture. An example of this feature used to interface Hall sensors is given in [Section 13.3.18](#) below.

13.3.18 Interfacing with Hall sensors

This is done using the advanced-control timers (TIM1) to generate PWM signals to drive the motor and another timer (TIM3) referred to as “interfacing timer” in [Figure 83](#). The “interfacing timer” captures the 3 timer input pins (CC1, CC2, CC3) connected through a XOR to the TI1 input channel (selected by setting the TI1S bit in the TIMx_CR2 register).

The slave mode controller is configured in reset mode; the slave input is TI1F_ED. Thus, each time one of the 3 inputs toggles, the counter restarts counting from 0. This creates a time base triggered by any change on the Hall inputs.

On the “interfacing timer”, capture/compare channel 1 is configured in capture mode, capture signal is TRC (See [Figure 66: Capture/compare channel \(example: channel 1 input stage\) on page 241](#)). The captured value, which corresponds to the time elapsed between 2 changes on the inputs, gives information about motor speed.

The “interfacing timer” can be used in output mode to generate a pulse which changes the configuration of the channels of the advanced-control timer (TIM1) (by triggering a COM event). The TIM1 timer is used to generate PWM signals to drive the motor. To do this, the interfacing timer channel must be programmed so that a positive pulse is generated after a programmed delay (in output compare or PWM mode). This pulse is sent to the advanced-control timer (TIM1) through the TRGO output.

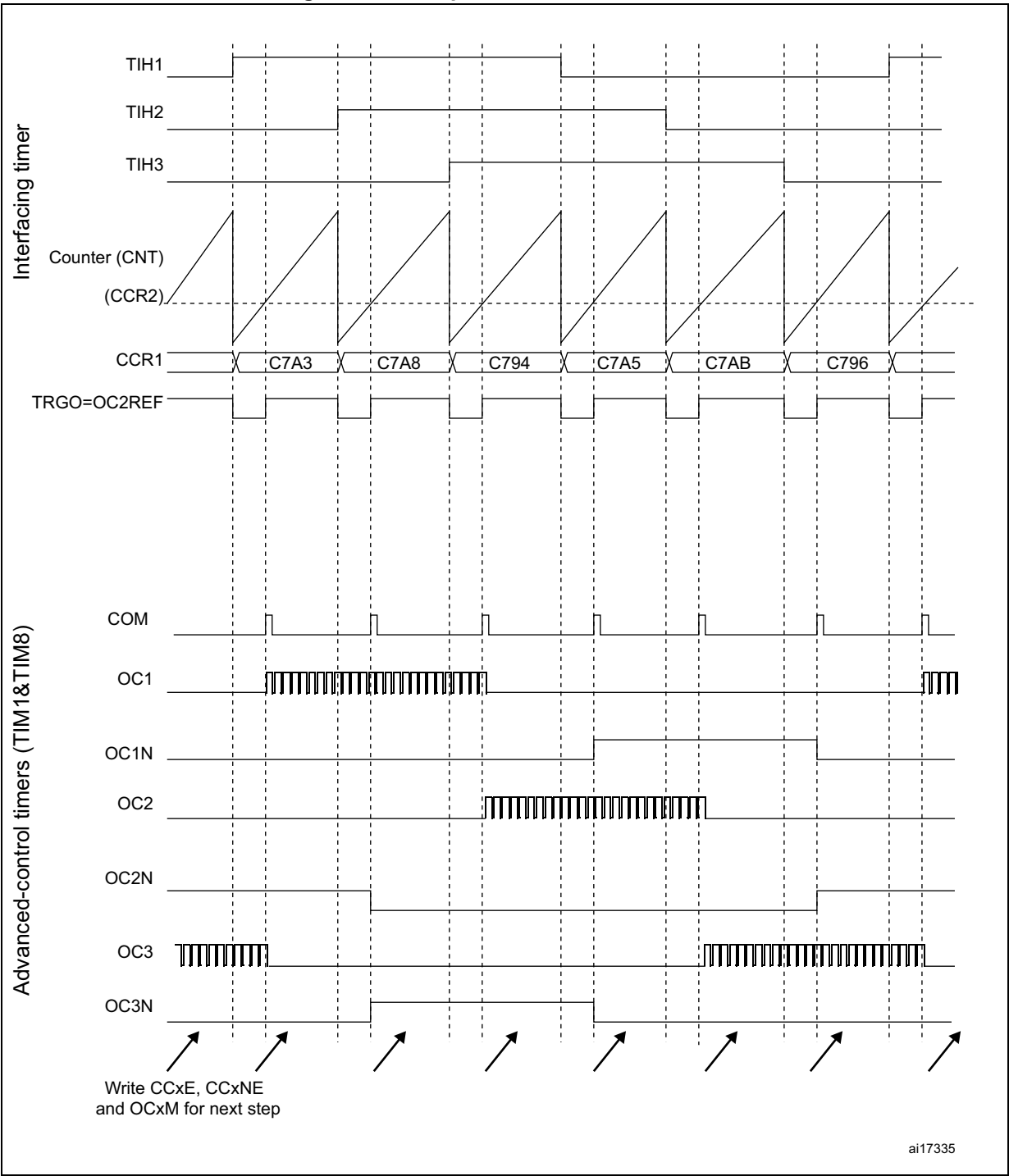
Example: you want to change the PWM configuration of your advanced-control timer TIM1 after a programmed delay each time a change occurs on the Hall inputs connected to one of the TIMx timers.

- Configure 3 timer inputs XORed to the TI1 input channel by writing the TI1S bit in the TIMx_CR2 register to ‘1’,
- Program the time base: write the TIMx_ARR to the max value (the counter must be cleared by the TI1 change. Set the prescaler to get a maximum counter period longer than the time between 2 changes on the sensors,
- Program channel 1 in capture mode (TRC selected): write the CC1S bits in the TIMx_CCMR1 register to ‘01’. You can also program the digital filter if needed,
- Program channel 2 in PWM 2 mode with the desired delay: write the OC2M bits to ‘111’ and the CC2S bits to ‘00’ in the TIMx_CCMR1 register,
- Select OC2REF as trigger output on TRGO: write the MMS bits in the TIMx_CR2 register to ‘101’,

In the advanced-control timer TIM1, the right ITR input must be selected as trigger input, the timer is programmed to generate PWM signals, the capture/compare control signals are preloaded (CCPC=1 in the TIMx_CR2 register) and the COM event is controlled by the trigger input (CCUS=1 in the TIMx_CR2 register). The PWM control bits (CCxE, OCxM) are written after a COM event for the next step (this can be done in an interrupt subroutine generated by the rising edge of OC2REF).

Figure 83 describes this example.

Figure 83. Example of hall sensor interface



13.3.19 TIMx and external trigger synchronization

The TIMx timer can be synchronized with an external trigger in several modes: Reset mode, Gated mode and Trigger mode.

Slave mode: Reset mode

The counter and its prescaler can be reinitialized in response to an event on a trigger input. Moreover, if the URS bit from the TIMx_CR1 register is low, an update event UEV is generated. Then all the preloaded registers (TIMx_ARR, TIMx_CCRx) are updated.

In the following example, the upcounter is cleared in response to a rising edge on TI1 input:

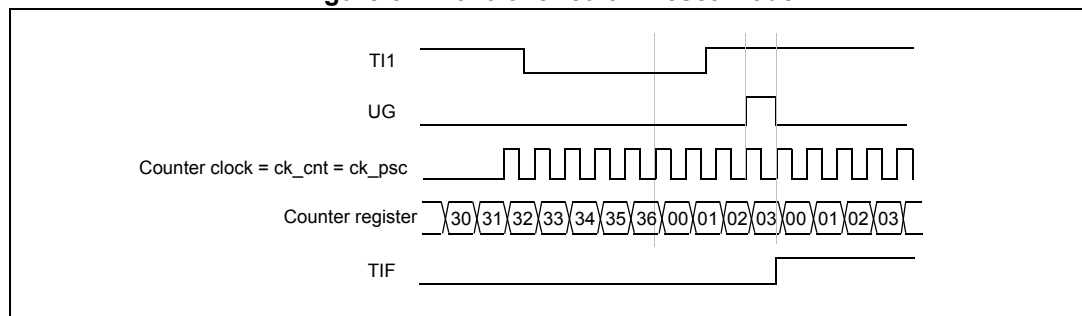
- Configure the channel 1 to detect rising edges on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S = 01 in the TIMx_CCMR1 register. Write CC1P=0 and CC1NP='0' in TIMx_CCER register to validate the polarity (and detect rising edges only).
- Configure the timer in reset mode by writing SMS=100 in TIMx_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx_SMCR register.
- Start the counter by writing CEN=1 in the TIMx_CR1 register.

For code example refer to the Appendix section [A.8.12: Reset mode code example](#).

The counter starts counting on the internal clock, then behaves normally until TI1 rising edge. When TI1 rises, the counter is cleared and restarts from 0. In the meantime, the trigger flag is set (TIF bit in the TIMx_SR register) and an interrupt request, or a DMA request can be sent if enabled (depending on the TIE and TDE bits in TIMx_DIER register).

The following figure shows this behavior when the auto-reload register TIMx_ARR=0x36. The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input.

Figure 84. Control circuit in reset mode



Slave mode: Gated mode

The counter can be enabled depending on the level of a selected input.

In the following example, the upcounter counts only when TI1 input is low:

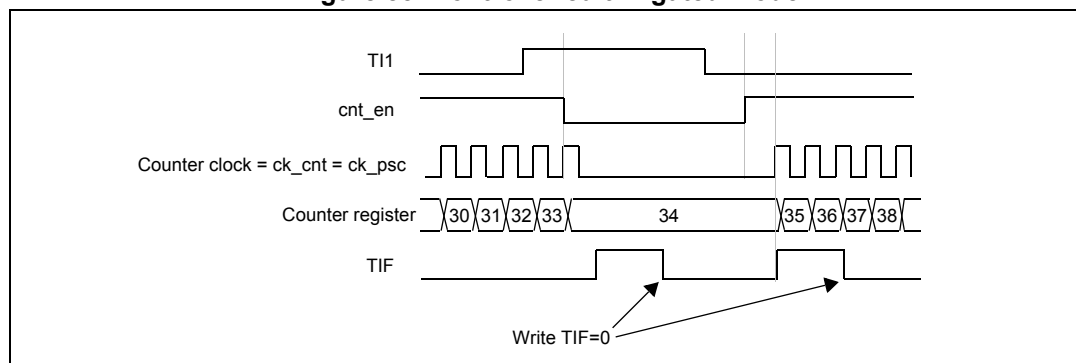
- Configure the channel 1 to detect low levels on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S=01 in TIMx_CCMR1 register. Write CC1P=1 and CC1NP='0' in TIMx_CCER register to validate the polarity (and detect low level only).
- Configure the timer in gated mode by writing SMS=101 in TIMx_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx_SMCR register.
- Enable the counter by writing CEN=1 in the TIMx_CR1 register (in gated mode, the counter doesn't start if CEN=0, whatever is the trigger input level).

For code example refer to the Appendix section [A.8.13: Gated mode code example](#).

The counter starts counting on the internal clock as long as TI1 is low and stops as soon as TI1 becomes high. The TIF flag in the TIMx_SR register is set both when the counter starts or stops.

The delay between the rising edge on TI1 and the actual stop of the counter is due to the resynchronization circuit on TI1 input.

Figure 85. Control circuit in gated mode



Slave mode: Trigger mode

The counter can start in response to an event on a selected input.

In the following example, the upcounter starts in response to a rising edge on TI2 input:

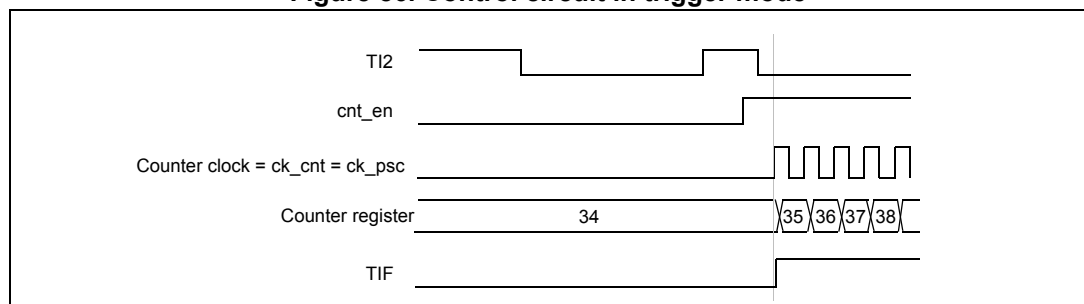
- Configure the channel 2 to detect rising edges on TI2. Configure the input filter duration (in this example, we don't need any filter, so we keep IC2F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC2S bits are configured to select the input capture source only, CC2S=01 in TIMx_CCMR1 register. Write CC2P=1 and CC2NP=0 in TIMx_CCER register to validate the polarity (and detect low level only).
- Configure the timer in trigger mode by writing SMS=110 in TIMx_SMCR register. Select TI2 as the input source by writing TS=110 in TIMx_SMCR register.

For code example refer to the Appendix section [A.8.14: Trigger mode code example](#).

When a rising edge occurs on TI2, the counter starts counting on the internal clock and the TIF flag is set.

The delay between the rising edge on TI2 and the actual start of the counter is due to the resynchronization circuit on TI2 input.

Figure 86. Control circuit in trigger mode



Slave mode: external clock mode 2 + trigger mode

The external clock mode 2 can be used in addition to another slave mode (except external clock mode 1 and encoder mode). In this case, the ETR signal is used as external clock input, and another input can be selected as trigger input (in reset mode, gated mode or trigger mode). It is recommended not to select ETR as TRGI through the TS bits of TIMx_SMCR register.

In the following example, the upcounter is incremented at each rising edge of the ETR signal as soon as a rising edge of TI1 occurs:

1. Configure the external trigger input circuit by programming the TIMx_SMCR register as follows:
 - ETF = 0000: no filter
 - ETPS=00: prescaler disabled
 - ETP=0: detection of rising edges on ETR and ECE=1 to enable the external clock mode 2.

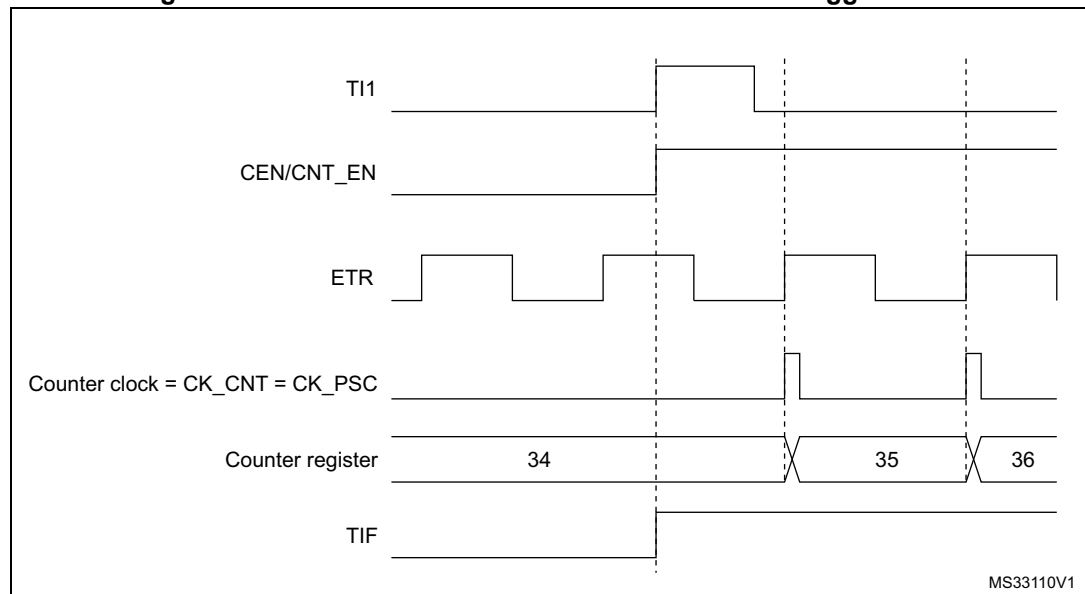
2. Configure the channel 1 as follows, to detect rising edges on TI:
 - IC1F=0000: no filter.
 - The capture prescaler is not used for triggering and does not need to be configured.
 - CC1S=01 in TIMx_CCMR1 register to select only the input capture source
 - CC1P=0 and CC1NP='0' in TIMx_CCER register to validate the polarity (and detect rising edge only).
3. Configure the timer in trigger mode by writing SMS=110 in TIMx_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx_SMCR register.

For code example refer to the Appendix section [A.8.15: External clock mode 2 + trigger mode code example](#).

A rising edge on TI1 enables the counter and sets the TIF flag. The counter then counts on ETR rising edges.

The delay between the rising edge of the ETR signal and the actual reset of the counter is due to the resynchronization circuit on ETRP input.

Figure 87. Control circuit in external clock mode 2 + trigger mode



13.3.20 Timer synchronization

The TIM timers are linked together internally for timer synchronization or chaining. Refer to [Section 14.3.15: Timer synchronization on page 331](#) for details.

13.3.21 Debug mode

When the microcontroller enters debug mode (Cortex™-M0 core halted), the TIMx counter either continues to work normally or stops, depending on DBG_TIMx_STOP configuration bit in DBG module.

13.4 TIM1 registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

13.4.1 TIM1 control register 1 (TIM1_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	CMS[1:0]		DIR	OPM	URS	UDIS	CEN
						rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:10 Reserved, must be kept at reset value.

Bits 9:8 **CKD[1:0]**: Clock division

This bit-field indicates the division ratio between the timer clock (CK_INT) frequency and the dead-time and sampling clock (t_{DTS}) used by the dead-time generators and the digital filters (ETR, Tlx),

00: $t_{DTS}=t_{CK\_INT}$

01: $t_{DTS}=2*t_{CK\_INT}$

10: $t_{DTS}=4*t_{CK\_INT}$

11: Reserved, do not program this value

Bit 7 **ARPE**: Auto-reload preload enable

0: TIMx_ARR register is not buffered

1: TIMx_ARR register is buffered

Bits 6:5 **CMS[1:0]**: Center-aligned mode selection

00: Edge-aligned mode. The counter counts up or down depending on the direction bit (DIR).

01: Center-aligned mode 1. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx_CCMRx register) are set only when the counter is counting down.

10: Center-aligned mode 2. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx_CCMRx register) are set only when the counter is counting up.

11: Center-aligned mode 3. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx_CCMRx register) are set both when the counter is counting up or down.

Note: It is not allowed to switch from edge-aligned mode to center-aligned mode as long as the counter is enabled (CEN=1).

Bit 4 **DIR**: Direction

0: Counter used as upcounter

1: Counter used as downcounter

Note: This bit is read only when the timer is configured in Center-aligned mode or Encoder mode.

Bit 3 **OPM**: One pulse mode

0: Counter is not stopped at update event

1: Counter stops counting at the next update event (clearing the bit CEN)

Bit 2 **URS**: Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generate an update interrupt or DMA request if enabled.

These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt or DMA request if enabled.

Bit 1 **UDIS**: Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

Bit 0 **CEN**: Counter enable

0: Counter disabled

1: Counter enabled

Note: External clock, gated mode and encoder mode can work only if the CEN bit has been previously set by software. However trigger mode can set the CEN bit automatically by hardware.

13.4.2 TIM1 control register 2 (TIM1_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	OIS4	OIS3N	OIS3	OIS2N	OIS2	OIS1N	OIS1	TI1S	MMS[2:0]			CCDS	CCUS	Res.	CCPC
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw		rw

Bit 15 **Reserved**, must be kept at reset value.

Bit 14 **OIS4**: Output Idle state 4 (OC4 output)

refer to OIS1 bit

Bit 13 **OIS3N**: Output Idle state 3 (OC3N output)

refer to OIS1N bit

Bit 12 **OIS3**: Output Idle state 3 (OC3 output)

refer to OIS1 bit

Bit 11 **OIS2N**: Output Idle state 2 (OC2N output)

refer to OIS1N bit

Bit 10 **OIS2**: Output Idle state 2 (OC2 output)

refer to OIS1 bit

Bit 9 **OIS1N**: Output Idle state 1 (OC1N output)

0: OC1N=0 after a dead-time when MOE=0

1: OC1N=1 after a dead-time when MOE=0

Note: This bit cannot be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 8 **OIS1**: Output Idle state 1 (OC1 output)

0: OC1=0 (after a dead-time if OC1N is implemented) when MOE=0

1: OC1=1 (after a dead-time if OC1N is implemented) when MOE=0

Note: This bit cannot be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 7 **TI1S**: TI1 selection

0: The TIMx_CH1 pin is connected to TI1 input

1: The TIMx_CH1, CH2 and CH3 pins are connected to the TI1 input (XOR combination)

Bits 6:4 **MMS[1:0]**: Master mode selection

These bits allow to select the information to be sent in master mode to slave timers for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIMx_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (slave mode controller configured in reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter Enable signal CNT_EN is used as trigger output (TRGO). It is useful to start several timers at the same time or to control a window in which a slave timer is enable. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode. When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in TIMx_SMCR register).

010: **Update** - The update event is selected as trigger output (TRGO). For instance a master timer can then be used as a prescaler for a slave timer.

011: **Compare Pulse** - The trigger output send a positive pulse when the CC1IF flag is to be set (even if it was already high), as soon as a capture or a compare match occurred. (TRGO).

100: **Compare** - OC1REF signal is used as trigger output (TRGO)

101: **Compare** - OC2REF signal is used as trigger output (TRGO)

110: **Compare** - OC3REF signal is used as trigger output (TRGO)

111: **Compare** - OC4REF signal is used as trigger output (TRGO)

Bit 3 **CCDS**: Capture/compare DMA selection

0: CCx DMA request sent when CCx event occurs

1: CCx DMA requests sent when update event occurs

Bit 2 **CCUS**: Capture/compare control update selection

0: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit only

1: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit or when an rising edge occurs on TRGI

Note: This bit acts only on channels that have a complementary output.

Bit 1 Reserved, must be kept at reset value.

Bit 0 **CCPC**: Capture/compare preloaded control

0: CCxE, CCxNE and OCxM bits are not preloaded

1: CCxE, CCxNE and OCxM bits are preloaded, after having been written, they are updated only when a communication event (COM) occurs (COMG bit set or rising edge detected on TRGI, depending on the CCUS bit).

Note: This bit acts only on channels that have a complementary output.

13.4.3 TIM1 slave mode control register (TIM1_SMCR)

Address offset: 0x08

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ETP	ECE	ETPS[1:0]		ETF[3:0]				MSM	TS[2:0]			OCCS	SMS[2:0]		
r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w

Bit 15 **ETP**: External trigger polarity

This bit selects whether ETR or $\overline{\text{ETR}}$ is used for trigger operations

0: ETR is non-inverted, active at high level or rising edge.

1: ETR is inverted, active at low level or falling edge.

Bit 14 **ECE**: External clock enable

This bit enables External clock mode 2.

0: External clock mode 2 disabled

1: External clock mode 2 enabled. The counter is clocked by any active edge on the ETRF signal.

Note: 1: Setting the ECE bit has the same effect as selecting external clock mode 1 with TRGI connected to ETRF (SMS=111 and TS=111).

2: It is possible to simultaneously use external clock mode 2 with the following slave modes: reset mode, gated mode and trigger mode. Nevertheless, TRGI must not be connected to ETRF in this case (TS bits must not be 111).

3: If external clock mode 1 and external clock mode 2 are enabled at the same time, the external clock input is ETRF.

Bits 13:12 **ETPS[1:0]**: External trigger prescaler

External trigger signal ETRP frequency must be at most 1/4 of TIMxCLK frequency. A prescaler can be enabled to reduce ETRP frequency. It is useful when inputting fast external clocks.

00: Prescaler OFF

01: ETRP frequency divided by 2

10: ETRP frequency divided by 4

11: ETRP frequency divided by 8

Bits 11:8 **ETF[3:0]**: External trigger filter

This bit-field then defines the frequency used to sample ETRP signal and the length of the digital filter applied to ETRP. The digital filter is made of an event counter in which N consecutive events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{DTS}

0001: $f_{SAMPLING} = f_{CK\_INT}$, $N = 2$

0010: $f_{SAMPLING} = f_{CK\_INT}$, $N = 4$

0011: $f_{SAMPLING} = f_{CK\_INT}$, $N = 8$

0100: $f_{SAMPLING} = f_{DTS} / 2$, $N = 6$

0101: $f_{SAMPLING} = f_{DTS} / 2$, $N = 8$

0110: $f_{SAMPLING} = f_{DTS} / 4$, $N = 6$

0111: $f_{SAMPLING} = f_{DTS} / 4$, $N = 8$

1000: $f_{SAMPLING} = f_{DTS} / 8$, $N = 6$

1001: $f_{SAMPLING} = f_{DTS} / 8$, $N = 8$

1010: $f_{SAMPLING} = f_{DTS} / 16$, $N = 5$

1011: $f_{SAMPLING} = f_{DTS} / 16$, $N = 6$

1100: $f_{SAMPLING} = f_{DTS} / 16$, $N = 8$

1101: $f_{SAMPLING} = f_{DTS} / 32$, $N = 5$

1110: $f_{SAMPLING} = f_{DTS} / 32$, $N = 6$

1111: $f_{SAMPLING} = f_{DTS} / 32$, $N = 8$

Note: Care must be taken that f_{DTS} is replaced in the formula by CK_INT when $ETF[3:0] = 1, 2$ or 3 .

Bit 7 **MSM**: Master/slave mode

0: No action

1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between the current timer and its slaves (through TRGO). It is useful if we want to synchronize several timers on a single external event.

Bits 6:4 **TS[2:0]**: Trigger selection

This bit-field selects the trigger input to be used to synchronize the counter.

- 000: Internal Trigger 0 (ITR0)
- 001: Reserved
- 010: Internal Trigger 2 (ITR2)
- 011: Internal Trigger 3 (ITR3)
- 100: TI1 Edge Detector (TI1F_ED)
- 101: Filtered Timer Input 1 (TI1FP1)
- 110: Filtered Timer Input 2 (TI2FP2)
- 111: External Trigger input (ETRF)

See [Table 45: TIMx Internal trigger connection on page 273](#) for more details on ITRx meaning for each Timer.

Note: These bits must be changed only when they are not used (e.g. when SMS=000) to avoid wrong edge detections at the transition.

Bit 3 **OCCS**: OCREF clear selection.

This bit is used to select the OCREF clear source.

- 0: OCREF_CLR_INT is connected to the OCREF_CLR input
- 1: OCREF_CLR_INT is connected to ETRF

Bits 2:0 **SMS**: Slave mode selection

When external signals are selected the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).

- 000: Slave mode disabled - if CEN = '1' then the prescaler is clocked directly by the internal clock.
- 001: Encoder mode 1 - Counter counts up/down on TI2FP1 edge depending on TI1FP2 level.
- 010: Encoder mode 2 - Counter counts up/down on TI1FP2 edge depending on TI2FP1 level.
- 011: Encoder mode 3 - Counter counts up/down on both TI1FP1 and TI2FP2 edges depending on the level of the other input.
- 100: Reset Mode - Rising edge of the selected trigger input (TRGI) reinitializes the counter and generates an update of the registers.
- 101: Gated Mode - The counter clock is enabled when the trigger input (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.
- 110: Trigger Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.
- 111: External Clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

Note: The gated mode must not be used if TI1F_ED is selected as the trigger input (TS='100'). Indeed, TI1F_ED outputs 1 pulse for each transition on TI1F, whereas the gated mode checks the level of the trigger signal.

Note: The clock of the slave timer must be enabled prior to receive events from the master timer, and must not be changed on-the-fly while triggers are received from the master timer.

Table 45. TIMx Internal trigger connection

Slave TIM	ITR0 (TS = 000)	ITR2 (TS = 010)	ITR3 (TS = 011)
TIM1	TIM15	TIM3	TIM17

13.4.4 TIM1 DMA/interrupt enable register (TIM1_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TDE	COMDE	CC4DE	CC3DE	CC2DE	CC1DE	UDE	BIE	TIE	COMIE	CC4IE	CC3IE	CC2IE	CC1IE	UIE
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 15 Reserved, must be kept at reset value.

Bit 14 **TDE**: Trigger DMA request enable

0: Trigger DMA request disabled

1: Trigger DMA request enabled

Bit 13 **COMDE**: COM DMA request enable

0: COM DMA request disabled

1: COM DMA request enabled

Bit 12 **CC4DE**: Capture/Compare 4 DMA request enable

0: CC4 DMA request disabled

1: CC4 DMA request enabled

Bit 11 **CC3DE**: Capture/Compare 3 DMA request enable

0: CC3 DMA request disabled

1: CC3 DMA request enabled

Bit 10 **CC2DE**: Capture/Compare 2 DMA request enable

0: CC2 DMA request disabled

1: CC2 DMA request enabled

Bit 9 **CC1DE**: Capture/Compare 1 DMA request enable

0: CC1 DMA request disabled

1: CC1 DMA request enabled

Bit 8 **UDE**: Update DMA request enable

0: Update DMA request disabled

1: Update DMA request enabled

Bit 7 **BIE**: Break interrupt enable

0: Break interrupt disabled

1: Break interrupt enabled

Bit 6 **TIE**: Trigger interrupt enable

0: Trigger interrupt disabled

1: Trigger interrupt enabled

Bit 5 **COMIE**: COM interrupt enable

0: COM interrupt disabled

1: COM interrupt enabled

Bit 4 **CC4IE**: Capture/Compare 4 interrupt enable

0: CC4 interrupt disabled

1: CC4 interrupt enabled

Bit 3 **CC3IE**: Capture/Compare 3 interrupt enable

0: CC3 interrupt disabled

1: CC3 interrupt enabled

Bit 2 **CC2IE**: Capture/Compare 2 interrupt enable

0: CC2 interrupt disabled

1: CC2 interrupt enabled

Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable

0: CC1 interrupt disabled

1: CC1 interrupt enabled

Bit 0 **UIE**: Update interrupt enable

0: Update interrupt disabled

1: Update interrupt enabled

13.4.5 TIM1 status register (TIM1_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	CC4OF	CC3OF	CC2OF	CC1OF	Res.	BIF	TIF	COMIF	CC4IF	CC3IF	CC2IF	CC1IF	UIF
			rc_w0	rc_w0	rc_w0	rc_w0		rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0

Bits 15:13 Reserved, must be kept at reset value.

Bit 12 **CC4OF**: Capture/Compare 4 overcapture flag
refer to CC1OF description

Bit 11 **CC3OF**: Capture/Compare 3 overcapture flag
refer to CC1OF description

Bit 10 **CC2OF**: Capture/Compare 2 overcapture flag
refer to CC1OF description

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag
This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.
0: No overcapture has been detected.
1: The counter value has been captured in TIMx_CCR1 register while CC1IF flag was already set

Bit 8 Reserved, must be kept at reset value.

Bit 7 **BIF**: Break interrupt flag
This flag is set by hardware as soon as the break input goes active. It can be cleared by software if the break input is not active.
0: No break event occurred.
1: An active level has been detected on the break input.

Bit 6 **TIF**: Trigger interrupt flag
This flag is set by hardware on trigger event (active edge detected on TRGI input when the slave mode controller is enabled in all modes but gated mode. It is cleared by software.
0: No trigger event occurred.
1: Trigger interrupt pending.

Bit 5 **COMIF**: COM interrupt flag
This flag is set by hardware on COM event (when Capture/compare Control bits - CCxE, CCxNE, OCxM - have been updated). It is cleared by software by writing it to '0'.
0: No COM event occurred.
1: COM interrupt pending.

Bit 4 **CC4IF**: Capture/Compare 4 interrupt flag
refer to CC1IF description

Bit 3 **CC3IF**: Capture/Compare 3 interrupt flag
refer to CC1IF description

Bit 2 **CC2IF**: Capture/Compare 2 interrupt flag
refer to CC1IF description

Bit 1 **CC1IF**: Capture/Compare 1 interrupt flag

If channel CC1 is configured as output:

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits in the TIMx_CR1 register description). It is cleared by software.

0: No match.

1: The content of the counter TIMx_CNT matches the content of the TIMx_CCR1 register. When the contents of TIMx_CCR1 are greater than the contents of TIMx_ARR, the CC1IF bit goes high on the counter overflow (in upcounting and up/down-counting modes) or underflow (in downcounting mode)

If channel CC1 is configured as input:

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx_CCR1 register.

0: No input capture occurred

1: The counter value has been captured in TIMx_CCR1 register (An edge has been detected on IC1 which matches the selected polarity)

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

–At overflow or underflow regarding the repetition counter value (update if repetition counter = 0) and if the UDIS=0 in the TIMx_CR1 register.

–When CNT is reinitialized by software using the UG bit in TIMx_EGR register, if URS=0 and UDIS=0 in the TIMx_CR1 register.

–When CNT is reinitialized by a trigger event (refer to [Section 13.4.3: TIM1 slave mode control register \(TIM1_SMCR\)](#)), if URS=0 and UDIS=0 in the TIMx_CR1 register.

13.4.6 TIM1 event generation register (TIM1_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BG	TG	COMG	CC4G	CC3G	CC2G	CC1G	UG
								w	w	w	w	w	w	w	w

Bits 15:8 Reserved, must be kept at reset value.

Bit 7 **BG**: Break generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A break event is generated. MOE bit is cleared and BIF flag is set. Related interrupt or DMA transfer can occur if enabled.

Bit 6 **TG**: Trigger generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: The TIF flag is set in TIMx_SR register. Related interrupt or DMA transfer can occur if enabled.

Bit 5 **COMG**: Capture/Compare control update generation

This bit can be set by software, it is automatically cleared by hardware

0: No action

1: When CCPC bit is set, it allows to update CCxE, CCxNE and OCxM bits

Note: This bit acts only on channels having a complementary output.

Bit 4 **CC4G**: Capture/Compare 4 generation

Refer to CC1G description

Bit 3 **CC3G**: Capture/Compare 3 generation

Refer to CC1G description

Bit 2 **CC2G**: Capture/Compare 2 generation

Refer to CC1G description

Bit 1 **CC1G**: Capture/Compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

If channel CC1 is configured as output:

CC1IF flag is set, Corresponding interrupt or DMA request is sent if enabled.

If channel CC1 is configured as input:

The current value of the counter is captured in TIMx_CCR1 register. The CC1IF flag is set, the corresponding interrupt or DMA request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: Reinitialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared if the center-aligned mode is selected or if DIR=0 (upcounting), else it takes the auto-reload value (TIMx_ARR) if DIR=1 (downcounting).

13.4.7 TIM1 capture/compare mode register 1 (TIM1_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CCxS bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OCxx describes its function when the channel is configured in output, ICxx describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OC2 CE	OC2M[2:0]			OC2 PE	OC2 FE	CC2S[1:0]		OC1 CE	OC1M[2:0]			OC1 PE	OC1 FE	CC1S[1:0]	
IC2F[3:0]			IC2PSC[1:0]		IC1F[3:0]			IC1PSC[1:0]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Output compare mode

Bit 15 **OC2CE**: Output Compare 2 clear enable

Bits 14:12 **OC2M[2:0]**: Output Compare 2 mode

Bit 11 **OC2PE**: Output Compare 2 preload enable

Bit 10 **OC2FE**: Output Compare 2 fast enable

Bits 9:8 **CC2S[1:0]**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output

01: CC2 channel is configured as input, IC2 is mapped on TI2

10: CC2 channel is configured as input, IC2 is mapped on TI1

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through the TS bit (TIMx_SMCR register)

Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx_CCER).

Bit 7 **OC1CE**: Output Compare 1 clear enable

OC1CE: Output Compare 1 Clear Enable

0: OC1Ref is not affected by the ETRF Input

1: OC1Ref is cleared as soon as a High level is detected on ETRF input

Bits 6:4 **OC1M**: Output Compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

000: Frozen - The comparison between the output compare register TIMx_CCR1 and the counter TIMx_CNT has no effect on the outputs (this mode is used to generate a timing base).

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

011: Toggle - OC1REF toggles when TIMx_CNT=TIMx_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx_CNT<TIMx_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF='0') as long as TIMx_CNT>TIMx_CCR1 else active (OC1REF='1').

111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx_CNT<TIMx_CCR1 else active. In downcounting, channel 1 is active as long as TIMx_CNT>TIMx_CCR1 else inactive.

Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S='00' (the channel is configured in output).

2: In PWM mode 1 or 2, the OCREF level changes only when the result of the comparison changes or when the output compare mode switches from "frozen" mode to "PWM" mode.

3: On channels having a complementary output, this bit field is preloaded. If the CCPC bit is set in the TIMx_CR2 register then the OC1M active bits take the new value from the preloaded bits only when a COM event is generated.

Bit 3 **OC1PE**: Output Compare 1 preload enable

0: Preload register on TIMx_CCR1 disabled. TIMx_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx_CCR1 enabled. Read/Write operations access the preload register. TIMx_CCR1 preload value is loaded in the active register at each update event.

Note: **1:** These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S='00' (the channel is configured in output).

2: The PWM mode can be used without validating the preload register only in one pulse mode (OPM bit set in TIMx_CR1 register). Else the behavior is not guaranteed.

Bit 2 **OC1FE**: Output Compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger in input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently from the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OCFE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output

01: CC1 channel is configured as input, IC1 is mapped on TI1

10: CC1 channel is configured as input, IC1 is mapped on TI2

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx_CCER).

Input capture mode

Bits 15:12 **IC2F**: Input capture 2 filter

Bits 11:10 **IC2PSC[1:0]**: Input capture 2 prescaler

Bits 9:8 **CC2S**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output

01: CC2 channel is configured as input, IC2 is mapped on TI2

10: CC2 channel is configured as input, IC2 is mapped on TI1

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx_CCER).

Bits 7:4 **IC1F[3:0]**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N consecutive events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{DTS}
 0001: $f_{SAMPLING} = f_{CK\_INT}$, $N = 2$
 0010: $f_{SAMPLING} = f_{CK\_INT}$, $N = 4$
 0011: $f_{SAMPLING} = f_{CK\_INT}$, $N = 8$
 0100: $f_{SAMPLING} = f_{DTS} / 2$, $N = 6$
 0101: $f_{SAMPLING} = f_{DTS} / 2$, $N = 8$
 0110: $f_{SAMPLING} = f_{DTS} / 4$, $N = 6$
 0111: $f_{SAMPLING} = f_{DTS} / 4$, $N = 8$
 1000: $f_{SAMPLING} = f_{DTS} / 8$, $N = 6$
 1001: $f_{SAMPLING} = f_{DTS} / 8$, $N = 8$
 1010: $f_{SAMPLING} = f_{DTS} / 16$, $N = 5$
 1011: $f_{SAMPLING} = f_{DTS} / 16$, $N = 6$
 1100: $f_{SAMPLING} = f_{DTS} / 16$, $N = 8$
 1101: $f_{SAMPLING} = f_{DTS} / 32$, $N = 5$
 1110: $f_{SAMPLING} = f_{DTS} / 32$, $N = 6$
 1111: $f_{SAMPLING} = f_{DTS} / 32$, $N = 8$

Note: Care must be taken that f_{DTS} is replaced in the formula by CK_INT when $ICx_F[3:0] = 1, 2$ or 3 .

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).
 The prescaler is reset as soon as $CC1E = '0'$ (TIMx_CCER register).

00: no prescaler, capture is done each time an edge is detected on the capture input
 01: capture is done once every 2 events
 10: capture is done once every 4 events
 11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output
 01: CC1 channel is configured as input, IC1 is mapped on TI1
 10: CC1 channel is configured as input, IC1 is mapped on TI2
 11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC1S bits are writable only when the channel is OFF ($CC1E = '0'$ in TIMx_CCER).

13.4.8 TIM1 capture/compare mode register 2 (TIM1_CCMR2)

Address offset: 0x1C

Reset value: 0x0000

Refer to the above CCMR1 register description.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
OC4 CE	OC4M[2:0]				OC4 PE	OC4 FE	CC4S[1:0]		OC3 CE	OC3M[2:0]				OC3 PE	OC3 FE	CC3S[1:0]	
IC4F[3:0]					IC4PSC[1:0]				IC3F[3:0]					IC3PSC[1:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw		

Output compare mode

Bit 15 **OC4CE**: Output compare 4 clear enable

Bits 14:12 **OC4M**: Output compare 4 mode

Bit 11 **OC4PE**: Output compare 4 preload enable

Bit 10 **OC4FE**: Output compare 4 fast enable

Bits 9:8 **CC4S**: Capture/Compare 4 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output

01: CC4 channel is configured as input, IC4 is mapped on TI4

10: CC4 channel is configured as input, IC4 is mapped on TI3

11: CC4 channel is configured as input, IC4 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC4S bits are writable only when the channel is OFF (CC4E = '0' in TIMx_CCER).

Bit 7 **OC3CE**: Output compare 3 clear enable

Bits 6:4 **OC3M**: Output compare 3 mode

Bit 3 **OC3PE**: Output compare 3 preload enable

Bit 2 **OC3FE**: Output compare 3 fast enable

Bits 1:0 **CC3S**: Capture/Compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3

10: CC3 channel is configured as input, IC3 is mapped on TI4

11: CC3 channel is configured as input, IC3 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC3S bits are writable only when the channel is OFF (CC3E = '0' in TIMx_CCER).

Input capture mode

Bits 15:12 **IC4F**: Input capture 4 filter

Bits 11:10 **IC4PSC**: Input capture 4 prescaler

Bits 9:8 **CC4S**: Capture/Compare 4 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output

01: CC4 channel is configured as input, IC4 is mapped on TI4

10: CC4 channel is configured as input, IC4 is mapped on TI3

11: CC4 channel is configured as input, IC4 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC4S bits are writable only when the channel is OFF (CC4E = '0' in TIMx_CCER).

Bits 7:4 **IC3F**: Input capture 3 filter

Bits 3:2 **IC3PSC**: Input capture 3 prescaler

Bits 1:0 **CC3S**: Capture/compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3

10: CC3 channel is configured as input, IC3 is mapped on TI4

11: CC3 channel is configured as input, IC3 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC3S bits are writable only when the channel is OFF (CC3E = '0' in TIMx_CCER).

13.4.9 TIM1 capture/compare enable register (TIM1_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	CC4P	CC4E	CC3NP	CC3NE	CC3P	CC3E	CC2NP	CC2NE	CC2P	CC2E	CC1NP	CC1NE	CC1P	CC1E
		rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:14 Reserved, must be kept at reset value.

Bit 13 **CC4P**: Capture/Compare 4 output polarity
refer to CC1P description

Bit 12 **CC4E**: Capture/Compare 4 output enable
refer to CC1E description

Bit 11 **CC3NP**: Capture/Compare 3 complementary output polarity
refer to CC1NP description

Bit 10 **CC3NE**: Capture/Compare 3 complementary output enable
refer to CC1NE description

Bit 9 **CC3P**: Capture/Compare 3 output polarity
refer to CC1P description

Bit 8 **CC3E**: Capture/Compare 3 output enable
refer to CC1E description

Bit 7 **CC2NP**: Capture/Compare 2 complementary output polarity
refer to CC1NP description

Bit 6 **CC2NE**: Capture/Compare 2 complementary output enable
refer to CC1NE description

Bit 5 **CC2P**: Capture/Compare 2 output polarity
refer to CC1P description

Bit 4 **CC2E**: Capture/Compare 2 output enable
refer to CC1E description

Bit 3 **CC1NP**: Capture/Compare 1 complementary output polarity

CC1 channel configuration as output:

- 0: OC1N active high.
- 1: OC1N active low.

CC1 channel configuration as input:

This bit is used in conjunction with CC1P to define the polarity of TI1FP1 and TI2FP1. Refer to CC1P description.

Note: On channels having a complementary output, this bit is preloaded. If the CCPC bit is set in the TIMx_CR2 register then the CC1NP active bit takes the new value from the preloaded bits only when a Commutation event is generated.

Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S="00" (the channel is configured in output).

Bit 2 **CC1NE**: Capture/Compare 1 complementary output enable

- 0: Off - OC1N is not active. OC1N level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.
- 1: On - OC1N signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.

Note: On channels having a complementary output, this bit is preloaded. If the CCPC bit is set in the TIMx_CR2 register then the CC1NE active bit takes the new value from the preloaded bits only when a Commutation event is generated.

Bit 1 **CC1P**: Capture/Compare 1 output polarity

CC1 channel configured as output:

- 0: OC1 active high
- 1: OC1 active low

CC1 channel configured as input:

CC1NP/CC1P bits select the active polarity of TI1FP1 and TI2FP1 for trigger or capture operations.

00: non-inverted/rising edge

The circuit is sensitive to TIxFP1 rising edge (capture or trigger operations in reset, external clock or trigger mode), TIxFP1 is not inverted (trigger operation in gated mode or encoder mode).

01: inverted/falling edge

The circuit is sensitive to TIxFP1 falling edge (capture or trigger operations in reset, external clock or trigger mode), TIxFP1 is inverted (trigger operation in gated mode or encoder mode).

10: reserved, do not use this configuration.

11: non-inverted/both edges

The circuit is sensitive to both TIxFP1 rising and falling edges (capture or trigger operations in reset, external clock or trigger mode), TIxFP1 is not inverted (trigger operation in gated mode). This configuration must not be used in encoder mode.

Note: On channels having a complementary output, this bit is preloaded. If the CCPC bit is set in the TIMx_CR2 register then the CC1P active bit takes the new value from the preloaded bits only when a Commutation event is generated.

Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 0 **CC1E**: Capture/Compare 1 output enable

CC1 channel configured as output:

0: Off - OC1 is not active. OC1 level is then function of MOE, OSSI, OSSR, OIS1, OIS1N and CC1NE bits.

1: On - OC1 signal is output on the corresponding output pin depending on MOE, OSSI, OSSR, OIS1, OIS1N and CC1NE bits.

CC1 channel configured as input:

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx_CCR1) or not.

0: Capture disabled.

1: Capture enabled.

Note: On channels having a complementary output, this bit is preloaded. If the CCPC bit is set in the TIMx_CR2 register then the CC1E active bit takes the new value from the preloaded bits only when a Commutation event is generated.

Table 46. Output control bits for complementary OCx and OCxN channels with break feature

Control bits					Output states ⁽¹⁾	
MOE bit	OSSI bit	OSSR bit	CCxE bit	CCxNE bit	OCx output state	OCxN output state
1	X	0	0	0	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	0	1	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		0	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
		1	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
		1	0	1	Off-State (output enabled with inactive state) OCx=CCxP, OCx_EN=1	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		1	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Off-State (output enabled with inactive state) OCxN=CCxNP, OCxN_EN=1
		1	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1

Table 46. Output control bits for complementary OCx and OCxN channels with break feature (continued)

Control bits					Output states ⁽¹⁾	
MOE bit	OSSI bit	OSSR bit	CCxE bit	CCxNE bit	OCx output state	OCxN output state
0	0	X	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
	0		0	1	Output Disabled (not driven by the timer) Asynchronously: OCx=CCxP, OCx_EN=0, OCxN=CCxNP, OCxN_EN=0 Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCx and OCxN both in active state.	
	0		1	0		
	0		1	1	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0 Off-State (output enabled with inactive state) Asynchronously: OCx=CCxP, OCx_EN=1, OCxN=CCxNP, OCxN_EN=1 Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCx and OCxN both in active state.	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
	1		0	0		
	1		0	1		
	1		1	0		
	1		1	1		

1. When both outputs of a channel are not used (CCxE = CCxNE = 0), the OISx, OISxN, CCxP and CCxNP bits must be kept cleared.

Note: The state of the external I/O pins connected to the complementary OCx and OCxN channels depends on the OCx and OCxN channel state and the GPIO registers.

13.4.10 TIM1 counter (TIM1_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 CNT[15:0]: Counter value

13.4.11 TIM1 prescaler (TIM1_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency (f_{CK_CNT}) is equal to $f_{CK\_PSC} / (PSC[15:0] + 1)$.

PSC contains the value to be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIMx_EGR register or through trigger controller when configured in “reset mode”).

13.4.12 TIM1 auto-reload register (TIM1_ARR)

Address offset: 0x2C

Reset value: 0xFFFF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 13.3.1: Time-base unit on page 223](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

13.4.13 TIM1 repetition counter register (TIM1_RCR)

Address offset: 0x30

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	REP[7:0]							
								rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:8 Reserved, must be kept at reset value.

Bits 7:0 **REP[7:0]**: Repetition counter value

These bits allow the user to set-up the update rate of the compare registers (i.e. periodic transfers from preload to active registers) when preload registers are enable, as well as the update interrupt generation rate, if this interrupt is enable.

Each time the REP_CNT related downcounter reaches zero, an update event is generated and it restarts counting from REP value. As REP_CNT is reloaded with REP value only at the repetition update event U_RC, any write to the TIMx_RCR register is not taken in account until the next repetition update event.

It means in PWM mode (REP+1) corresponds to:

- the number of PWM periods in edge-aligned mode
- the number of half PWM period in center-aligned mode.

13.4.14 TIM1 capture/compare register 1 (TIM1_CCR1)

Address offset: 0x34

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR1[15:0]**: Capture/Compare 1 value

If channel CC1 is configured as output:

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signaled on OC1 output.

If channel CC1 is configured as input:

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

13.4.15 TIM1 capture/compare register 2 (TIM1_CCR2)

Address offset: 0x38

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR2[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR2[15:0]**: Capture/Compare 2 value

If channel CC2 is configured as output:

CCR2 is the value to be loaded in the actual capture/compare 2 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR2 register (bit OC2PE). Else the preload value is copied in the active capture/compare 2 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signalled on OC2 output.

If channel CC2 is configured as input:

CCR2 is the counter value transferred by the last input capture 2 event (IC2).

13.4.16 TIM1 capture/compare register 3 (TIM1_CCR3)

Address offset: 0x3C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR3[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR3[15:0]**: Capture/Compare value

If channel CC3 is configured as output:

CCR3 is the value to be loaded in the actual capture/compare 3 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR3 register (bit OC3PE). Else the preload value is copied in the active capture/compare 3 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signalled on OC3 output.

If channel CC3 is configured as input:

CCR3 is the counter value transferred by the last input capture 3 event (IC3).

13.4.17 TIM1 capture/compare register 4 (TIM1_CCR4)

Address offset: 0x40

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR4[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR4[15:0]**: Capture/Compare value

If channel CC4 is configured as output:

CCR4 is the value to be loaded in the actual capture/compare 4 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR4 register (bit OC4PE). Else the preload value is copied in the active capture/compare 4 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signalled on OC4 output.

If channel CC4 is configured as input:

CCR4 is the counter value transferred by the last input capture 4 event (IC4).

13.4.18 TIM1 break and dead-time register (TIM1_BDTR)

Address offset: 0x44

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK[1:0]		DTG[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Note: As the bits AOE, BKP, BKE, OSSI, OSSR and DTG[7:0] can be write-locked depending on the LOCK configuration, it can be necessary to configure all of them during the first write access to the TIMx_BDTR register.

Bit 15 **MOE**: Main output enable

This bit is cleared asynchronously by hardware as soon as the break input is active. It is set by software or automatically depending on the AOE bit. It is acting only on the channels which are configured in output.

0: OC and OCN outputs are disabled or forced to idle state.

1: OC and OCN outputs are enabled if their respective enable bits are set (CCxE, CCxNE in TIMx_CCER register).

See OC/OCN enable description for more details ([Section 13.4.9: TIM1 capture/compare enable register \(TIM1_CCER\) on page 284](#)).

Bit 14 **AOE**: Automatic output enable

0: MOE can be set only by software

1: MOE can be set by software or automatically at the next update event (if the break input is not be active)

Note: This bit cannot be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 13 **BKP**: Break polarity

- 0: Break input BRK is active low
- 1: Break input BRK is active high

Note: This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.

Bit 12 **BKE**: Break enable

- 0: Break inputs (BRK and CCS clock failure event) disabled
- 1: Break inputs (BRK and CCS clock failure event) enabled

Note: This bit cannot be modified when LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.

Bit 11 **OSSR**: Off-state selection for Run mode

This bit is used when MOE=1 on channels having a complementary output which are configured as outputs. OSSR is not implemented if no complementary output is implemented in the timer.

See OC/OCN enable description for more details ([Section 13.4.9: TIM1 capture/compare enable register \(TIM1_CCER\) on page 284](#)).

- 0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0).
- 1: When inactive, OC/OCN outputs are enabled with their inactive level as soon as CCxE=1 or CCxNE=1. Then, OC/OCN enable output signal=1

Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 10 **OSSI**: Off-state selection for Idle mode

This bit is used when MOE=0 on channels configured as outputs.

See OC/OCN enable description for more details ([Section 13.4.9: TIM1 capture/compare enable register \(TIM1_CCER\) on page 284](#)).

- 0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0).
- 1: When inactive, OC/OCN outputs are forced first with their idle level as soon as CCxE=1 or CCxNE=1. OC/OCN enable output signal=1

Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx_BDTR register).

Bits 9:8 **LOCK[1:0]**: Lock configuration

These bits offer a write protection against software errors.

- 00: LOCK OFF - No bit is write protected.
- 01: LOCK Level 1 = DTG bits in TIMx_BDTR register, OISx and OISxN bits in TIMx_CR2 register and BKE/BKP/AOE bits in TIMx_BDTR register can no longer be written.
- 10: LOCK Level 2 = LOCK Level 1 + CC Polarity bits (CCxP/CCxNP bits in TIMx_CCER register, as long as the related channel is configured in output through the CCxS bits) as well as OSSR and OSSI bits can no longer be written.
- 11: LOCK Level 3 = LOCK Level 2 + CC Control bits (OCxM and OCxPE bits in TIMx_CCMRx registers, as long as the related channel is configured in output through the CCxS bits) can no longer be written.

Note: The LOCK bits can be written only once after the reset. Once the TIMx_BDTR register has been written, their content is frozen until the next reset.

Bits 7:0 **DTG[7:0]**: Dead-time generator setup

This bit-field defines the duration of the dead-time inserted between the complementary outputs. DT correspond to this duration.

DTG[7:5]=0xx => $DT = DTG[7:0] \times t_{dtg}$ with $t_{dtg} = t_{DTS}$.

DTG[7:5]=10x => $DT = (64 + DTG[5:0]) \times t_{dtg}$ with $T_{dtg} = 2 \times t_{DTS}$.

DTG[7:5]=110 => $DT = (32 + DTG[4:0]) \times t_{dtg}$ with $T_{dtg} = 8 \times t_{DTS}$.

DTG[7:5]=111 => $DT = (32 + DTG[4:0]) \times t_{dtg}$ with $T_{dtg} = 16 \times t_{DTS}$.

Example if $T_{DTS} = 125$ ns (8 MHz), dead-time possible values are:

0 to 15875 ns by 125 ns steps,

16 us to 31750 ns by 250 ns steps,

32 us to 63 us by 1 us steps,

64 us to 126 us by 2 us steps

Note: This bit-field can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register).

13.4.19 TIM1 DMA control register (TIM1_DCR)

Address offset: 0x48

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBL[4:0]					Res.	Res.	Res.	DBA[4:0]				
			rw	rw	rw	rw	rw				rw	rw	rw	rw	rw

Bits 15:13 Reserved, must be kept at reset value.

Bits 12:8 **DBL[4:0]**: DMA burst length

This 5-bit vector defines the number of DMA transfers (the timer recognizes a burst transfer when a read or a write access is done to the TIMx_DMAR address)

00000: 1 transfer

00001: 2 transfers

00010: 3 transfers

...

10001: 18 transfers

Bits 7:5 Reserved, must be kept at reset value.

Bits 4:0 **DBA[4:0]**: DMA base address

This 5-bit vector defines the base-address for DMA transfers (when read/write access are done through the TIMx_DMAR address). DBA is defined as an offset starting from the address of the TIMx_CR1 register.

Example:

00000: TIMx_CR1,

00001: TIMx_CR2,

00010: TIMx_SMCR,

...

Example: Let us consider the following transfer: DBL = 7 transfers and DBA = TIMx_CR1. In this case the transfer is done to/from 7 registers starting from the TIMx_CR1 address.

13.4.20 TIM1 DMA address for full transfer (TIM1_DMAR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMAB[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DMAB[15:0]**: DMA register for burst accesses

A read or write operation to the DMAR register accesses the register located at the address (TIMx_CR1 address) + (DBA + DMA index) x 4

where TIMx_CR1 address is the address of the control register 1, DBA is the DMA base address configured in TIMx_DCR register, DMA index is automatically controlled by the DMA transfer, and ranges from 0 to DBL (DBL configured in TIMx_DCR).

Example of how to use the DMA burst feature

In this example the timer DMA burst feature is used to update the contents of the CCRx registers (x = 2, 3, 4) with the DMA transferring half words into the CCRx registers.

This is done in the following steps:

1. Configure the corresponding DMA channel as follows:
 - DMA channel peripheral address is the DMAR register address
 - DMA channel memory address is the address of the buffer in the RAM containing the data to be transferred by DMA into CCRx registers.
 - Number of data to transfer = 3 (See note below).
 - Circular mode disabled.
2. Configure the DCR register by configuring the DBA and DBL bit fields as follows:
DBL = 3 transfers, DBA = 0xE.
3. Enable the TIMx update DMA request (set the UDE bit in the DIER register).
4. Enable TIMx
5. Enable the DMA channel

Note: This example is for the case where every CCRx register to be updated once. If every CCRx register is to be updated twice for example, the number of data to transfer should be 6. Let's take the example of a buffer in the RAM containing data1, data2, data3, data4, data5 and data6. The data is transferred to the CCRx registers as follows: on the first update DMA request, data1 is transferred to CCR2, data2 is transferred to CCR3, data3 is transferred to CCR4 and on the second update DMA request, data4 is transferred to CCR2, data5 is transferred to CCR3 and data6 is transferred to CCR4.

13.4.21 TIM1 register map

TIM1 registers are mapped as 16-bit addressable registers as described in the table below:

Table 47. TIM1 register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0		
0x00	TIM1_CR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CKD [1:0]			CMS [1:0]		DIR	OPM	URS	UDIS	CEN		
	Reset value																																		
0x04	TIM1_CR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OIS4	OIS3N	OIS3	OIS2N	OIS2	OIS1N	OIS1	THS	MMS[2:0]			CCDS	CCUS	Res.	CCPC		
	Reset value																																		
0x08	TIM1_SMCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ETP	ECE	ETPS [1:0]		ETF[3:0]		MSM		TS[2:0]		OCCS		SMS[2:0]					
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x0C	TIM1_DIER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TDE	COMDE	CC4DE	CC3DE	CC2DE	CC1DE	UDE	BIE	TIE	COMIE	CC4IE	CC3IE	CC2IE	CC1IE	UIE		
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x10	TIM1_SR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC4OF	CC3OF	CC2OF	CC1OF	Res.	BIF	TIF	COMIF	CC4IF	CC3IF	CC2IF	CC1IF	UIF		
	Reset value																				0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x14	TIM1_EGR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BG	TG	COM	CC4G	CC3G	CC2G	CC1G	UG		
	Reset value																									0	0	0	0	0	0	0	0	0	
0x18	TIM1_CCMR1 Output compare mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OC2CE	OC2M [2:0]		OC2PE		OC2FE		CC2S [1:0]		OC1CE		OC1M [2:0]		OC1PE		CC1S [1:0]		
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	TIM1_CCMR1 Input capture mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IC2F[3:0]		IC2 PSC [1:0]		CC2S [1:0]		IC1F[3:0]		IC1 PSC [1:0]		CC1S [1:0]							
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x1C	TIM1_CCMR2 Output compare mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OC4CE	OC4M [2:0]		OC4PE		OC4FE		CC4S [1:0]		OC3CE		OC3M [2:0]		OC3PE		CC3S [1:0]		
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
	TIM1_CCMR2 Input capture mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IC4F[3:0]		IC4 PSC [1:0]		CC4S [1:0]		IC3F[3:0]		IC3 PSC [1:0]		CC3S [1:0]							
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x20	TIM1_CCER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC4P	CC4E	CC3NP	CC3NE	CC3P	CC3E	CC2NP	CC2NE	CC2P	CC2E	CC1NP	CC1NE	CC1P	CC1E		
	Reset value																				0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x24	TIM1_CNT	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CNT[15:0]																	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x28	TIM1_PSC	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PSC[15:0]																	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x2C	TIM1_ARR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ARR[15:0]																	
	Reset value																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
0x30	TIM1_RCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	REP[7:0]									
	Reset value																									0	0	0	0	0	0	0	0	0	0

Table 47. TIM1 register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x34	TIM1_CCR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CCR1[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x38	TIM1_CCR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CCR2[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x3C	TIM1_CCR3	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CCR3[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x40	TIM1_CCR4	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CCR4[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x44	TIM1_BDTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK [1:0]	DT[7:0]								
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x48	TIM1_DCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBL[4:0]				Res.	Res.	Res.	DBA[4:0]					
	Reset value																				0	0	0	0	0				0	0	0	0	0
0x4C	TIM1_DMAR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DMAB[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

14 General-purpose timers (TIM3)

14.1 TIM3 introduction

The general-purpose timers consist of a 16-bit auto-reload counter driven by a programmable prescaler.

They may be used for a variety of purposes, including measuring the pulse lengths of input signals (*input capture*) or generating output waveforms (*output compare and PWM*).

Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the RCC clock controller prescalers.

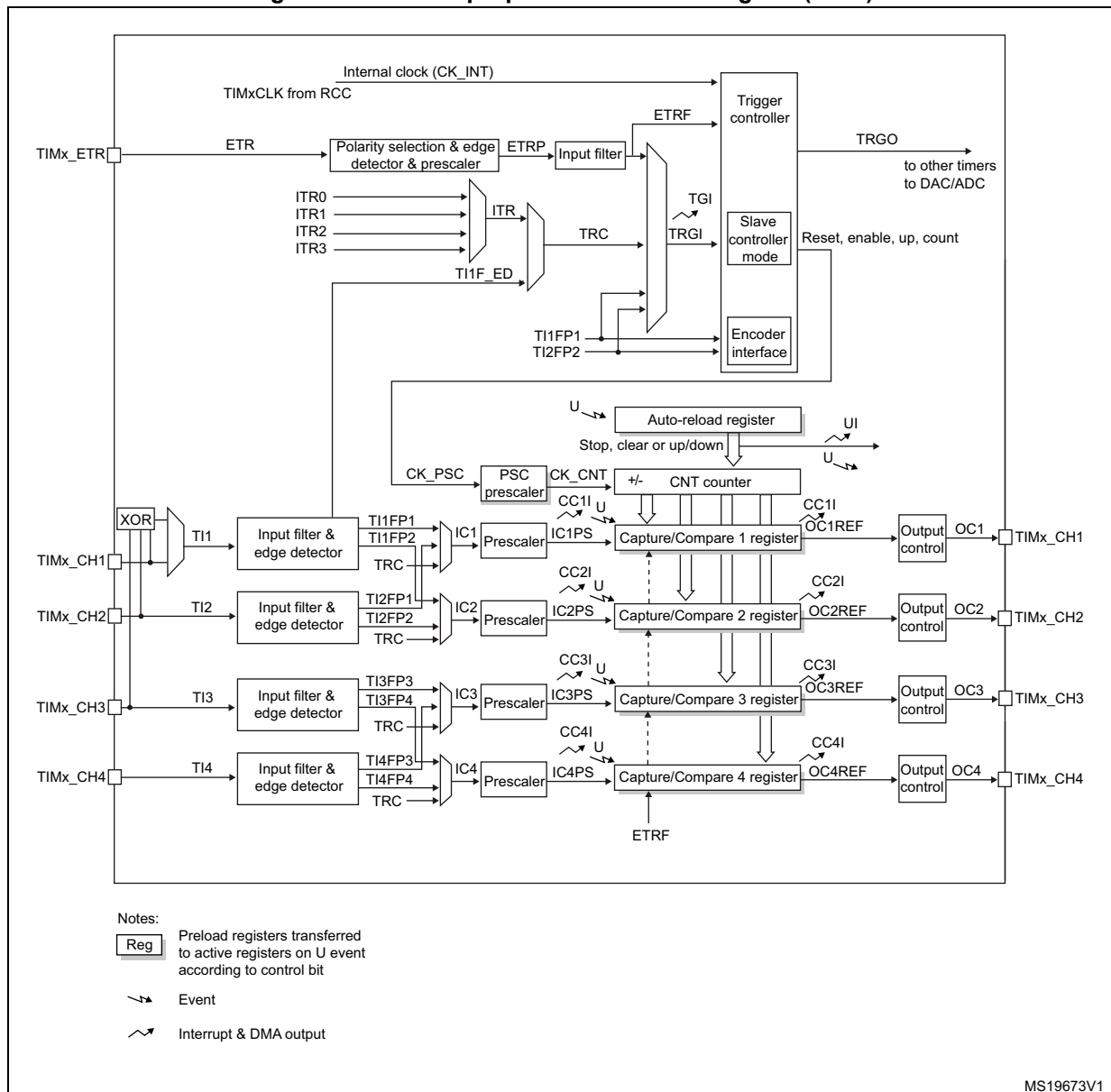
The timers are completely independent, and do not share any resources. They can be synchronized together as described in [Section 14.3.15](#).

14.2 TIM3 main features

General-purpose TIMx timer features include:

- 16-bit (TIM3) up, down, up/down auto-reload counter.
- 16-bit programmable prescaler used to divide (also “on the fly”) the counter clock frequency by any factor between 1 and 65535.
- Up to 4 independent channels for:
 - Input capture
 - Output compare
 - PWM generation (Edge- and Center-aligned modes)
 - One-pulse mode output
- Synchronization circuit to control the timer with external signals and to interconnect several timers.
- Interrupt/DMA generation on the following events:
 - Update: counter overflow/underflow, counter initialization (by software or internal/external trigger)
 - Trigger event (counter start, stop, initialization or count by internal/external trigger)
 - Input capture
 - Output compare
- Supports incremental (quadrature) encoder and hall-sensor circuitry for positioning purposes
- Trigger input for external clock or cycle-by-cycle current management

Figure 88. General-purpose timer block diagram (TIM3)



14.3 TIM3 functional description

14.3.1 Time-base unit

The main block of the programmable timer is a 16-bit/32-bit counter with its related auto-reload register. The counter can count up but also down or both up and down. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter Register (TIMx_CNT)
- Prescaler Register (TIMx_PSC)
- Auto-Reload Register (TIMx_ARR)

The auto-reload register is preloaded. Writing to or reading from the auto-reload register accesses the preload register. The content of the preload register are transferred into the shadow register permanently or at each update event (UEV), depending on the auto-reload preload enable bit (ARPE) in TIMx_CR1 register. The update event is sent when the counter reaches the overflow (or underflow when downcounting) and if the UDIS bit equals 0 in the TIMx_CR1 register. It can also be generated by software. The generation of the update event is described in detail for each configuration.

The counter is clocked by the prescaler output CK_CNT, which is enabled only when the counter enable bit (CEN) in TIMx_CR1 register is set (refer also to the slave mode controller description to get more details on counter enabling).

Note that the actual counter enable signal CNT_EN is set 1 clock cycle after CEN.

Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit/32-bit register (in the TIMx_PSC register). It can be changed on the fly as this control register is buffered. The new prescaler ratio is taken into account at the next update event.

[Figure 89](#) and [Figure 90](#) give some examples of the counter behavior when the prescaler ratio is changed on the fly:

Figure 89. Counter timing diagram with prescaler division change from 1 to 2

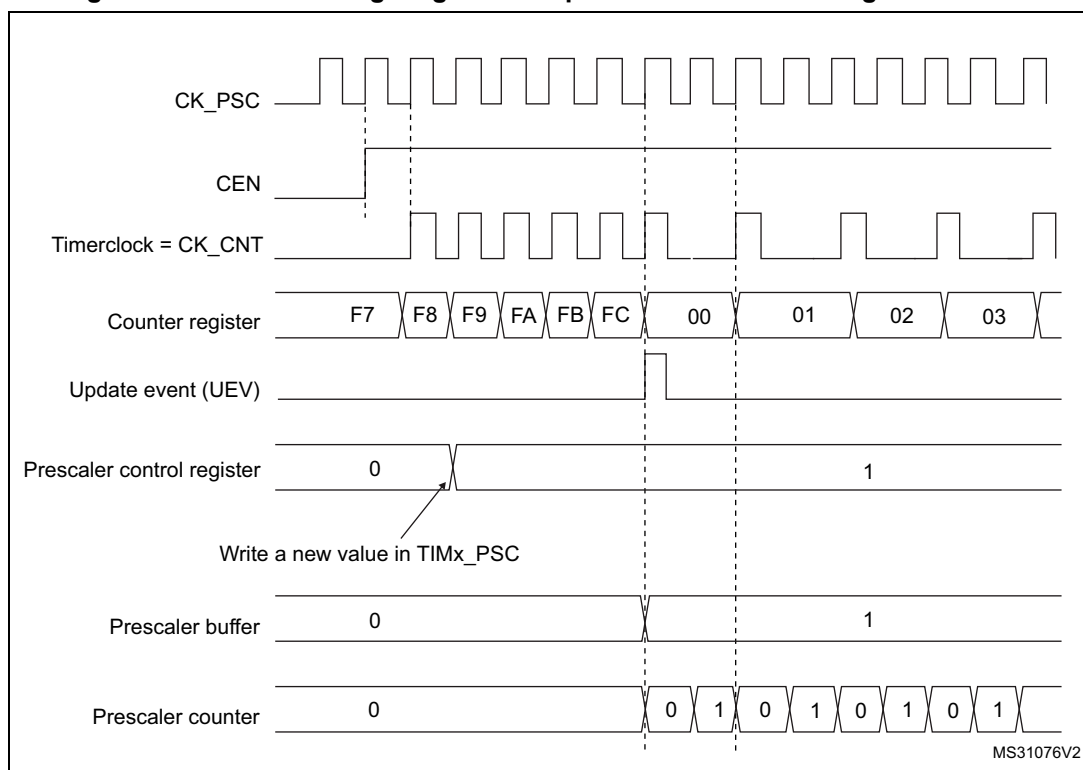
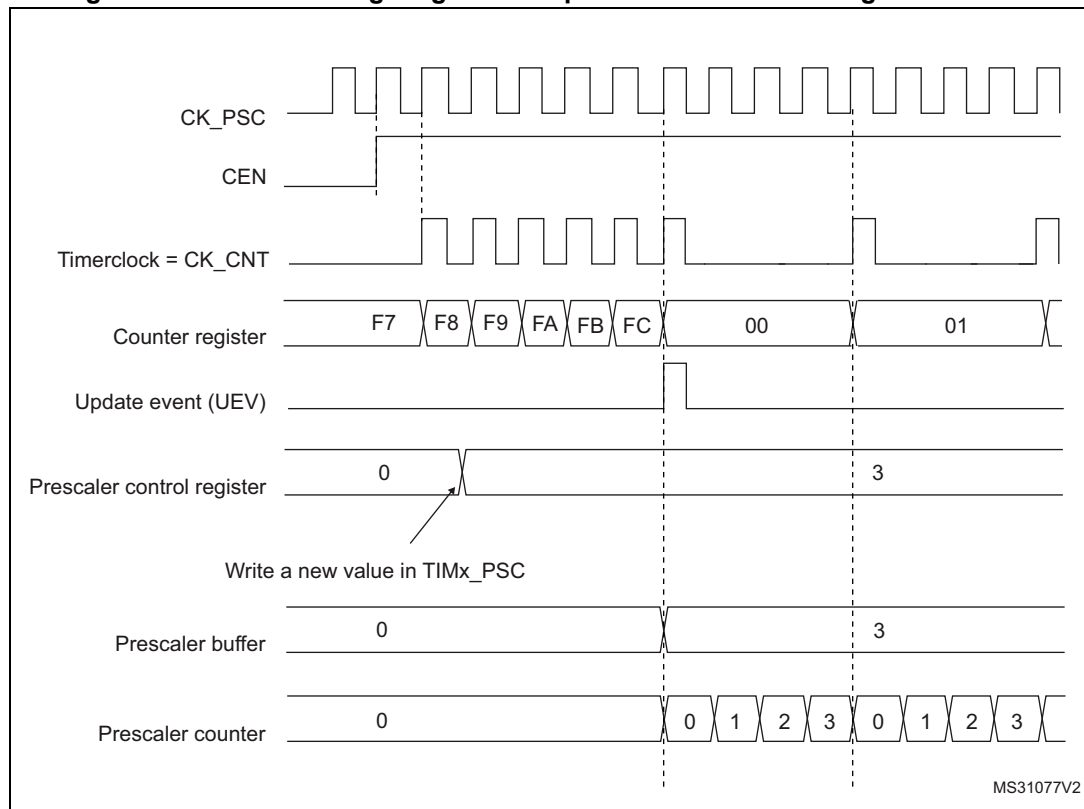


Figure 90. Counter timing diagram with prescaler division change from 1 to 4

14.3.2 Counter modes

Upcounting mode

In upcounting mode, the counter counts from 0 to the auto-reload value (content of the TIMx_ARR register), then restarts from 0 and generates a counter overflow event.

An Update event can be generated at each counter overflow or by setting the UG bit in the TIMx_EGR register (by software or by using the slave mode controller).

The UEV event can be disabled by software by setting the UDIS bit in TIMx_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescale rate does not change). In addition, if the URS bit (update request selection) in TIMx_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx_SR register) is set (depending on the URS bit):

- The buffer of the prescaler is reloaded with the preload value (content of the TIMx_PSC register)
- The auto-reload shadow register is updated with the preload value (TIMx_ARR)

The following figures show some examples of the counter behavior for different clock frequencies when TIMx_ARR=0x36.

Figure 91. Counter timing diagram, internal clock divided by 1

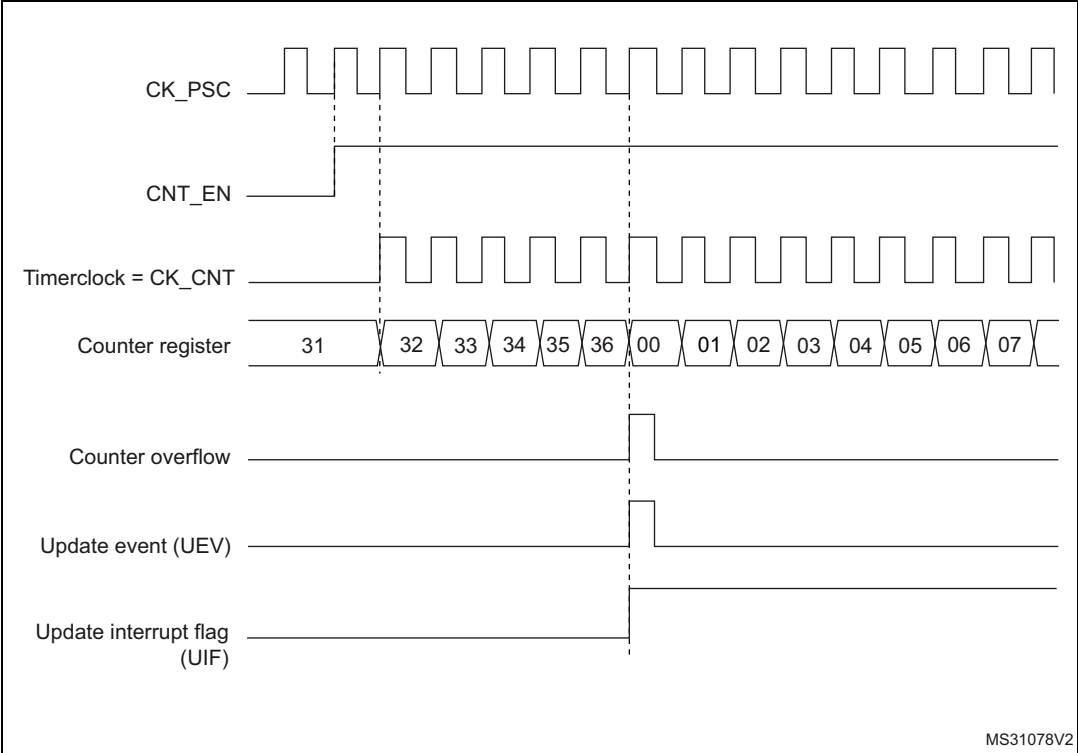


Figure 92. Counter timing diagram, internal clock divided by 2

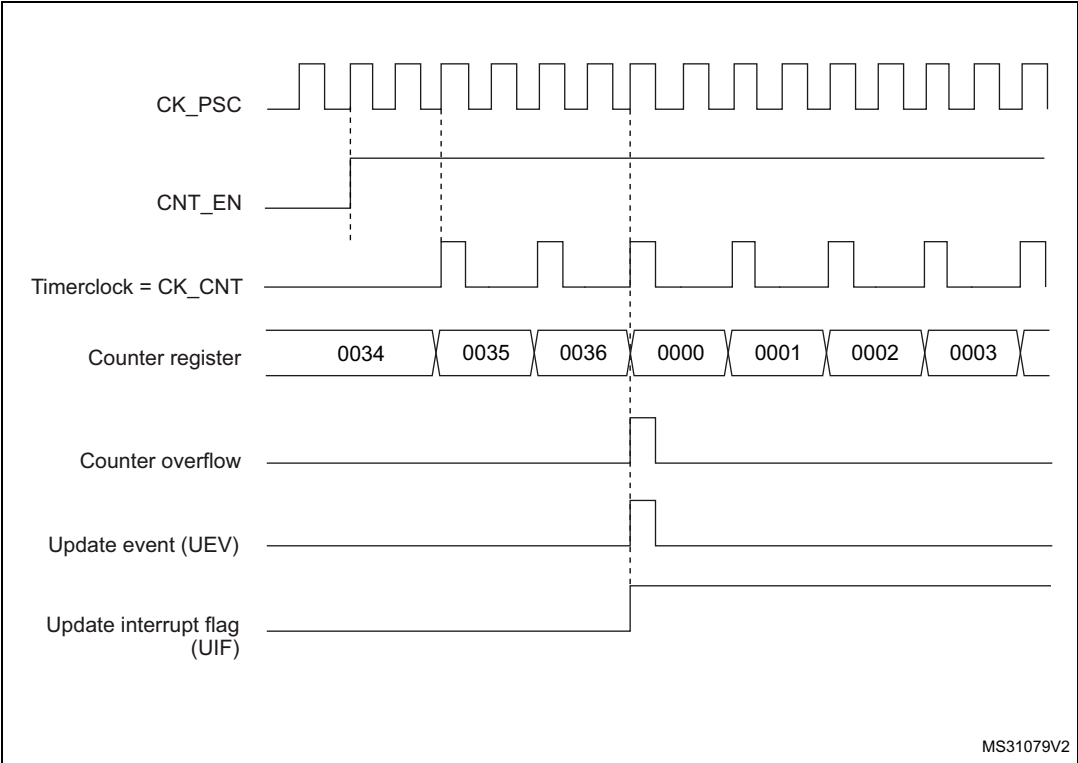


Figure 93. Counter timing diagram, internal clock divided by 4

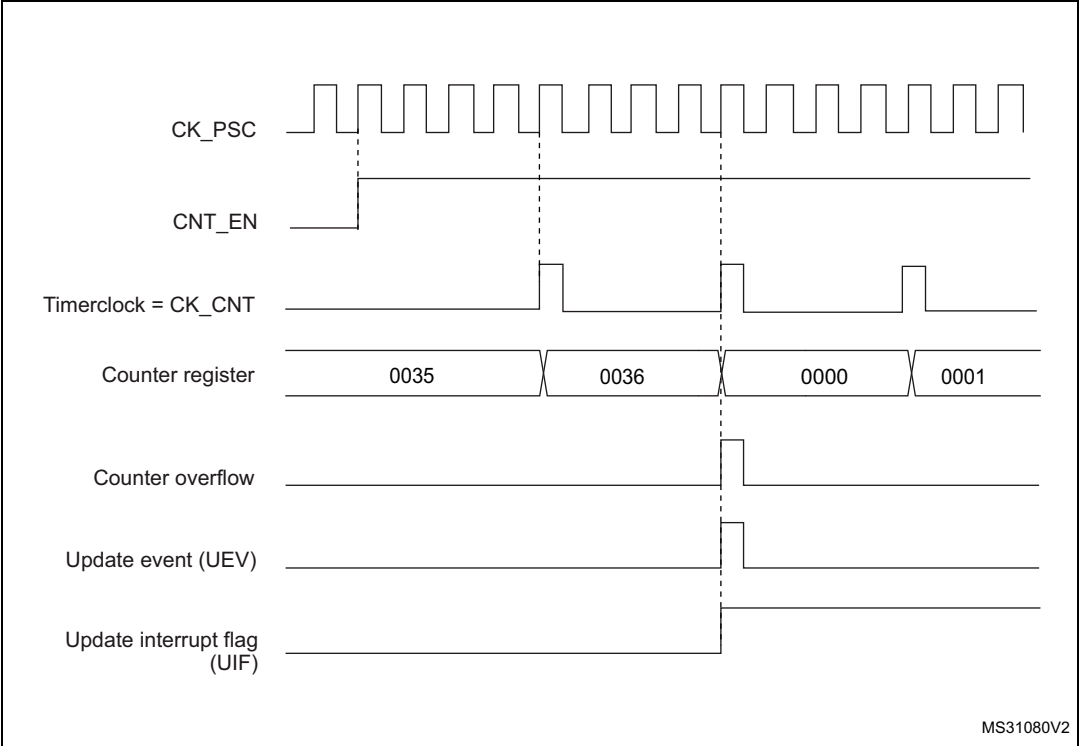


Figure 94. Counter timing diagram, internal clock divided by N

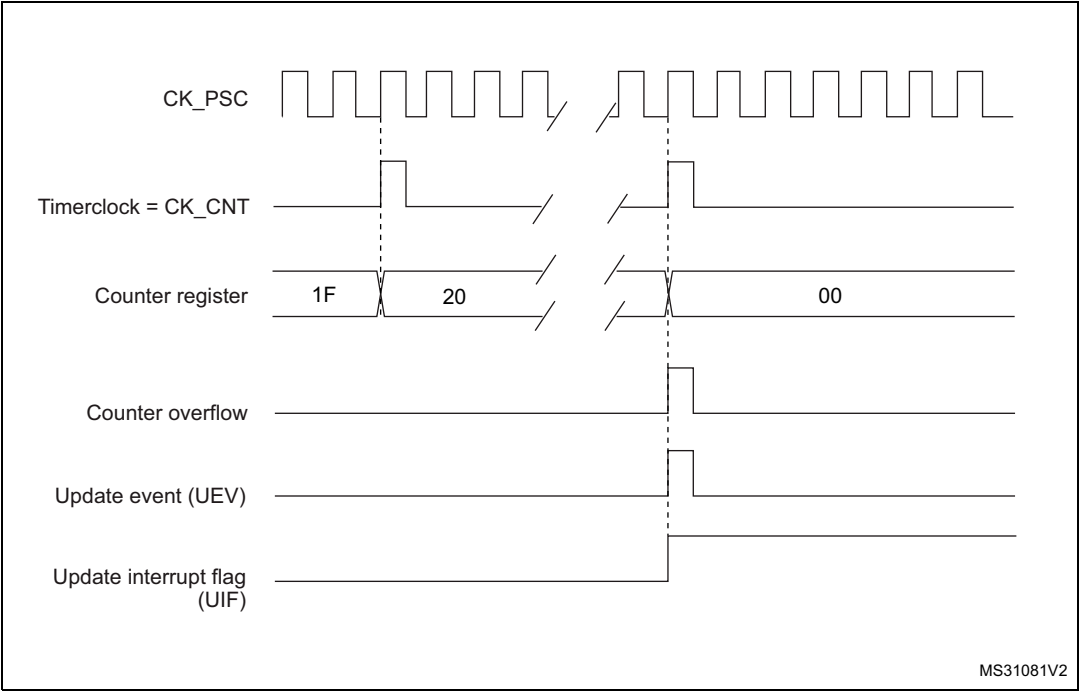


Figure 95. Counter timing diagram, Update event when ARPE=0 (TIMx_ARR not preloaded)

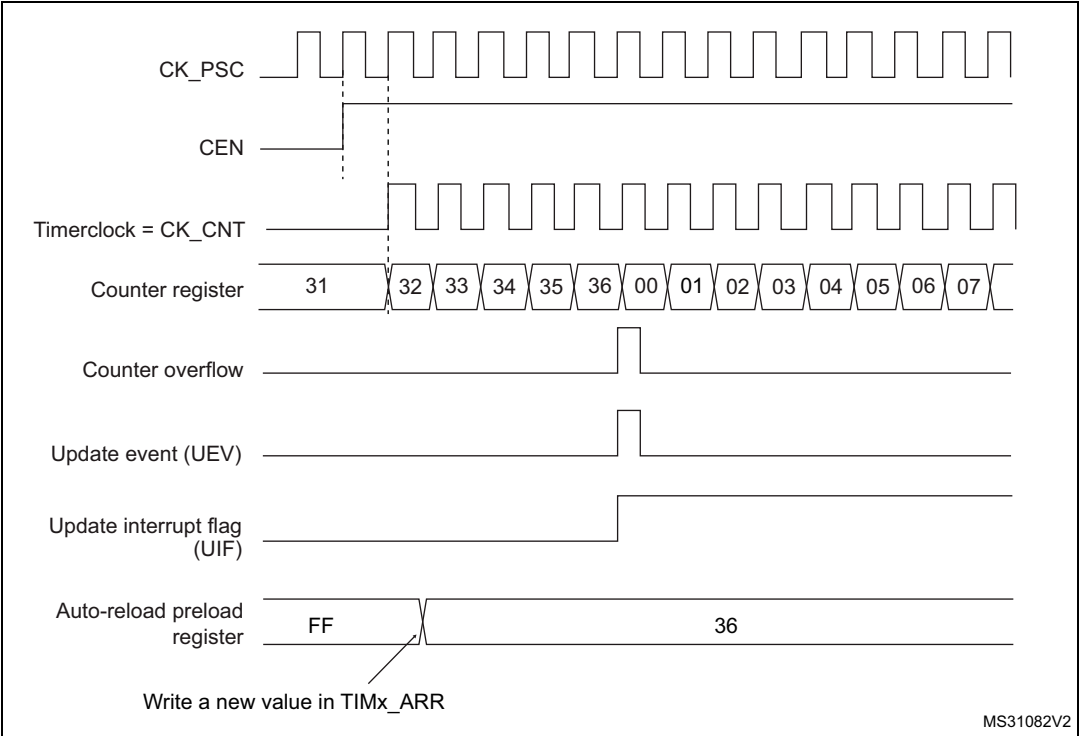
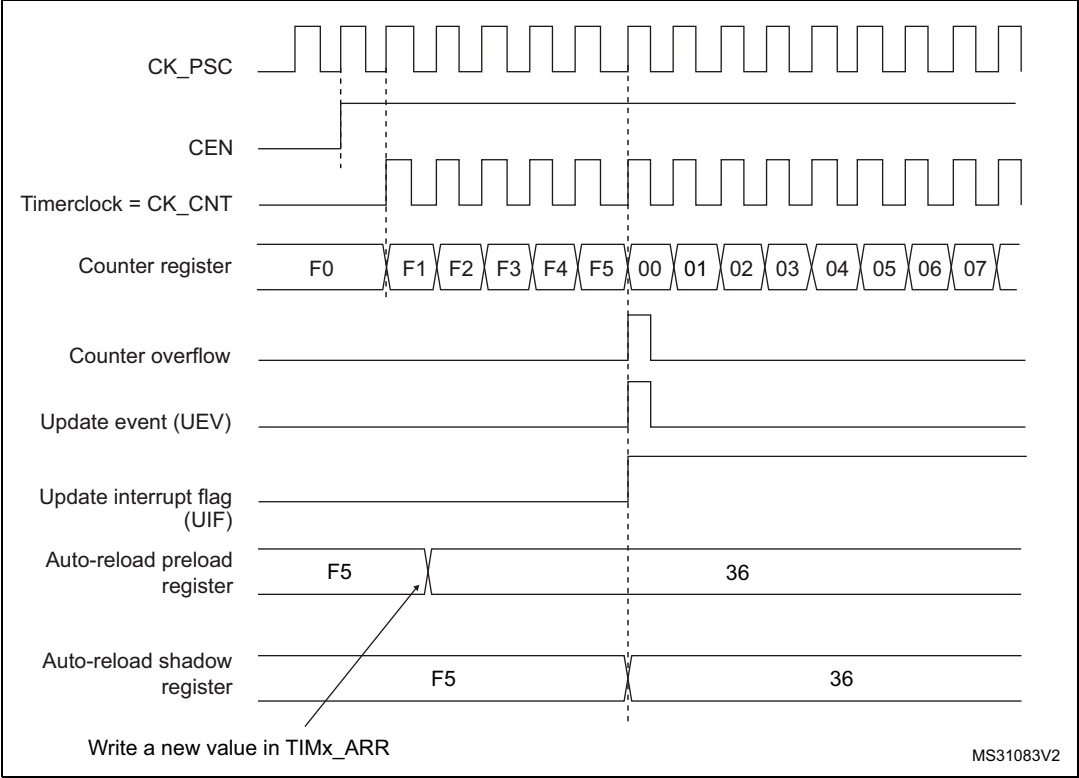


Figure 96. Counter timing diagram, Update event when ARPE=1 (TIMx_ARR preloaded)



Downcounting mode

In downcounting mode, the counter counts from the auto-reload value (content of the TIMx_ARR register) down to 0, then restarts from the auto-reload value and generates a counter underflow event.

An Update event can be generated at each counter underflow or by setting the UG bit in the TIMx_EGR register (by software or by using the slave mode controller)

The UEV update event can be disabled by software by setting the UDIS bit in TIMx_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until UDIS bit has been written to 0. However, the counter restarts from the current auto-reload value, whereas the counter of the prescaler restarts from 0 (but the prescale rate doesn't change).

In addition, if the URS bit (update request selection) in TIMx_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx_SR register) is set (depending on the URS bit):

- The buffer of the prescaler is reloaded with the preload value (content of the TIMx_PSC register).
- The auto-reload active register is updated with the preload value (content of the TIMx_ARR register). Note that the auto-reload is updated before the counter is reloaded, so that the next period is the expected one.

The following figures show some examples of the counter behavior for different clock frequencies when TIMx_ARR=0x36.

Figure 97. Counter timing diagram, internal clock divided by 1

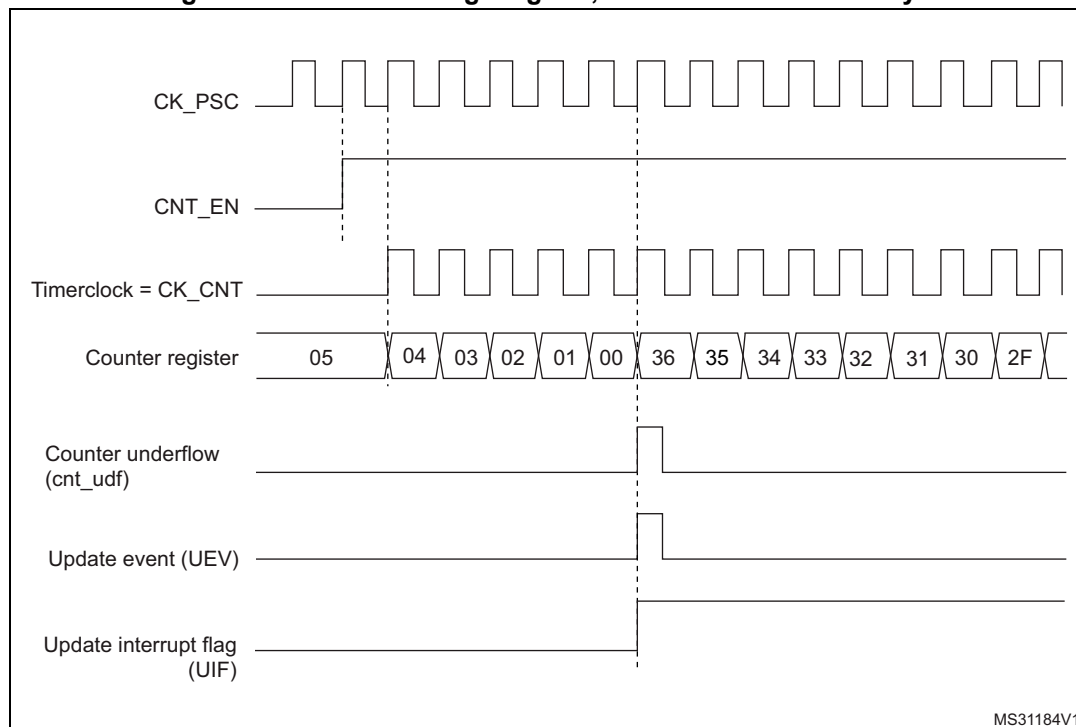


Figure 98. Counter timing diagram, internal clock divided by 2

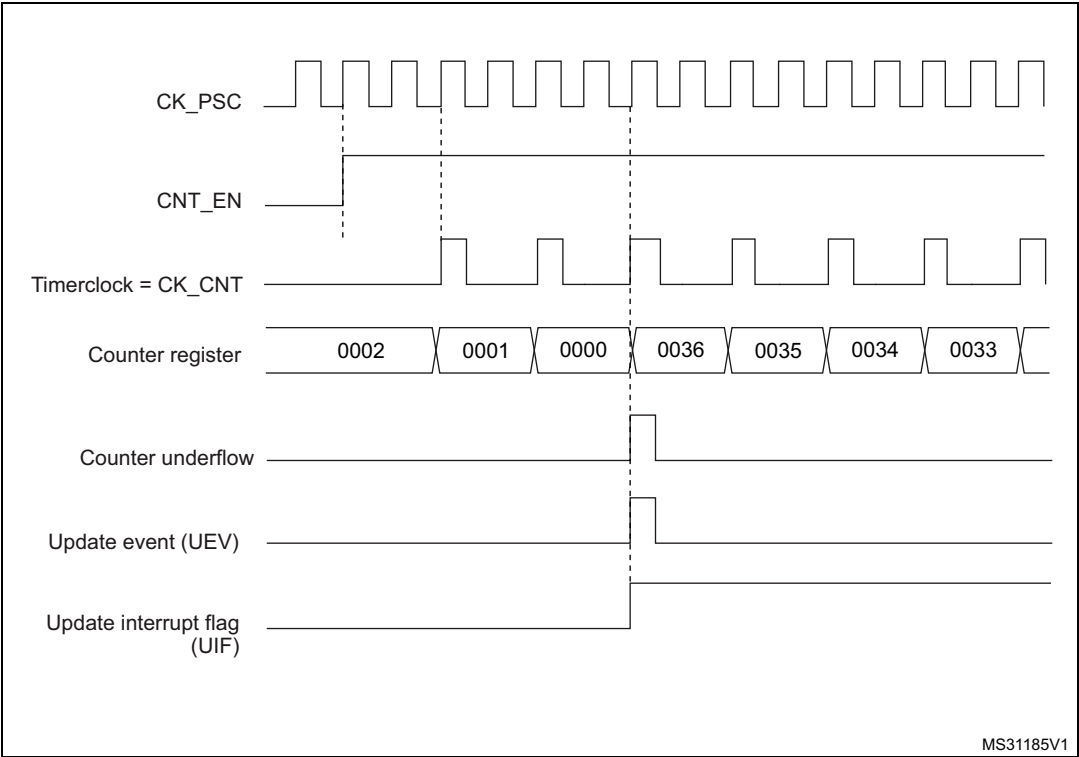


Figure 99. Counter timing diagram, internal clock divided by 4

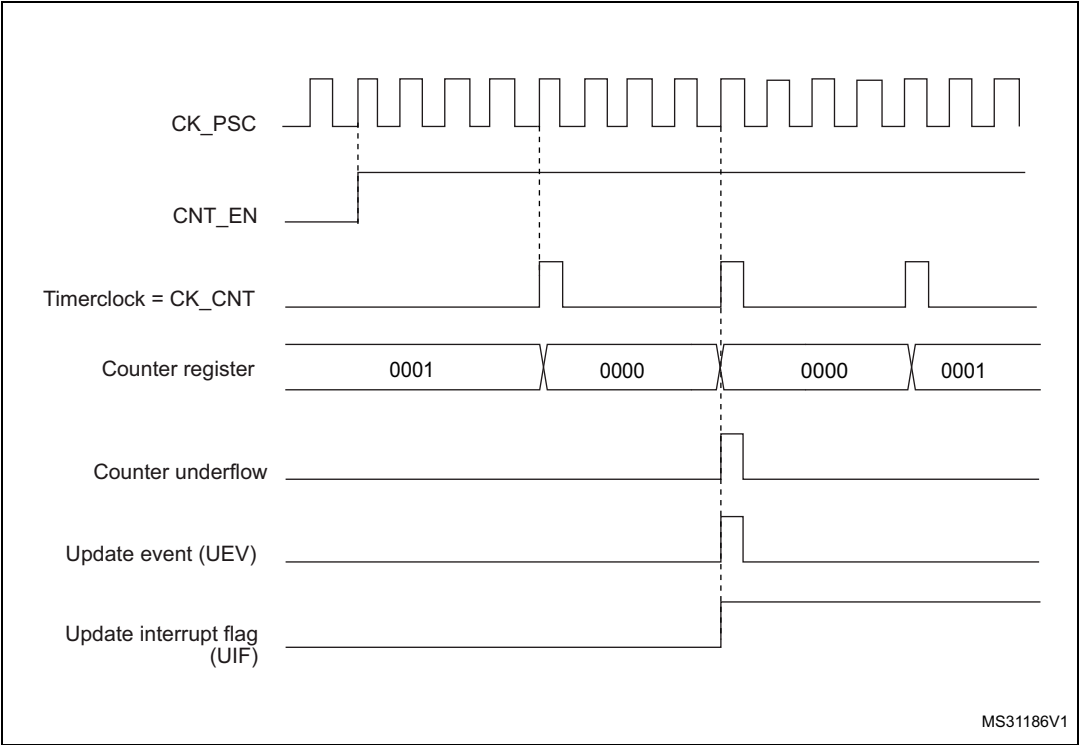


Figure 100. Counter timing diagram, internal clock divided by N

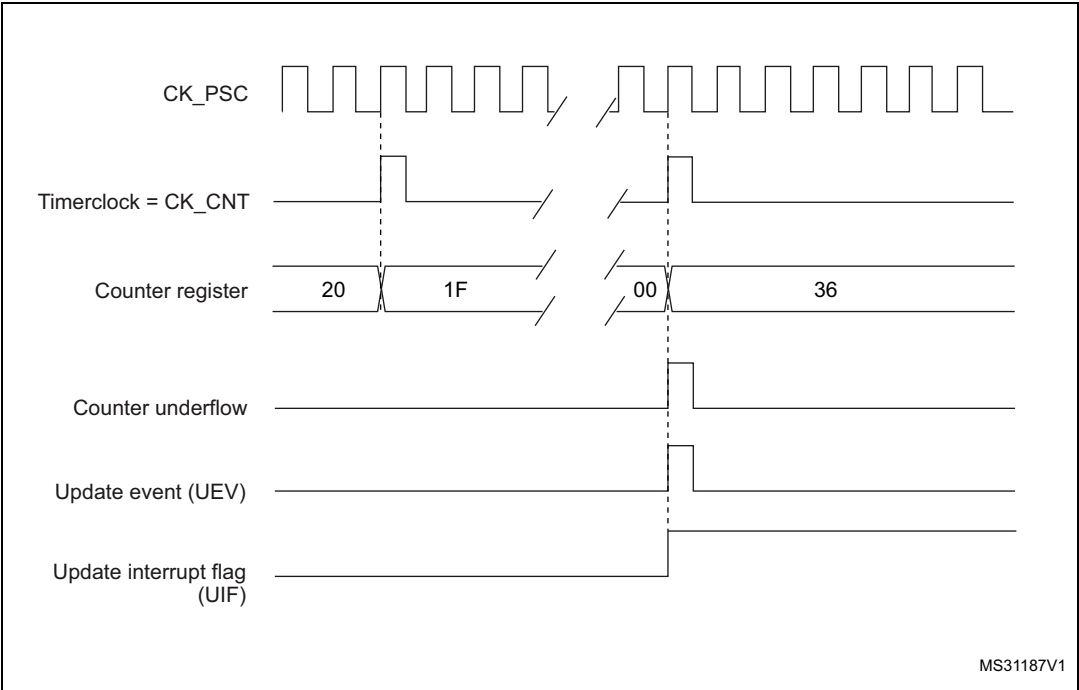
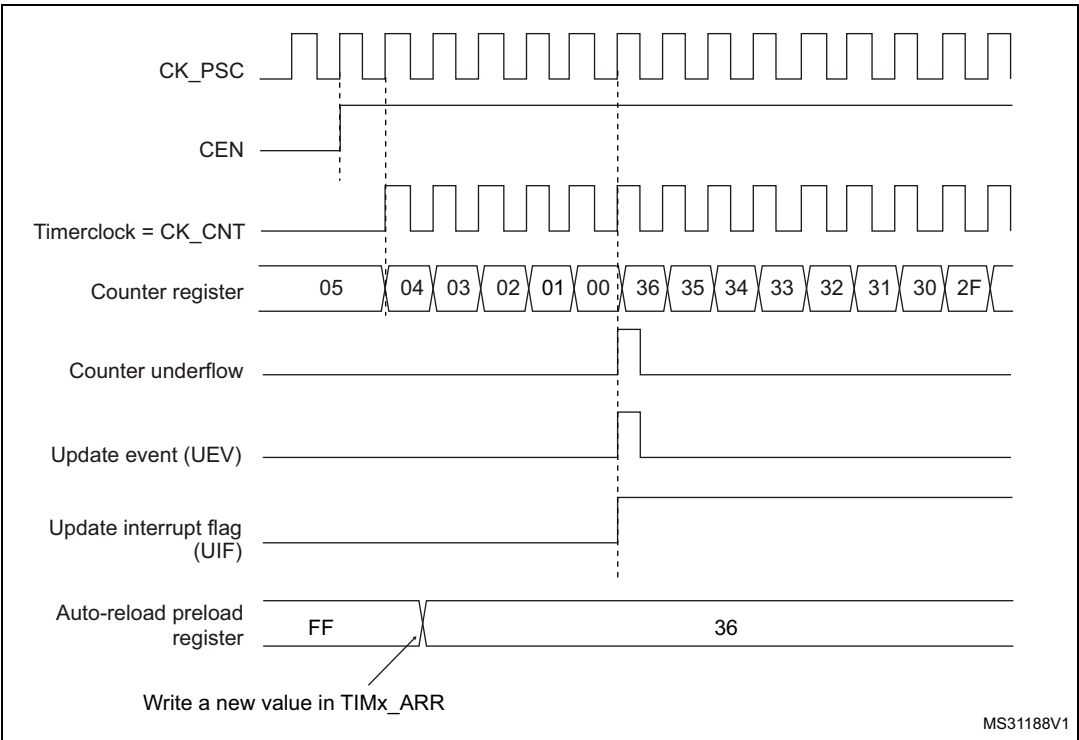


Figure 101. Counter timing diagram, Update event when repetition counter is not used



Center-aligned mode (up/down counting)

In center-aligned mode, the counter counts from 0 to the auto-reload value (content of the TIMx_ARR register) – 1, generates a counter overflow event, then counts from the auto-reload value down to 1 and generates a counter underflow event. Then it restarts counting from 0.

Center-aligned mode is active when the CMS bits in TIMx_CR1 register are not equal to '00'. The Output compare interrupt flag of channels configured in output is set when: the counter counts down (Center aligned mode 1, CMS = "01"), the counter counts up (Center aligned mode 2, CMS = "10") the counter counts up and down (Center aligned mode 3, CMS = "11").

In this mode, the direction bit (DIR from TIMx_CR1 register) cannot be written. It is updated by hardware and gives the current direction of the counter.

The update event can be generated at each counter overflow and at each counter underflow or by setting the UG bit in the TIMx_EGR register (by software or by using the slave mode controller) also generates an update event. In this case, the counter restarts counting from 0, as well as the counter of the prescaler.

The UEV update event can be disabled by software by setting the UDIS bit in TIMx_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter continues counting up and down, based on the current auto-reload value.

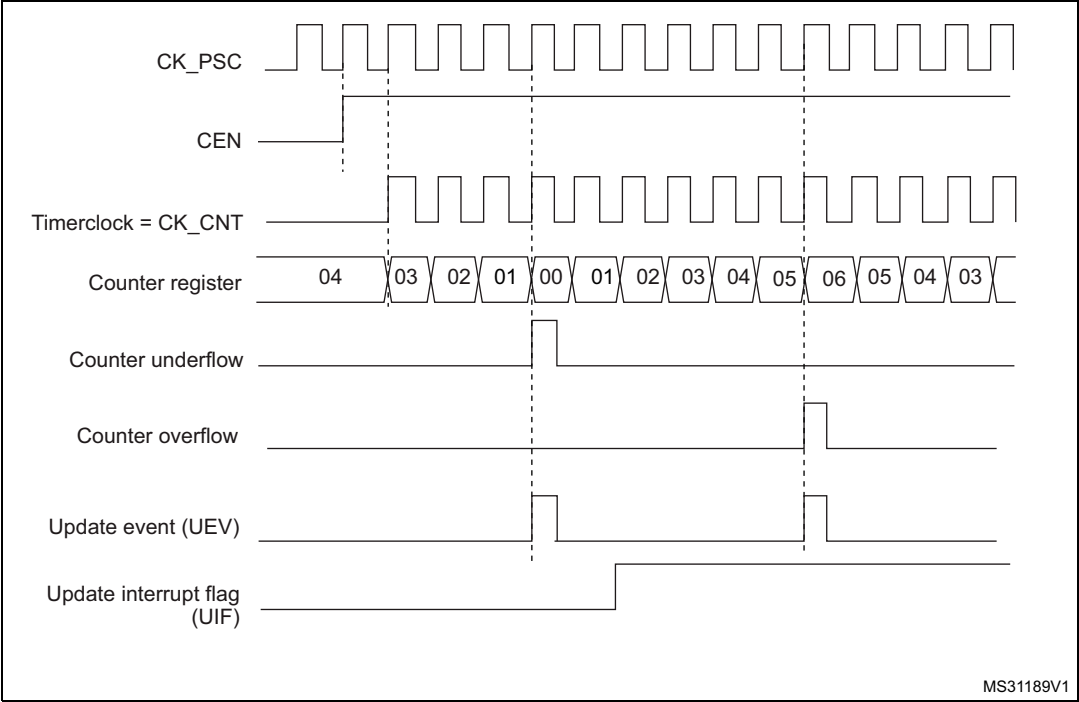
In addition, if the URS bit (update request selection) in TIMx_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupt when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx_SR register) is set (depending on the URS bit):

- The buffer of the prescaler is reloaded with the preload value (content of the TIMx_PSC register).
- The auto-reload active register is updated with the preload value (content of the TIMx_ARR register). Note that if the update source is a counter overflow, the auto-reload is updated before the counter is reloaded, so that the next period is the expected one (the counter is loaded with the new value).

The following figures show some examples of the counter behavior for different clock frequencies.

Figure 102. Counter timing diagram, internal clock divided by 1, TIMx_ARR=0x6



1. Here, center-aligned mode 1 is used (for more details refer to [Section 14.4.1: TIM3 control register 1 \(TIM3_CR1\) on page 338](#)).

Figure 103. Counter timing diagram, internal clock divided by 2

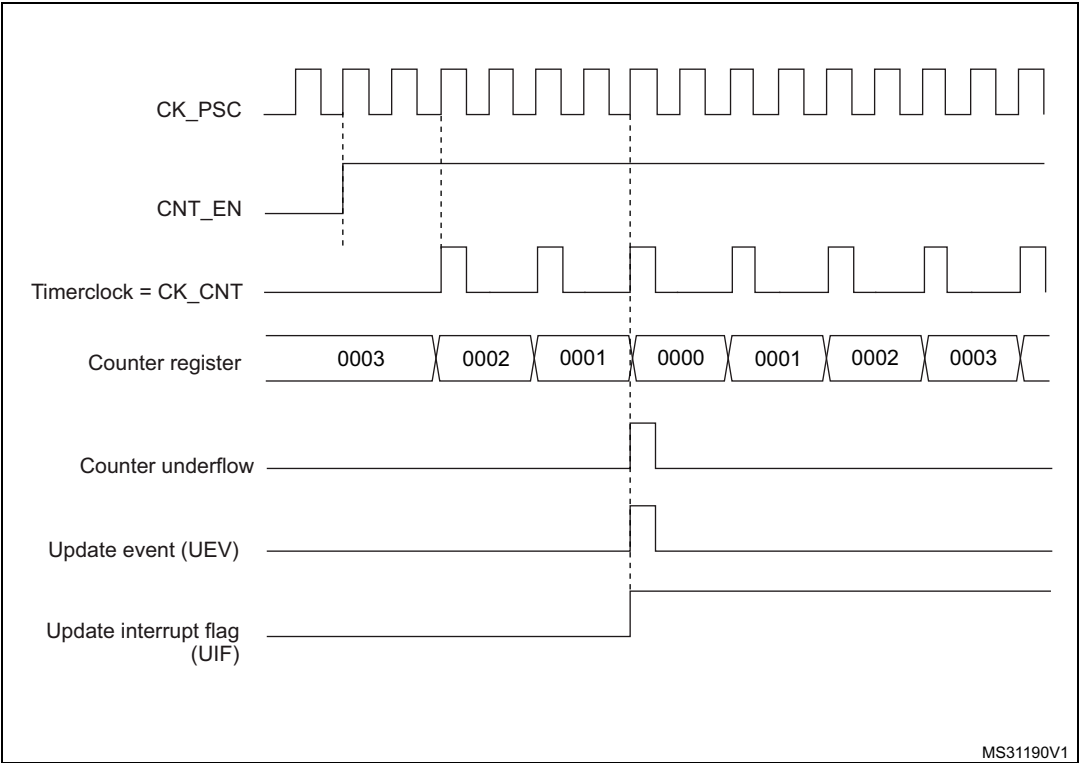
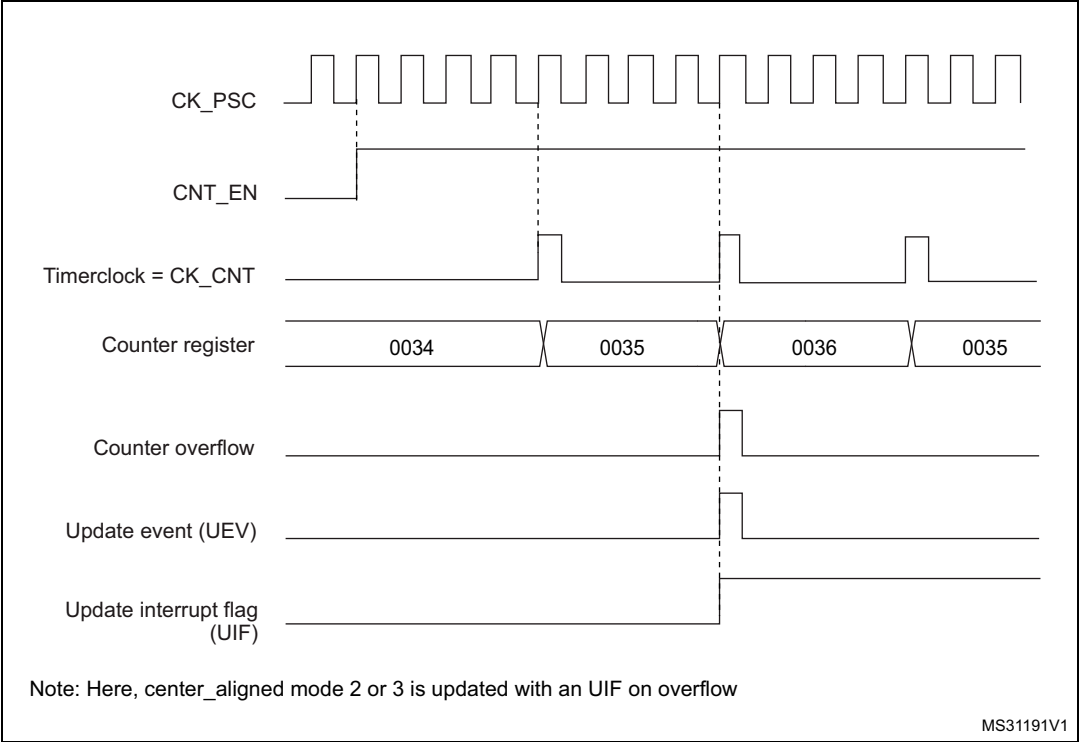


Figure 104. Counter timing diagram, internal clock divided by 4, TIMx_ARR=0x36



- 1. Center-aligned mode 2 or 3 is used with an UIF on overflow.

Figure 105. Counter timing diagram, internal clock divided by N

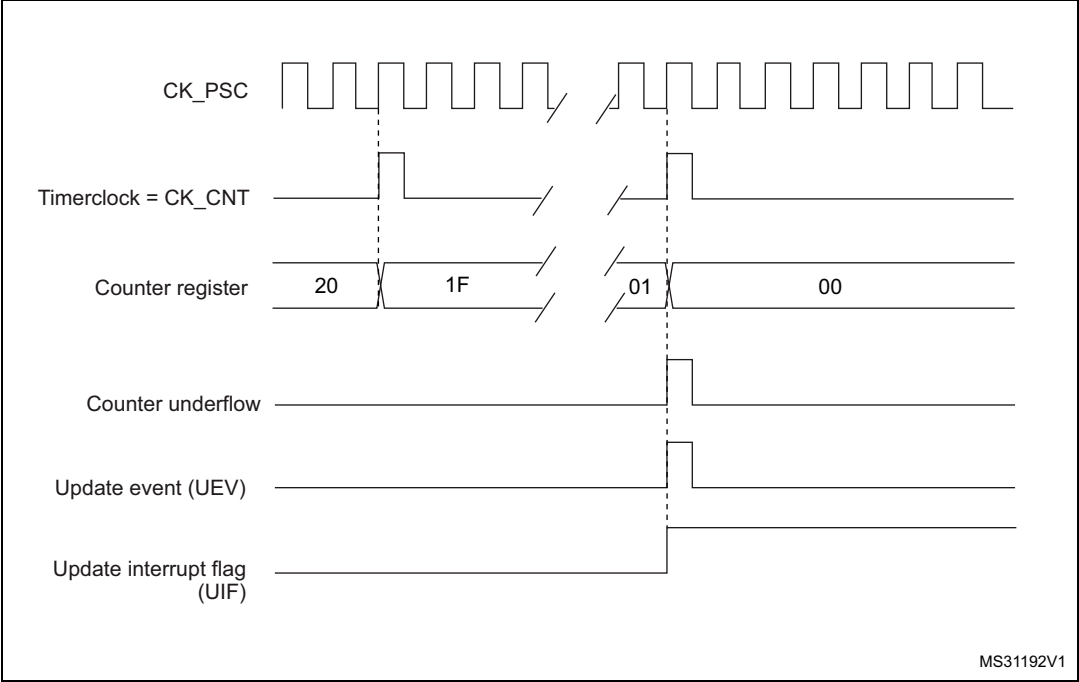


Figure 106. Counter timing diagram, Update event with ARPE=1 (counter underflow)

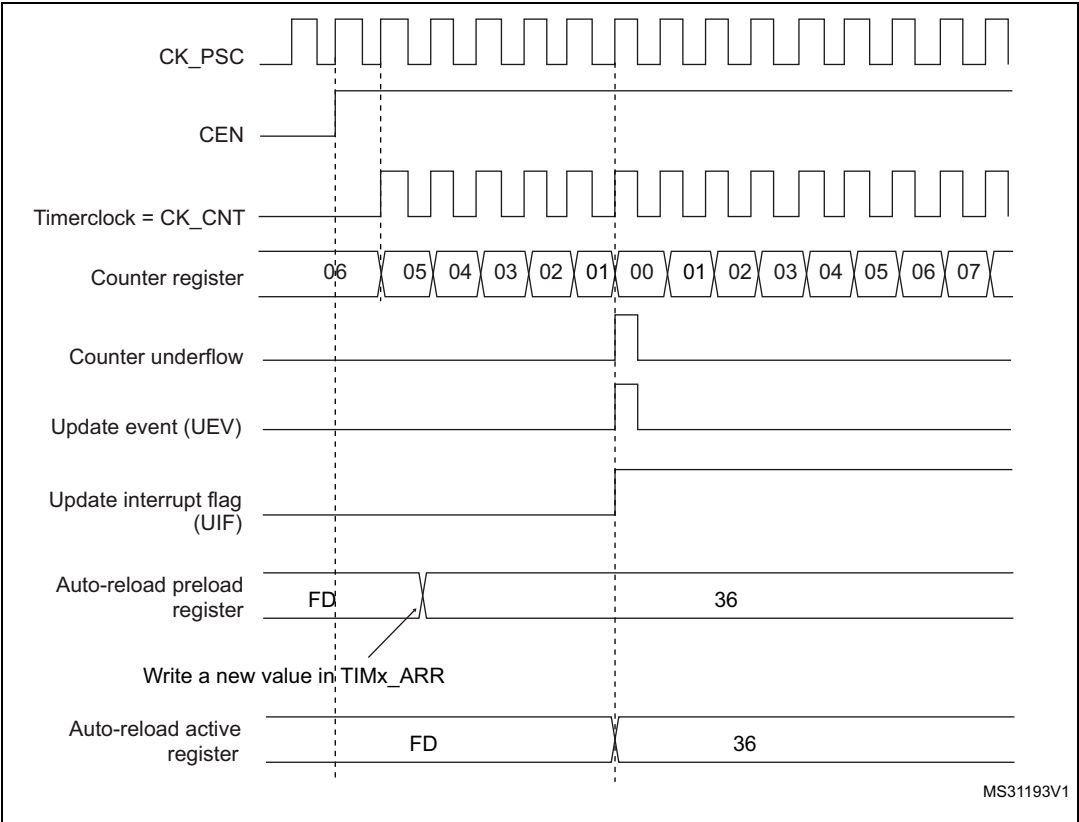
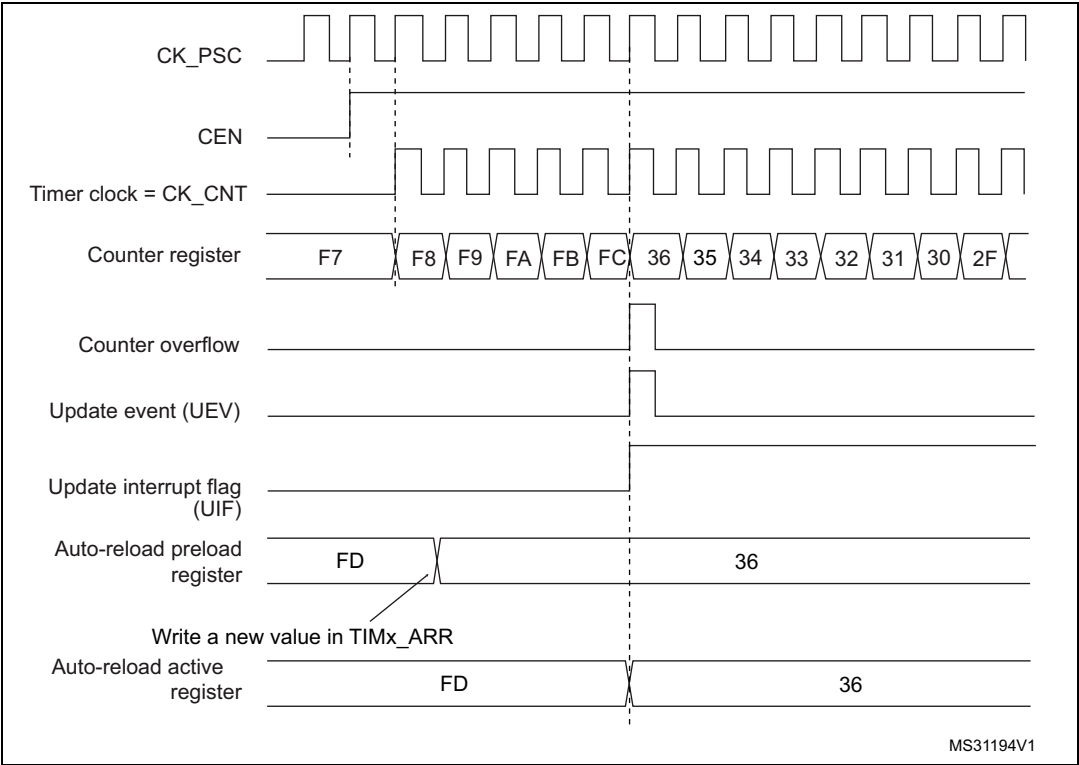


Figure 107. Counter timing diagram, Update event with ARPE=1 (counter overflow)



14.3.3 Clock sources

The counter clock can be provided by the following clock sources:

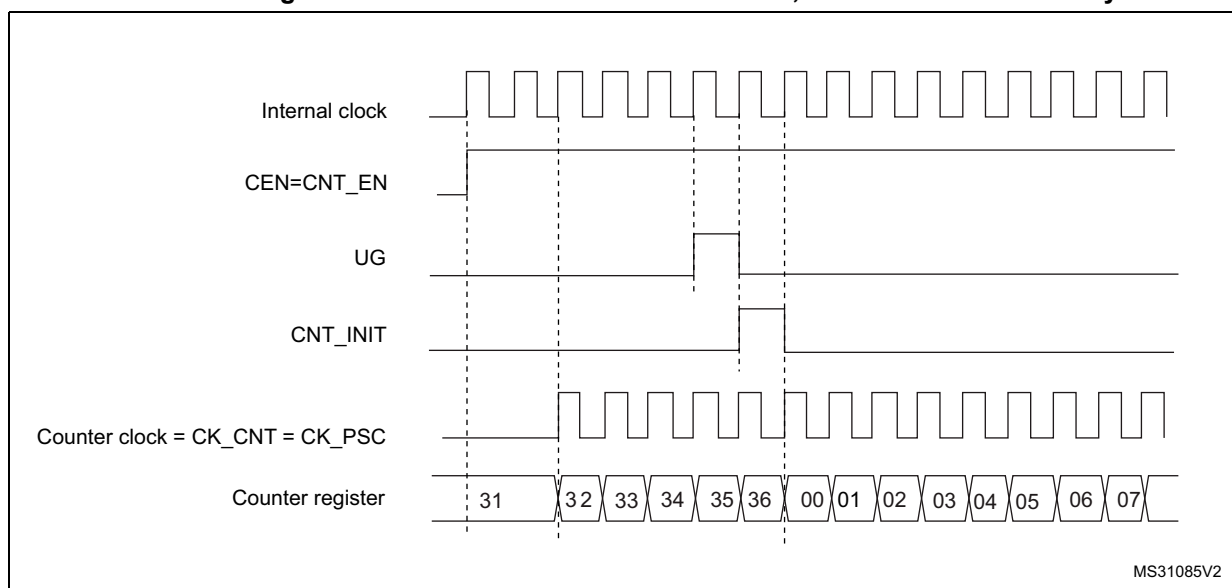
- Internal clock (CK_INT)
- External clock mode1: external input pin (TIx)
- External clock mode2: external trigger input (ETR)
- Internal trigger inputs (ITRx): using one timer as prescaler for another timer, for example, you can configure Timer 1 to act as a prescaler for Timer 2. Refer to : [Using one timer as prescaler for another on page 332](#) for more details.

Internal clock source (CK_INT)

If the slave mode controller is disabled (SMS=000 in the TIMx_SMCR register), then the CEN, DIR (in the TIMx_CR1 register) and UG bits (in the TIMx_EGR register) are actual control bits and can be changed only by software (except UG which remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK_INT.

[Figure 108](#) shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

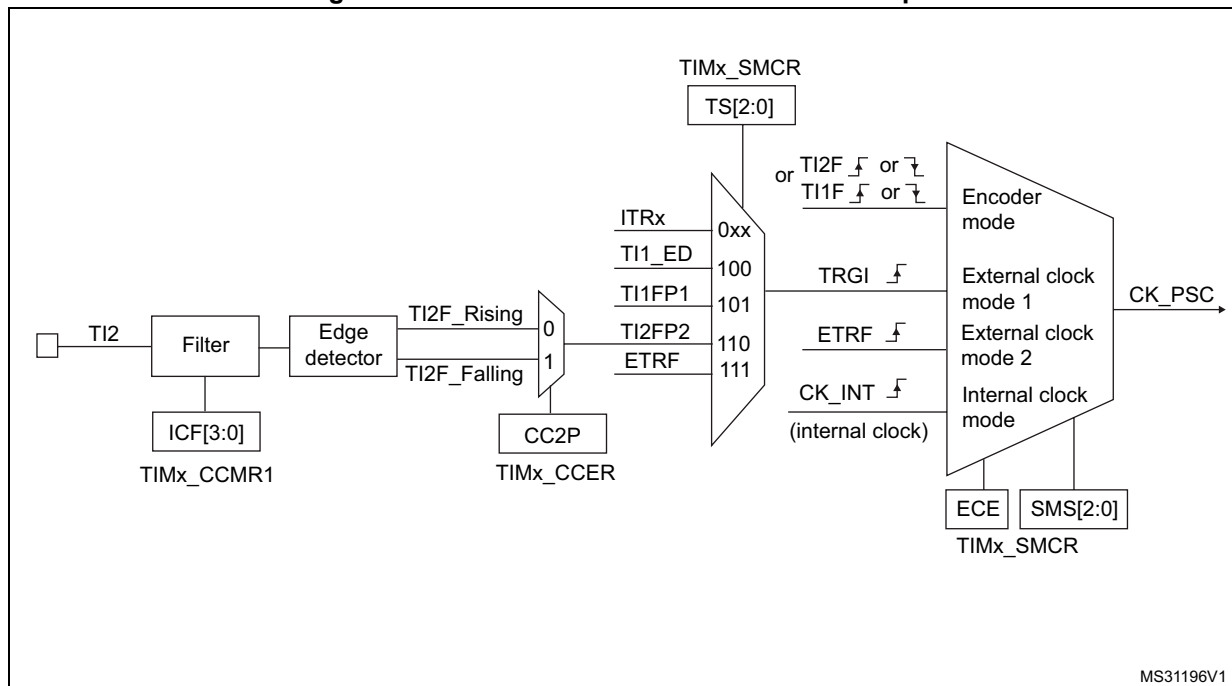
Figure 108. Control circuit in normal mode, internal clock divided by 1



External clock source mode 1

This mode is selected when SMS=111 in the TIMx_SMCR register. The counter can count at each rising or falling edge on a selected input.

Figure 109. TI2 external clock connection example



For example, to configure the upcounter to count in response to a rising edge on the TI2 input, use the following procedure:

1. Configure channel 2 to detect rising edges on the TI2 input by writing CC2S= '01 in the TIMx_CCMR1 register.
2. Configure the input filter duration by writing the IC2F[3:0] bits in the TIMx_CCMR1 register (if no filter is needed, keep IC2F=0000).

Note:

The capture prescaler is not used for triggering, so you don't need to configure it.

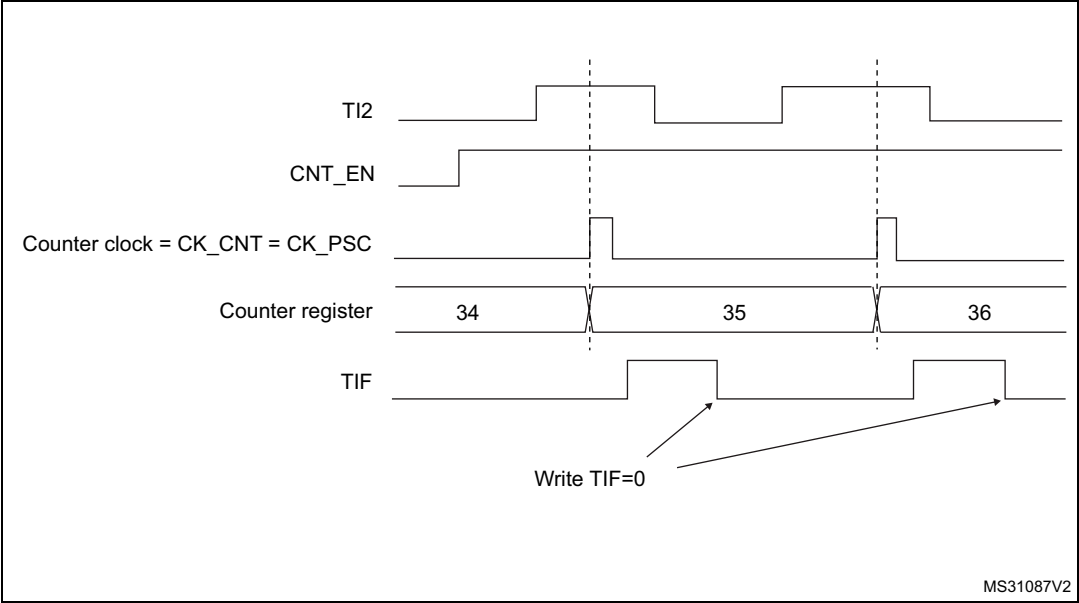
3. Select rising edge polarity by writing CC2P=0 and CC2NP=0 in the TIMx_CCER register.
4. Configure the timer in external clock mode 1 by writing SMS=111 in the TIMx_SMCR register.
5. Select TI2 as the input source by writing TS=110 in the TIMx_SMCR register.
6. Enable the counter by writing CEN=1 in the TIMx_CR1 register.

For code example refer to the Appendix section [A.8.2: Up counter on each 2 ETR rising edges code example](#).

When a rising edge occurs on TI2, the counter counts once and the TIF flag is set.

The delay between the rising edge on TI2 and the actual clock of the counter is due to the resynchronization circuit on TI2 input.

Figure 110. Control circuit in external clock mode 1



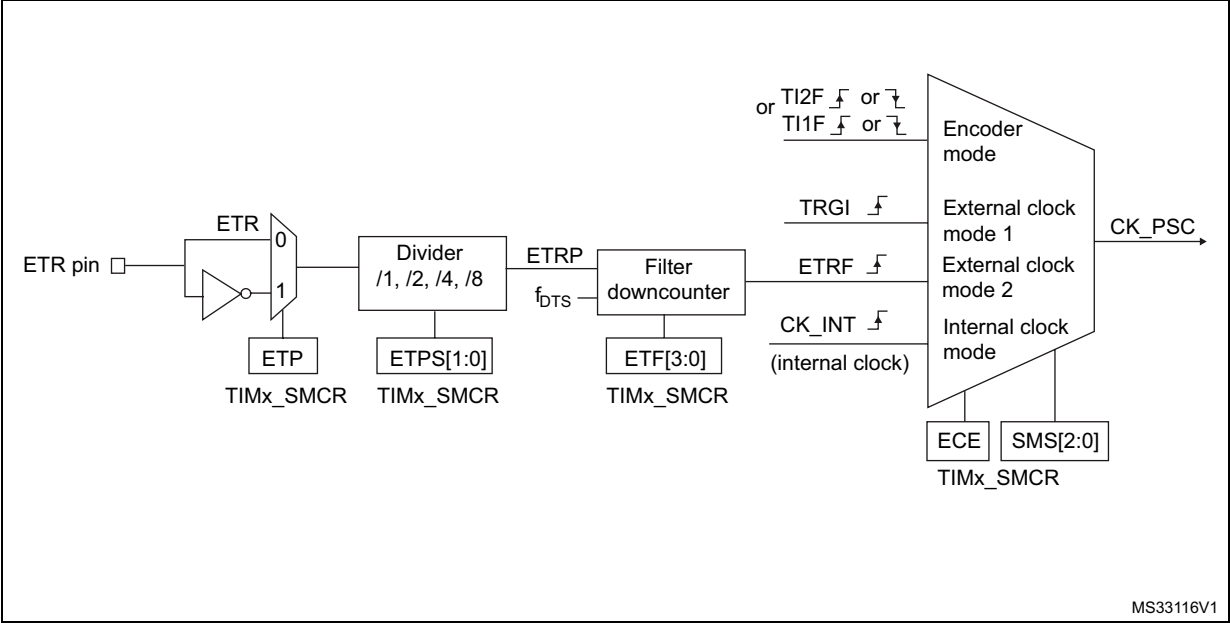
External clock source mode 2

This mode is selected by writing ECE=1 in the TIMx_SMCR register.

The counter can count at each rising or falling edge on the external trigger input ETR.

The [Figure 111](#) gives an overview of the external trigger input block.

Figure 111. External trigger input block



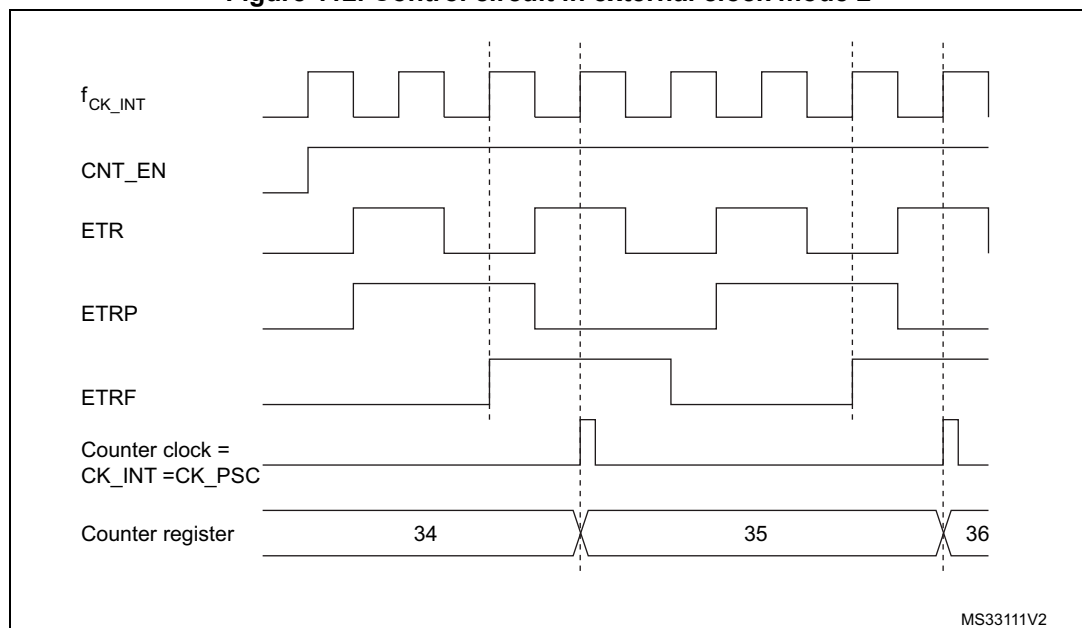
For example, to configure the upcounter to count each 2 rising edges on ETR, use the following procedure:

1. As no filter is needed in this example, write ETF[3:0]=0000 in the TIMx_SMCR register.
2. Set the prescaler by writing ETPS[1:0]=01 in the TIMx_SMCR register
3. Select rising edge detection on the ETR pin by writing ETP=0 in the TIMx_SMCR register
4. Enable external clock mode 2 by writing ECE=1 in the TIMx_SMCR register.
5. Enable the counter by writing CEN=1 in the TIMx_CR1 register.

The counter counts once each 2 ETR rising edges.

The delay between the rising edge on ETR and the actual clock of the counter is due to the resynchronization circuit on the ETRP signal.

Figure 112. Control circuit in external clock mode 2



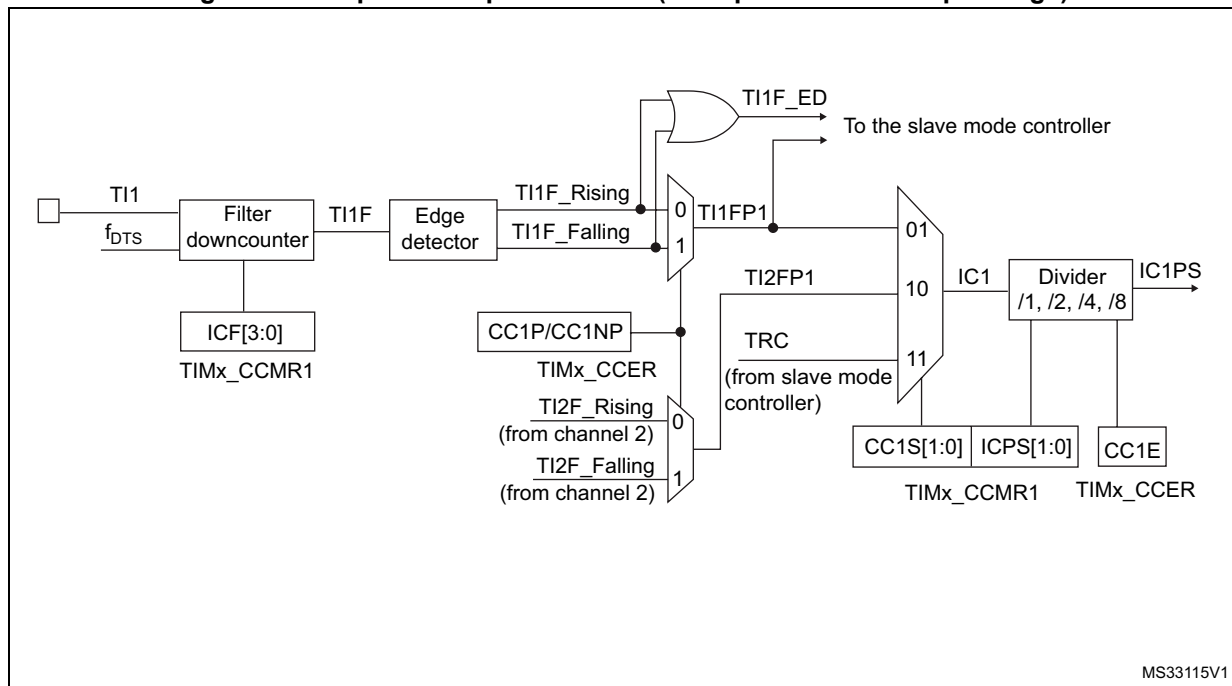
14.3.4 Capture/compare channels

Each Capture/Compare channel is built around a capture/compare register (including a shadow register), a input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

The following figure gives an overview of one Capture/Compare channel.

The input stage samples the corresponding TIx input to generate a filtered signal TIxF. Then, an edge detector with polarity selection generates a signal (TIxFPx) which can be used as trigger input by the slave mode controller or as the capture command. It is prescaled before the capture register (ICxPS).

Figure 113. Capture/compare channel (example: channel 1 input stage)



The output stage generates an intermediate waveform which is then used for reference: OCxRef (active high). The polarity acts at the end of the chain.

Figure 114. Capture/compare channel 1 main circuit

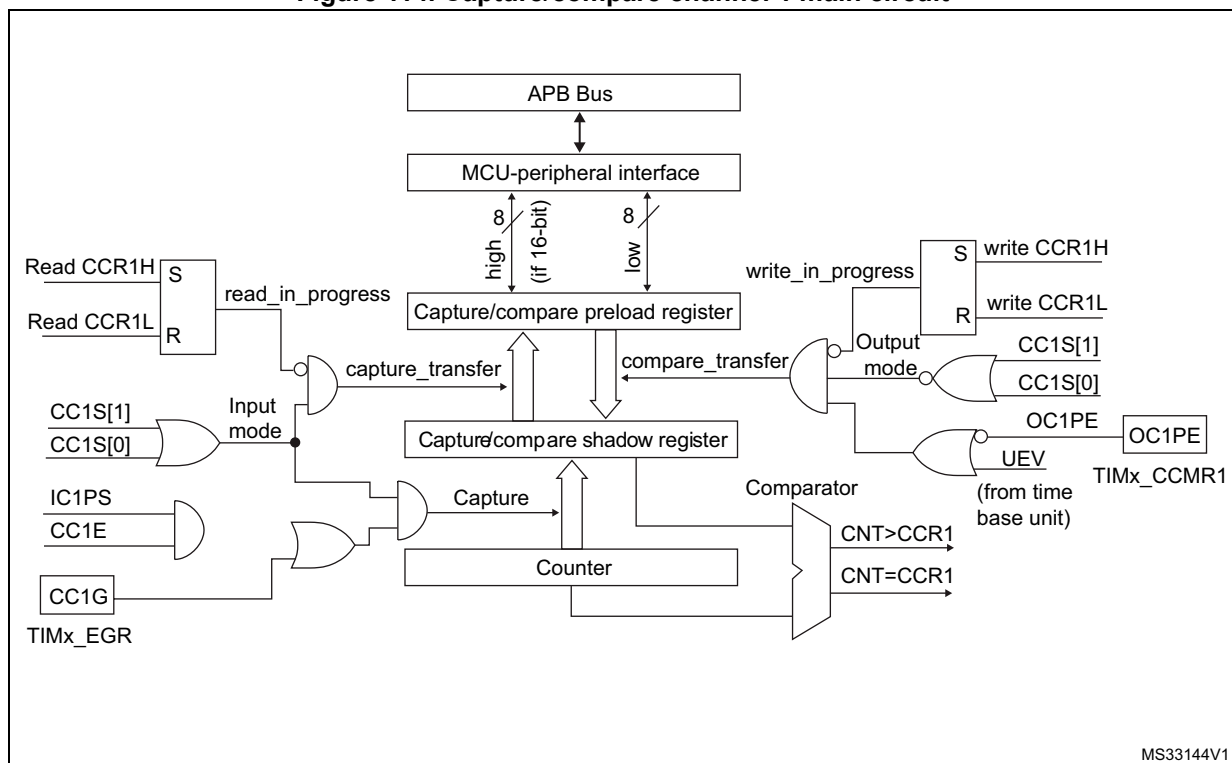
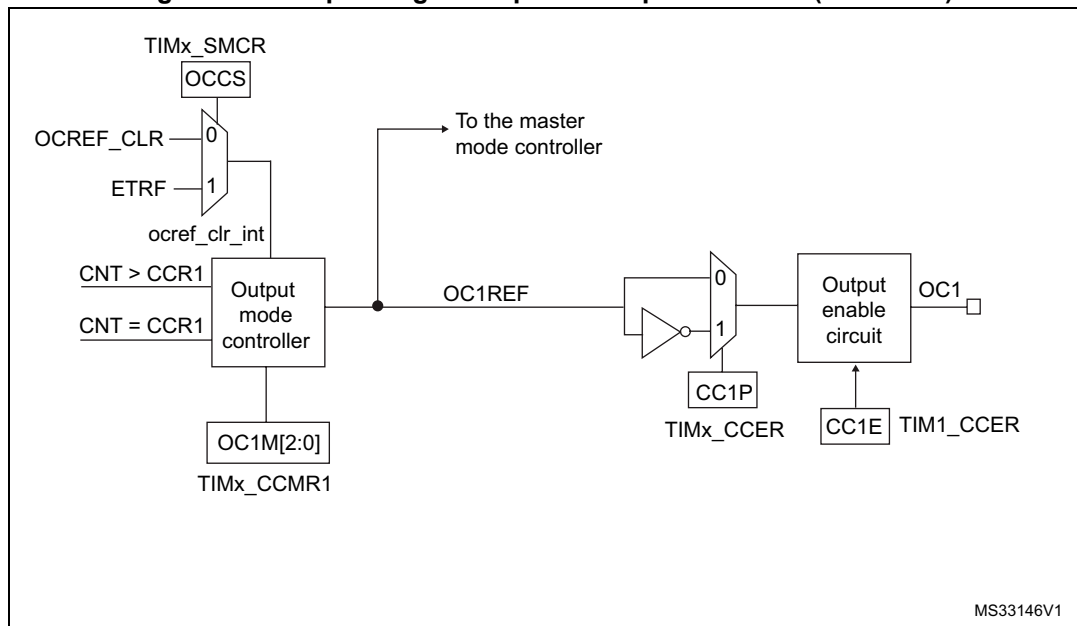


Figure 115. Output stage of capture/compare channel (channel 1)

The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register.

In capture mode, captures are actually done in the shadow register, which is copied into the preload register.

In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

14.3.5 Input capture mode

In Input capture mode, the Capture/Compare Registers (TIMx_CCRx) are used to latch the value of the counter after a transition detected by the corresponding ICx signal. When a capture occurs, the corresponding CCXIF flag (TIMx_SR register) is set and an interrupt or a DMA request can be sent if they are enabled. If a capture occurs while the CCxIF flag was already high, then the over-capture flag CCxOF (TIMx_SR register) is set. CCxIF can be cleared by software by writing it to 0 or by reading the captured data stored in the TIMx_CCRx register. CCxOF is cleared when you write it to 0.

The following example shows how to capture the counter value in TIMx_CCR1 when TI1 input rises. To do this, use the following procedure:

- Select the active input: TIMx_CCR1 must be linked to the TI1 input, so write the CC1S bits to 01 in the TIMx_CCMR1 register. As soon as CC1S becomes different from 00, the channel is configured in input and the TIMx_CCR1 register becomes read-only.
- Program the input filter duration you need with respect to the signal you connect to the timer (when the input is one of the TIx (ICxF bits in the TIMx_CCMRx register). Let's imagine that, when toggling, the input signal is not stable during at least 5 internal clock cycles. We must program a filter duration longer than these 5 clock cycles. We can validate a transition on TI1 when 8 consecutive samples with the new level have been

detected (sampled at f_{DTS} frequency). Then write IC1F bits to 0011 in the TIMx_CCMR1 register.

- Select the edge of the active transition on the TI1 channel by writing the CC1P and CC1NP bits to 0 in the TIMx_CCER register (rising edge in this case).
- Program the input prescaler. In our example, we wish the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to 00 in the TIMx_CCMR1 register).
- Enable capture from the counter into the capture register by setting the CC1E bit in the TIMx_CCER register.
- If needed, enable the related interrupt request by setting the CC1IE bit in the TIMx_DIER register, and/or the DMA request by setting the CC1DE bit in the TIMx_DIER register.

For code example refer to the Appendix section [A.8.3: Input capture configuration code example](#).

When an input capture occurs:

- The TIMx_CCR1 register gets the value of the counter on the active transition.
- CC1IF flag is set (interrupt flag). CC1OF is also set if at least two consecutive captures occurred whereas the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.
- A DMA request is generated depending on the CC1DE bit.

For code example refer to the Appendix section [A.8.4: Input capture data management code example](#).

In order to handle the overcapture, it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

Note: IC interrupt and/or DMA requests can be generated by software by setting the corresponding CCxG bit in the TIMx_EGR register.

14.3.6 PWM input mode

This mode is a particular case of input capture mode. The procedure is the same except:

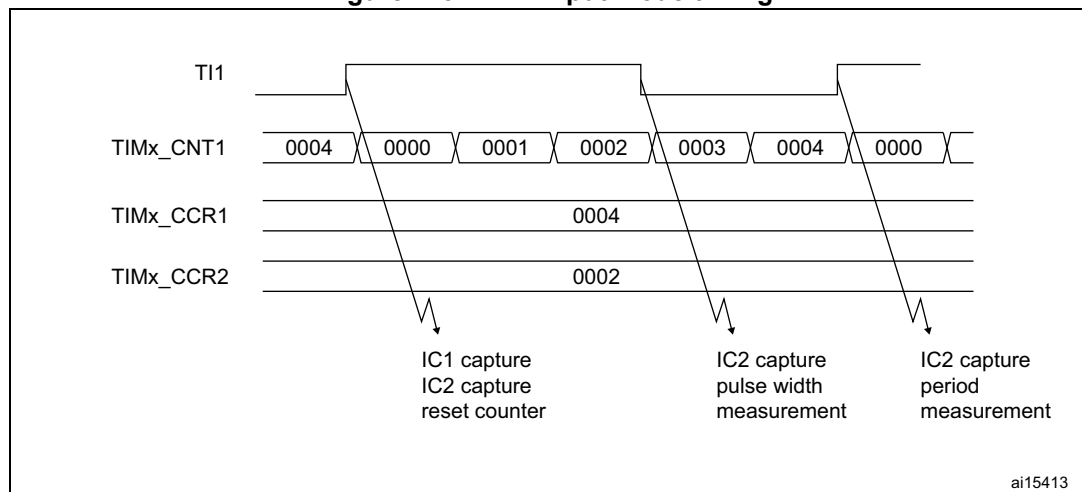
- Two ICx signals are mapped on the same TIx input.
- These 2 ICx signals are active on edges with opposite polarity.
- One of the two TIxFP signals is selected as trigger input and the slave mode controller is configured in reset mode.

For example, you can measure the period (in TIMx_CCR1 register) and the duty cycle (in TIMx_CCR2 register) of the PWM applied on TI1 using the following procedure (depending on CK_INT frequency and prescaler value):

- Select the active input for TIMx_CCR1: write the CC1S bits to 01 in the TIMx_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP1 (used both for capture in TIMx_CCR1 and counter clear): write the CC1P to '0' and the CC1NP bit to '0' (active on rising edge).
- Select the active input for TIMx_CCR2: write the CC2S bits to 10 in the TIMx_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP2 (used for capture in TIMx_CCR2): write the CC2P bit to '1' and the CC2NP bit to '0' (active on falling edge).
- Select the valid trigger input: write the TS bits to 101 in the TIMx_SMCR register (TI1FP1 selected).
- Configure the slave mode controller in reset mode: write the SMS bits to 100 in the TIMx_SMCR register.
- Enable the captures: write the CC1E and CC2E bits to '1' in the TIMx_CCER register.

For code example refer to the Appendix section [A.8.5: PWM input configuration code example](#).

Figure 116. PWM input mode timing



14.3.7 Forced output mode

In output mode (CCxS bits = 00 in the TIMx_CCMRx register), each output compare signal (OCxREF and then OCx) can be forced to active or inactive level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal (ocxref/OCx) to its active level, you just need to write 101 in the OCxM bits in the corresponding TIMx_CCMRx register. Thus ocxref is forced high (OCxREF is always active high) and OCx get opposite value to CCxP polarity bit.

e.g.: CCxP=0 (OCx active high) => OCx is forced to high level.

ocxref signal can be forced low by writing the OCxM bits to 100 in the TIMx_CCMRx register.

Anyway, the comparison between the TIMx_CCRx shadow register and the counter is still performed and allows the flag to be set. Interrupt and DMA requests can be sent accordingly. This is described in the Output Compare Mode section.

14.3.8 Output compare mode

This function is used to control an output waveform or indicating when a period of time has elapsed.

When a match is found between the capture/compare register and the counter, the output compare function:

- Assigns the corresponding output pin to a programmable value defined by the output compare mode (OCxM bits in the TIMx_CCMRx register) and the output polarity (CCxP bit in the TIMx_CCER register). The output pin can keep its level (OCxM=000), be set active (OCxM=001), be set inactive (OCxM=010) or can toggle (OCxM=011) on match.
- Sets a flag in the interrupt status register (CCxIF bit in the TIMx_SR register).
- Generates an interrupt if the corresponding interrupt mask is set (CCxIE bit in the TIMx_DIER register).
- Sends a DMA request if the corresponding enable bit is set (CCxDE bit in the TIMx_DIER register, CCDS bit in the TIMx_CR2 register for the DMA request selection).

The TIMx_CCRx registers can be programmed with or without preload registers using the OCxPE bit in the TIMx_CCMRx register.

In output compare mode, the update event UEV has no effect on ocxref and OCx output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse (in One-pulse mode).

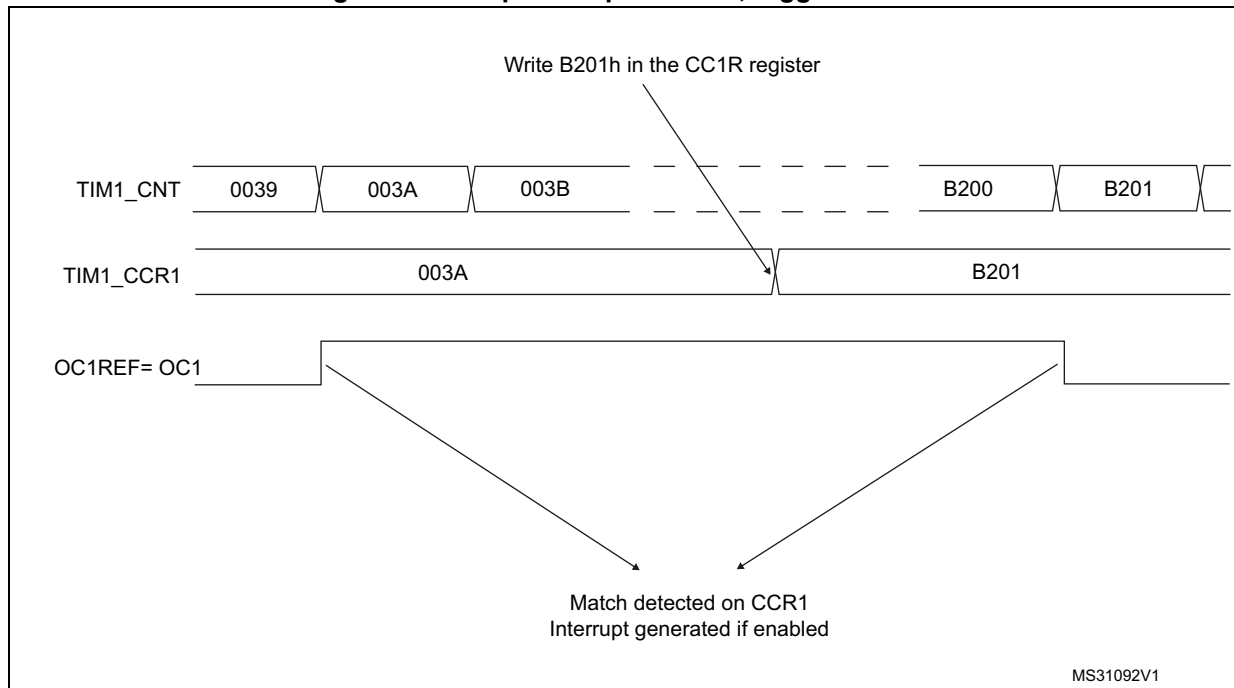
Procedure:

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the TIMx_ARR and TIMx_CCRx registers.
3. Set the CCxIE and/or CCxDE bits if an interrupt and/or a DMA request is to be generated.
4. Select the output mode. For example, you must write OCxM=011, OCxPE=0, CCxP=0 and CCxE=1 to toggle OCx output pin when CNT matches CCRx, CCRx preload is not used, OCx is enabled and active high.
5. Enable the counter by setting the CEN bit in the TIMx_CR1 register.

For code example refer to the Appendix section [A.8.7: Output compare configuration code example](#).

The TIMx_CCRx register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled (OCxPE=0, else TIMx_CCRx shadow register is updated only at the next update event UEV). An example is given in [Figure 117](#).

Figure 117. Output compare mode, toggle on OC1



14.3.9 PWM mode

Pulse width modulation mode allows you to generate a signal with a frequency determined by the value of the TIMx_ARR register and a duty cycle determined by the value of the TIMx_CCRx register.

The PWM mode can be selected independently on each channel (one PWM per OCx output) by writing 110 (PWM mode 1) or '111 (PWM mode 2) in the OCxM bits in the TIMx_CCMRx register. You must enable the corresponding preload register by setting the OCxPE bit in the TIMx_CCMRx register, and eventually the auto-reload preload register (in upcounting or center-aligned modes) by setting the ARPE bit in the TIMx_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIMx_EGR register.

OCx polarity is software programmable using the CCxP bit in the TIMx_CCER register. It can be programmed as active high or active low. OCx output is enabled by the CCxE bit in the TIMx_CCER register. Refer to the TIMx_CCERx register description for more details.

In PWM mode (1 or 2), TIMx_CNT and TIMx_CCRx are always compared to determine whether $TIMx\_CCRx \leq TIMx\_CNT$ or $TIMx\_CNT \leq TIMx\_CCRx$ (depending on the direction of the counter). However, to comply with the OCREF_CLR functionality (OCREF can be

cleared by an external event through the ETR signal until the next PWM period), the OCREF signal is asserted only:

- When the result of the comparison changes, or
- When the output compare mode (OCxM bits in TIMx_CCMRx register) switches from the “frozen” configuration (no comparison, OCxM=‘000) to one of the PWM modes (OCxM=‘110 or ‘111).

This forces the PWM by software while the timer is running.

The timer is able to generate PWM in edge-aligned mode or center-aligned mode depending on the CMS bits in the TIMx_CR1 register.

PWM edge-aligned mode

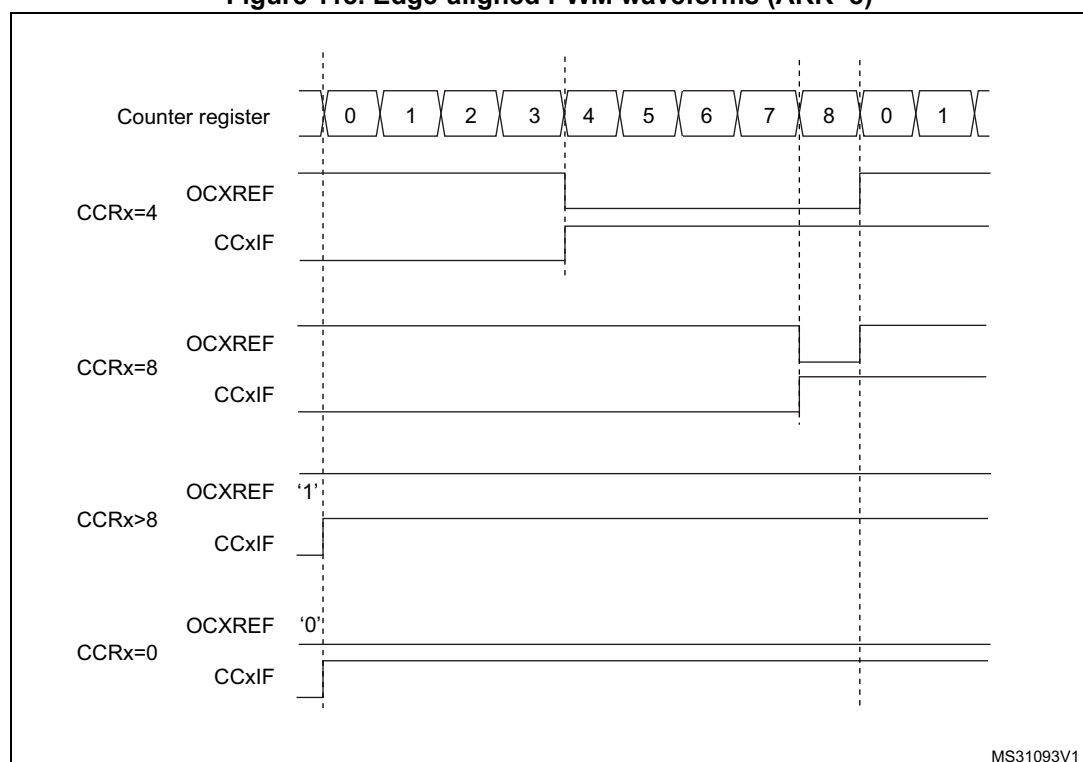
Upcounting configuration

Upcounting is active when the DIR bit in the TIMx_CR1 register is low. Refer to the [Section : Upcounting mode on page 299](#).

In the following example, we consider PWM mode 1. The reference PWM signal OCxREF is high as long as $TIMx\_CNT < TIMx\_CCRx$ else it becomes low. If the compare value in TIMx_CCRx is greater than the auto-reload value (in TIMx_ARR) then OCxREF is held at ‘1’. If the compare value is 0 then OCxREF is held at ‘0’. [Figure 118](#) shows some edge-aligned PWM waveforms in an example where $TIMx\_ARR=8$.

For code example refer to the Appendix section [A.8.9: Center-aligned PWM configuration example](#).

Figure 118. Edge-aligned PWM waveforms (ARR=8)



Downcounting configuration

Downcounting is active when DIR bit in TIMx_CR1 register is high. Refer to [Downcounting mode on page 303](#)

In PWM mode 1, the reference signal ocxref is low as long as $TIMx\_CNT > TIMx\_CCRx$ else it becomes high. If the compare value in TIMx_CCRx is greater than the auto-reload value in TIMx_ARR, then ocxref is held at '1. 0% PWM is not possible in this mode.

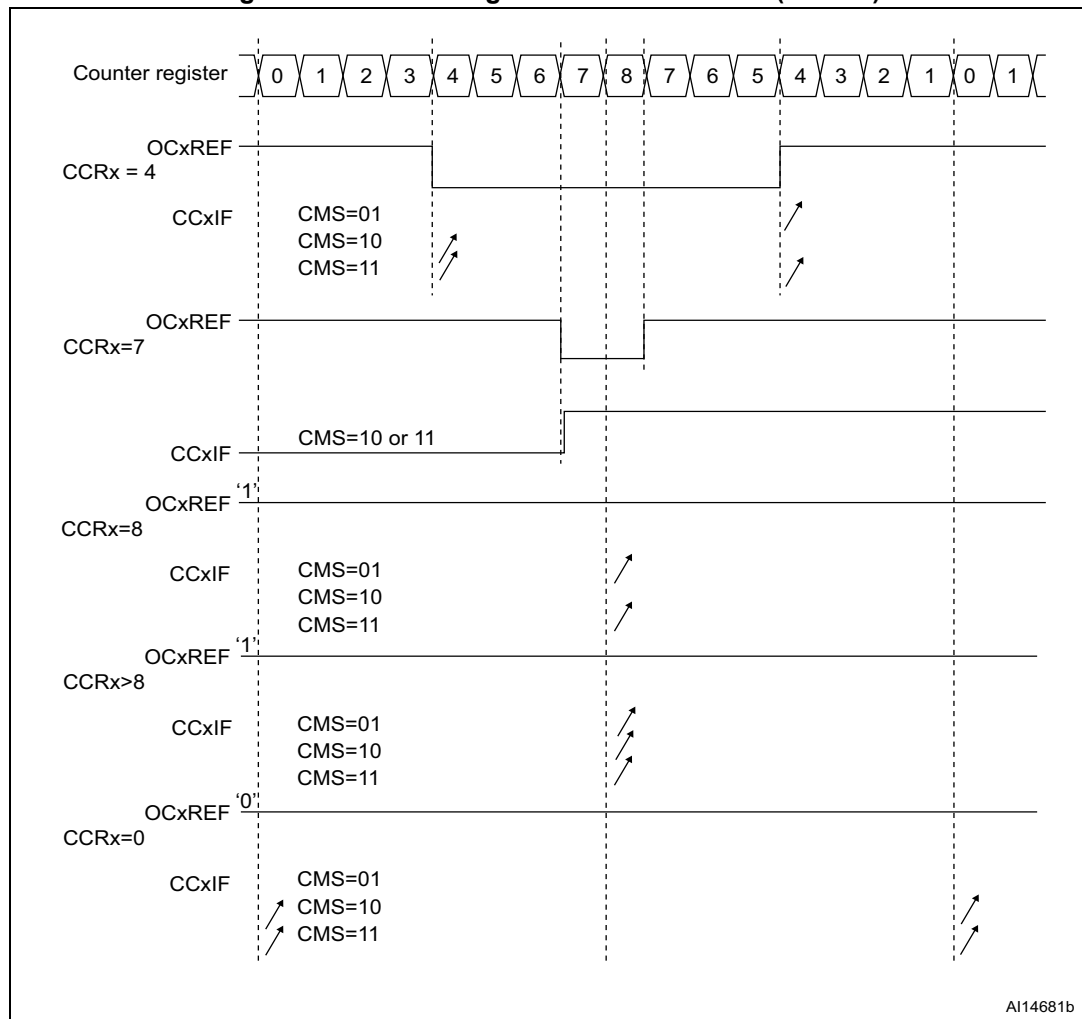
PWM center-aligned mode

Center-aligned mode is active when the CMS bits in TIMx_CR1 register are different from '00 (all the remaining configurations having the same effect on the ocxref/OCx signals). The compare flag is set when the counter counts up, when it counts down or both when it counts up and down depending on the CMS bits configuration. The direction bit (DIR) in the TIMx_CR1 register is updated by hardware and must not be changed by software. Refer to the [Center-aligned mode \(up/down counting\) on page 306](#).

[Figure 119](#) shows some center-aligned PWM waveforms in an example where:

- TIMx_ARR=8,
- PWM mode is the PWM mode 1,
- The flag is set when the counter counts down corresponding to the center-aligned mode 1 selected for CMS=01 in TIMx_CR1 register.

Figure 119. Center-aligned PWM waveforms (ARR=8)



Hints on using center-aligned mode:

- When starting in center-aligned mode, the current up-down configuration is used. It means that the counter counts up or down depending on the value written in the DIR bit in the TIMx_CR1 register. Moreover, the DIR and CMS bits must not be changed at the same time by the software.
- Writing to the counter while running in center-aligned mode is not recommended as it can lead to unexpected results. In particular:
 - The direction is not updated if you write a value in the counter that is greater than the auto-reload value (TIMx_CNT > TIMx_ARR). For example, if the counter was counting up, it continues to count up.
 - The direction is updated if you write 0 or write the TIMx_ARR value in the counter but no Update Event UEV is generated.
- The safest way to use center-aligned mode is to generate an update by software (setting the UG bit in the TIMx_EGR register) just before starting the counter and not to write the counter while it is running.

14.3.10 One-pulse mode

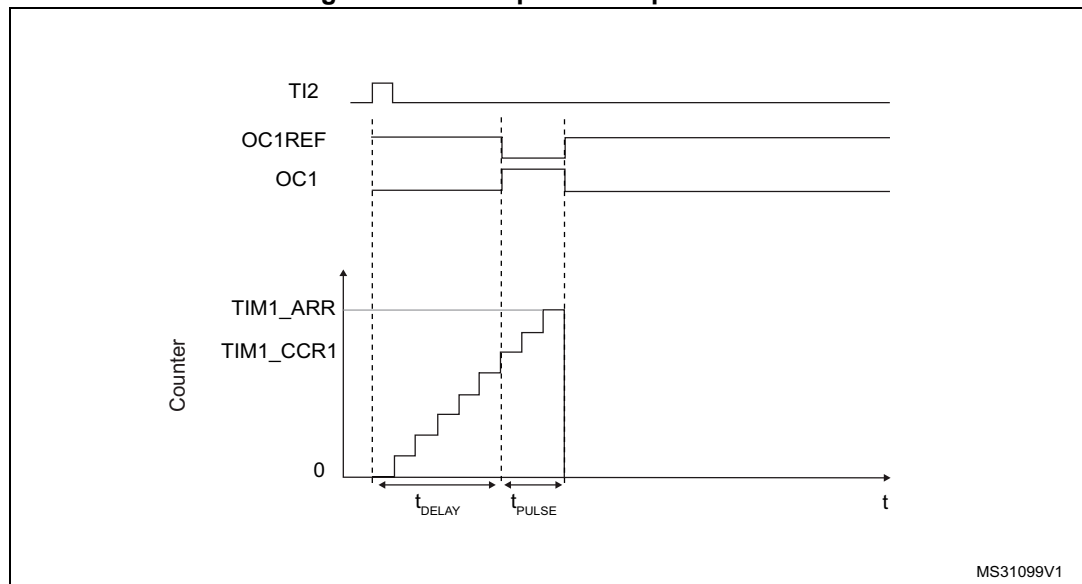
One-pulse mode (OPM) is a particular case of the previous modes. It allows the counter to be started in response to a stimulus and to generate a pulse with a programmable length after a programmable delay.

Starting the counter can be controlled through the slave mode controller. Generating the waveform can be done in output compare mode or PWM mode. You select One-pulse mode by setting the OPM bit in the TIMx_CR1 register. This makes the counter stop automatically at the next update event UEV.

A pulse can be correctly generated only if the compare value is different from the counter initial value. Before starting (when the timer is waiting for the trigger), the configuration must be:

- In upcounting: $CNT < CCRx \leq ARR$ (in particular, $0 < CCRx$),
- In downcounting: $CNT > CCRx$.

Figure 120. Example of one-pulse mode



For example you may want to generate a positive pulse on OC1 with a length of t_{PULSE} and after a delay of t_{DELAY} as soon as a positive edge is detected on the TI2 input pin.

Use TI2FP2 as trigger 1:

- Map TI2FP2 on TI2 by writing CC2S=01 in the TIMx_CCMR1 register.
- TI2FP2 must detect a rising edge, write CC2P=0 and CC2NP='0' in the TIMx_CCER register.
- Configure TI2FP2 as trigger for the slave mode controller (TRGI) by writing TS=110 in the TIMx_SMCR register.
- TI2FP2 is used to start the counter by writing SMS to '110 in the TIMx_SMCR register (trigger mode).

The OPM waveform is defined by writing the compare registers (taking into account the clock frequency and the counter prescaler).

- The t_{DELAY} is defined by the value written in the TIMx_CCR1 register.
- The t_{PULSE} is defined by the difference between the auto-reload value and the compare value (TIMx_ARR - TIMx_CCR1 + 1).
- Let's say you want to build a waveform with a transition from '0' to '1' when a compare match occurs and a transition from '1' to '0' when the counter reaches the auto-reload value. To do this you enable PWM mode 2 by writing OC1M=111 in the TIMx_CCMR1 register. You can optionally enable the preload registers by writing OC1PE=1 in the TIMx_CCMR1 register and ARPE in the TIMx_CR1 register. In this case you have to write the compare value in the TIMx_CCR1 register, the auto-reload value in the TIMx_ARR register, generate an update by setting the UG bit and wait for external trigger event on TI2. CC1P is written to '0' in this example.

In our example, the DIR and CMS bits in the TIMx_CR1 register should be low.

For code example refer to the Appendix section [A.8.16: One-Pulse mode code example](#).

You only want 1 pulse (Single mode), so you write '1' in the OPM bit in the TIMx_CR1 register to stop the counter at the next update event (when the counter rolls over from the auto-reload value back to 0). When OPM bit in the TIMx_CR1 register is set to '0', so the Repetitive Mode is selected.

Particular case: OCx fast enable

In One-pulse mode, the edge detection on Tlx input set the CEN bit which enables the counter. Then the comparison between the counter and the compare value makes the output toggle. But several clock cycles are needed for these operations and it limits the minimum delay $t_{\text{DELAY min}}$ we can get.

If you want to output a waveform with the minimum delay, you can set the OCxFE bit in the TIMx_CCMRx register. Then OCxRef (and OCx) are forced in response to the stimulus, without taking in account the comparison. Its new level is the same as if a compare match had occurred. OCxFE acts only if the channel is configured in PWM1 or PWM2 mode.

For code example refer to the part of code, conditioned by PULSE_WITHOUT_DELAY > 0 in the Appendix section [A.8.16: One-Pulse mode code example](#).

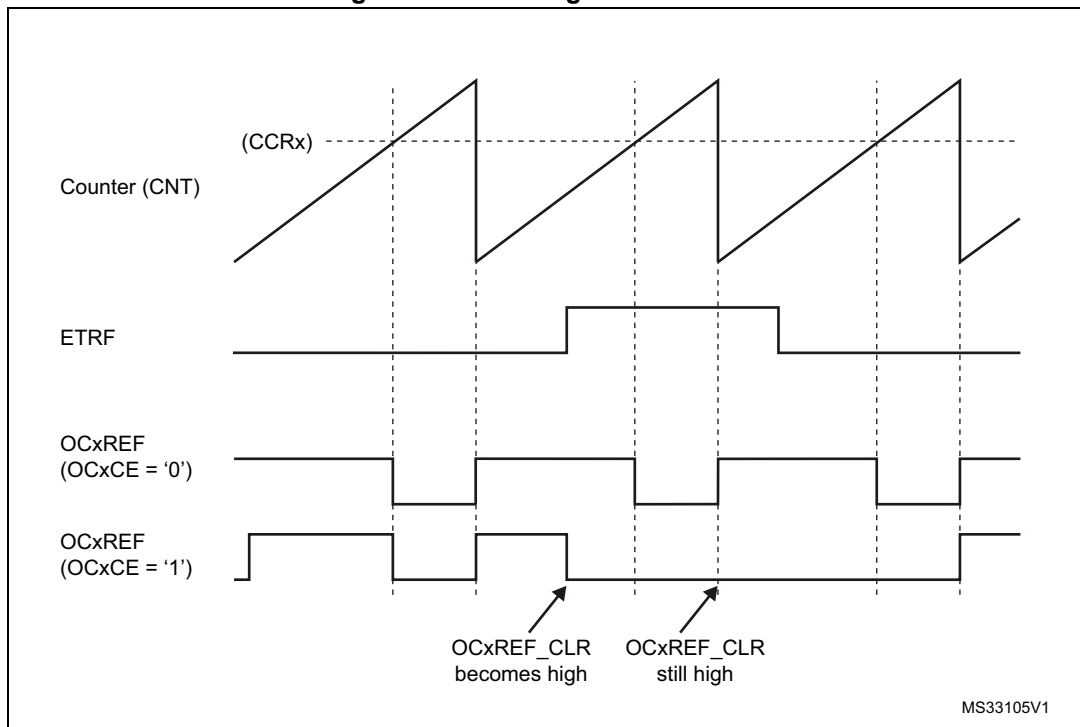
14.3.11 Clearing the OCxREF signal on an external event

1. The external trigger prescaler should be kept off: bits ETPS[1:0] in the TIMx_SMCR register are cleared to 00.
2. The external clock mode 2 must be disabled: bit ECE in the TIM1_SMCR register is cleared to 0.
3. The external trigger polarity (ETP) and the external trigger filter (ETF) can be configured according to the application's needs.

For code example refer to the Appendix section [A.8.10: ETR configuration to clear OCxREF code example](#).

[Figure 121](#) shows the behavior of the OCxREF signal when the ETRF input becomes high, for both values of the OCxCE enable bit. In this example, the timer TIMx is programmed in PWM mode.

Figure 121. Clearing TIMx OCxREF



1. In case of a PWM with a 100% duty cycle (if $CCR_x > ARR$), OCxREF is enabled again at the next counter overflow.

14.3.12 Encoder interface mode

To select Encoder Interface mode write $SMS = '001'$ in the TIMx_SMCR register if the counter is counting on TI2 edges only, $SMS = 010$ if it is counting on TI1 edges only and $SMS = 011$ if it is counting on both TI1 and TI2 edges.

Select the TI1 and TI2 polarity by programming the CC1P and CC2P bits in the TIMx_CCER register. CC1NP and CC2NP must be kept cleared. When needed, you can program the input filter as well.

The two inputs TI1 and TI2 are used to interface to an incremental encoder. Refer to [Table 48](#). The counter is clocked by each valid transition on TI1FP1 or TI2FP2 (TI1 and TI2 after input filter and polarity selection, TI1FP1=TI1 if not filtered and not inverted, TI2FP2=TI2 if not filtered and not inverted) assuming that it is enabled (CEN bit in TIMx_CR1 register written to '1'). The sequence of transitions of the two inputs is evaluated and generates count pulses as well as the direction signal. Depending on the sequence the counter counts up or down, the DIR bit in the TIMx_CR1 register is modified by hardware accordingly. The DIR bit is calculated at each transition on any input (TI1 or TI2), whatever the counter is counting on TI1 only, TI2 only or both TI1 and TI2.

Encoder interface mode acts simply as an external clock with direction selection. This means that the counter just counts continuously between 0 and the auto-reload value in the TIMx_ARR register (0 to ARR or ARR down to 0 depending on the direction). So you must configure TIMx_ARR before starting. In the same way, the capture, compare, prescaler, trigger output features continue to work as normal.

In this mode, the counter is modified automatically following the speed and the direction of the incremental encoder and its content, therefore, always represents the encoder's

position. The count direction correspond to the rotation direction of the connected sensor. The table summarizes the possible combinations, assuming TI1 and TI2 don't switch at the same time.

Table 48. Counting direction versus encoder signals

Active edge	Level on opposite signal (TI1FP1 for TI2, TI2FP2 for TI1)	TI1FP1 signal		TI2FP2 signal	
		Rising	Falling	Rising	Falling
Counting on TI1 only	High	Down	Up	No Count	No Count
	Low	Up	Down	No Count	No Count
Counting on TI2 only	High	No Count	No Count	Up	Down
	Low	No Count	No Count	Down	Up
Counting on TI1 and TI2	High	Down	Up	Up	Down
	Low	Up	Down	Down	Up

An external incremental encoder can be connected directly to the MCU without external interface logic. However, comparators are normally be used to convert the encoder's differential outputs to digital signals. This greatly increases noise immunity. The third encoder output which indicate the mechanical zero position, may be connected to an external interrupt input and trigger a counter reset.

[Figure 122](#) gives an example of counter operation, showing count signal generation and direction control. It also shows how input jitter is compensated where both edges are selected. This might occur if the sensor is positioned near to one of the switching points. For this example we assume that the configuration is the following:

- CC1S= 01 (TIMx_CCMR1 register, TI1FP1 mapped on TI1)
- CC2S= 01 (TIMx_CCMR2 register, TI2FP2 mapped on TI2)
- CC1P=0, CC1NP = '0' (TIMx_CCER register, TI1FP1 noninverted, TI1FP1=TI1)
- CC2P=0, CC2NP = '0' (TIMx_CCER register, TI2FP2 noninverted, TI2FP2=TI2)
- SMS= 011 (TIMx_SMCR register, both inputs are active on both rising and falling edges)
- CEN= 1 (TIMx_CR1 register, Counter is enabled)

For code example refer to the Appendix section [A.8.10: ETR configuration to clear OCxREF code example](#).

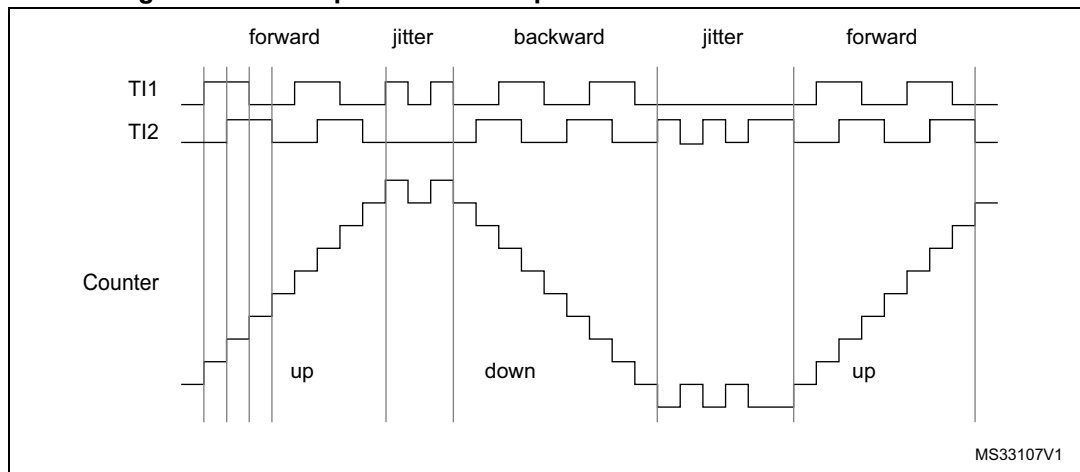
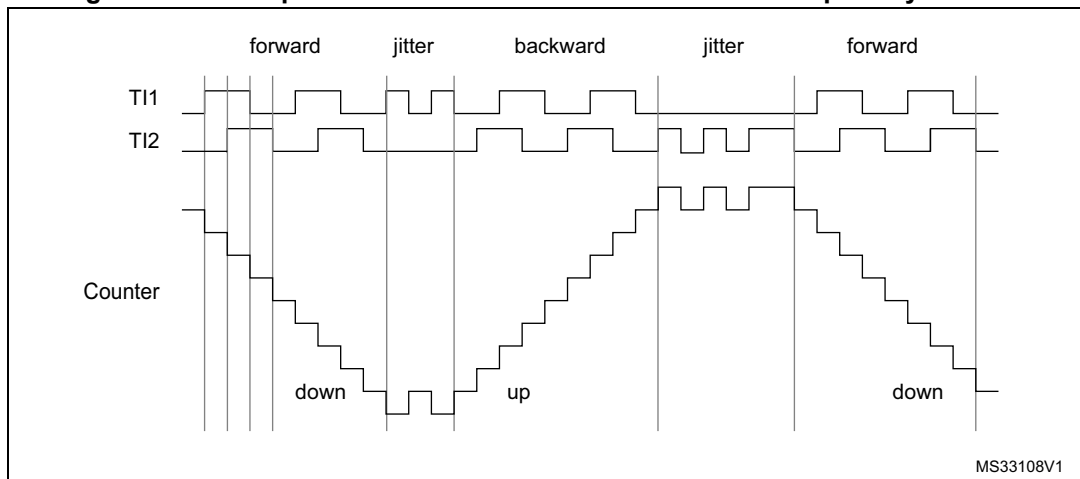
Figure 122. Example of counter operation in encoder interface mode

Figure 123 gives an example of counter behavior when TI1FP1 polarity is inverted (same configuration as above except CC1P=1).

Figure 123. Example of encoder interface mode with TI1FP1 polarity inverted

The timer, when configured in Encoder Interface mode provides information on the sensor's current position. You can obtain dynamic information (speed, acceleration, deceleration) by measuring the period between two encoder events using a second timer configured in capture mode. The output of the encoder which indicates the mechanical zero can be used for this purpose. Depending on the time between two events, the counter can also be read at regular times. You can do this by latching the counter value into a third input capture register if available (then the capture signal must be periodic and can be generated by another timer). when available, it is also possible to read its value through a DMA request generated by a Real-Time clock.

14.3.13 Timer input XOR function

The TI1S bit in the TIM1_CR2 register, allows the input filter of channel 1 to be connected to the output of a XOR gate, combining the three input pins TIMx_CH1 to TIMx_CH3.

The XOR output can be used with all the timer input functions such as trigger or input capture.

An example of this feature used to interface Hall sensors is given in [Section 13.3.18 on page 262](#).

14.3.14 Timers and external trigger synchronization

The TIMx Timers can be synchronized with an external trigger in several modes: Reset mode, Gated mode and Trigger mode.

Slave mode: Reset mode

The counter and its prescaler can be reinitialized in response to an event on a trigger input. Moreover, if the URS bit from the TIMx_CR1 register is low, an update event UEV is generated. Then all the preloaded registers (TIMx_ARR, TIMx_CCRx) are updated.

In the following example, the upcounter is cleared in response to a rising edge on TI1 input:

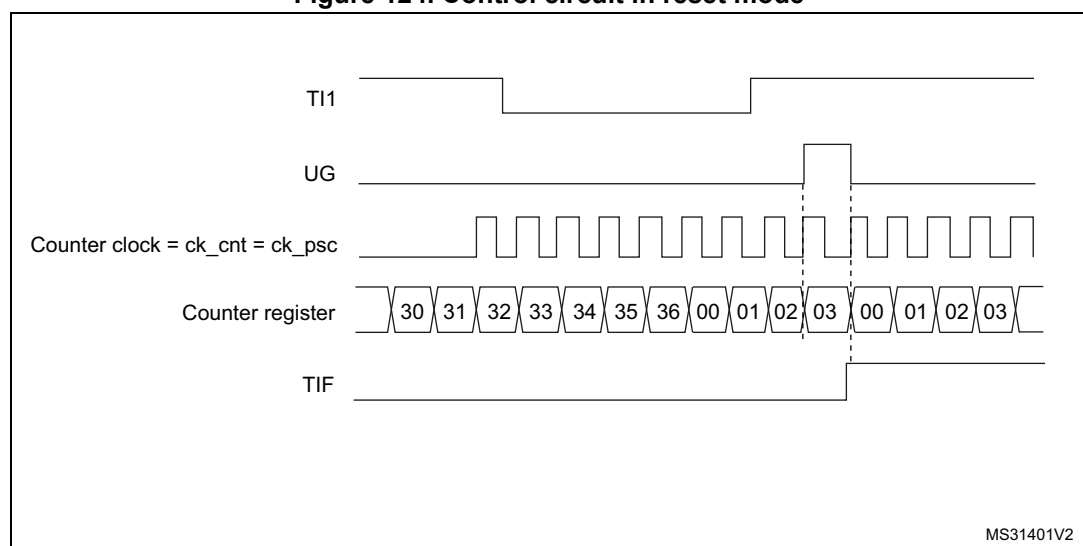
- Configure the channel 1 to detect rising edges on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S = 01 in the TIMx_CCMR1 register. Write CC1P=0 and CC1NP=0 in TIMx_CCER register to validate the polarity (and detect rising edges only).
- Configure the timer in reset mode by writing SMS=100 in TIMx_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx_SMCR register.
- Start the counter by writing CEN=1 in the TIMx_CR1 register.

For code example refer to the Appendix section [A.8.12: Reset mode code example](#).

The counter starts counting on the internal clock, then behaves normally until TI1 rising edge. When TI1 rises, the counter is cleared and restarts from 0. In the meantime, the trigger flag is set (TIF bit in the TIMx_SR register) and an interrupt request, or a DMA request can be sent if enabled (depending on the TIE and TDE bits in TIMx_DIER register).

The following figure shows this behavior when the auto-reload register TIMx_ARR=0x36. The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input.

Figure 124. Control circuit in reset mode



Slave mode: Gated mode

The counter can be enabled depending on the level of a selected input.

In the following example, the upcounter counts only when TI1 input is low:

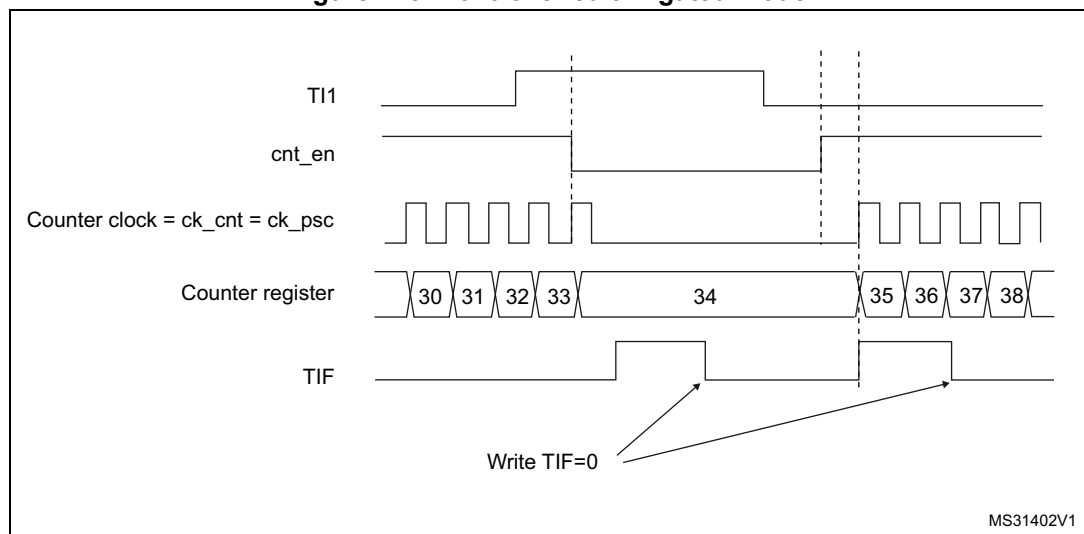
- Configure the channel 1 to detect low levels on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S=01 in TIMx_CCMR1 register. Write CC1P=1 and CC1NP=0 in TIMx_CCER register to validate the polarity (and detect low level only).
- Configure the timer in gated mode by writing SMS=101 in TIMx_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx_SMCR register.
- Enable the counter by writing CEN=1 in the TIMx_CR1 register (in gated mode, the counter doesn't start if CEN=0, whatever is the trigger input level).

For code example refer to the Appendix section [A.8.13: Gated mode code example](#).

The counter starts counting on the internal clock as long as TI1 is low and stops as soon as TI1 becomes high. The TIF flag in the TIMx_SR register is set both when the counter starts or stops.

The delay between the rising edge on TI1 and the actual stop of the counter is due to the resynchronization circuit on TI1 input.

Figure 125. Control circuit in gated mode



1. The configuration "CCxP=CCxNP=1" (detection of both rising and falling edges) does not have any effect in gated mode because gated mode acts on a level and not on an edge.

Slave mode: Trigger mode

The counter can start in response to an event on a selected input.

In the following example, the upcounter starts in response to a rising edge on TI2 input:

- Configure the channel 2 to detect rising edges on TI2. Configure the input filter duration (in this example, we don't need any filter, so we keep IC2F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. CC2S bits are selecting the input capture source only, CC2S=01 in TIMx_CCMR1 register. Write

CC2P=1 and CC2NP=0 in TIMx_CCER register to validate the polarity (and detect low level only).

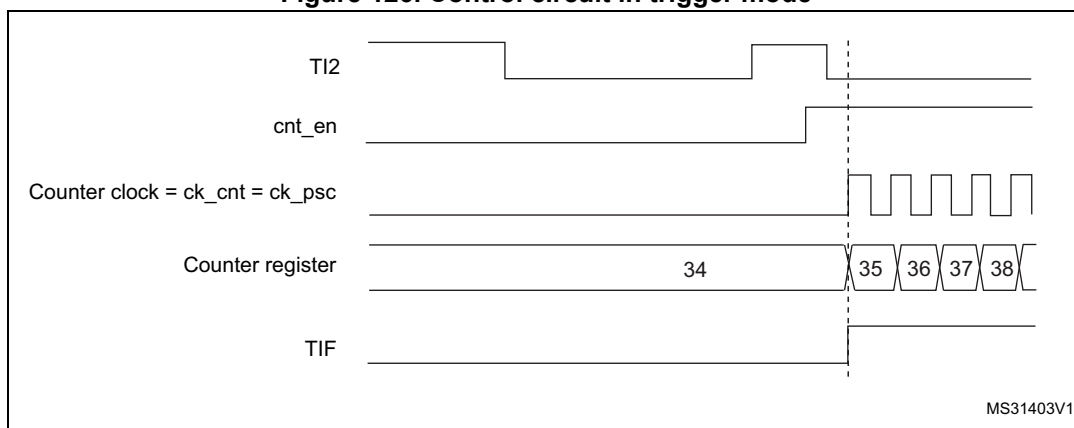
- Configure the timer in trigger mode by writing SMS=110 in TIMx_SMCR register. Select TI2 as the input source by writing TS=110 in TIMx_SMCR register.

For code example refer to the Appendix section [A.8.14: Trigger mode code example](#).

When a rising edge occurs on TI2, the counter starts counting on the internal clock and the TIF flag is set.

The delay between the rising edge on TI2 and the actual start of the counter is due to the resynchronization circuit on TI2 input.

Figure 126. Control circuit in trigger mode



Slave mode: External Clock mode 2 + trigger mode

The external clock mode 2 can be used in addition to another slave mode (except external clock mode 1 and encoder mode). In this case, the ETR signal is used as external clock input, and another input can be selected as trigger input when operating in reset mode, gated mode or trigger mode. It is recommended not to select ETR as TRGI through the TS bits of TIMx_SMCR register.

In the following example, the upcounter is incremented at each rising edge of the ETR signal as soon as a rising edge of TI1 occurs:

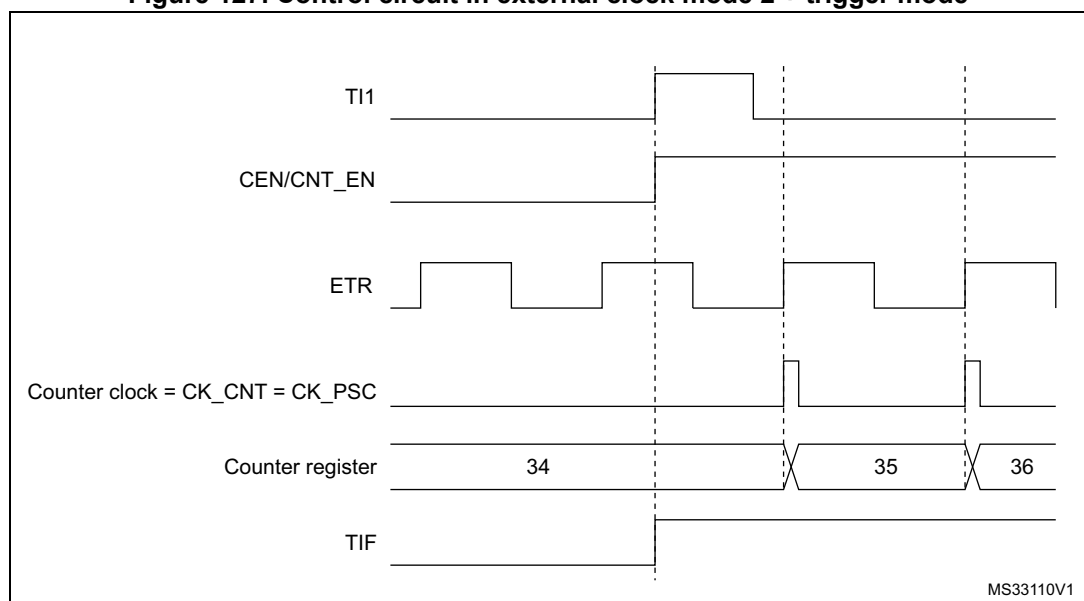
1. Configure the external trigger input circuit by programming the TIMx_SMCR register as follows:
 - ETF = 0000: no filter
 - ETPS=00: prescaler disabled
 - ETP=0: detection of rising edges on ETR and ECE=1 to enable the external clock mode 2.
2. Configure the channel 1 as follows, to detect rising edges on TI:
 - IC1F=0000: no filter.
 - The capture prescaler is not used for triggering and does not need to be configured.
 - CC1S=01 in TIMx_CCMR1 register to select only the input capture source
 - CC1P=0 and CC1NP=0 in TIMx_CCER register to validate the polarity (and detect rising edge only).
3. Configure the timer in trigger mode by writing SMS=110 in TIMx_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx_SMCR register.

For code example refer to the Appendix section [A.8.15: External clock mode 2 + trigger mode code example](#).

A rising edge on TI1 enables the counter and sets the TIF flag. The counter then counts on ETR rising edges.

The delay between the rising edge of the ETR signal and the actual reset of the counter is due to the resynchronization circuit on ETRP input.

Figure 127. Control circuit in external clock mode 2 + trigger mode



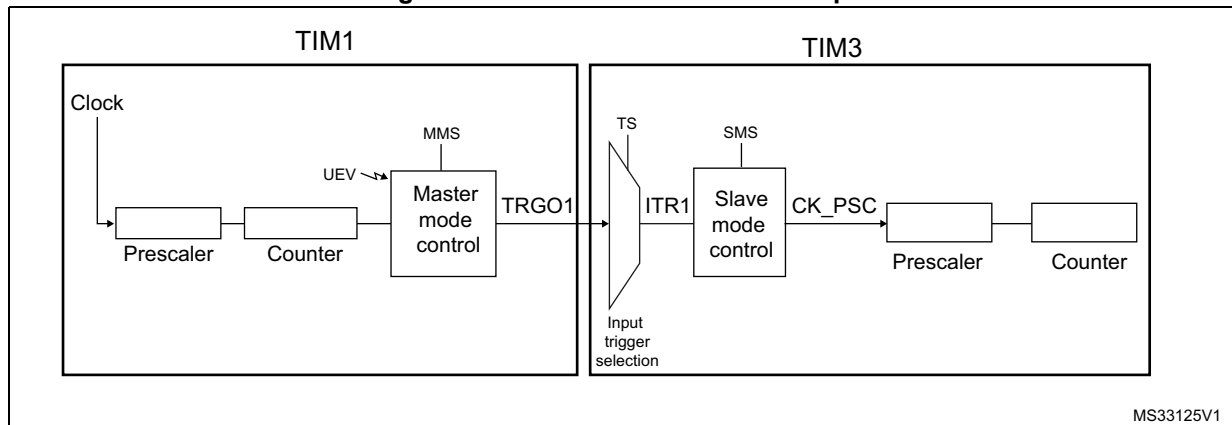
14.3.15 Timer synchronization

The TIMx timers are linked together internally for timer synchronization or chaining. When one Timer is configured in Master Mode, it can reset, start, stop or clock the counter of another Timer configured in Slave Mode.

[Figure 128: Master/Slave timer example](#) presents an overview of the trigger selection and the master mode selection blocks.

Using one timer as prescaler for another

Figure 128. Master/Slave timer example



For example, you can configure Timer 1 to act as a prescaler for Timer 3. Refer to [Figure 128](#). To do this:

- Configure Timer 1 in master mode so that it outputs a periodic trigger signal on each update event UEV. If you write MMS=010 in the TIM1_CR2 register, a rising edge is output on TRGO1 each time an update event is generated.
- To connect the TRGO1 output of Timer 1 to Timer 3, Timer 3 must be configured in slave mode using ITR1 as internal trigger. You select this through the TS bits in the TIM3_SMCR register (writing TS=000).
- Then the Timer2's slave mode controller should be configured in external clock mode 1 (write SMS=111 in the TIM3_SMCR register). This causes Timer 3 to be clocked by the rising edge of the periodic Timer 1 trigger signal (which correspond to the timer 1 counter overflow).
- Finally both timers must be enabled by setting their respective CEN bits within their respective TIMx_CR1 registers. Make sure to enable Timer2 before enabling Timer1.

For code example refer to the Appendix section [A.8.17: Timer prescaling another timer code example](#).

Note: If OCx is selected on Timer 1 as trigger output (MMS=1xx), its rising edge is used to clock the counter of timer 3.

Using one timer to enable another timer

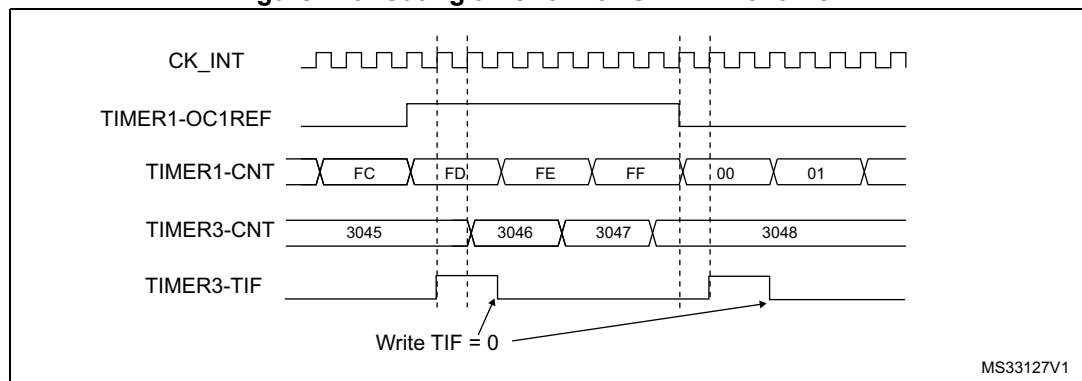
In this example, we control the enable of Timer 3 with the output compare 1 of Timer 1. Refer to [Figure 128](#) for connections. Timer 3 counts on the divided internal clock only when OC1REF of Timer 1 is high. Both counter clock frequencies are divided by 3 by the prescaler compared to CK_INT ($f_{CK\_CNT} = f_{CK\_INT}/3$).

- Configure Timer 1 master mode to send its Output Compare 1 Reference (OC1REF) signal as trigger output (MMS=100 in the TIM1_CR2 register).
- Configure the Timer 1 OC1REF waveform (TIM1_CCMR1 register).
- Configure Timer 3 to get the input trigger from Timer 1 (TS=000 in the TIM3_SMCR register).
- Configure Timer 3 in gated mode (SMS=101 in TIM3_SMCR register).
- Enable Timer 3 by writing '1 in the CEN bit (TIM3_CR1 register).
- Start Timer 1 by writing '1 in the CEN bit (TIM1_CR1 register).

For code example refer to the Appendix section [A.8.18: Timer enabling another timer code example](#).

Note: The counter 3 clock is not synchronized with counter 1, this mode only affects the Timer 3 counter enable signal.

Figure 129. Gating timer 3 with OC1REF of timer 1



In the example in [Figure 129](#), the Timer 3 counter and prescaler are not initialized before being started. So they start counting from their current value. It is possible to start from a given value by resetting both timers before starting Timer 1. You can then write any value you want in the timer counters. The timers can easily be reset by software using the UG bit in the TIMx_EGR registers.

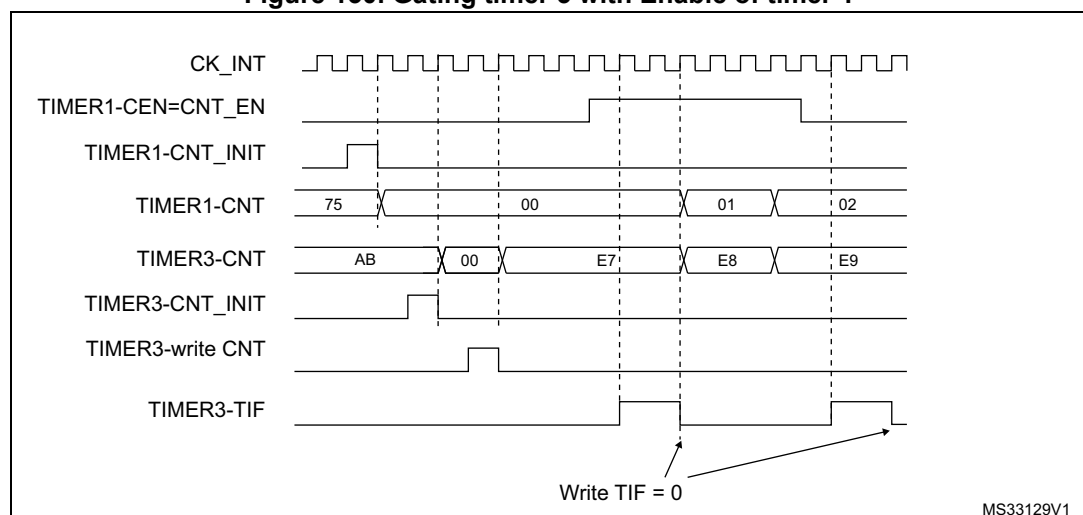
In the next example, we synchronize Timer 1 and Timer 3. Timer 1 is the master and starts from 0. Timer 3 is the slave and starts from 0xE7. The prescaler ratio is the same for both

timers. Timer 3 stops when Timer 1 is disabled by writing '0 to the CEN bit in the TIM1_CR1 register:

- Configure Timer 1 master mode to send its Counter Enable signal (CNT_EN) as a trigger output (MMS=001 in the TIM1_CR2 register).
- Configure the Timer 1 OC1REF waveform (TIM1_CCMR1 register).
- Configure Timer 3 to get the input trigger from Timer 1 (TS=000 in the TIM3_SMCR register).
- Configure Timer 3 in gated mode (SMS=101 in TIM3_SMCR register).
- Reset Timer 1 by writing '1 in UG bit (TIM1_EGR register).
- Reset Timer 3 by writing '1 in UG bit (TIM3_EGR register).
- Initialize Timer 3 to 0xE7 by writing '0xE7' in the timer 3 counter (TIM3_CNTL).
- Enable Timer 3 by writing '1 in the CEN bit (TIM3_CR1 register).
- Start Timer 1 by writing '1 in the CEN bit (TIM1_CR1 register).
- Stop Timer 1 by writing '0 in the CEN bit (TIM1_CR1 register).

For code example refer to the Appendix section [A.8.19: Master and slave synchronization code example](#).

Figure 130. Gating timer 3 with Enable of timer 1

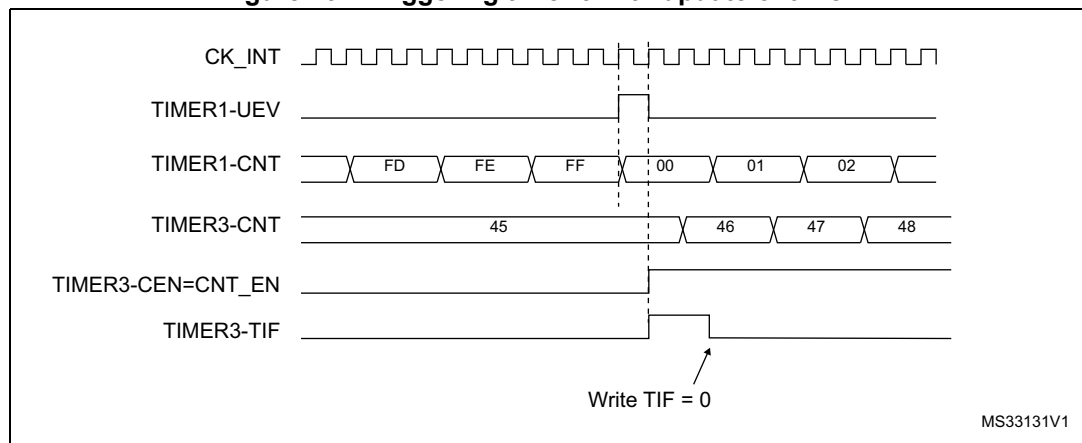


Using one timer to start another timer

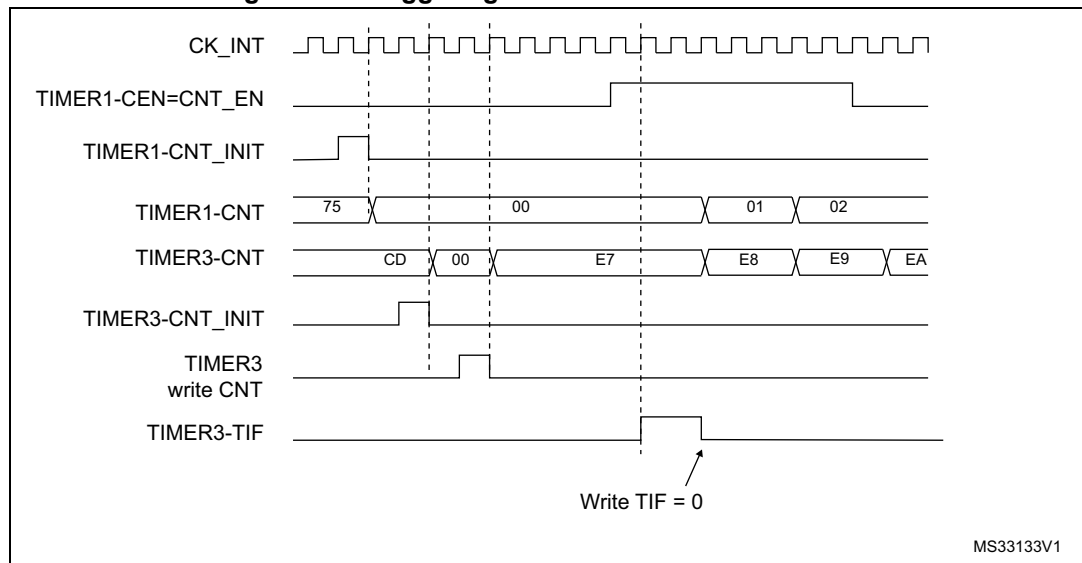
In this example, we set the enable of Timer 3 with the update event of Timer 1. Refer to [Figure 128](#) for connections. Timer 3 starts counting from its current value (which can be nonzero) on the divided internal clock as soon as the update event is generated by Timer 1. When Timer 3 receives the trigger signal its CEN bit is automatically set and the counter counts until we write '0 to the CEN bit in the TIM3_CR1 register. Both counter clock frequencies are divided by 3 by the prescaler compared to CK_INT ($f_{CK\_CNT} = f_{CK\_INT}/3$).

- Configure Timer 1 master mode to send its Update Event (UEV) as trigger output (MMS=010 in the TIM1_CR2 register).
- Configure the Timer 1 period (TIM1_ARR registers).
- Configure Timer 3 to get the input trigger from Timer 1 (TS=000 in the TIM3_SMCR register).
- Configure Timer 3 in trigger mode (SMS=110 in TIM3_SMCR register).
- Start Timer 1 by writing '1 in the CEN bit (TIM1_CR1 register).

Figure 131. Triggering timer 3 with update of timer 1



As in the previous example, you can initialize both counters before starting counting. [Figure 132](#) shows the behavior with the same configuration as in [Figure 131](#) but in trigger mode instead of gated mode (SMS=110 in the TIM3_SMCR register).

Figure 132. Triggering timer 3 with Enable of timer 1

MS33133V1

Starting 2 timers synchronously in response to an external trigger

In this example, we set the enable of timer 1 when its TI1 input rises, and the enable of Timer 3 with the enable of Timer 1. Refer to [Figure 128](#) for connections. To ensure the counters are aligned, Timer 1 must be configured in Master/Slave mode (slave with respect to TI1, master with respect to Timer 3):

- Configure Timer 1 master mode to send its Enable as trigger output (MMS=001 in the TIM1_CR2 register).
- Configure Timer 1 slave mode to get the input trigger from TI1 (TS=100 in the TIM1_SMCR register).
- Configure Timer 1 in trigger mode (SMS=110 in the TIM1_SMCR register).
- Configure the Timer 1 in Master/Slave mode by writing MSM=1 (TIM1_SMCR register).
- Configure Timer 3 to get the input trigger from Timer 1 (TS=000 in the TIM3_SMCR register).
- Configure Timer 3 in trigger mode (SMS=110 in the TIM3_SMCR register).

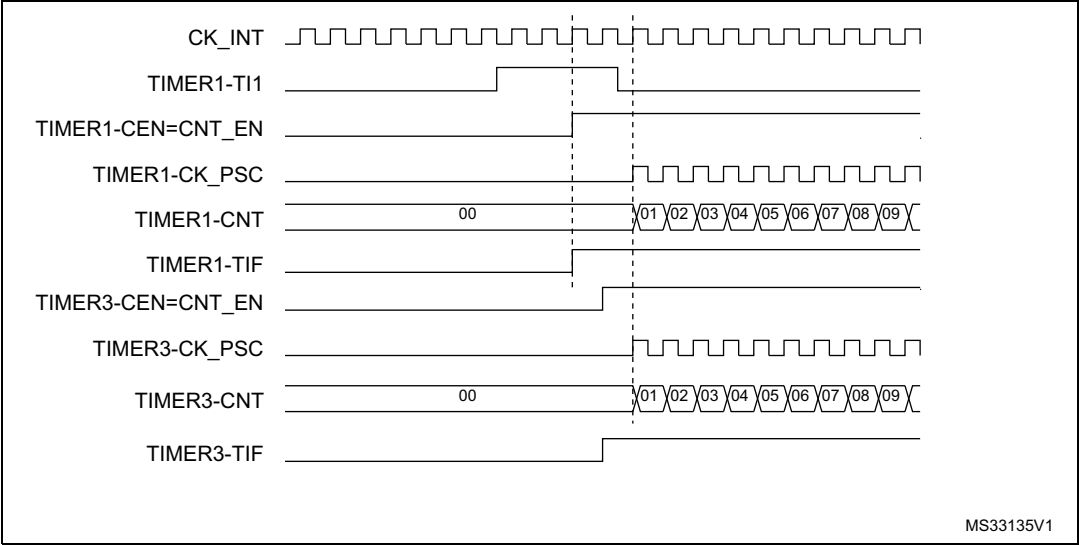
For code example refer to the Appendix section [A.8.20: Two timers synchronized by an external trigger code example](#).

When a rising edge occurs on TI1 (Timer 1), both counters start counting synchronously on the internal clock and both TIF flags are set.

Note:

In this example both timers are initialized before starting (by setting their respective UG bits). Both counters start from 0, but you can easily insert an offset between them by writing any of the counter registers (TIMx_CNT). You can see that the master/slave mode insert a delay between CNT_EN and CK_PSC on timer 1.

Figure 133. Triggering timer 1 and 3 with timer 1 TI1 input



14.3.16 Debug mode

When the microcontroller enters debug mode (ARM® Cortex®-M0 core - halted), the TIMx counter either continues to work normally or stops, depending on DBG_TIMx_STOP configuration bit in DBGMCU module.

14.4 TIM3 registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

14.4.1 TIM3 control register 1 (TIM3_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	CMS		DIR	OPM	URS	UDIS	CEN
						rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:10 Reserved, always read as 0.

Bits 9:8 **CKD**: Clock division

This bit-field indicates the division ratio between the timer clock (CK_INT) frequency and sampling clock used by the digital filters (ETR, Tlx),

00: $t_{DTS} = t_{CK\_INT}$

01: $t_{DTS} = 2 \times t_{CK\_INT}$

10: $t_{DTS} = 4 \times t_{CK\_INT}$

11: Reserved

Bit 7 **ARPE**: Auto-reload preload enable

0: TIMx_ARR register is not buffered

1: TIMx_ARR register is buffered

Bits 6:5 **CMS**: Center-aligned mode selection

00: Edge-aligned mode. The counter counts up or down depending on the direction bit (DIR).

01: Center-aligned mode 1. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx_CCMRx register) are set only when the counter is counting down.

10: Center-aligned mode 2. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx_CCMRx register) are set only when the counter is counting up.

11: Center-aligned mode 3. The counter counts up and down alternatively. Output compare interrupt flags of channels configured in output (CCxS=00 in TIMx_CCMRx register) are set both when the counter is counting up or down.

Note: It is not allowed to switch from edge-aligned mode to center-aligned mode as long as the counter is enabled (CEN=1)

Bit 4 **DIR**: Direction

0: Counter used as upcounter

1: Counter used as downcounter

Note: This bit is read only when the timer is configured in Center-aligned mode or Encoder mode.

Bit 3 **OPM**: One-pulse mode

0: Counter is not stopped at update event

1: Counter stops counting at the next update event (clearing the bit CEN)

Bit 2 URS: Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generate an update interrupt or DMA request if enabled.

These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt or DMA request if enabled.

Bit 1 UDIS: Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

Bit 0 CEN: Counter enable

0: Counter disabled

1: Counter enabled

Note: External clock, gated mode and encoder mode can work only if the CEN bit has been previously set by software. However trigger mode can set the CEN bit automatically by hardware.

CEN is cleared automatically in one-pulse mode, when an update event occurs.

14.4.2 TIM3 control register 2 (TIM3_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TI1S	MMS[2:0]			CCDS	Res.	Res.	Res.
								rw	rw	rw	rw	rw			

Bits 15:8 Reserved, must be kept at reset value.

Bit 7 **TI1S**: TI1 selection

0: The TIMx_CH1 pin is connected to TI1 input

1: The TIMx_CH1, CH2 and CH3 pins are connected to the TI1 input (XOR combination)

See also [Section 13.3.18: Interfacing with Hall sensors on page 262](#)

Bits 6:4 **MMS**: Master mode selection

These bits allow to select the information to be sent in master mode to slave timers for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIMx_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (slave mode controller configured in reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter enable signal, CNT_EN, is used as trigger output (TRGO). It is useful to start several timers at the same time or to control a window in which a slave timer is enabled. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode.

When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in TIMx_SMCR register).

010: **Update** - The update event is selected as trigger output (TRGO). For instance a master timer can then be used as a prescaler for a slave timer.

011: **Compare Pulse** - The trigger output send a positive pulse when the CC1IF flag is to be set (even if it was already high), as soon as a capture or a compare match occurred. (TRGO)

100: **Compare** - OC1REF signal is used as trigger output (TRGO)

101: **Compare** - OC2REF signal is used as trigger output (TRGO)

110: **Compare** - OC3REF signal is used as trigger output (TRGO)

111: **Compare** - OC4REF signal is used as trigger output (TRGO)

Bit 3 **CCDS**: Capture/compare DMA selection

0: CCx DMA request sent when CCx event occurs

1: CCx DMA requests sent when update event occurs

Bits 2:0 Reserved, always read as 0.

14.4.3 TIM3 slave mode control register (TIM3_SMCR)

Address offset: 0x08

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ETP	ECE	ETPS[1:0]		ETF[3:0]				MSM	TS[2:0]			OCCS	SMS[2:0]		
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bit 15 **ETP**: External trigger polarity

This bit selects whether ETR or $\overline{\text{ETR}}$ is used for trigger operations

0: ETR is noninverted, active at high level or rising edge

1: ETR is inverted, active at low level or falling edge

Bit 14 **ECE**: External clock enable

This bit enables External clock mode 2.

0: External clock mode 2 disabled

1: External clock mode 2 enabled. The counter is clocked by any active edge on the ETRF signal.

1: Setting the ECE bit has the same effect as selecting external clock mode 1 with TRGI connected to ETRF (SMS=111 and TS=111).

2: It is possible to simultaneously use external clock mode 2 with the following slave modes: reset mode, gated mode and trigger mode. Nevertheless, TRGI must not be connected to ETRF in this case (TS bits must not be 111).

3: If external clock mode 1 and external clock mode 2 are enabled at the same time, the external clock input is ETRF.

Bits 13:12 **ETPS**: External trigger prescaler

External trigger signal ETRP frequency must be at most 1/4 of CK_INT frequency. A prescaler can be enabled to reduce ETRP frequency. It is useful when inputting fast external clocks.

00: Prescaler OFF

01: ETRP frequency divided by 2

10: ETRP frequency divided by 4

11: ETRP frequency divided by 8

Bits 11:8 **ETF[3:0]**: External trigger filter

This bit-field defines the frequency used to sample ETRP signal and the length of the digital filter applied to ETRP. The digital filter is made of an event counter in which N consecutive events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{DTS}

0001: $f_{SAMPLING} = f_{CK\_INT}$, $N = 2$

0010: $f_{SAMPLING} = f_{CK\_INT}$, $N = 4$

0011: $f_{SAMPLING} = f_{CK\_INT}$, $N = 8$

0100: $f_{SAMPLING} = f_{DTS} / 2$, $N = 6$

0101: $f_{SAMPLING} = f_{DTS} / 2$, $N = 8$

0110: $f_{SAMPLING} = f_{DTS} / 4$, $N = 6$

0111: $f_{SAMPLING} = f_{DTS} / 4$, $N = 8$

1000: $f_{SAMPLING} = f_{DTS} / 8$, $N = 6$

1001: $f_{SAMPLING} = f_{DTS} / 8$, $N = 8$

1010: $f_{SAMPLING} = f_{DTS} / 16$, $N = 5$

1011: $f_{SAMPLING} = f_{DTS} / 16$, $N = 6$

1100: $f_{SAMPLING} = f_{DTS} / 16$, $N = 8$

1101: $f_{SAMPLING} = f_{DTS} / 32$, $N = 5$

1110: $f_{SAMPLING} = f_{DTS} / 32$, $N = 6$

1111: $f_{SAMPLING} = f_{DTS} / 32$, $N = 8$

Note: Care must be taken that f_{DTS} is replaced in the formula by CK_INT when $ETF[3:0] = 1, 2$ or 3 .

Bit 7 **MSM**: Master/Slave mode

0: No action

1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between the current timer and its slaves (through TRGO). It is useful if we want to synchronize several timers on a single external event.

Bits 6:4 **TS**: Trigger selection

This bit-field selects the trigger input to be used to synchronize the counter.

000: Internal Trigger 0 (ITR0).

001: Internal Trigger 1 (ITR1).

010: Internal Trigger 2 (ITR2).

011: Internal Trigger 3 (ITR3).

100: TI1 Edge Detector (TI1F_ED)

101: Filtered Timer Input 1 (TI1FP1)

110: Filtered Timer Input 2 (TI2FP2)

111: External Trigger input (ETRF)

See [Table 49: TIM3 internal trigger connection on page 343](#) for more details on ITRx meaning for each Timer.

Note: These bits must be changed only when they are not used (e.g. when $SMS=000$) to avoid wrong edge detections at the transition.

Bit 3 **OCCS**: OCREF clear selection.

This bit is used to select the OCREF clear source.

0: OCREF_CLR_INT is connected to the OCREF_CLR input

1: OCREF_CLR_INT is connected to ETRF

Bits 2:0 **SMS**: Slave mode selection

When external signals are selected the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).

000: Slave mode disabled - if CEN = '1 then the prescaler is clocked directly by the internal clock.

001: Encoder mode 1 - Counter counts up/down on TI2FP1 edge depending on TI1FP2 level.

010: Encoder mode 2 - Counter counts up/down on TI1FP2 edge depending on TI2FP1 level.

011: Encoder mode 3 - Counter counts up/down on both TI1FP1 and TI2FP2 edges depending on the level of the other input.

100: Reset Mode - Rising edge of the selected trigger input (TRGI) reinitializes the counter and generates an update of the registers.

101: Gated Mode - The counter clock is enabled when the trigger input (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.

110: Trigger Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.

111: External Clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

Note: The gated mode must not be used if TI1F_ED is selected as the trigger input (TS=100). Indeed, TI1F_ED outputs 1 pulse for each transition on TI1F, whereas the gated mode checks the level of the trigger signal.

Note: The clock of the slave timer must be enabled prior to receive events from the master timer, and must not be changed on-the-fly while triggers are received from the master timer.

Table 49. TIM3 internal trigger connection

Slave TIM	ITR0 (TS = 000)	ITR2 (TS = 010)	ITR3 (TS = 011)
TIM3	TIM1	TIM15	TIM14

14.4.4 TIM3 DMA/Interrupt enable register (TIM3_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TDE	Res.	CC4DE	CC3DE	CC2DE	CC1DE	UDE	Res.	TIE	Res.	CC4IE	CC3IE	CC2IE	CC1IE	UIE
	rw		rw	rw	rw	rw	rw		rw		rw	rw	rw	rw	rw

Bit 15 Reserved, must be kept at reset value.

Bit 14 **TDE**: Trigger DMA request enable

0: Trigger DMA request disabled.

1: Trigger DMA request enabled.

Bit 13 Reserved, always read as 0

Bit 12 **CC4DE**: Capture/Compare 4 DMA request enable

0: CC4 DMA request disabled.

1: CC4 DMA request enabled.

- Bit 11 **CC3DE**: Capture/Compare 3 DMA request enable
 0: CC3 DMA request disabled.
 1: CC3 DMA request enabled.
- Bit 10 **CC2DE**: Capture/Compare 2 DMA request enable
 0: CC2 DMA request disabled.
 1: CC2 DMA request enabled.
- Bit 9 **CC1DE**: Capture/Compare 1 DMA request enable
 0: CC1 DMA request disabled.
 1: CC1 DMA request enabled.
- Bit 8 **UDE**: Update DMA request enable
 0: Update DMA request disabled.
 1: Update DMA request enabled.
- Bit 7 Reserved, must be kept at reset value.
- Bit 6 **TIE**: Trigger interrupt enable
 0: Trigger interrupt disabled.
 1: Trigger interrupt enabled.
- Bit 5 Reserved, must be kept at reset value.
- Bit 4 **CC4IE**: Capture/Compare 4 interrupt enable
 0: CC4 interrupt disabled.
 1: CC4 interrupt enabled.
- Bit 3 **CC3IE**: Capture/Compare 3 interrupt enable
 0: CC3 interrupt disabled
 1: CC3 interrupt enabled
- Bit 2 **CC2IE**: Capture/Compare 2 interrupt enable
 0: CC2 interrupt disabled
 1: CC2 interrupt enabled
- Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable
 0: CC1 interrupt disabled
 1: CC1 interrupt enabled
- Bit 0 **UIE**: Update interrupt enable
 0: Update interrupt disabled
 1: Update interrupt enabled

14.4.5 TIM3 status register (TIM3_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	CC4OF	CC3OF	CC2OF	CC1OF	Res.	Res.	TIF	Res.	CC4IF	CC3IF	CC2IF	CC1IF	UIF
			rc_w0	rc_w0	rc_w0	rc_w0			rc_w0		rc_w0	rc_w0	rc_w0	rc_w0	rc_w0

Bit 15:13 Reserved, always read as 0.

Bit 12 **CC4OF**: Capture/Compare 4 overcapture flag
Refer to CC1OF description

Bit 11 **CC3OF**: Capture/Compare 3 overcapture flag
Refer to CC1OF description

Bit 10 **CC2OF**: Capture/compare 2 overcapture flag
Refer to CC1OF description

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag
This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.
0: No overcapture has been detected
1: The counter value has been captured in TIMx_CCR1 register while CC1IF flag was already set

Bits 8:7 Reserved, always read as 0.

Bit 6 **TIF**: Trigger interrupt flag
This flag is set by hardware on trigger event (active edge detected on TRGI input when the slave mode controller is enabled in all modes but gated mode. It is set when the counter starts or stops when gated mode is selected. It is cleared by software.
0: No trigger event occurred
1: Trigger interrupt pending

Bit 5 Reserved, always read as 0.

Bit 4 **CC4IF**: Capture/Compare 4 interrupt flag
Refer to CC1IF description

Bit 3 **CC3IF**: Capture/Compare 3 interrupt flag
Refer to CC1IF description

Bit 2 **CC2IF**: Capture/Compare 2 interrupt flag
Refer to CC1IF description

Bit 1 **CC1IF**: Capture/compare 1 interrupt flag

If channel CC1 is configured as output:

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits in the TIMx_CR1 register description). It is cleared by software.

0: No match

1: The content of the counter TIMx_CNT matches the content of the TIMx_CCR1 register.

When the contents of TIMx_CCR1 are greater than the contents of TIMx_ARR, the CC1IF bit goes high on the counter overflow (in upcounting and up/down-counting modes) or underflow (in downcounting mode)

If channel CC1 is configured as input:

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx_CCR1 register.

0: No input capture occurred

1: The counter value has been captured in TIMx_CCR1 register (An edge has been detected on IC1 which matches the selected polarity)

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending.

This bit is set by hardware when the registers are updated:

At overflow or underflow and if UDIS=0 in the TIMx_CR1 register.

When CNT is reinitialized by software using the UG bit in TIMx_EGR register, if URS=0 and UDIS=0 in the TIMx_CR1 register.

When CNT is reinitialized by a trigger event (refer to the synchro control register description), if URS=0 and UDIS=0 in the TIMx_CR1 register.

14.4.6 TIM3 event generation register (TIM3_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TG	Res.	CC4G	CC3G	CC2G	CC1G	UG
									w		w	w	w	w	w

Bits 15:7 Reserved, must be kept at reset value.

Bit 6 **TG**: Trigger generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: The TIF flag is set in TIMx_SR register. Related interrupt or DMA transfer can occur if enabled.

Bit 5 Reserved, must be kept at reset value.

Bit 4 **CC4G**: Capture/compare 4 generation

Refer to CC1G description

Bit 3 **CC3G**: Capture/compare 3 generation

Refer to CC1G description

Bit 2 **CC2G**: Capture/compare 2 generation

Refer to CC1G description

Bit 1 **CC1G**: Capture/compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

If channel CC1 is configured as output:

CC1IF flag is set, Corresponding interrupt or DMA request is sent if enabled.

If channel CC1 is configured as input:

The current value of the counter is captured in TIMx_CCR1 register. The CC1IF flag is set, the corresponding interrupt or DMA request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: Re-initialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared if the center-aligned mode is selected or if DIR=0 (upcounting), else it takes the auto-reload value (TIMx_ARR) if DIR=1 (downcounting).

14.4.7 TIM3 capture/compare mode register 1 (TIM3_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CCxS bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OCxx describes its function when the channel is configured in output, ICxx describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OC2CE	OC2M[2:0]			OC2PE	OC2FE	CC2S[1:0]		OC1CE	OC1M[2:0]			OC1PE	OC1FE	CC1S[1:0]	
IC2F[3:0]				IC2PSC[1:0]				IC1F[3:0]			IC1PSC[1:0]				
r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w

Output compare mode

Bit 15 **OC2CE**: Output compare 2 clear enable

Bits 14:12 **OC2M[2:0]**: Output compare 2 mode

Bit 11 **OC2PE**: Output compare 2 preload enable

Bit 10 **OC2FE**: Output compare 2 fast enable

Bits 9:8 **CC2S[1:0]**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output

01: CC2 channel is configured as input, IC2 is mapped on TI2

10: CC2 channel is configured as input, IC2 is mapped on TI1

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through the TS bit (TIMx_SMCR register)

Note: CC2S bits are writable only when the channel is OFF (CC2E = 0 in TIMx_CCER).

Bit 7 **OC1CE**: Output compare 1 clear enable

OC1CE: Output Compare 1 Clear Enable

0: OC1Ref is not affected by the ETRF input

1: OC1Ref is cleared as soon as a High level is detected on ETRF input

Bits 6:4 **OC1M**: Output compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

000: Frozen - The comparison between the output compare register TIMx_CCR1 and the counter TIMx_CNT has no effect on the outputs.(this mode is used to generate a timing base).

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

011: Toggle - OC1REF toggles when TIMx_CNT=TIMx_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx_CNT<TIMx_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF=0) as long as TIMx_CNT>TIMx_CCR1 else active (OC1REF=1).

111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx_CNT<TIMx_CCR1 else active. In downcounting, channel 1 is active as long as TIMx_CNT>TIMx_CCR1 else inactive.

Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S=00 (the channel is configured in output).

2: In PWM mode 1 or 2, the OCREF level changes only when the result of the comparison changes or when the output compare mode switches from "frozen" mode to "PWM" mode.

Bit 3 **OC1PE**: Output compare 1 preload enable

0: Preload register on TIMx_CCR1 disabled. TIMx_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx_CCR1 enabled. Read/Write operations access the preload register. TIMx_CCR1 preload value is loaded in the active register at each update event.

Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S=00 (the channel is configured in output).

2: The PWM mode can be used without validating the preload register only in one-pulse mode (OPM bit set in TIMx_CR1 register). Else the behavior is not guaranteed.

Bit 2 **OC1FE**: Output compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger in input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently from the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OCFE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output.

01: CC1 channel is configured as input, IC1 is mapped on TI1.

10: CC1 channel is configured as input, IC1 is mapped on TI2.

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC1S bits are writable only when the channel is OFF (CC1E = 0 in TIMx_CCER).

Input capture mode

Bits 15:12 **IC2F**: Input capture 2 filter

Bits 11:10 **IC2PSC[1:0]**: Input capture 2 prescaler

Bits 9:8 **CC2S**: Capture/compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output.

01: CC2 channel is configured as input, IC2 is mapped on TI2.

10: CC2 channel is configured as input, IC2 is mapped on TI1.

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC2S bits are writable only when the channel is OFF (CC2E = 0 in TIMx_CCER).

Bits 7:4 **IC1F**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N consecutive events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{DTS}

0001: $f_{SAMPLING} = f_{CK\_INT}$, $N = 2$

0010: $f_{SAMPLING} = f_{CK\_INT}$, $N = 4$

0011: $f_{SAMPLING} = f_{CK\_INT}$, $N = 8$

0100: $f_{SAMPLING} = f_{DTS} / 2$, $N = 6$

0101: $f_{SAMPLING} = f_{DTS} / 2$, $N = 8$

0110: $f_{SAMPLING} = f_{DTS} / 4$, $N = 6$

0111: $f_{SAMPLING} = f_{DTS} / 4$, $N = 8$

1000: $f_{SAMPLING} = f_{DTS} / 8$, $N = 6$

1001: $f_{SAMPLING} = f_{DTS} / 8$, $N = 8$

1010: $f_{SAMPLING} = f_{DTS} / 16$, $N = 5$

1011: $f_{SAMPLING} = f_{DTS} / 16$, $N = 6$

1100: $f_{SAMPLING} = f_{DTS} / 16$, $N = 8$

1101: $f_{SAMPLING} = f_{DTS} / 32$, $N = 5$

1110: $f_{SAMPLING} = f_{DTS} / 32$, $N = 6$

1111: $f_{SAMPLING} = f_{DTS} / 32$, $N = 8$

Note: Care must be taken that f_{DTS} is replaced in the formula by CK_INT when $ICx[3:0] = 1, 2$ or 3 .

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).

The prescaler is reset as soon as CC1E=0 (TIMx_CCER register).

00: no prescaler, capture is done each time an edge is detected on the capture input

01: capture is done once every 2 events

10: capture is done once every 4 events

11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output

01: CC1 channel is configured as input, IC1 is mapped on TI1

10: CC1 channel is configured as input, IC1 is mapped on TI2

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC1S bits are writable only when the channel is OFF (CC1E = 0 in TIMx_CCER).

14.4.8 TIM3 capture/compare mode register 2 (TIM3_CCMR2)

Address offset: 0x1C

Reset value: 0x0000

Refer to the above CCMR1 register description.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OC4CE	OC4M[2:0]			OC4PE	OC4FE	CC4S[1:0]		OC3CE	OC3M[2:0]			OC3PE	OC3FE	CC3S[1:0]	
IC4F[3:0]				IC4PSC[1:0]				IC3F[3:0]			IC3PSC[1:0]				
r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w

Output compare mode

Bit 15 **OC4CE**: Output compare 4 clear enable

Bits 14:12 **OC4M**: Output compare 4 mode

Bit 11 **OC4PE**: Output compare 4 preload enable

Bit 10 **OC4FE**: Output compare 4 fast enable

Bits 9:8 **CC4S**: Capture/Compare 4 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output

01: CC4 channel is configured as input, IC4 is mapped on TI4

10: CC4 channel is configured as input, IC4 is mapped on TI3

11: CC4 channel is configured as input, IC4 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC4S bits are writable only when the channel is OFF (CC4E = 0 in TIMx_CCER).

Bit 7 **OC3CE**: Output compare 3 clear enable

Bits 6:4 **OC3M**: Output compare 3 mode

Bit 3 **OC3PE**: Output compare 3 preload enable

Bit 2 **OC3FE**: Output compare 3 fast enable

Bits 1:0 **CC3S**: Capture/Compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3

10: CC3 channel is configured as input, IC3 is mapped on TI4

11: CC3 channel is configured as input, IC3 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC3S bits are writable only when the channel is OFF (CC3E = 0 in TIMx_CCER).

Input capture mode

Bits 15:12 **IC4F**: Input capture 4 filter

Bits 11:10 **IC4PSC**: Input capture 4 prescaler

Bits 9:8 **CC4S**: Capture/Compare 4 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC4 channel is configured as output

01: CC4 channel is configured as input, IC4 is mapped on TI4

10: CC4 channel is configured as input, IC4 is mapped on TI3

11: CC4 channel is configured as input, IC4 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC4S bits are writable only when the channel is OFF (CC4E = 0 in TIMx_CCER).

Bits 7:4 **IC3F**: Input capture 3 filter

Bits 3:2 **IC3PSC**: Input capture 3 prescaler

Bits 1:0 **CC3S**: Capture/Compare 3 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC3 channel is configured as output

01: CC3 channel is configured as input, IC3 is mapped on TI3

10: CC3 channel is configured as input, IC3 is mapped on TI4

11: CC3 channel is configured as input, IC3 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC3S bits are writable only when the channel is OFF (CC3E = 0 in TIMx_CCER).

14.4.9 TIM3 capture/compare enable register (TIM3_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CC4NP	Res.	CC4P	CC4E	CC3NP	Res.	CC3P	CC3E	CC2NP	Res.	CC2P	CC2E	CC1NP	Res.	CC1P	CC1E
rw		rw	rw	rw		rw	rw	rw		rw	rw	rw		rw	rw

Bit 15 **CC4NP**: Capture/Compare 4 output Polarity.

Refer to CC1NP description

Bit 14 Reserved, always read as 0.

Bit 13 **CC4P**: Capture/Compare 4 output Polarity.

Refer to CC1P description

Bit 12 **CC4E**: Capture/Compare 4 output enable.

Refer to CC1E description

Bit 11 **CC3NP**: Capture/Compare 3 output Polarity.

Refer to CC1NP description

Bit 10 Reserved, always read as 0.

Bit 9 **CC3P**: Capture/Compare 3 output Polarity.

Refer to CC1P description

Bit 8 **CC3E**: Capture/Compare 3 output enable.

Refer to CC1E description

- Bit 7 **CC2NP**: *Capture/Compare 2 output Polarity.*
Refer to CC1NP description
- Bit 6 Reserved, always read as 0.
- Bit 5 **CC2P**: *Capture/Compare 2 output Polarity.*
Refer to CC1P description
- Bit 4 **CC2E**: *Capture/Compare 2 output enable.*
Refer to CC1E description
- Bit 3 **CC1NP**: *Capture/Compare 1 output Polarity.*
CC1 channel configured as output:
 CC1NP must be kept cleared in this case.
CC1 channel configured as input:
 This bit is used in conjunction with CC1P to define TI1FP1/TI2FP1 polarity. refer to CC1P description.
- Bit 2 Reserved, always read as 0.
- Bit 1 **CC1P**: *Capture/Compare 1 output Polarity.*
CC1 channel configured as output:
 0: OC1 active high
 1: OC1 active low
CC1 channel configured as input:
 CC1NP/CC1P bits select TI1FP1 and TI2FP1 polarity for trigger or capture operations.
 00: noninverted/rising edge
 Circuit is sensitive to TIxFP1 rising edge (capture, trigger in reset, external clock or trigger mode), TIxFP1 is not inverted (trigger in gated mode, encoder mode).
 01: inverted/falling edge
 Circuit is sensitive to TIxFP1 falling edge (capture, trigger in reset, external clock or trigger mode), TIxFP1 is inverted (trigger in gated mode, encoder mode).
 10: reserved, do not use this configuration.
 11: noninverted/both edges
 Circuit is sensitive to both TIxFP1 rising and falling edges (capture, trigger in reset, external clock or trigger mode), TIxFP1 is not inverted (trigger in gated mode). This configuration must not be used for encoder mode.
- Bit 0 **CC1E**: *Capture/Compare 1 output enable.*
CC1 channel configured as output:
 0: Off - OC1 is not active
 1: On - OC1 signal is output on the corresponding output pin
CC1 channel configured as input:
 This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx_CCR1) or not.
 0: Capture disabled
 1: Capture enabled

Table 50. Output control bit for standard OCx channels

CCxE bit	OCx output state
0	Output Disabled (OCx=0, OCx_EN=0)
1	OCx=OCxREF + Polarity, OCx_EN=1

Note: The state of the external IO pins connected to the standard OCx channels depends on the OCx channel state and the GPIO registers.

14.4.10 TIM3 counter (TIM3_CNT)

Address offset: 0x24

Reset value: 0x00000000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CNT[15:0]**: Low counter value

14.4.11 TIM3 prescaler (TIM3_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency CK_CNT is equal to $f_{CK\_PSC} / (PSC[15:0] + 1)$.

PSC contains the value to be loaded in the active prescaler register at each update event.

14.4.12 TIM3 auto-reload register (TIM3_ARR)

Address offset: 0x2C

Reset value: 0xFFFFFFFF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Low Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to [Section 14.3.1: Time-base unit on page 297](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

14.4.13 TIM3 capture/compare register 1 (TIM3_CCR1)

Address offset: 0x34

Reset value: 0x00000000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR1[15:0]**: Low Capture/Compare 1 value

If channel CC1 is configured as output:

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR1 register (bit OC1PE). Otherwise the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signaled on OC1 output.

If channel CC1 is configured as input:

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

14.4.14 TIM3 capture/compare register 2 (TIM3_CCR2)

Address offset: 0x38

Reset value: 0x00000000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR2[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR2[15:0]**: Low Capture/Compare 2 value

If channel CC2 is configured as output:

CCR2 is the value to be loaded in the actual capture/compare 2 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR2 register (bit OC2PE). Else the preload value is copied in the active capture/compare 2 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signaled on OC2 output.

If channel CC2 is configured as input:

CCR2 is the counter value transferred by the last input capture 2 event (IC2).

14.4.15 TIM3 capture/compare register 3 (TIM3_CCR3)

Address offset: 0x3C

Reset value: 0x00000000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR3[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR3[15:0]**: Low Capture/Compare 3 value

If channel CC3 is configured as output:

CCR3 is the value to be loaded in the actual capture/compare 3 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR3 register (bit OC3PE). Else the preload value is copied in the active capture/compare 3 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signaled on OC3 output.

If channel CC3 is configured as input:

CCR3 is the counter value transferred by the last input capture 3 event (IC3).

14.4.16 TIM3 capture/compare register 4 (TIM3_CCR4)

Address offset: 0x40

Reset value: 0x00000000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR4[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR4[15:0]**: Low Capture/Compare 4 value

1. If CC4 channel is configured as output (CC4S bits):
CCR4 is the value to be loaded in the actual capture/compare 4 register (preload value). It is loaded permanently if the preload feature is not selected in the TIMx_CCMR4 register (bit OC4PE). Otherwise, the preload value is copied in the active capture/compare 4 register when an update event occurs.
The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signaled on OC4 output.
2. If CC4 channel is configured as input (CC4S bits in TIMx_CCMR4 register):
CCR4 is the counter value transferred by the last input capture 4 event (IC4).

14.4.17 TIM3 DMA control register (TIM3_DCR)

Address offset: 0x48

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBL[4:0]					Res.	Res.	Res.	DBA[4:0]				
			rw	rw	rw	rw	rw				rw	rw	rw	rw	rw

Bits 15:13 Reserved, always read as 0.

Bits 12:8 **DBL[4:0]**: DMA burst length

This 5-bit vector defines the number of DMA transfers (the timer recognizes a burst transfer when a read or a write access is done to the TIMx_DMAR address).

00000: 1 transfer,
00001: 2 transfers,
00010: 3 transfers,
...
10001: 18 transfers.

Bits 7:5 Reserved, always read as 0.

Bits 4:0 **DBA[4:0]**: DMA base address

This 5-bit vector defines the base-address for DMA transfers (when read/write access are done through the TIMx_DMAR address). DBA is defined as an offset starting from the address of the TIMx_CR1 register.

Example:

00000: TIMx_CR1,
00001: TIMx_CR2,
00010: TIMx_SMCR,
...

Example: Let us consider the following transfer: DBL = 7 transfers & DBA = TIMx_CR1. In this case the transfer is done to/from 7 registers starting from the TIMx_CR1 address.

14.4.18 TIM3 DMA address for full transfer (TIM3_DMAR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMAB[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DMAB[15:0]**: DMA register for burst accesses
A read or write operation to the DMAR register accesses the register located at the address (TIMx_CR1 address) + (DBA + DMA index) x 4
where TIMx_CR1 address is the address of the control register 1, DBA is the DMA base address configured in TIMx_DCR register, DMA index is automatically controlled by the DMA transfer, and ranges from 0 to DBL (DBL configured in TIMx_DCR).

Example of how to use the DMA burst feature

In this example the timer DMA burst feature is used to update the contents of the CCRx registers (x = 2, 3, 4) with the DMA transferring half words into the CCRx registers.

This is done in the following steps:

1. Configure the corresponding DMA channel as follows:
 - DMA channel peripheral address is the DMAR register address
 - DMA channel memory address is the address of the buffer in the RAM containing the data to be transferred by DMA into CCRx registers.
 - Number of data to transfer = 3 (See note below).
 - Circular mode disabled.
2. Configure the DCR register by configuring the DBA and DBL bit fields as follows:
DBL = 3 transfers, DBA = 0xE.
3. Enable the TIMx update DMA request (set the UDE bit in the DIER register).
4. Enable TIMx
5. Enable the DMA channel

For code example refer to the Appendix section [A.8.20: Two timers synchronized by an external trigger code example](#).

Note: *This example is for the case where every CCRx register to be updated once. If every CCRx register is to be updated twice for example, the number of data to transfer should be 6. Let us take the example of a buffer in the RAM containing data1, data2, data3, data4, data5 and data6. The data is transferred to the CCRx registers as follows: on the first update DMA request, data1 is transferred to CCR2, data2 is transferred to CCR3, data3 is transferred to CCR4 and on the second update DMA request, data4 is transferred to CCR2, data5 is transferred to CCR3 and data6 is transferred to CCR4.*

14.4.19 TIM3 register map

TIM3 registers are mapped as described in the table below:

Table 51. TIM3 register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x00	TIM3_CR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CKD [1:0]		ARPE		CMS [1:0]		DIR	OPM	URS	UDIS	CEN
	Reset value																							0	0	0	0	0	0	0	0	0	0	
0x04	TIM3_CR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	T1S	MMS[2:0]		CCDS		Res.	Res.	Res.	
	Reset value																									0	0	0	0	0				
0x08	TIM3_SMCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ETP	ECE	ETPS [1:0]		ETF[3:0]			MSM	TS[2:0]		OCCS	SMS[2:0]					
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x0C	TIM3_DIER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.		TDE	Res.	CC4DE	CC3DE	CC2DE	CC1DE	UDE	Res.	TIE	Res.	CC4IE	CC3IE	CC2IE	CC1IE	UIE	
	Reset value																		0		0	0	0	0	0		0		0	0	0	0	0	
0x10	TIM3_SR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC4OF	CC3OF	CC2OF	CC1OF	Res.	Res.	TIF	Res.	CC4IF	CC3IF	CC2IF	CC1IF	UIF	
	Reset value																				0	0	0	0			0		0	0	0	0	0	
0x14	TIM3_EGR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TG	Res.	CC4G	CC3G	CC2G	CC1G	UG		
	Reset value																									0		0	0	0	0	0	0	
0x18	TIM3_CCMR1 Output compare mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OC2CE	OC2M [2:0]		OC2PE	OC2FE	CC2S [1:0]	OC1CE	OC1M [2:0]	OC1PE	OC1FE	CC1S [1:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	TIM3_CCMR1 Input capture mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IC2F[3:0]			IC2PSC [1:0]	CC2S [1:0]	IC1F[3:0]		IC1PSC [1:0]	CC1S [1:0]								
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x1C	TIM3_CCMR2 Output compare mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OC4CE	OC4M [2:0]		OC4PE	OC4FE	CC4S [1:0]	OC3CE	OC3M [2:0]	OC3PE	OC3FE	CC3S [1:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
	TIM3_CCMR2 Input capture mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IC4F[3:0]			IC4PSC [1:0]	CC4S [1:0]	IC3F[3:0]		IC3PSC [1:0]	CC3S [1:0]								
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x20	TIM3_CCER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC4NP	Res.	CC4P	CC4E	CC3NP	Res.	CC3P	CC3E	CC2NP	Res.	CC2P	CC2E	CC1NP	Res.	CC1P	CC1E	
	Reset value																	0		0	0	0		0	0	0		0	0	0	0	0	0	
0x24	TIM3_CNT	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CNT[15:0]																
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x28	TIM3_PSC	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PSC[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x2C	TIM3_ARR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ARR[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x30	Reserved	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value																																	

Table 51. TIM3 register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x34	TIM3_CCR1	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	CCR1[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x38	TIM3_CCR2	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	CCR2[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x3C	TIM3_CCR3	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	CCR3[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x40	TIM3_CCR4	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	CCR4[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x44	Reserved	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value																																	
0x48	TIM3_DCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBL[4:0]				Res.	Res.	Res.	DBA[4:0]						
	Reset value																				0	0	0	0	0		Res.			0	0	0	0	0
0x4C	TIM3_DMAR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DMAB[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

15 Basic timer (TIM6/TIM7)

This section applies to STM32F030x8, STM32F070xB and STM32F030xC devices only. TIM7 is available only on STM32F070xB and STM32F030xC devices.

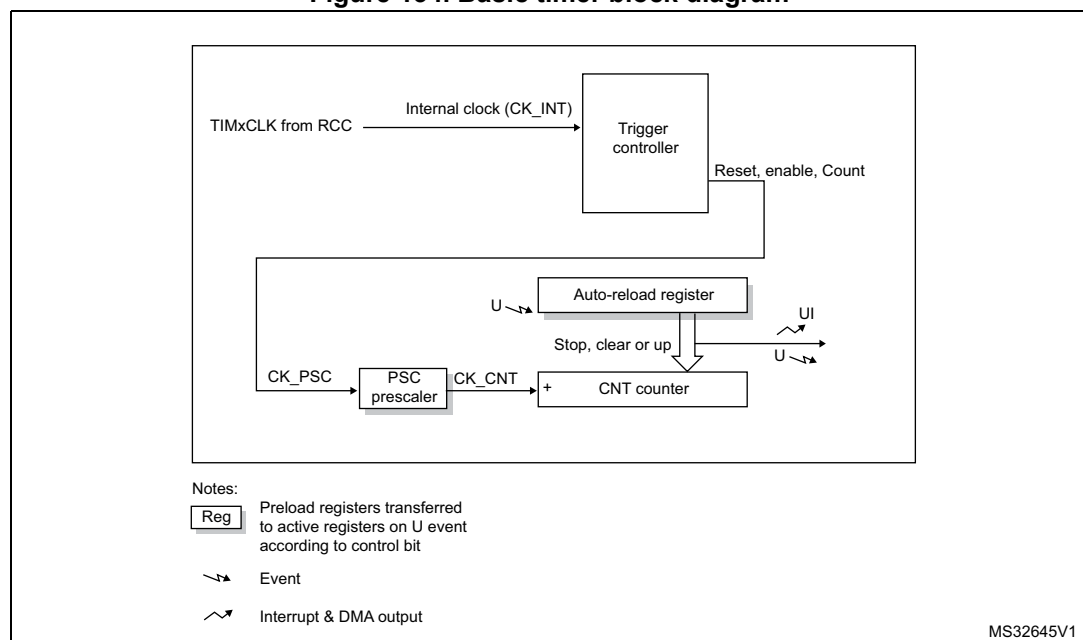
15.1 TIM6/TIM7 introduction

The basic timer TIM6 consists of a 16-bit auto-reload counter driven by a programmable prescaler.

15.2 TIM6/TIM7 main features

- 16-bit auto-reload upcounter
- 16-bit programmable prescaler used to divide (also “on the fly”) the counter clock frequency by any factor between 1 and 65535
- Interrupt/DMA generation on the update event: counter overflow

Figure 134. Basic timer block diagram



15.3 TIM6/TIM7 functional description

15.3.1 Time-base unit

The main block of the programmable timer is a 16-bit upcounter with its related auto-reload register. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter Register (TIMx_CNT)
- Prescaler Register (TIMx_PSC)
- Auto-Reload Register (TIMx_ARR)

The auto-reload register is preloaded. The preload register is accessed each time an attempt is made to write or read the auto-reload register. The contents of the preload register are transferred into the shadow register permanently or at each update event UEV, depending on the auto-reload preload enable bit (ARPE) in the TIMx_CR1 register. The update event is sent when the counter reaches the overflow value and if the UDIS bit equals 0 in the TIMx_CR1 register. It can also be generated by software. The generation of the update event is described in detail for each configuration.

The counter is clocked by the prescaler output CK_CNT, which is enabled only when the counter enable bit (CEN) in the TIMx_CR1 register is set.

Note that the actual counter enable signal CNT_EN is set 1 clock cycle after CEN.

Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit register (in the TIMx_PSC register). It can be changed on the fly as the TIMx_PSC control register is buffered. The new prescaler ratio is taken into account at the next update event.

[Figure 135](#) and [Figure 136](#) give some examples of the counter behavior when the prescaler ratio is changed on the fly.

Figure 135. Counter timing diagram with prescaler division change from 1 to 2

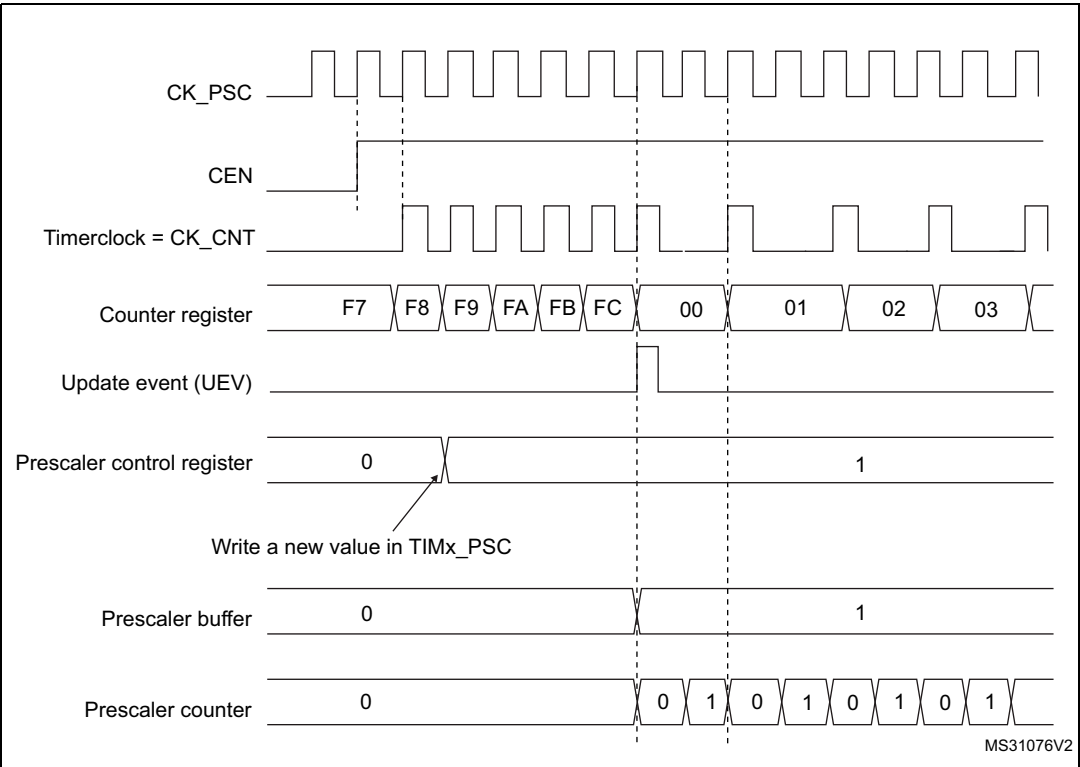
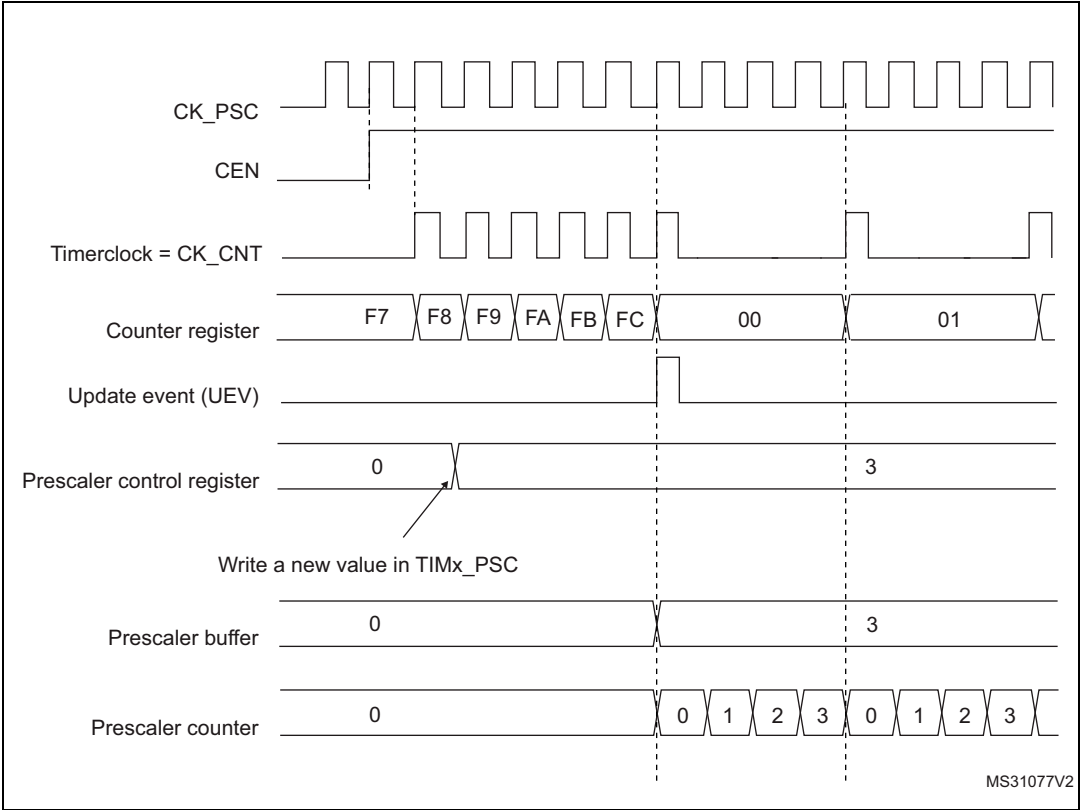


Figure 136. Counter timing diagram with prescaler division change from 1 to 4



15.3.2 Counter modes

The counter counts from 0 to the auto-reload value (contents of the TIMx_ARR register), then restarts from 0 and generates a counter overflow event.

An update event can be generated at each counter overflow or by setting the UG bit in the TIMx_EGR register (by software or by using the slave mode controller).

The UEV event can be disabled by software by setting the UDIS bit in the TIMx_CR1 register. This avoids updating the shadow registers while writing new values into the preload registers. In this way, no update event occurs until the UDIS bit has been written to 0, however, the counter and the prescaler counter both restart from 0 (but the prescale rate does not change). In addition, if the URS (update request selection) bit in the TIMx_CR1 register is set, setting the UG bit generates an update event UEV, but the UIF flag is not set (so no interrupt or DMA request is sent).

When an update event occurs, all the registers are updated and the update flag (UIF bit in the TIMx_SR register) is set (depending on the URS bit):

- The buffer of the prescaler is reloaded with the preload value (contents of the TIMx_PSC register)
- The auto-reload shadow register is updated with the preload value (TIMx_ARR)

The following figures show some examples of the counter behavior for different clock frequencies when TIMx_ARR = 0x36.

Figure 137. Counter timing diagram, internal clock divided by 1

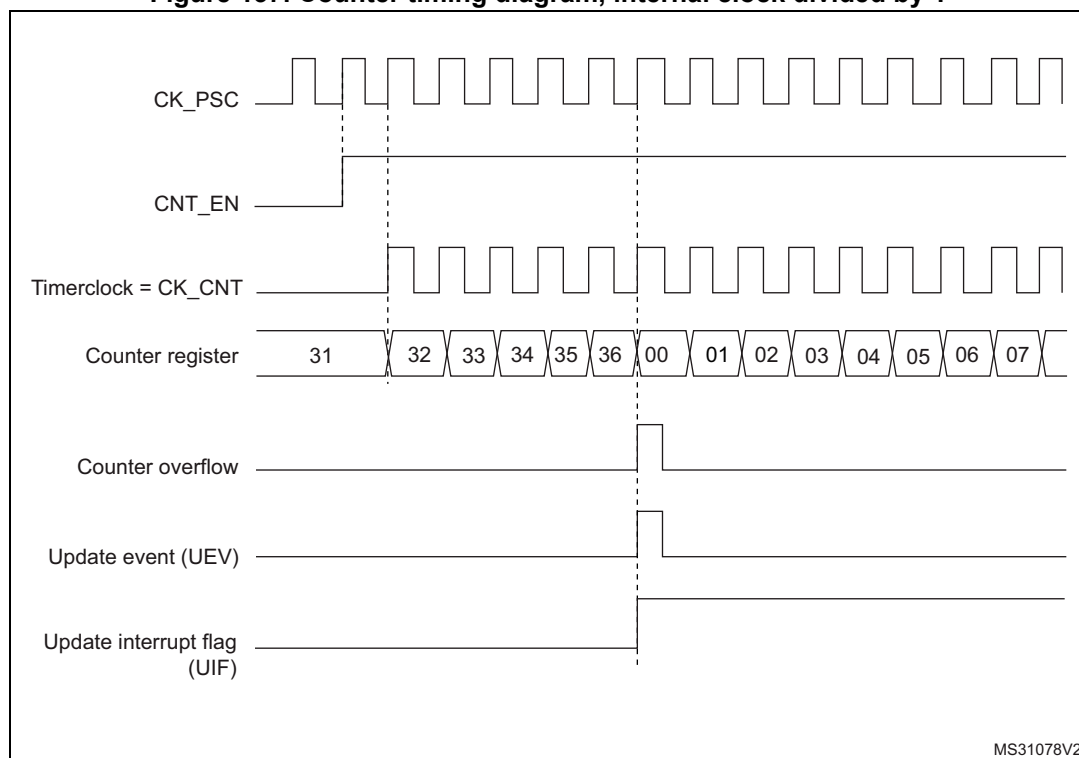


Figure 138. Counter timing diagram, internal clock divided by 2

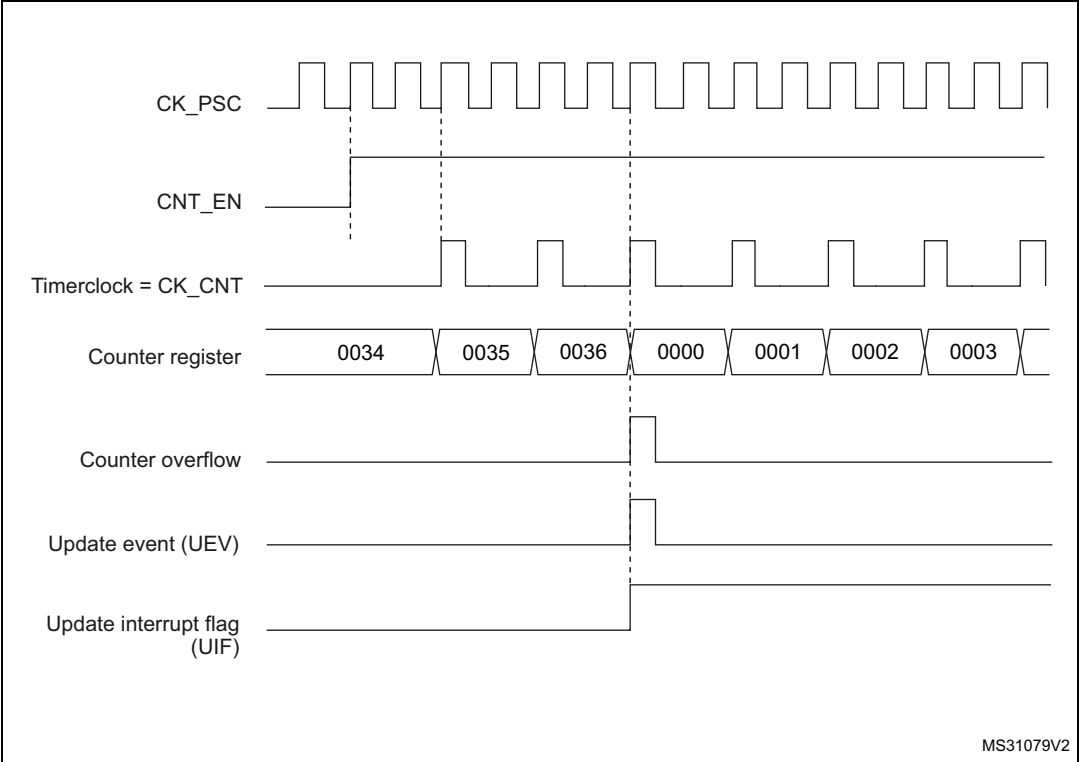


Figure 139. Counter timing diagram, internal clock divided by 4

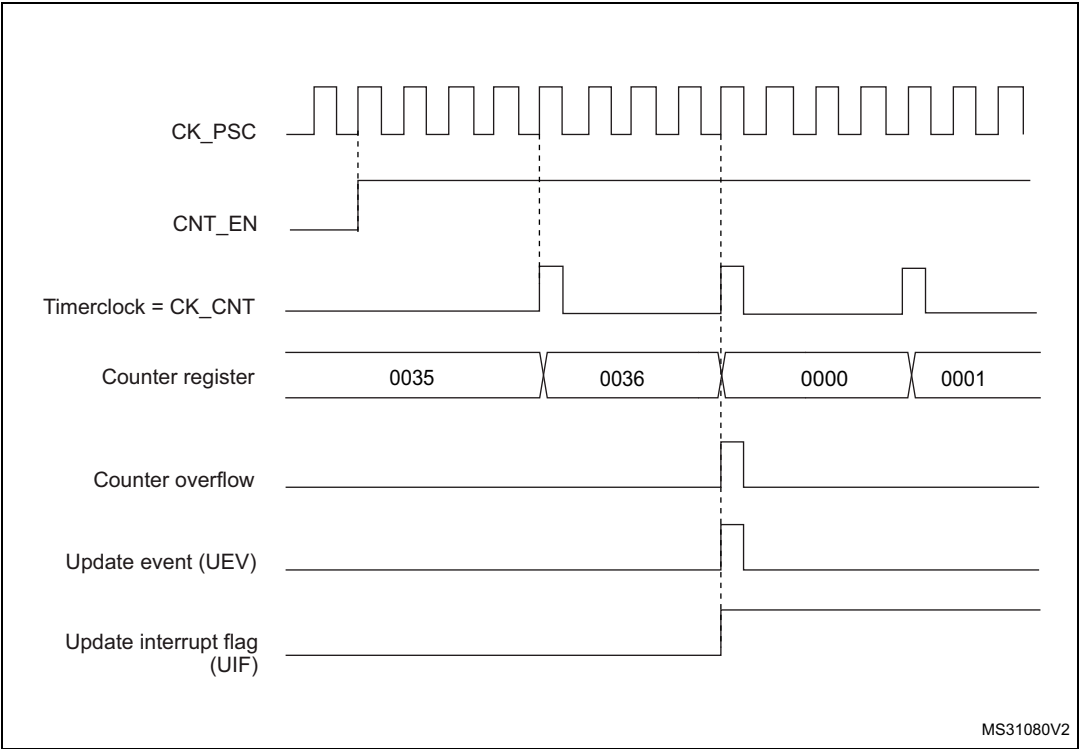


Figure 140. Counter timing diagram, internal clock divided by N

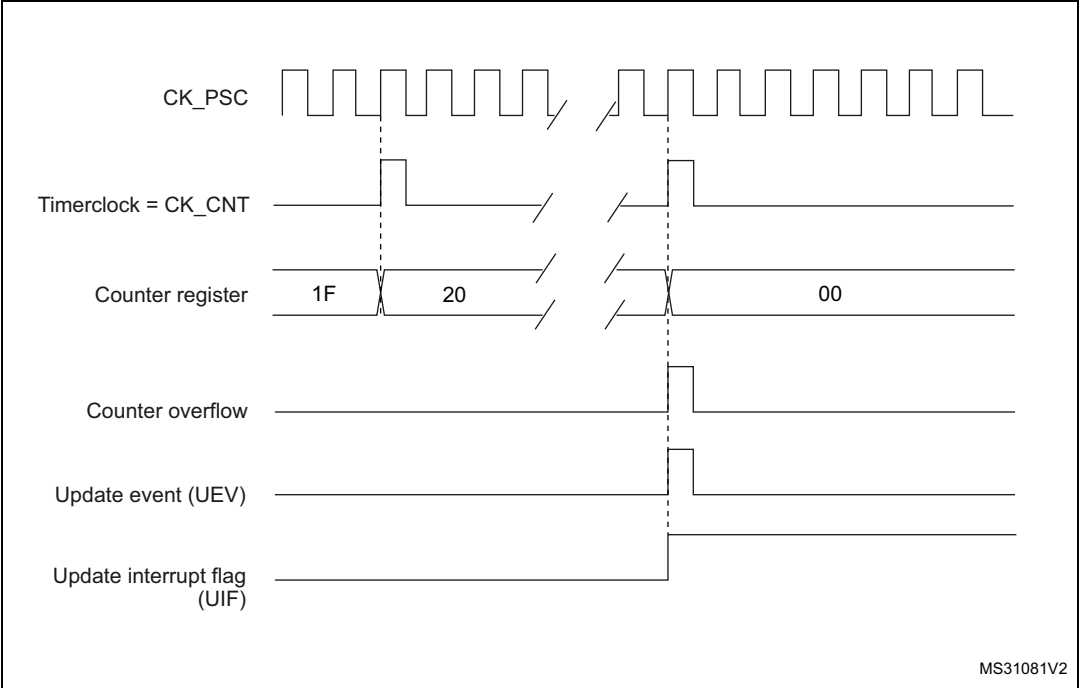


Figure 141. Counter timing diagram, update event when ARPE = 0 (TIMx_ARR not preloaded)

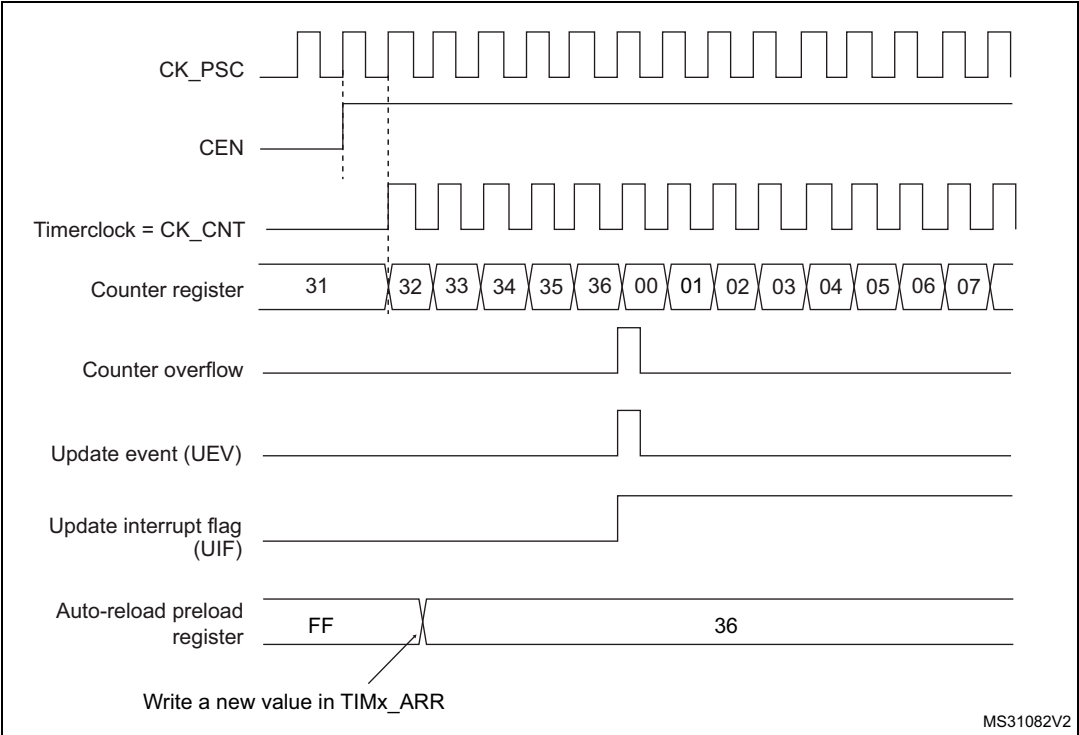
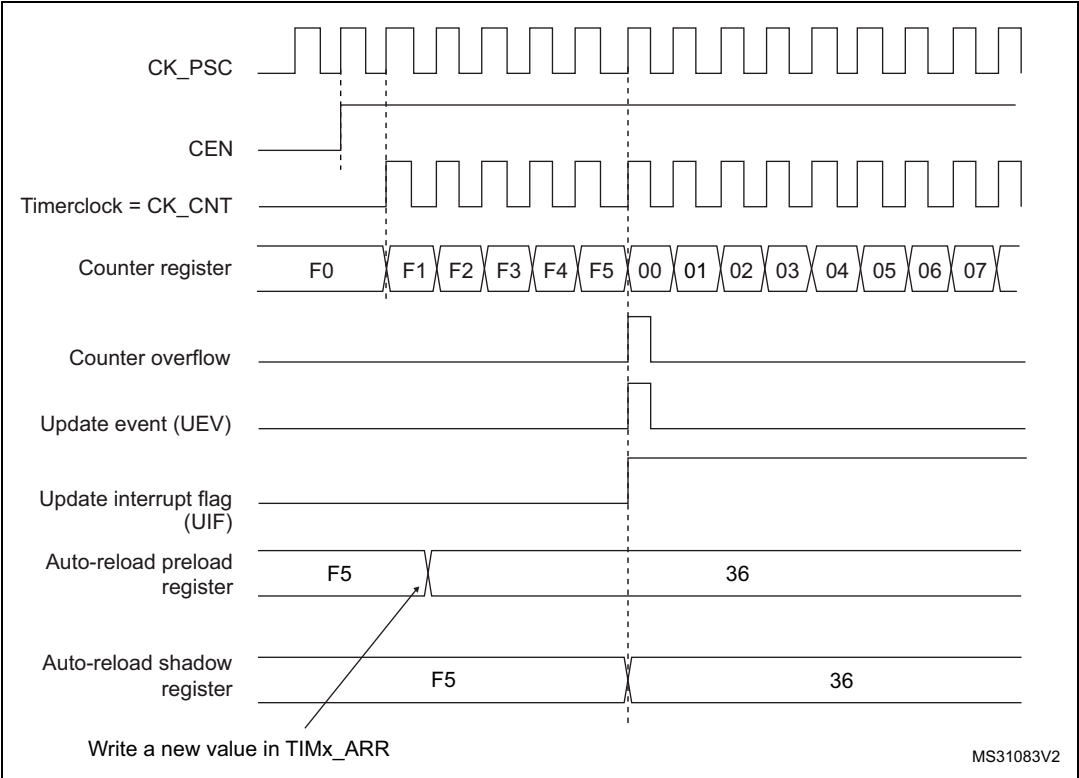


Figure 142. Counter timing diagram, update event when ARPE=1 (TIMx_ARR preloaded)



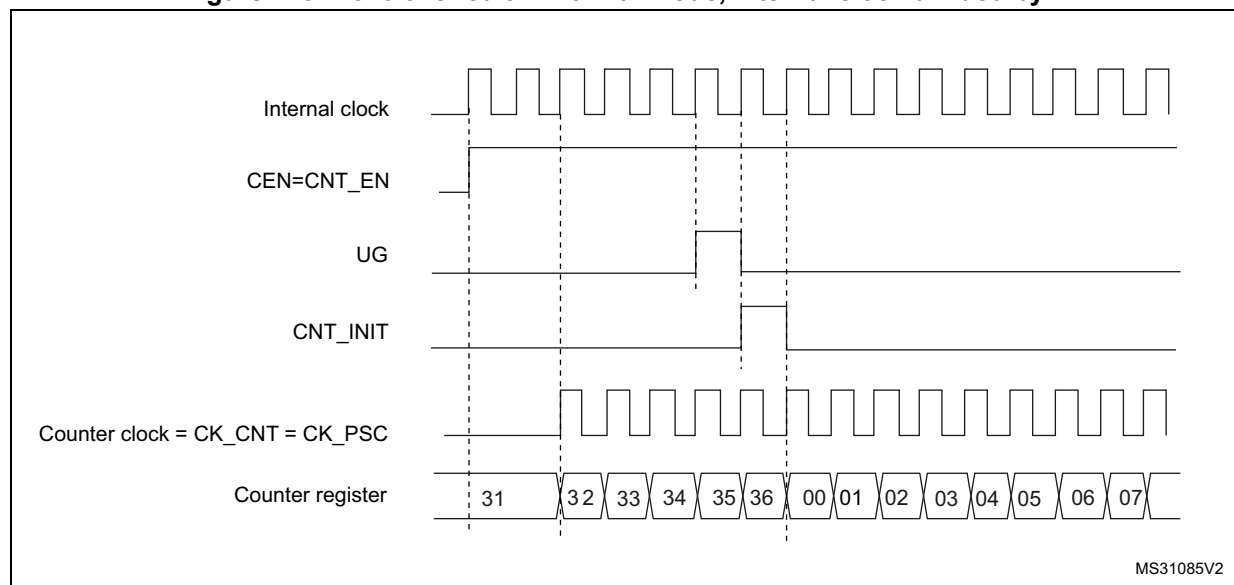
15.3.3 Clock source

The counter clock is provided by the Internal clock (CK_INT) source.

The CEN (in the TIMx_CR1 register) and UG bits (in the TIMx_EGR register) are actual control bits and can be changed only by software (except for UG that remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK_INT.

Figure 143 shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

Figure 143. Control circuit in normal mode, internal clock divided by 1



15.3.4 Debug mode

When the microcontroller enters the debug mode (Cortex™-M0 core - halted), the TIMx counter either continues to work normally or stops, depending on the DBG_TIMx_STOP configuration bit in the DBG module.

15.4 TIM6/TIM7 registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

15.4.1 TIM6/TIM7 control register 1 (TIMx_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ARPE	Res.	Res.	Res.	OPM	URS	UDIS	CEN
								rw				rw	rw	rw	rw

Bits 15:8 Reserved, always read as 0.

Bit 7 **ARPE**: Auto-reload preload enable

0: TIMx_ARR register is not buffered.

1: TIMx_ARR register is buffered.

Bits 6:4 Reserved, always read as 0.

Bit 3 **OPM**: One-pulse mode

0: Counter is not stopped at update event

1: Counter stops counting at the next update event (clearing the CEN bit).

Bit 2 **URS**: Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generates an update interrupt or DMA request if enabled.

These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt or DMA request if enabled.

Bit 1 **UDIS**: Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

Bit 0 **CEN**: Counter enable

0: Counter disabled

1: Counter enabled

Note: Gated mode can work only if the CEN bit has been previously set by software.

However trigger mode can set the CEN bit automatically by hardware.

CEN is cleared automatically in one-pulse mode, when an update event occurs.

15.4.2 TIM6/TIM7 DMA/Interrupt enable register (TIMx_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	UDE	Res.	Res.	Res.	Res.	Res.	Res.	Res.	UIE
							rw								rw

Bit 15:9 Reserved, must be kept at reset value.

Bit 8 **UDE**: Update DMA request enable

0: Update DMA request disabled.

1: Update DMA request enabled.

Bits 7:1 Reserved, must be kept at reset value.

Bit 0 **UIE**: Update interrupt enable

0: Update interrupt disabled.

1: Update interrupt enabled.

15.4.3 TIM6/TIM7 status register (TIMx_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	UIF
															rc_w0

Bits 15:1 Reserved, must be kept at reset value.

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

–At overflow or underflow regarding the repetition counter value and if UDIS = 0 in the TIMx_CR1 register.

–When CNT is reinitialized by software using the UG bit in the TIMx_EGR register, if URS = 0 and UDIS = 0 in the TIMx_CR1 register.

15.4.4 TIM6/TIM7 event generation register (TIMx_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	UG
															w

Bits 15:1 Reserved, must be kept at reset value.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action.

1: Re-initializes the timer counter and generates an update of the registers. Note that the prescaler counter is cleared too (but the prescaler ratio is not affected).

15.4.5 TIM6/TIM7 counter (TIMx_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 15:0 **CNT[15:0]**: Counter value

15.4.6 TIM6/TIM7 prescaler (TIMx_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency CK_CNT is equal to $f_{CK\_PSC} / (PSC[15:0] + 1)$.

PSC contains the value to be loaded into the active prescaler register at each update event.

15.4.7 TIM6/TIM7 auto-reload register (TIMx_ARR)

Address offset: 0x2C

Reset value: 0xFFFF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded into the actual auto-reload register.

Refer to [Section 15.3.1: Time-base unit on page 362](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

15.4.8 TIM6/TIM7 register map

TIMx registers are mapped as 16-bit addressable registers as described in the table below:

Table 52. TIM6/TIM7 register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
0x00	TIMx_CR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0	ARPE	Res.	Res.	Res.	OPM	URS	UDIS	CEN			
	Reset value																													0	0	0	0				
0x0C	TIMx_DIER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	UDE	Res.	Res.	Res.	Res.	Res.	Res.	Res.	UIS	UIE			
	Reset value																								0						0	0	0				
0x10	TIMx_SR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	UIF				
	Reset value																															0	0				
0x14	TIMx_EGR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	UG				
	Reset value																																0				
0x24	TIMx_CNT	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CNT[15:0]																			
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
0x28	TIMx_PSC	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PSC[15:0]																			
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0				
0x2C	TIMx_ARR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ARR[15:0]																			
	Reset value																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1					

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

16 General-purpose timer (TIM14)

16.1 TIM14 introduction

The TIM14 general-purpose timer consists of a 16-bit auto-reload counter driven by a programmable prescaler.

It may be used for a variety of purposes, including measuring the pulse lengths of input signals (input capture) or generating output waveforms (output compare, PWM).

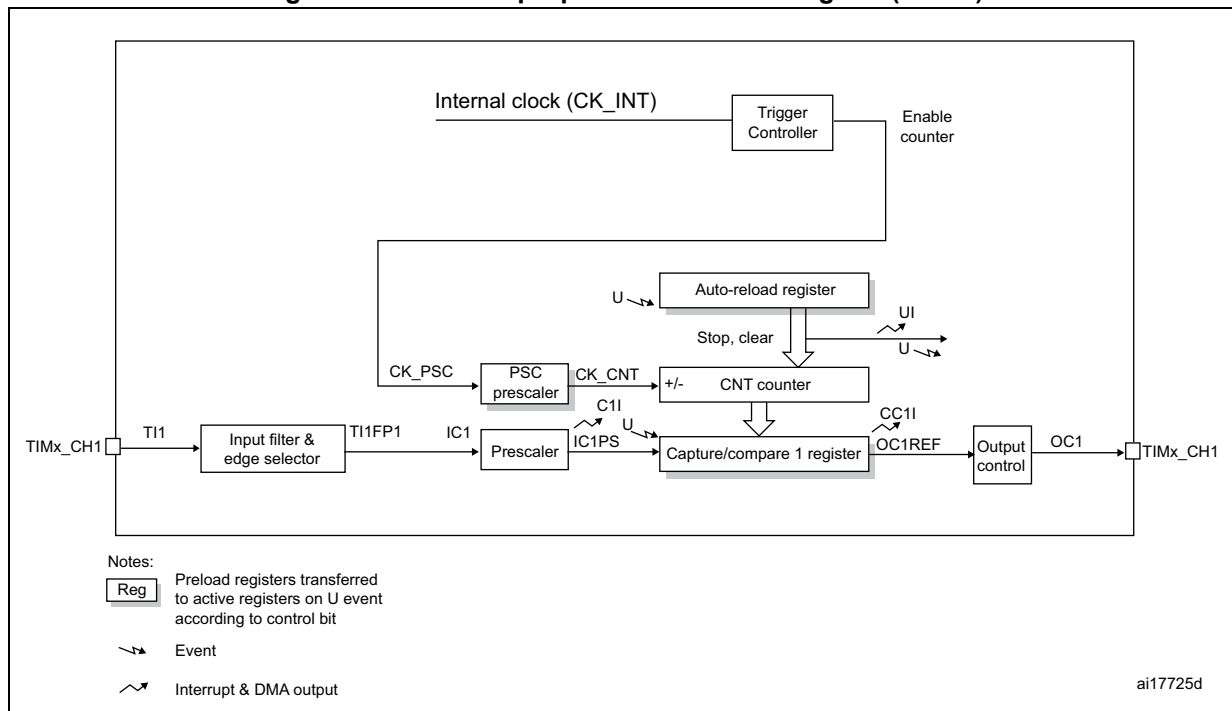
Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the RCC clock controller prescalers.

The TIM14 timer is completely independent, and does not share any resources. It can be synchronized together as described in [Section 14.3.15](#).

16.2 TIM14 main features

- 16-bit auto-reload upcounter
- 16-bit programmable prescaler used to divide the counter clock frequency by any factor between 1 and 65535 (can be changed “on the fly”)
- independent channel for:
 - Input capture
 - Output compare
 - PWM generation (edge-aligned mode)
- Interrupt generation on the following events:
 - Update: counter overflow, counter initialization (by software)
 - Input capture
 - Output compare

Figure 144. General-purpose timer block diagram (TIM14)



16.3 TIM14 functional description

16.3.1 Time-base unit

The main block of the programmable advanced-control timer is a 16-bit counter with its related auto-reload register. The counter can count up. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter register (TIMx_CNT)
- Prescaler register (TIMx_PSC)
- Auto-reload register (TIMx_ARR)

The auto-reload register is preloaded. Writing to or reading from the auto-reload register accesses the preload register. The content of the preload register are transferred into the shadow register permanently or at each update event (UEV), depending on the auto-reload preload enable bit (ARPE) in TIMx_CR1 register. The update event is sent when the counter reaches the overflow and if the UDIS bit equals 0 in the TIMx_CR1 register. It can also be generated by software. The generation of the update event is described in detailed for each configuration.

The counter is clocked by the prescaler output CK_CNT, which is enabled only when the counter enable bit (CEN) in TIMx_CR1 register is set (refer also to the slave mode controller description to get more details on counter enabling).

Note that the counter starts counting 1 clock cycle after setting the CEN bit in the TIMx_CR1 register.

Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit register (in the TIMx_PSC register). It can be changed on the fly as this control register is buffered. The new prescaler ratio is taken into account at the next update event.

Figure 146 and Figure 147 give some examples of the counter behavior when the prescaler ratio is changed on the fly.

Figure 145. Counter timing diagram with prescaler division change from 1 to 2

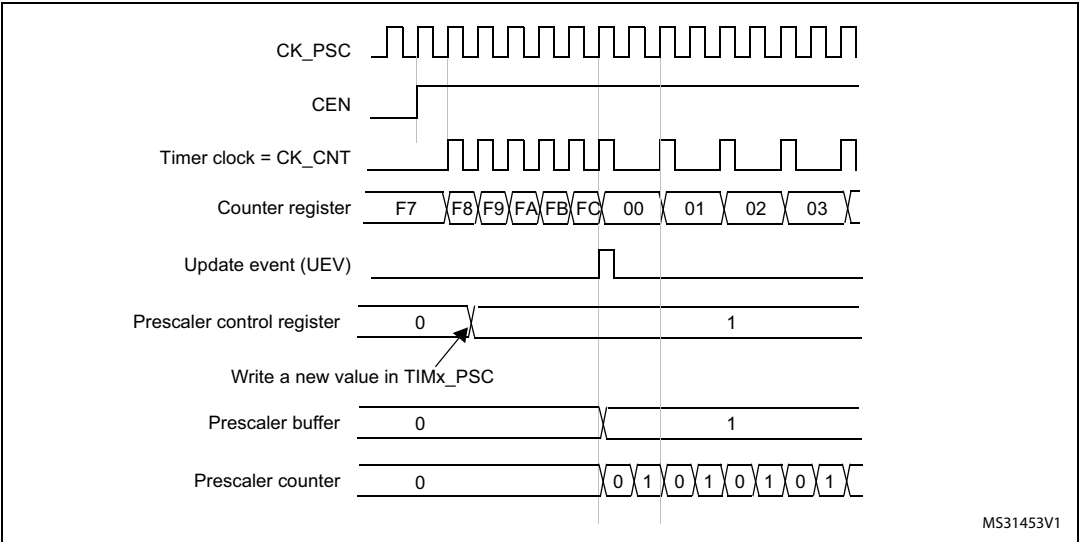
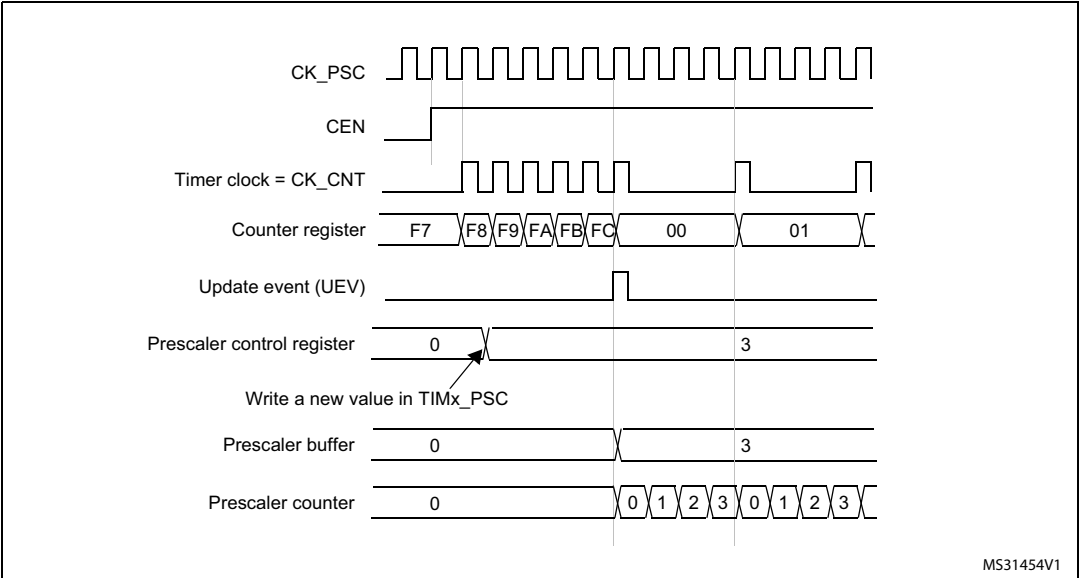


Figure 146. Counter timing diagram with prescaler division change from 1 to 4



16.3.2 Counter modes

Upcounting mode

In upcounting mode, the counter counts from 0 to the auto-reload value (content of the TIMx_ARR register), then restarts from 0 and generates a counter overflow event.

Setting the UG bit in the TIMx_EGR register also generates an update event.

The UEV event can be disabled by software by setting the UDIS bit in the TIMx_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescale rate does not change). In addition, if the URS bit (update request selection) in TIMx_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx_SR register) is set (depending on the URS bit):

- The auto-reload shadow register is updated with the preload value (TIMx_ARR),
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx_PSC register).

The following figures show some examples of the counter behavior for different clock frequencies when TIMx_ARR=0x36.

Figure 147. Counter timing diagram, internal clock divided by 1

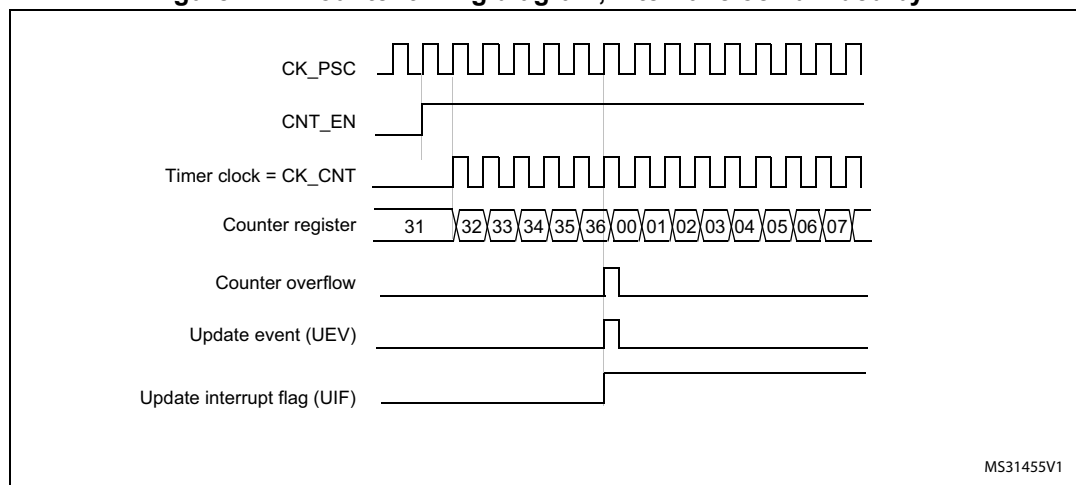


Figure 148. Counter timing diagram, internal clock divided by 2

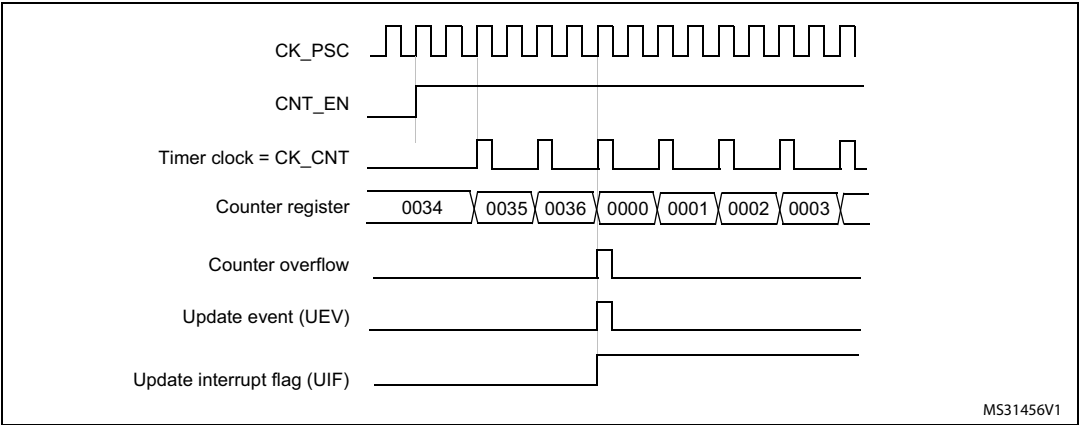


Figure 149. Counter timing diagram, internal clock divided by 4

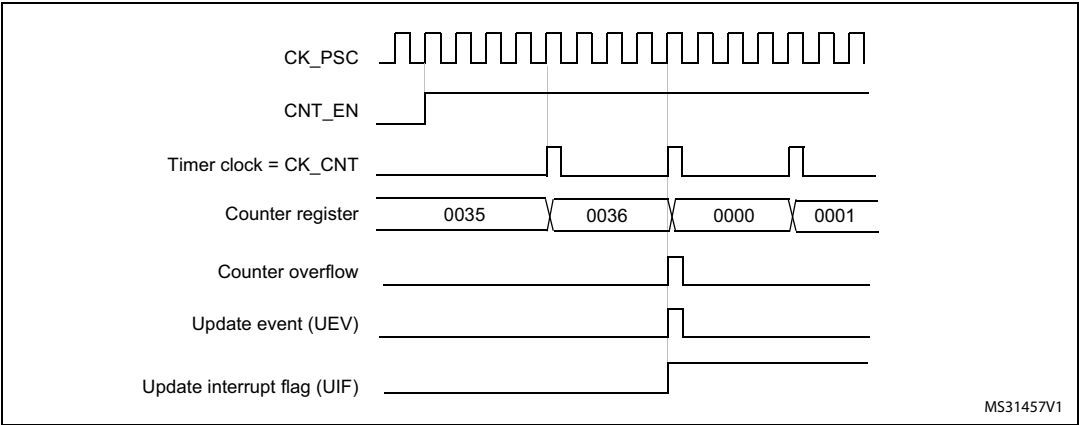


Figure 150. Counter timing diagram, internal clock divided by N

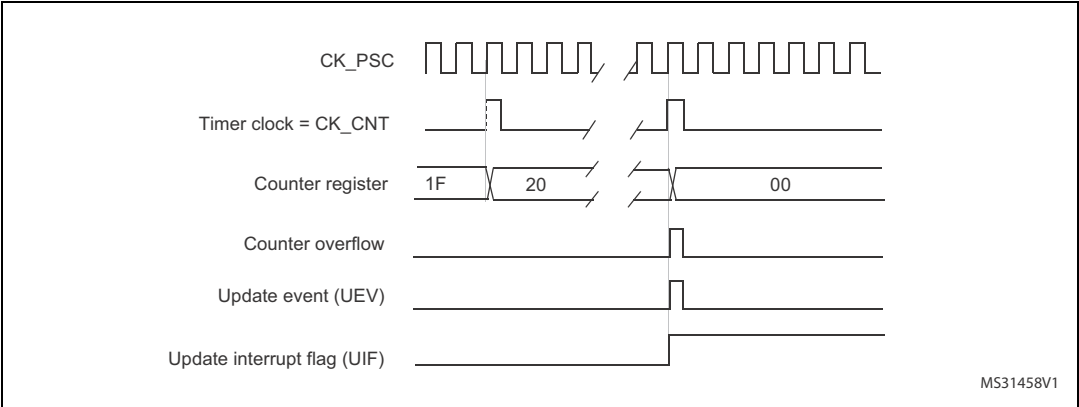


Figure 151. Counter timing diagram, update event when ARPE=0 (TIMx_ARR not preloaded)

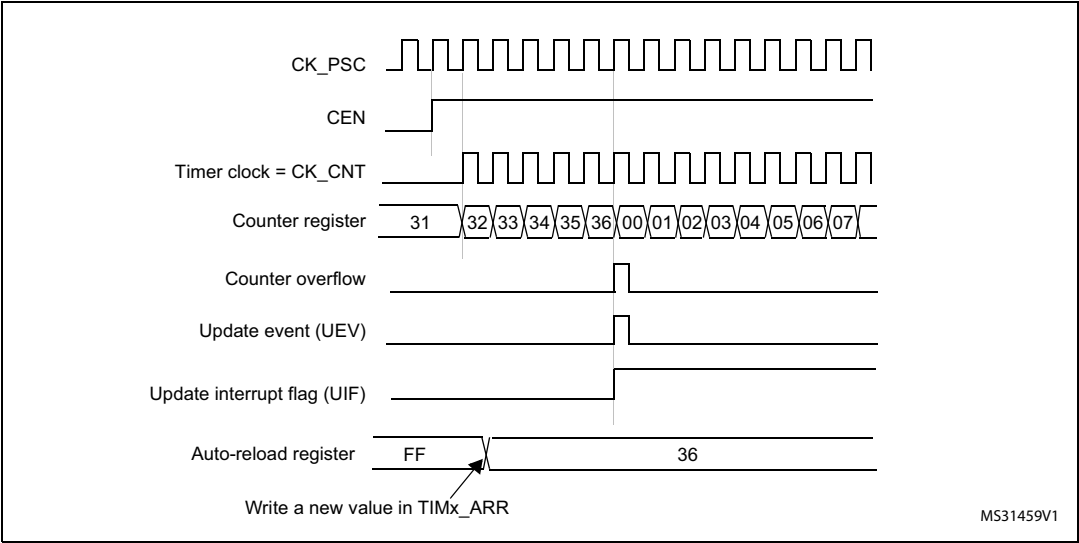
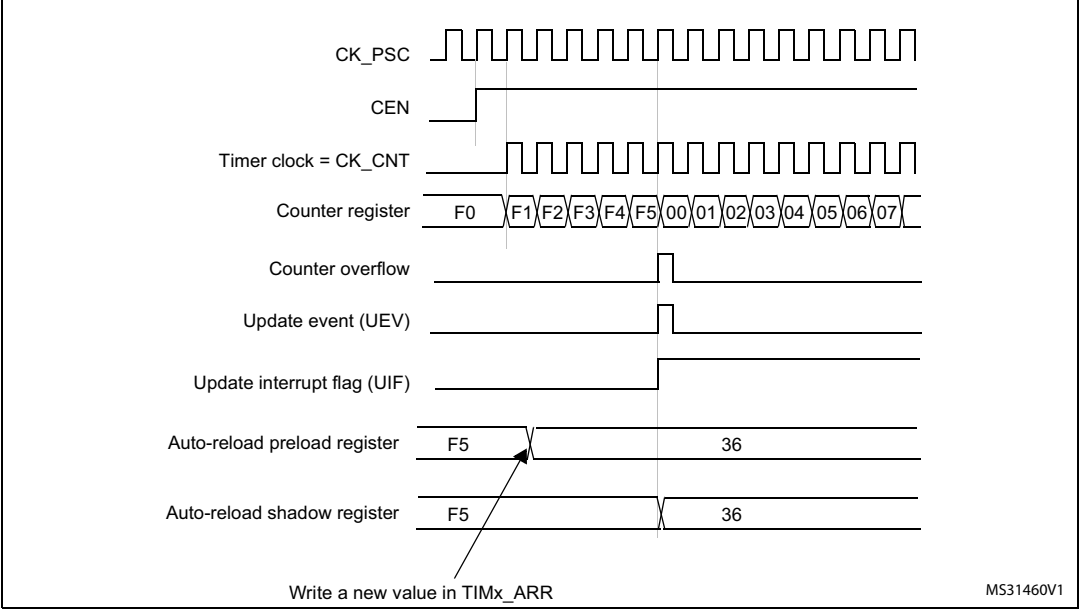


Figure 152. Counter timing diagram, update event when ARPE=1 (TIMx_ARR preloaded)



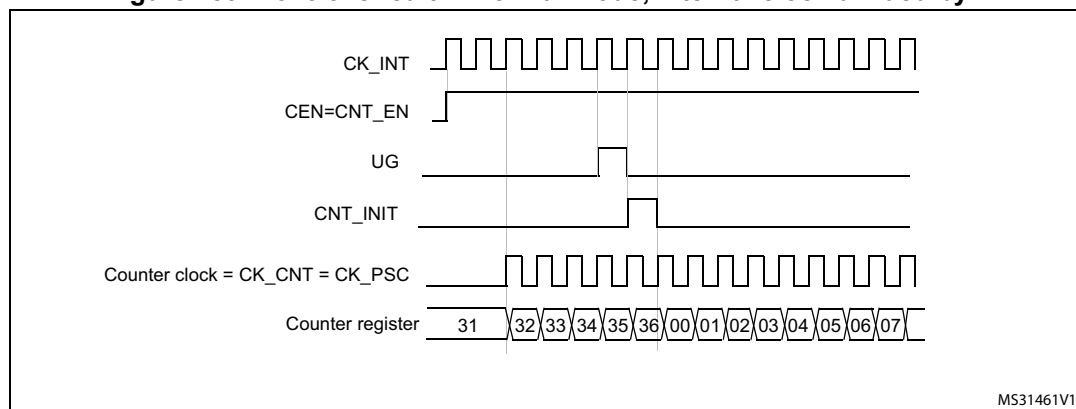
16.3.3 Clock source

The counter clock is provided by the Internal clock (CK_INT) source.

The CEN (in the TIMx_CR1 register) and UG bits (in the TIMx_EGR register) are actual control bits and can be changed only by software (except for UG that remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK_INT.

Figure 153 shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

Figure 153. Control circuit in normal mode, internal clock divided by 1



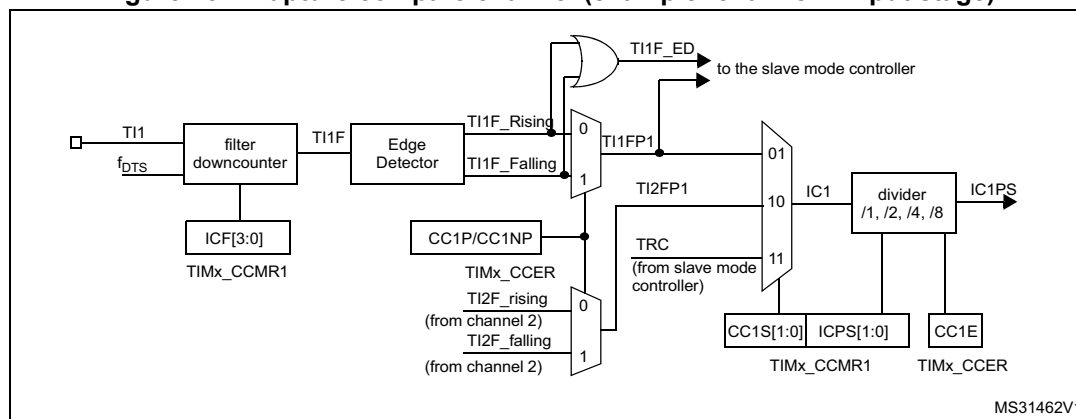
16.3.4 Capture/compare channels

Each Capture/Compare channel is built around a capture/compare register (including a shadow register), a input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

Figure 154 to Figure 156 give an overview of one capture/compare channel.

The input stage samples the corresponding Tix input to generate a filtered signal TIxF. Then, an edge detector with polarity selection generates a signal (TIxFPx) which can be used as trigger input by the slave mode controller or as the capture command. It is prescaled before the capture register (ICxPS).

Figure 154. Capture/compare channel (example: channel 1 input stage)



The output stage generates an intermediate waveform which is then used for reference: OCxRef (active high). The polarity acts at the end of the chain.

Figure 155. Capture/compare channel 1 main circuit

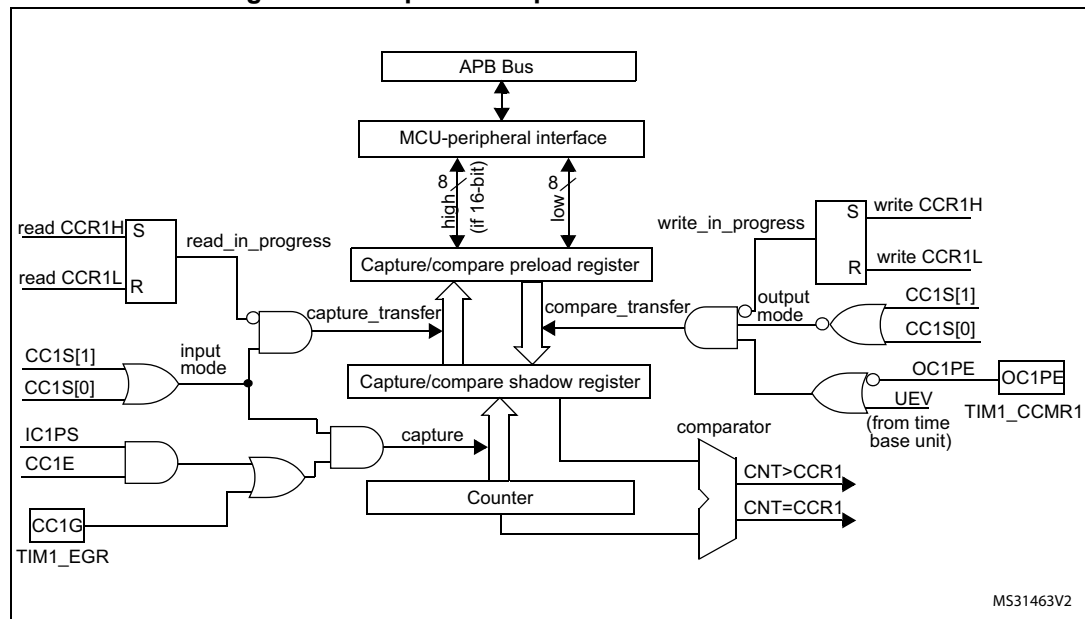
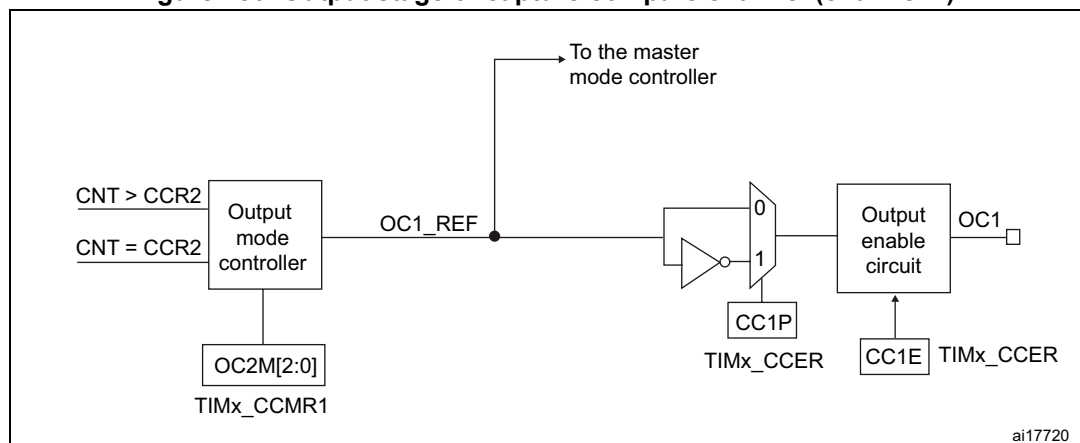


Figure 156. Output stage of capture/compare channel (channel 1)



The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register.

In capture mode, captures are actually done in the shadow register, which is copied into the preload register.

In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

16.3.5 Input capture mode

In Input capture mode, the Capture/Compare Registers (TIMx_CCRx) are used to latch the value of the counter after a transition detected by the corresponding ICx signal. When a capture occurs, the corresponding CCXIF flag (TIMx_SR register) is set and an interrupt or a DMA request can be sent if they are enabled. If a capture occurs while the CCXIF flag was already high, then the over-capture flag CCxOF (TIMx_SR register) is set. CCXIF can be cleared by software by writing it to '0' or by reading the captured data stored in the TIMx_CCRx register. CCxOF is cleared when you write it to '0'.

The following example shows how to capture the counter value in TIMx_CCR1 when TI1 input rises. To do this, use the following procedure:

1. Select the active input: TIMx_CCR1 must be linked to the TI1 input, so write the CC1S bits to '01' in the TIMx_CCMR1 register. As soon as CC1S becomes different from '00', the channel is configured in input mode and the TIMx_CCR1 register becomes read-only.
2. Program the input filter duration you need with respect to the signal you connect to the timer (when the input is one of the TIx (ICxF bits in the TIMx_CCMRx register). Let us imagine that, when toggling, the input signal is not stable during at most 5 internal clock cycles. We must program a filter duration longer than these 5 clock cycles. We can validate a transition on TI1 when 8 consecutive samples with the new level have been detected (sampled at f_{DTS} frequency). Then write IC1F bits to '0011' in the TIMx_CCMR1 register.
3. Select the edge of the active transition on the TI1 channel by programming CC1P and CC1NP bits to '00' in the TIMx_CCER register (rising edge in this case).
4. Program the input prescaler. In our example, we wish the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to '00' in the TIMx_CCMR1 register).
5. Enable capture from the counter into the capture register by setting the CC1E bit in the TIMx_CCER register.
6. If needed, enable the related interrupt request by setting the CC1IE bit in the TIMx_DIER register.

For code example refer to the Appendix section [A.8.3: Input capture configuration code example](#).

When an input capture occurs:

- The TIMx_CCR1 register gets the value of the counter on the active transition.
- CC1IF flag is set (interrupt flag). CC1OF is also set if at least two consecutive captures occurred whereas the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.

For code example refer to the Appendix section [A.8.4: Input capture data management code example](#).

In order to handle the overcapture, it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

Note: IC interrupt requests can be generated by software by setting the corresponding CCxG bit in the TIMx_EGR register.

16.3.6 Forced output mode

In output mode (CCxS bits = '00' in the TIMx_CCMRx register), each output compare signal (OCxREF and then OCx) can be forced to active or inactive level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal (OCXREF/OCx) to its active level, you just need to write '101' in the OCxM bits in the corresponding TIMx_CCMRx register. Thus OCXREF is forced high (OCxREF is always active high) and OCx get opposite value to CCxP polarity bit.

For example: CCxP='0' (OCx active high) => OCx is forced to high level.

The OCxREF signal can be forced low by writing the OCxM bits to '100' in the TIMx_CCMRx register.

The comparison between the TIMx_CCRx shadow register and the counter is still performed and allows the flag to be set. Interrupt requests can be sent accordingly. This is described in the output compare mode section below.

16.3.7 Output compare mode

This function is used to control an output waveform or to indicate when a period of time has elapsed.

When a match is found between the capture/compare register and the counter, the output compare function:

1. Assigns the corresponding output pin to a programmable value defined by the output compare mode (OCxM bits in the TIMx_CCMRx register) and the output polarity (CCxP bit in the TIMx_CCER register). The output pin can keep its level (OCXM='000'), be set active (OCXM='001'), be set inactive (OCXM='010') or can toggle (OCXM='011') on match.
2. Sets a flag in the interrupt status register (CCxIF bit in the TIMx_SR register).
3. Generates an interrupt if the corresponding interrupt mask is set (CCXIE bit in the TIMx_DIER register).

The TIMx_CCRx registers can be programmed with or without preload registers using the OCxPE bit in the TIMx_CCMRx register.

In output compare mode, the update event UEV has no effect on OCxREF and OCx output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse (in One-pulse mode).

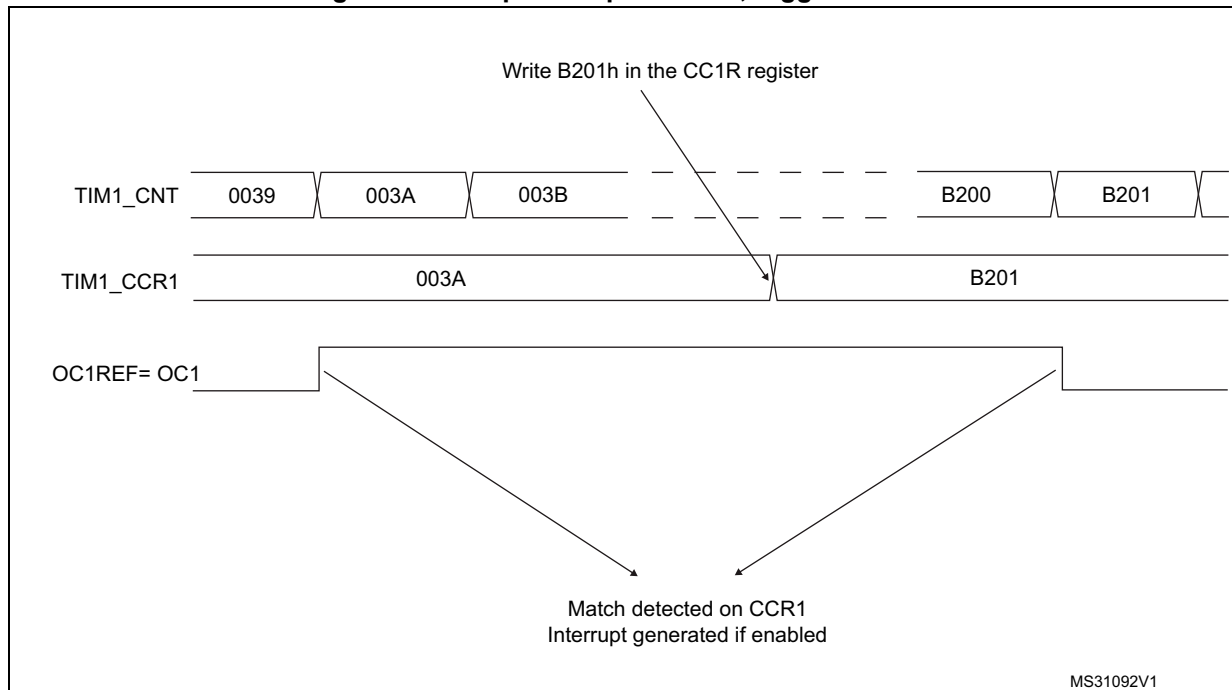
Procedure:

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the TIMx_ARR and TIMx_CCRx registers.
3. Set the CCxIE bit if an interrupt request is to be generated.
4. Select the output mode. For example:
 - Write OCxM = '011' to toggle OCx output pin when CNT matches CCRx
 - Write OCxPE = '0' to disable preload register
 - Write CCxP = '0' to select active high polarity
 - Write CCxE = '1' to enable the output
5. Enable the counter by setting the CEN bit in the TIMx_CR1 register.

For code example refer to the Appendix section [A.8.7: Output compare configuration code example](#).

The TIMx_CCRx register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled (OCxPE='0', else TIMx_CCRx shadow register is updated only at the next update event UEV). An example is given in [Figure 157](#).

Figure 157. Output compare mode, toggle on OC1



16.3.8 PWM mode

Pulse Width Modulation mode allows you to generate a signal with a frequency determined by the value of the TIMx_ARR register and a duty cycle determined by the value of the TIMx_CCRx register.

The PWM mode can be selected independently on each channel (one PWM per OCx output) by writing '110' (PWM mode 1) or '111' (PWM mode 2) in the OCxM bits in the TIMx_CCMRx register. You must enable the corresponding preload register by setting the OCxPE bit in the TIMx_CCMRx register, and eventually the auto-reload preload register (in upcounting or center-aligned modes) by setting the ARPE bit in the TIMx_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIMx_EGR register.

The OCx polarity is software programmable using the CCxP bit in the TIMx_CCER register. It can be programmed as active high or active low. The OCx output is enabled by the CCxE bit in the TIMx_CCER register. Refer to the TIMx_CCERx register description for more details.

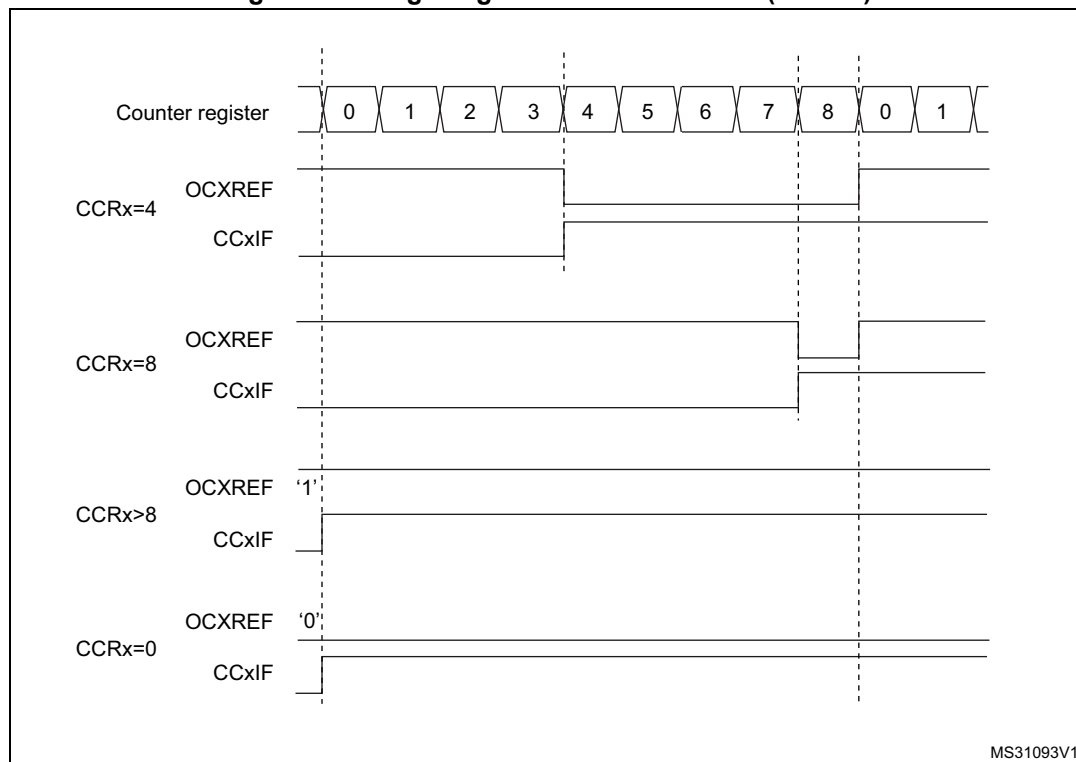
In PWM mode (1 or 2), TIMx_CNT and TIMx_CCRx are always compared to determine whether $TIMx\_CNT \leq TIMx\_CCRx$.

The timer is able to generate PWM in edge-aligned mode only since the counter is upcounting.

PWM edge-aligned mode

In the following example, we consider PWM mode 1. The reference PWM signal OCxREF is high as long as TIMx_CNT < TIMx_CCRx else it becomes low. If the compare value in TIMx_CCRx is greater than the auto-reload value (in TIMx_ARR) then OCxREF is held at '1'. If the compare value is 0 then OCxRef is held at '0'. [Figure 158](#) shows some edge-aligned PWM waveforms in an example where TIMx_ARR=8.

Figure 158. Edge-aligned PWM waveforms (ARR=8)



For code example refer to the Appendix section [A.8.8: Edge-aligned PWM configuration example](#).

16.3.9 Debug mode

When the microcontroller enters debug mode (Cortex™-M0 core halted), the TIMx counter either continues to work normally or stops, depending on DBG_TIMx_STOP configuration bit in DBG module.

16.4 TIM14 registers

16.4.1 TIM14 control register 1 (TIM14_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	Res.	Res.	Res.	Res.	URS	UDIS	CEN
						rw	rw	rw					rw	rw	rw

Bits 15:10 Reserved, must be kept at reset value.

Bits 9:8 **CKD**: Clock division

This bit-field indicates the division ratio between the timer clock (CK_INT) frequency and sampling clock used by the digital filters (ETR, Tlx),

- 00: $t_{DTS} = t_{CK\_INT}$
- 01: $t_{DTS} = 2 \times t_{CK\_INT}$
- 10: $t_{DTS} = 4 \times t_{CK\_INT}$
- 11: Reserved

Bit 7 **ARPE**: Auto-reload preload enable

- 0: TIMx_ARR register is not buffered
- 1: TIMx_ARR register is buffered

Bits 6:3 Reserved, must be kept at reset value.

Bit 2 **URS**: Update request source

This bit is set and cleared by software to select the update interrupt (UEV) sources.

- 0: Any of the following events generate an UEV if enabled:
 - Counter overflow
 - Setting the UG bit
- 1: Only counter overflow generates an UEV if enabled.

Bit 1 **UDIS**: Update disable

This bit is set and cleared by software to enable/disable update interrupt (UEV) event generation.

- 0: UEV enabled. An UEV is generated by one of the following events:
 - Counter overflow
 - Setting the UG bit.

Buffered registers are then loaded with their preload values.

- 1: UEV disabled. No UEV is generated, shadow registers keep their value (ARR, PSC, CCRx). The counter and the prescaler are reinitialized if the UG bit is set.

Bit 0 **CEN**: Counter enable

- 0: Counter disabled
- 1: Counter enabled

16.4.2 TIM14 interrupt enable register (TIM14_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1IE	UIE
														rw	rw

Bits 15:2 Reserved, must be kept at reset value.

Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable

0: CC1 interrupt disabled

1: CC1 interrupt enabled

Bit 0 **UIE**: Update interrupt enable

0: Update interrupt disabled

1: Update interrupt enabled

16.4.3 TIM14 status register (TIM14_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CC1OF	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1IF	UIF
						rc_w0								rc_w0	rc_w0

Bit 15:10 Reserved, must be kept at reset value.

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

0: No overcapture has been detected.

1: The counter value has been captured in TIMx_CCR1 register while CC1IF flag was already set

Bits 8:2 Reserved, must be kept at reset value.

Bit 1 **CC1IF**: Capture/compare 1 interrupt flag

If channel CC1 is configured as output:

This flag is set by hardware when the counter matches the compare value. It is cleared by software.

0: No match.

1: The content of the counter TIMx_CNT matches the content of the TIMx_CCR1 register.

When the contents of TIMx_CCR1 are greater than the contents of TIMx_ARR, the CC1IF bit goes high on the counter overflow.

If channel CC1 is configured as input:

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx_CCR1 register.

0: No input capture occurred.

1: The counter value has been captured in TIMx_CCR1 register (an edge has been detected on IC1 which matches the selected polarity).

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

- At overflow and if UDIS='0' in the TIMx_CR1 register.
- When CNT is reinitialized by software using the UG bit in TIMx_EGR register, if URS='0' and UDIS='0' in the TIMx_CR1 register.

16.4.4 TIM14 event generation register (TIM14_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1G	UG
														w	w

Bits 15:2 Reserved, must be kept at reset value.

Bit 1 **CC1G**: Capture/compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

If channel CC1 is configured as output:

CC1IF flag is set, Corresponding interrupt or is sent if enabled.

If channel CC1 is configured as input:

The current value of the counter is captured in TIMx_CCR1 register. The CC1IF flag is set, the corresponding interrupt is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: Re-initialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared.

16.4.5 TIM14 capture/compare mode register 1 (TIM14_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CCxS bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OCxx describes its function when the channel is configured in output, ICxx describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OC1M[2:0]			OC1PE	OC1FE	CC1S[1:0]	
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IC1F[3:0]			IC1PSC[1:0]				
								rw	rw	rw	rw	rw	rw	rw	rw

Output compare mode

Bits 15:7 Reserved

Bits 6:4 **OC1M**: Output compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 is derived. OC1REF is active high whereas OC1 active level depends on CC1P bit.

000: Frozen. The comparison between the output compare register TIMx_CCR1 and the counter TIMx_CNT has no effect on the outputs.

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

011: Toggle - OC1REF toggles when TIMx_CNT = TIMx_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - Channel 1 is active as long as TIMx_CNT < TIMx_CCR1 else inactive.

111: PWM mode 2 - Channel 1 is inactive as long as TIMx_CNT < TIMx_CCR1 else active.

Note: In PWM mode 1 or 2, the OCREF level changes when the result of the comparison changes or when the output compare mode switches from frozen to PWM mode.

Bit 3 OC1PE: Output compare 1 preload enable

0: Preload register on TIMx_CCR1 disabled. TIMx_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx_CCR1 enabled. Read/Write operations access the preload register. TIMx_CCR1 preload value is loaded in the active register at each update event.

Note: The PWM mode can be used without validating the preload register only in one pulse mode (OPM bit set in TIMx_CR1 register). Else the behavior is not guaranteed.

Bit 2 OC1FE: Output compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger in input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. OC is then set to the compare level independently of the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OC1FE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 CC1S: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output.

01: CC1 channel is configured as input, IC1 is mapped on TI1.

10: Reserved

11: Reserved

Note: CC1S bits are writable only when the channel is OFF (CC1E = 0 in TIMx_CCER).

Input capture mode

Bits 15:8 Reserved

Bits 7:4 **IC1F**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{DTS}
 0001: $f_{SAMPLING} = f_{CK\_INT}$, $N = 2$
 0010: $f_{SAMPLING} = f_{CK\_INT}$, $N = 4$
 0011: $f_{SAMPLING} = f_{CK\_INT}$, $N = 8$
 0100: $f_{SAMPLING} = f_{DTS} / 2$, $N = 6$
 0101: $f_{SAMPLING} = f_{DTS} / 2$, $N = 8$
 0110: $f_{SAMPLING} = f_{DTS} / 4$, $N = 6$
 0111: $f_{SAMPLING} = f_{DTS} / 4$, $N = 8$
 1000: $f_{SAMPLING} = f_{DTS} / 8$, $N = 6$
 1001: $f_{SAMPLING} = f_{DTS} / 8$, $N = 8$
 1010: $f_{SAMPLING} = f_{DTS} / 16$, $N = 5$
 1011: $f_{SAMPLING} = f_{DTS} / 16$, $N = 6$
 1100: $f_{SAMPLING} = f_{DTS} / 16$, $N = 8$
 1101: $f_{SAMPLING} = f_{DTS} / 32$, $N = 5$
 1110: $f_{SAMPLING} = f_{DTS} / 32$, $N = 6$
 1111: $f_{SAMPLING} = f_{DTS} / 32$, $N = 8$

Note: Care must be taken that f_{DTS} is replaced in the formula by CK_INT when $ICx[3:0] = 1, 2$ or 3 .

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).

The prescaler is reset as soon as $CC1E = 0$ (TIMx_CCER register).

00: no prescaler, capture is done each time an edge is detected on the capture input
 01: capture is done once every 2 events
 10: capture is done once every 4 events
 11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

0: CC1 channel is configured as output
 01: CC1 channel is configured as input, IC1 is mapped on TI1
 10:
 11:

Note: CC1S bits are writable only when the channel is OFF ($CC1E = 0$ in TIMx_CCER).

16.4.6 TIM14 capture/compare enable register (TIM14_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1NP	Res.	CC1P	CC1E
												rw		rw	rw

Bits 15:4 Reserved, must be kept at reset value.

Bit 3 **CC1NP**: Capture/Compare 1 complementary output Polarity.

CC1 channel configured as output: CC1NP must be kept cleared.

CC1 channel configured as input: CC1NP bit is used in conjunction with CC1P to define TI1FP1 polarity (refer to CC1P description).

Bit 2 Reserved, must be kept at reset value.

Bit 1 **CC1P**: Capture/Compare 1 output Polarity.

CC1 channel configured as output:

0: OC1 active high

1: OC1 active low

CC1 channel configured as input:

The CC1P bit selects TI1FP1 and TI2FP1 polarity for trigger or capture operations.

00: noninverted/rising edge

Circuit is sensitive to TI1FP1 rising edge (capture mode), TI1FP1 is not inverted.

01: inverted/falling edge

Circuit is sensitive to TI1FP1 falling edge (capture mode), TI1FP1 is inverted.

10: reserved, do not use this configuration.

11: noninverted/both edges

Circuit is sensitive to both TI1FP1 rising and falling edges (capture mode), TI1FP1 is not inverted.

Bit 0 **CC1E**: Capture/Compare 1 output enable.

CC1 channel configured as output:

0: Off - OC1 is not active

1: On - OC1 signal is output on the corresponding output pin

CC1 channel configured as input:

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx_CCR1) or not.

0: Capture disabled

1: Capture enabled

Table 53. Output control bit for standard OCx channels

CCxE bit	OCx output state
0	Output Disabled (OCx='0', OCx_EN='0')
1	OCx=OCxREF + Polarity, OCx_EN='1'

Note: The state of the external I/O pins connected to the standard OCx channels depends on the OCx channel state and the GPIO registers.

16.4.7 TIM14 counter (TIM14_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 15:0 **CNT[15:0]**: Counter value

16.4.8 TIM14 prescaler (TIM14_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency CK_CNT is equal to $f_{CK\_PSC} / (PSC[15:0] + 1)$.

PSC contains the value to be loaded in the active prescaler register at each update event.

16.4.9 TIM14 auto-reload register (TIM14_ARR)

Address offset: 0x2C

Reset value: 0xFFFF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 16.3.1: Time-base unit on page 375](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

16.4.10 TIM14 capture/compare register 1 (TIM14_CCR1)

Address offset: 0x34

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR1[15:0]**: Capture/Compare 1 value

If channel CC1 is configured as output:

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signaled on OC1 output.

If channel CC1 is configured as input:

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

16.4.11 TIM14 option register (TIM14_OR)

Address offset: 0x50

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TI1_RMP	
														rw	rw

Bits 15:2 Reserved, must be kept at reset value.

Bit 1:0 **TI1_RMP [1:0]**: Timer Input 1 remap

Set and cleared by software.

00: TIM14 Channel1 is connected to the GPIO. Refer to the alternate function mapping in the device datasheets.

01: TIM14 Channel1 is connected to the RTCCLK.

10: TIM14 Channel1 is connected to the HSE/32 Clock.

11: TIM14 Channel1 is connected to the microcontroller clock output (MCO), this selection is controlled by the MCO[2:0] bits of the Clock configuration register (RCC_CFGR) (see [Section 7.4.2: Clock configuration register \(RCC_CFGR\)](#)).

16.4.12 TIM14 register map

TIM14 registers are mapped as 16-bit addressable registers as described in the table below:

Table 54. TIM14 register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x00	TIM14_CR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CKD [1:0]							URS	UDIS	CEN	
	Reset value																							0	0	0				0	0	0		
0x08	Reserved	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value																																	
0x0C	TIM14_DIER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1IE	UIE	
	Reset value																														0	0	0	
0x10	TIM14_SR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1OF		Res.	Res.	Res.	Res.	Res.	CC1IF	UIF	
	Reset value																							0							0	0	0	
0x14	TIM14_EGR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1G	UG	
	Reset value																														0	0	0	
0x18	TIM14_CCMR1 Output compare mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					OC1M [2:0]	OC1PE	OC1FE	CC1S [1:0]	
	Reset value																										0	0	0	0	0	0	0	0
	TIM14_CCMR1 Input capture mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					IC1F[3:0]	IC1 PSC [1:0]	CC1S [1:0]			
	Reset value																										0	0	0	0	0	0	0	0
0x1C	Reserved	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value																																	
0x20	TIM14_CCER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1NP	Res.	CC1P	CC1E
	Reset value																												0		0	0	0	0
0x24	TIM14_CNT	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CNT[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x28	TIM14_PSC	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PSC[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x2C	TIM14_ARR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ARR[15:0]																
	Reset value																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
0x30	Reserved	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value																																	
0x34	TIM14_CCR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CCR1[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 54. TIM14 register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x38 to 0x4C	Reserved	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value																																
0x50	TIM14_OR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
	Reset value																															0	T11_RMP



17 General-purpose timers (TIM15/16/17)

TIM15 is not available on STM32F030x4 and STM32F030x6 devices.

17.1 TIM15/16/17 introduction

The TIM15/16/17 timers consist of a 16-bit auto-reload counter driven by a programmable prescaler.

They may be used for a variety of purposes, including measuring the pulse lengths of input signals (input capture) or generating output waveforms (output compare, PWM, complementary PWM with dead-time insertion).

Pulse lengths and waveform periods can be modulated from a few microseconds to several milliseconds using the timer prescaler and the RCC clock controller prescalers.

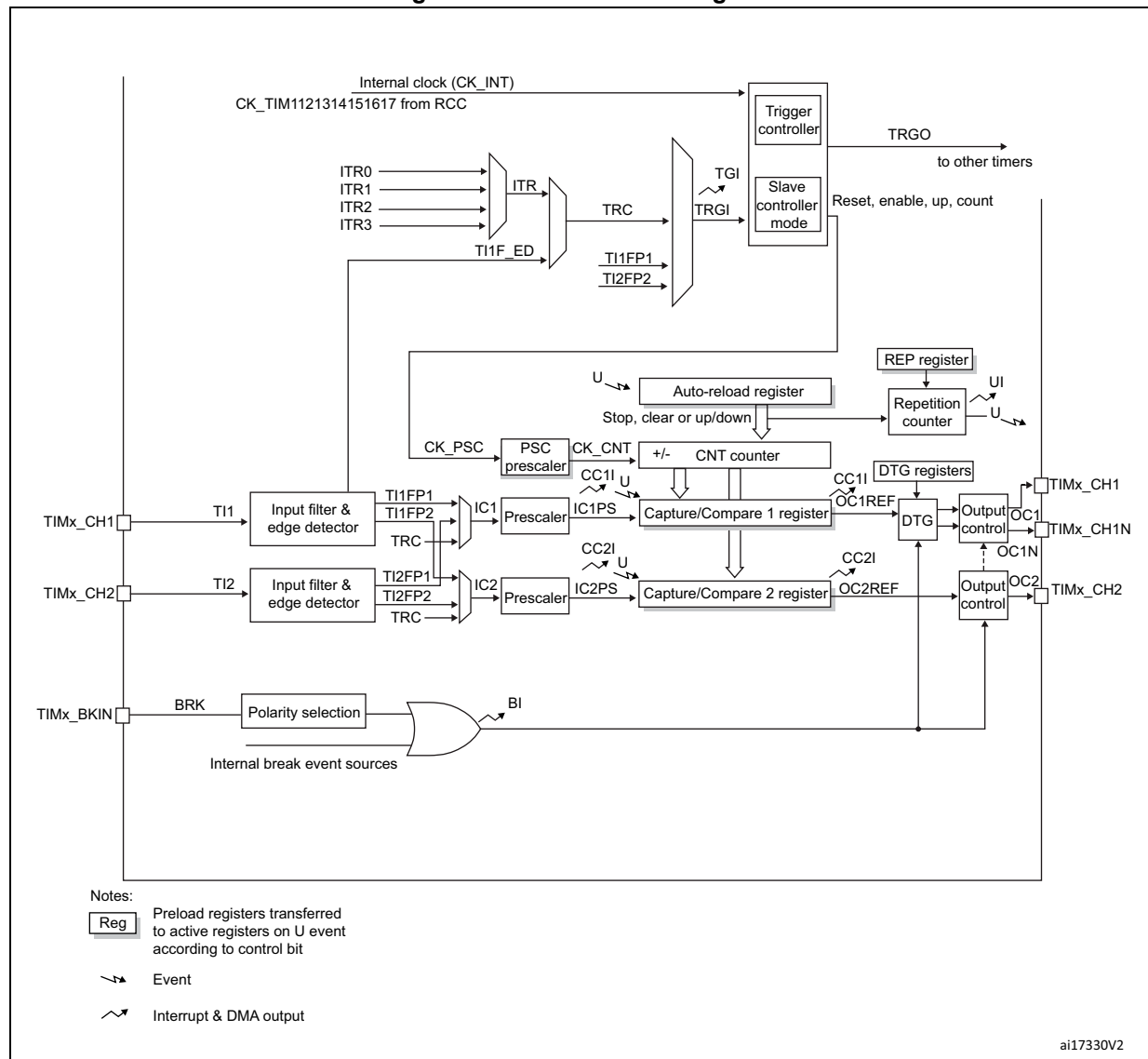
The TIM15/16/17 timers are completely independent, and do not share any resources. The TIM15 can be synchronized with other timers.

17.2 TIM15 main features

TIM15 includes the following features:

- 16-bit auto-reload upcounter
- 16-bit programmable prescaler used to divide (also “on the fly”) the counter clock frequency by any factor between 1 and 65535
- Up to 2 independent channels for:
 - Input capture
 - Output compare
 - PWM generation (Edge-aligned mode)
 - One-pulse mode output
- Complementary outputs with programmable dead-time (for channel 1 only)
- Synchronization circuit to control the timer with external signals and to interconnect several timers together
- Repetition counter to update the timer registers only after a given number of cycles of the counter
- Break input to put the timer’s output signals in the reset state or a known state
- Interrupt/DMA generation on the following events:
 - Update: counter overflow, counter initialization (by software or internal/external trigger)
 - Trigger event (counter start, stop, initialization or count by internal/external trigger)
 - Input capture
 - Output compare
 - Break input (interrupt request)

Figure 159. TIM15 block diagram

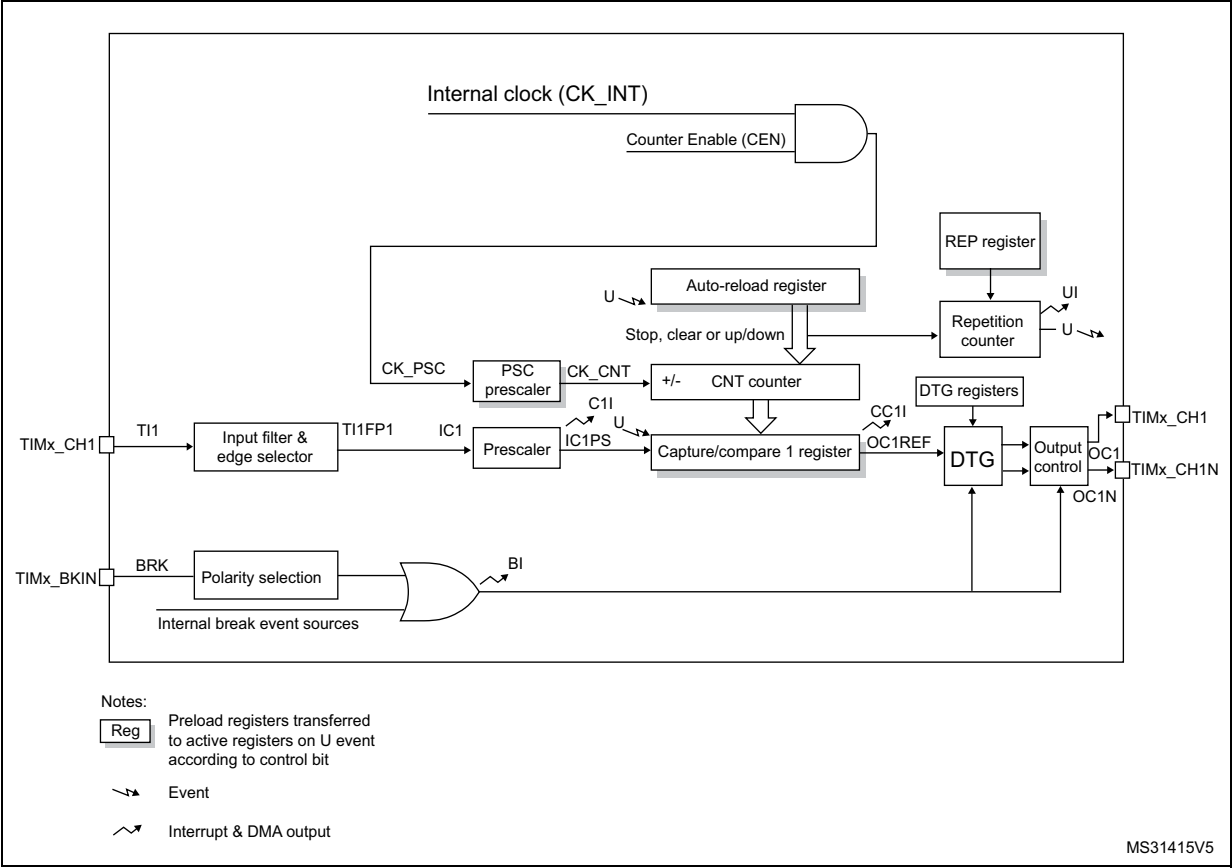


17.3 TIM16 and TIM17 main features

The TIM16 and TIM17 timers include the following features:

- 16-bit auto-reload upcounter
- 16-bit programmable prescaler used to divide (also “on the fly”) the counter clock frequency by any factor between 1 and 65535
- One channel for:
 - Input capture
 - Output compare
 - PWM generation (Edge-aligned mode)
 - One-pulse mode output
- Complementary outputs with programmable dead-time
- Repetition counter to update the timer registers only after a given number of cycles of the counter
- Break input to put the timer’s output signals in the reset state or a known state
- Interrupt/DMA generation on the following events:
 - Update: counter overflow
 - Input capture
 - Output compare
 - Break input

Figure 160. TIM16 and TIM17 block diagram



17.4 TIM15/16/17 functional description

17.4.1 Time-base unit

The main block of the programmable advanced-control timer is a 16-bit counter with its related auto-reload register. The counter can count up, down or both up and down. The counter clock can be divided by a prescaler.

The counter, the auto-reload register and the prescaler register can be written or read by software. This is true even when the counter is running.

The time-base unit includes:

- Counter register (TIMx_CNT)
- Prescaler register (TIMx_PSC)
- Auto-reload register (TIMx_ARR)
- Repetition counter register (TIMx_RCR)

The auto-reload register is preloaded. Writing to or reading from the auto-reload register accesses the preload register. The content of the preload register are transferred into the shadow register permanently or at each update event (UEV), depending on the auto-reload preload enable bit (ARPE) in TIMx_CR1 register. The update event is sent when the counter reaches the overflow (or underflow when downcounting) and if the UDIS bit equals 0 in the TIMx_CR1 register. It can also be generated by software. The generation of the update event is described in detailed for each configuration.

The counter is clocked by the prescaler output CK_CNT, which is enabled only when the counter enable bit (CEN) in TIMx_CR1 register is set (refer also to the slave mode controller description to get more details on counter enabling).

Note that the counter starts counting 1 clock cycle after setting the CEN bit in the TIMx_CR1 register.

Prescaler description

The prescaler can divide the counter clock frequency by any factor between 1 and 65536. It is based on a 16-bit counter controlled through a 16-bit register (in the TIMx_PSC register). It can be changed on the fly as this control register is buffered. The new prescaler ratio is taken into account at the next update event.

[Figure 146](#) and [Figure 147](#) give some examples of the counter behavior when the prescaler ratio is changed on the fly:

Figure 161. Counter timing diagram with prescaler division change from 1 to 2

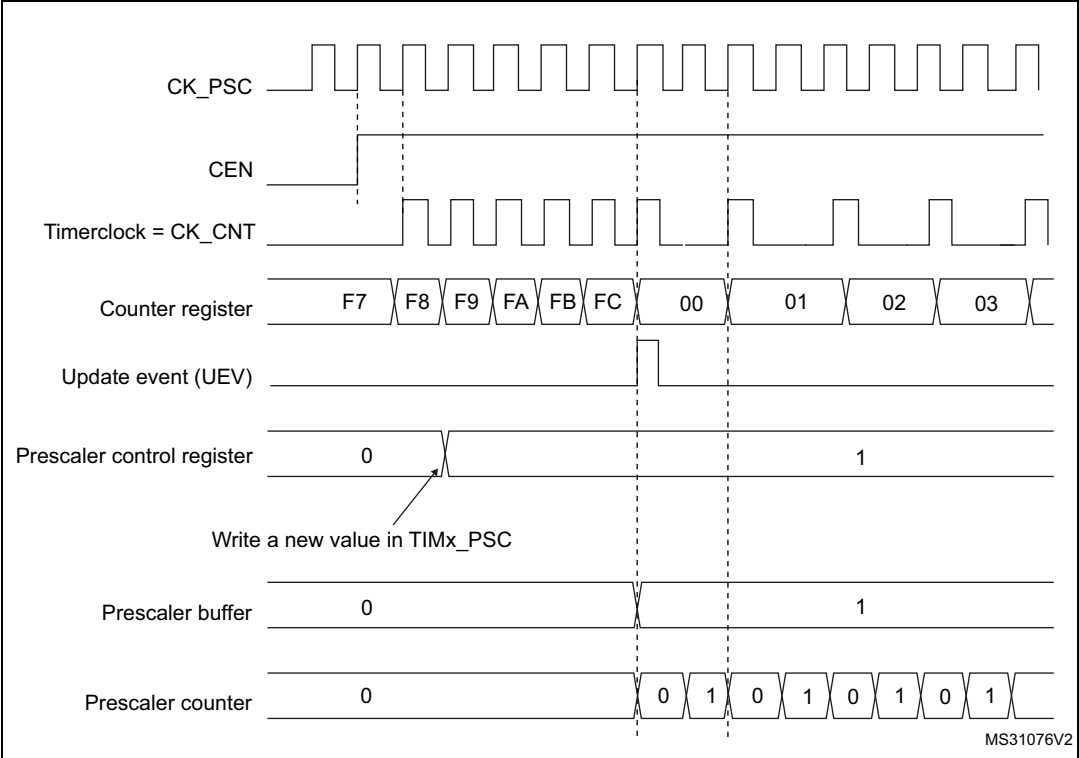
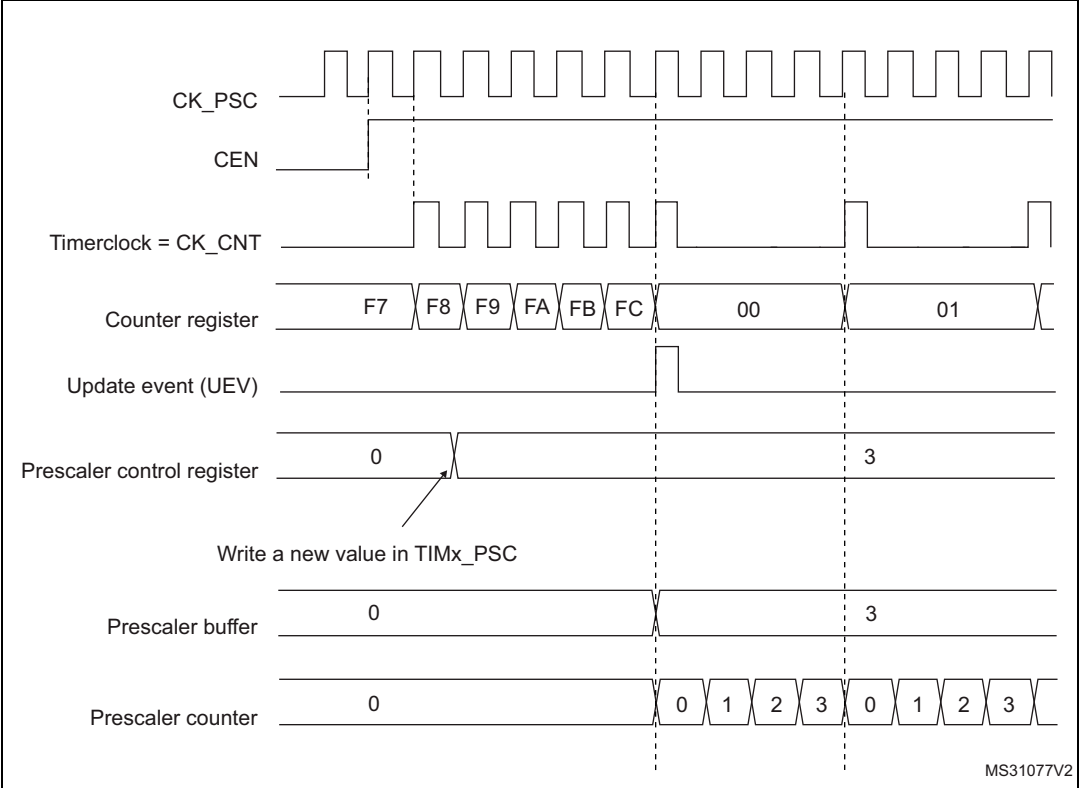


Figure 162. Counter timing diagram with prescaler division change from 1 to 4



17.4.2 Counter modes

Upcounting mode

In upcounting mode, the counter counts from 0 to the auto-reload value (content of the TIMx_ARR register), then restarts from 0 and generates a counter overflow event.

If the repetition counter is used, the update event (UEV) is generated after upcounting is repeated for the number of times programmed in the repetition counter register (TIMx_RCR). Else the update event is generated at each counter overflow.

Setting the UG bit in the TIMx_EGR register (by software or by using the slave mode controller) also generates an update event.

The UEV event can be disabled by software by setting the UDIS bit in the TIMx_CR1 register. This is to avoid updating the shadow registers while writing new values in the preload registers. Then no update event occurs until the UDIS bit has been written to 0. However, the counter restarts from 0, as well as the counter of the prescaler (but the prescale rate does not change). In addition, if the URS bit (update request selection) in TIMx_CR1 register is set, setting the UG bit generates an update event UEV but without setting the UIF flag (thus no interrupt or DMA request is sent). This is to avoid generating both update and capture interrupts when clearing the counter on the capture event.

When an update event occurs, all the registers are updated and the update flag (UIF bit in TIMx_SR register) is set (depending on the URS bit):

- The repetition counter is reloaded with the content of TIMx_RCR register,
- The auto-reload shadow register is updated with the preload value (TIMx_ARR),
- The buffer of the prescaler is reloaded with the preload value (content of the TIMx_PSC register).

The following figures show some examples of the counter behavior for different clock frequencies when TIMx_ARR=0x36.

Figure 163. Counter timing diagram, internal clock divided by 1

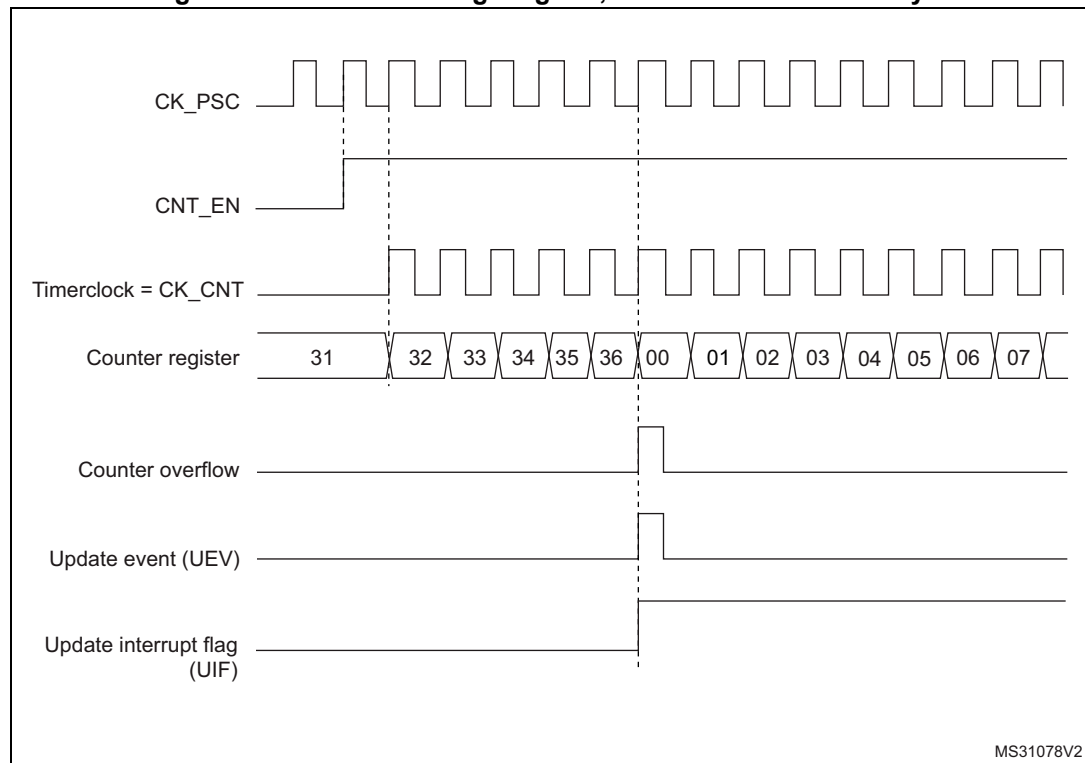


Figure 164. Counter timing diagram, internal clock divided by 2

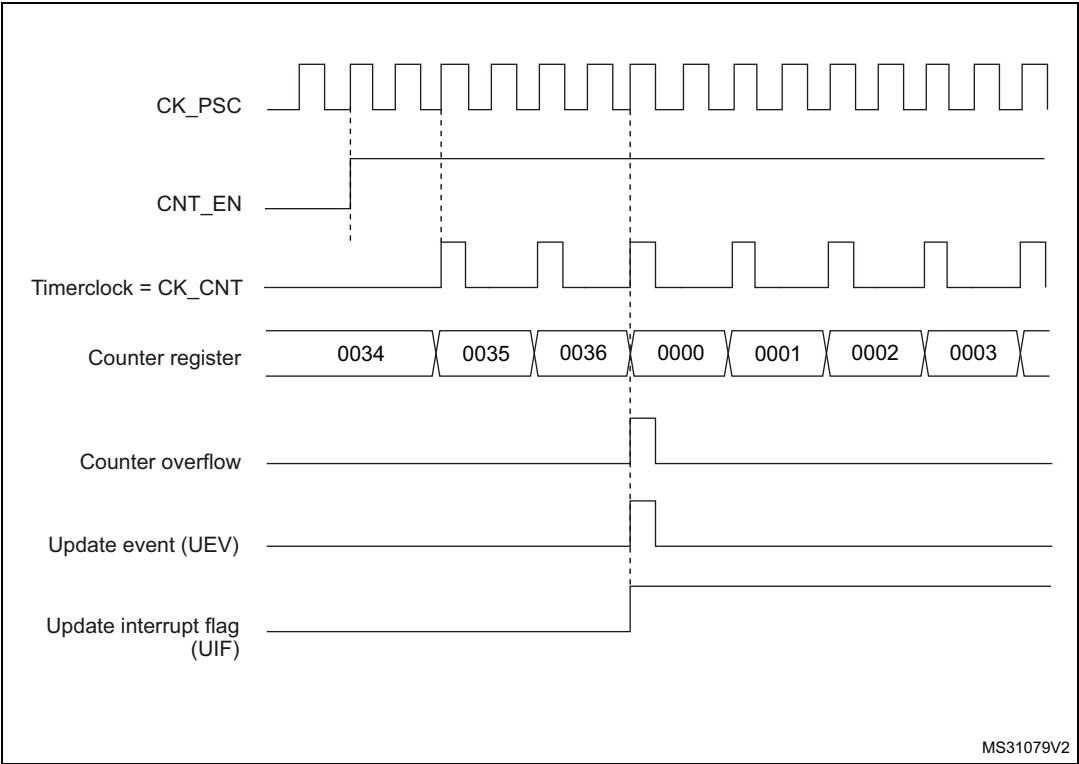


Figure 165. Counter timing diagram, internal clock divided by 4

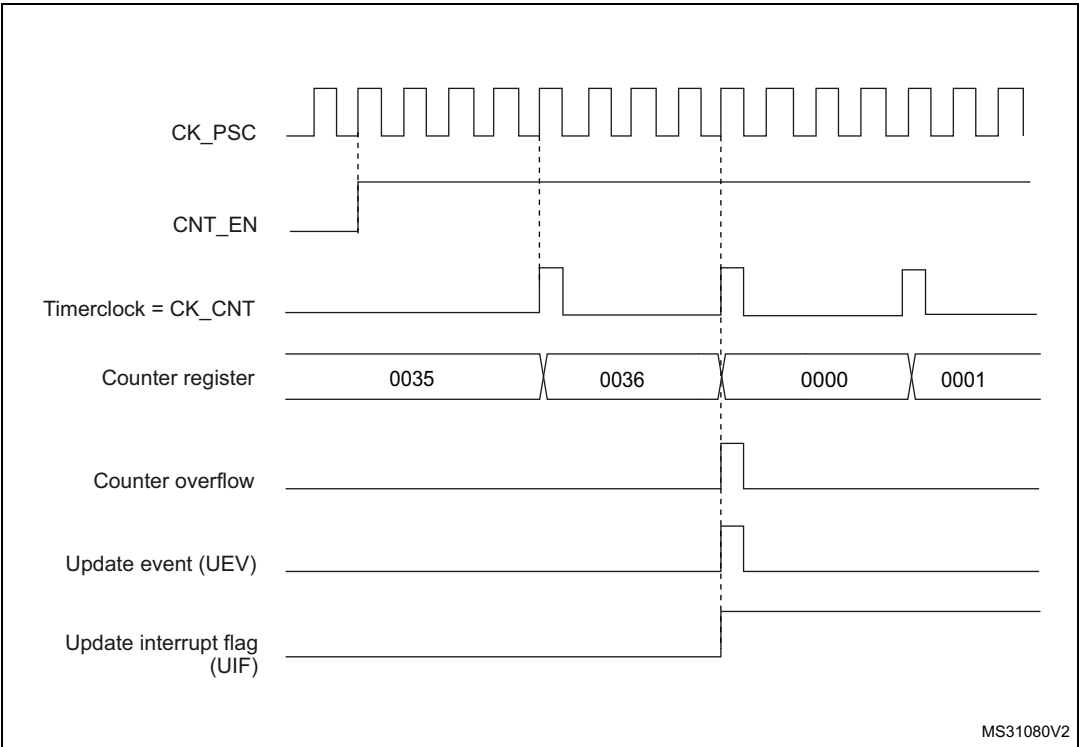


Figure 166. Counter timing diagram, internal clock divided by N

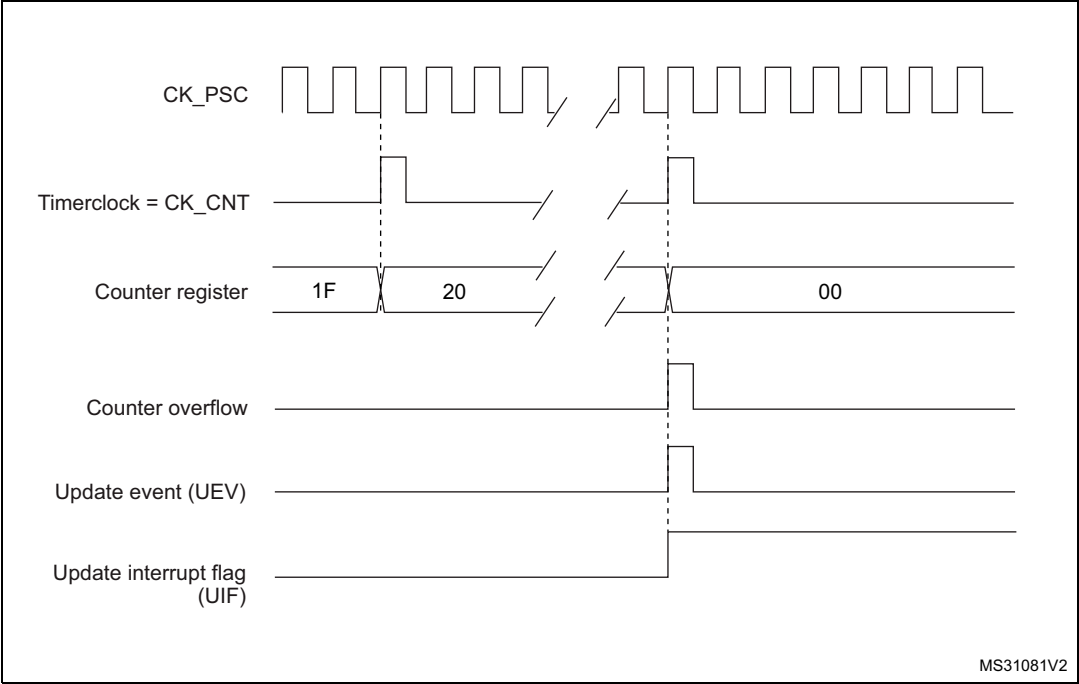


Figure 167. Counter timing diagram, update event when ARPE=0 (TIMx_ARR not preloaded)

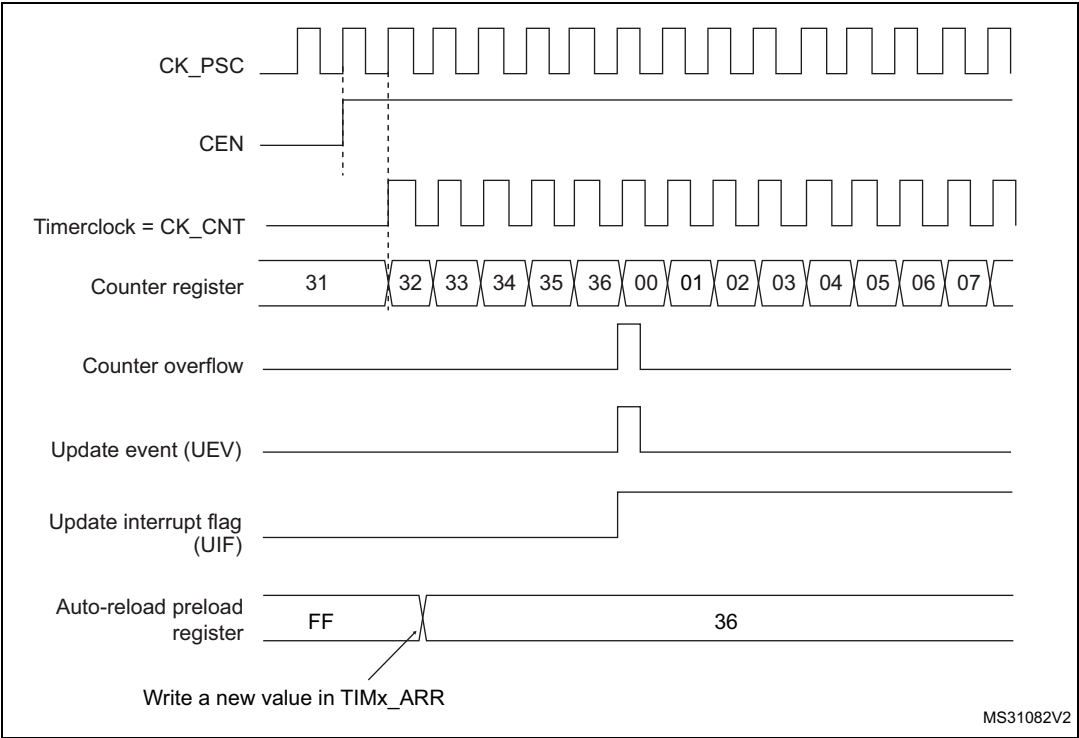
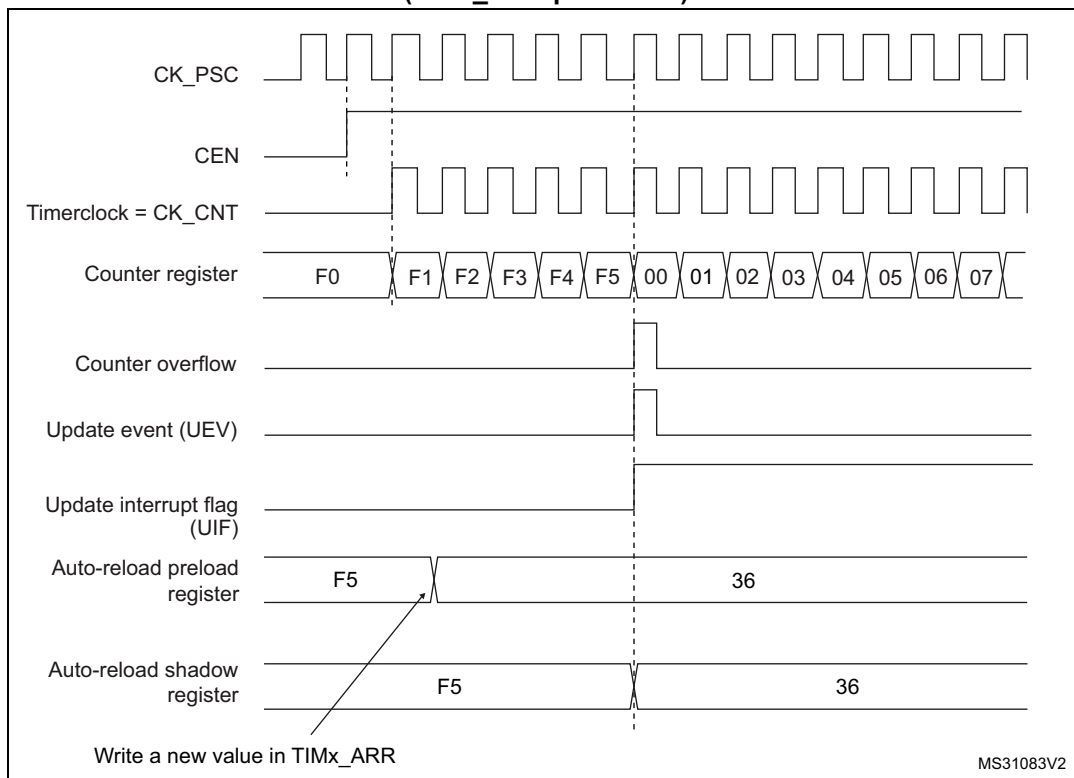


Figure 168. Counter timing diagram, update event when ARPE=1 (TIMx_ARR preloaded)



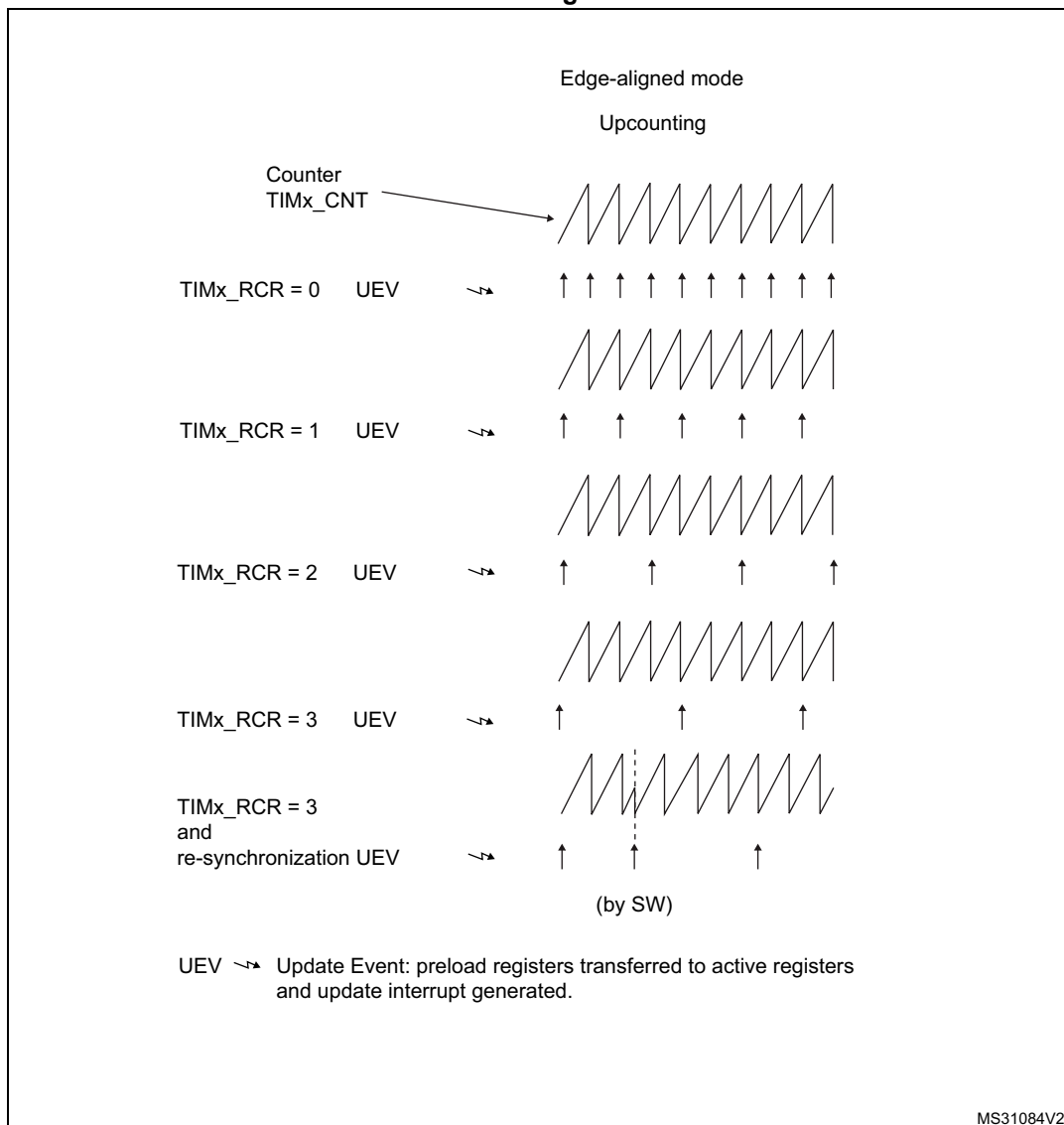
17.4.3 Repetition counter

[Section 16.3.1: Time-base unit](#) describes how the update event (UEV) is generated with respect to the counter overflows/underflows. It is actually generated only when the repetition counter has reached zero. This can be useful when generating PWM signals.

This means that data are transferred from the preload registers to the shadow registers (TIMx_ARR auto-reload register, TIMx_PSC prescaler register, but also TIMx_CCRx capture/compare registers in compare mode) every N counter overflows or underflows, where N is the value in the TIMx_RCR repetition counter register.

The repetition counter is decremented at each counter overflow in upcounting mode.

The repetition counter is an auto-reload type; the repetition rate is maintained as defined by the TIMx_RCR register value (refer to [Figure 169](#)). When the update event is generated by software (by setting the UG bit in TIMx_EGR register) or by hardware through the slave mode controller, it occurs immediately whatever the value of the repetition counter is and the repetition counter is reloaded with the content of the TIMx_RCR register.

Figure 169. Update rate examples depending on mode and TIMx_RCR register settings

17.4.4 Clock sources

The counter clock can be provided by the following clock sources:

- Internal clock (CK_INT)
- External clock mode1: external input pin (only for TIM15)
- Internal trigger inputs (ITRx) (only for TIM15): using one timer as the prescaler for another timer, for example, you can configure TIM1 to act as a prescaler for TIM15. Refer to [Using one timer as prescaler for another](#) for more details.

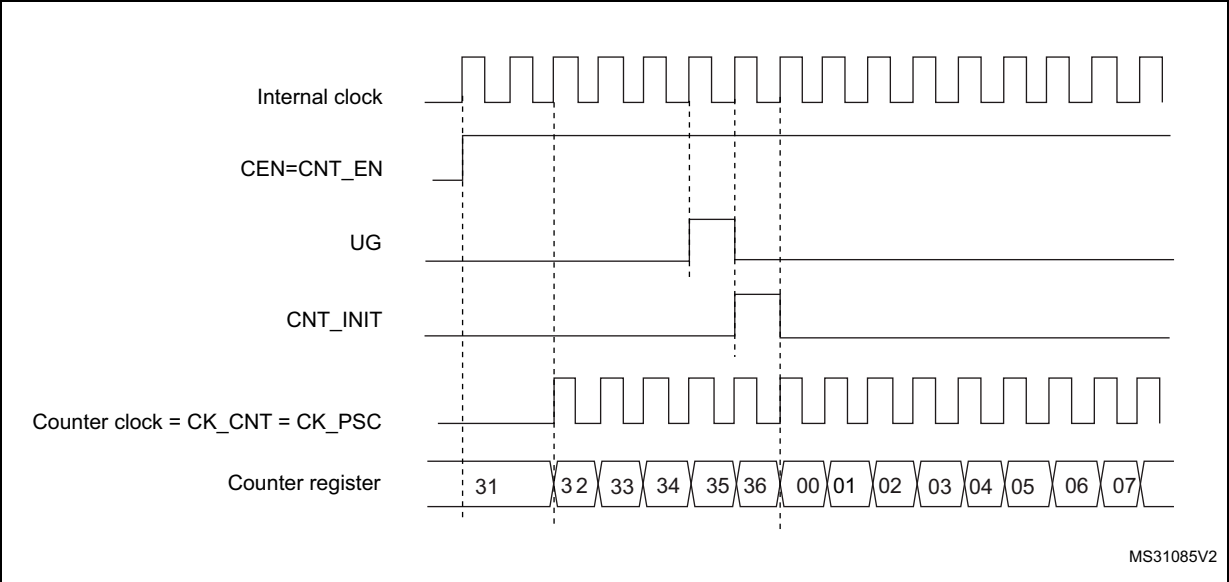
Internal clock source (CK_INT)

For TIM5 if the slave mode controller is disabled (SMS=000), then the CEN, DIR (in the TIMx_CR1 register) and UG bits (in the TIMx_EGR register) are actual control bits and can

be changed only by software (except UG which remains cleared automatically). As soon as the CEN bit is written to 1, the prescaler is clocked by the internal clock CK_INT.

Figure 16.3.4 shows the behavior of the control circuit and the upcounter in normal mode, without prescaler.

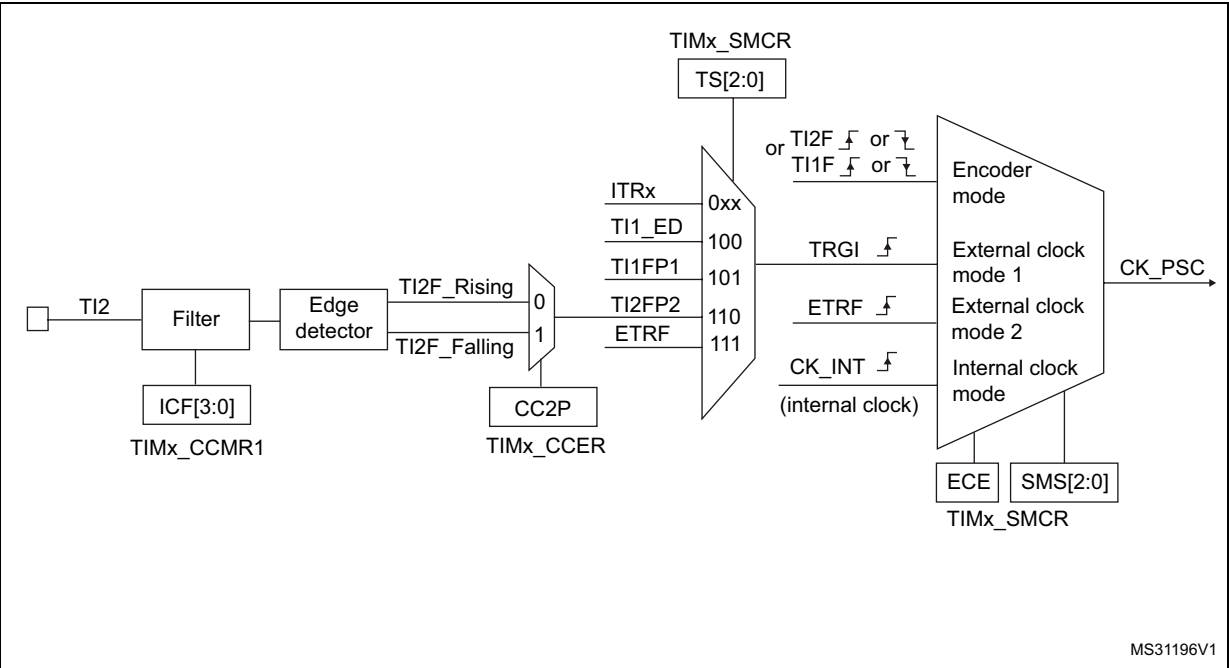
Figure 170. Control circuit in normal mode, internal clock divided by 1



External clock source mode 1

This mode is selected when SMS=111 in the TIMx_SMCR register. The counter can count at each rising or falling edge on a selected input.

Figure 171. TI2 external clock connection example



For example, to configure the upcounter to count in response to a rising edge on the TI2 input, use the following procedure:

1. Configure channel 2 to detect rising edges on the TI2 input by writing CC2S = '01' in the TIMx_CCMR1 register.
2. Configure the input filter duration by writing the IC2F[3:0] bits in the TIMx_CCMR1 register (if no filter is needed, keep IC2F=0000).
3. Select rising edge polarity by writing CC2P=0 in the TIMx_CCER register.
4. Configure the timer in external clock mode 1 by writing SMS=111 in the TIMx_SMCR register.
5. Select TI2 as the trigger input source by writing TS=110 in the TIMx_SMCR register.
6. Enable the counter by writing CEN=1 in the TIMx_CR1 register.

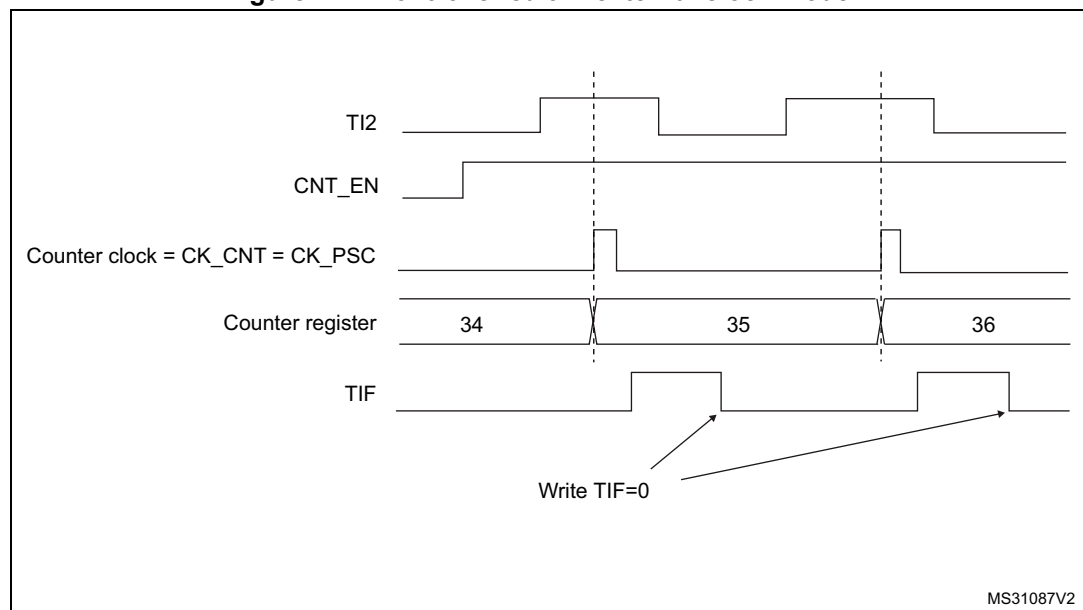
Note: The capture prescaler is not used for triggering, so you don't need to configure it.

For code example refer to the Appendix section [A.8.1: Upcounter on TI2 rising edge code example](#).

When a rising edge occurs on TI2, the counter counts once and the TIF flag is set.

The delay between the rising edge on TI2 and the actual clock of the counter is due to the resynchronization circuit on TI2 input.

Figure 172. Control circuit in external clock mode 1



17.4.5 Capture/compare channels

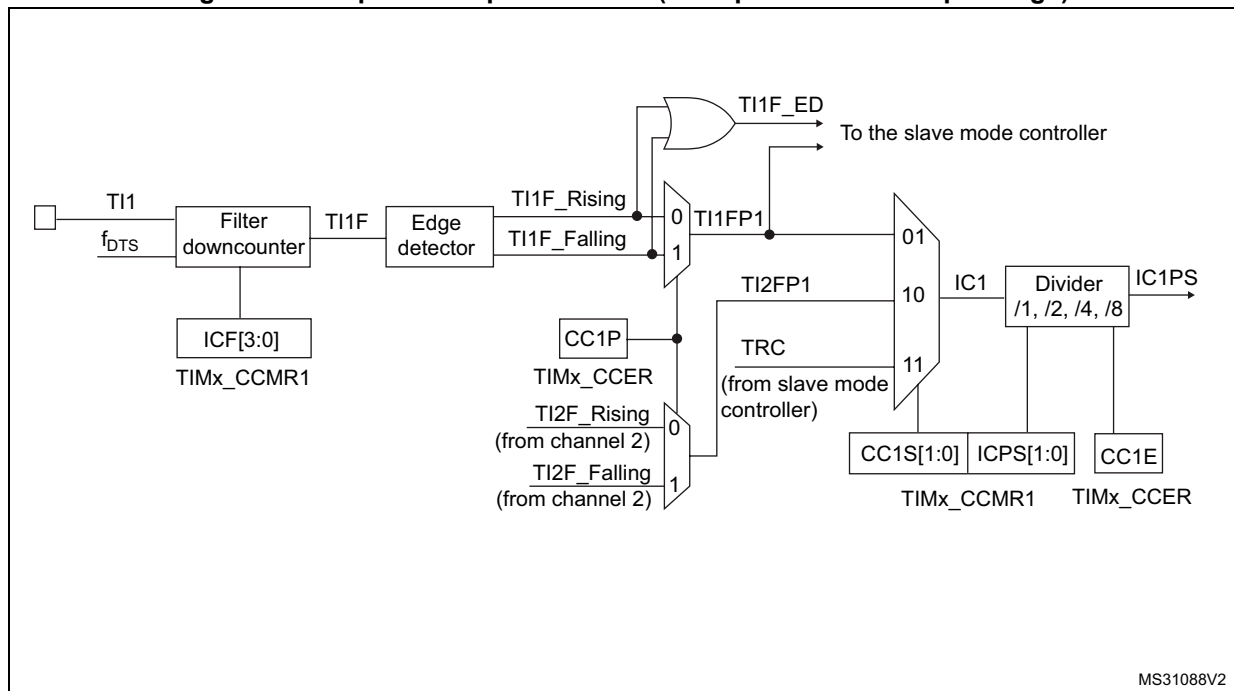
Each Capture/Compare channel is built around a capture/compare register (including a shadow register), a input stage for capture (with digital filter, multiplexing and prescaler) and an output stage (with comparator and output control).

[Figure 154](#) to [Figure 176](#) give an overview of one Capture/Compare channel.

The input stage samples the corresponding TIx input to generate a filtered signal TIxF. Then, an edge detector with polarity selection generates a signal (TIxFPx) which can be

used as trigger input by the slave mode controller or as the capture command. It is prescaled before the capture register (ICxPS).

Figure 173. Capture/compare channel (example: channel 1 input stage)



MS31088V2

The output stage generates an intermediate waveform which is then used for reference: OCxRef (active high). The polarity acts at the end of the chain.

Figure 174. Capture/compare channel 1 main circuit

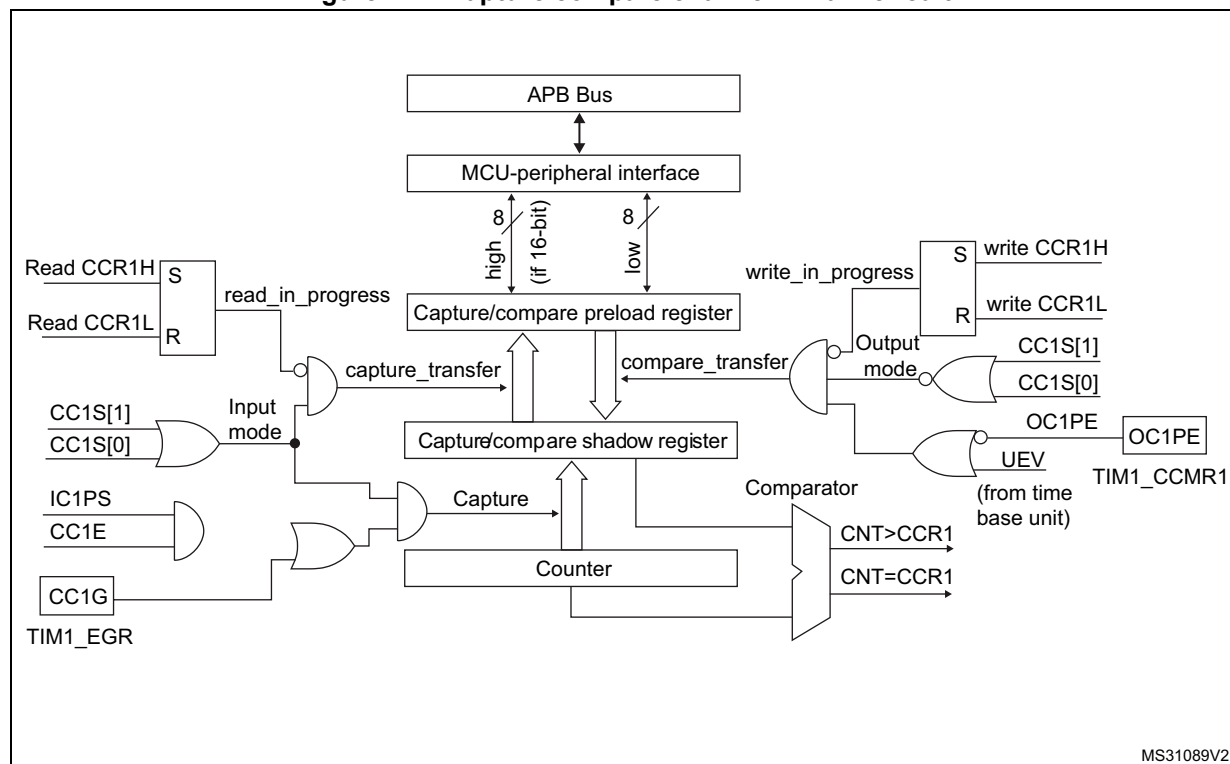


Figure 175. Output stage of capture/compare channel (channel 1)

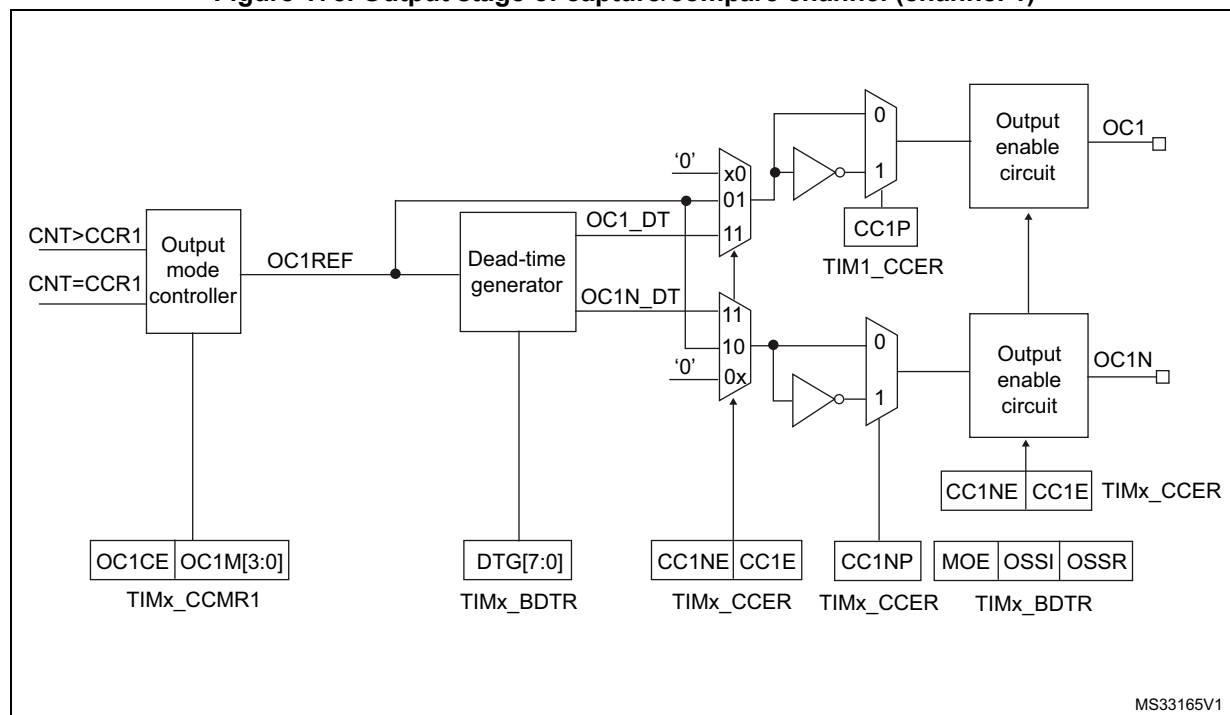
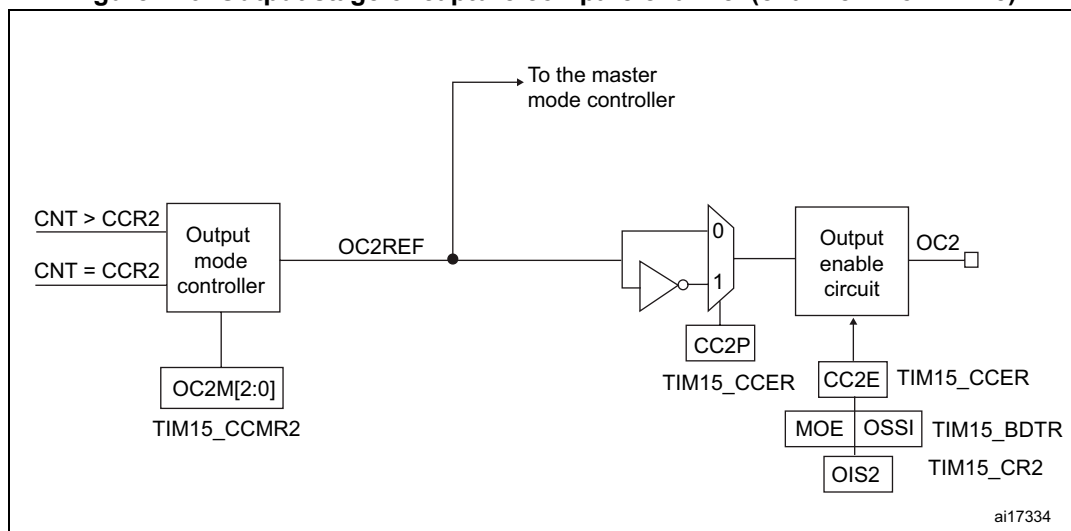


Figure 176. Output stage of capture/compare channel (channel 2 for TIM15)



The capture/compare block is made of one preload register and one shadow register. Write and read always access the preload register.

In capture mode, captures are actually done in the shadow register, which is copied into the preload register.

In compare mode, the content of the preload register is copied into the shadow register which is compared to the counter.

17.4.6 Input capture mode

In Input capture mode, the Capture/Compare Registers (TIMx_CCRx) are used to latch the value of the counter after a transition detected by the corresponding ICx signal. When a capture occurs, the corresponding CCXIF flag (TIMx_SR register) is set and an interrupt or a DMA request can be sent if they are enabled. If a capture occurs while the CCxIF flag was already high, then the over-capture flag CCxOF (TIMx_SR register) is set. CCxIF can be cleared by software by writing it to '0' or by reading the captured data stored in the TIMx_CCRx register. CCxOF is cleared when you write it to '0'.

The following example shows how to capture the counter value in TIMx_CCR1 when TI1 input rises. To do this, use the following procedure:

- Select the active input: TIMx_CCR1 must be linked to the TI1 input, so write the CC1S bits to 01 in the TIMx_CCMR1 register. As soon as CC1S becomes different from 00, the channel is configured in input and the TIMx_CCR1 register becomes read-only.
- Program the input filter duration you need with respect to the signal you connect to the timer (when the input is one of the TIx (ICxF bits in the TIMx_CCMRx register). Let's imagine that, when toggling, the input signal is not stable during at most 5 internal clock cycles. We must program a filter duration longer than these 5 clock cycles. We can validate a transition on TI1 when 8 consecutive samples with the new level have been

detected (sampled at f_{DTS} frequency). Then write IC1F bits to 0011 in the TIMx_CCMR1 register.

- Select the edge of the active transition on the TI1 channel by writing CC1P bit to 0 in the TIMx_CCER register (rising edge in this case).
- Program the input prescaler. In our example, we wish the capture to be performed at each valid transition, so the prescaler is disabled (write IC1PS bits to '00' in the TIMx_CCMR1 register).
- Enable capture from the counter into the capture register by setting the CC1E bit in the TIMx_CCER register.
- If needed, enable the related interrupt request by setting the CC1IE bit in the TIMx_DIER register, and/or the DMA request by setting the CC1DE bit in the TIMx_DIER register.

For code example refer to the Appendix section [A.8.3: Input capture configuration code example](#).

When an input capture occurs:

- The TIMx_CCR1 register gets the value of the counter on the active transition.
- CC1IF flag is set (interrupt flag). CC1OF is also set if at least two consecutive captures occurred whereas the flag was not cleared.
- An interrupt is generated depending on the CC1IE bit.
- A DMA request is generated depending on the CC1DE bit.

For code example refer to the Appendix section [A.8.4: Input capture data management code example](#).

In order to handle the overcapture, it is recommended to read the data before the overcapture flag. This is to avoid missing an overcapture which could happen after reading the flag and before reading the data.

Note: IC interrupt and/or DMA requests can be generated by software by setting the corresponding CCxG bit in the TIMx_EGR register.

17.4.7 PWM input mode (only for TIM15)

This mode is a particular case of input capture mode. The procedure is the same except:

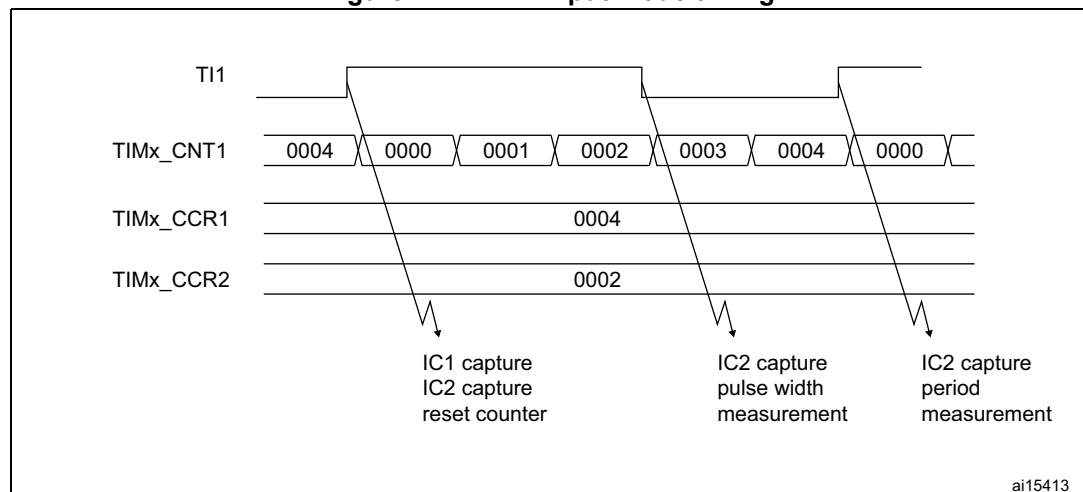
- Two ICx signals are mapped on the same TIx input.
- These 2 ICx signals are active on edges with opposite polarity.
- One of the two TIxFP signals is selected as trigger input and the slave mode controller is configured in reset mode.

For example, you can measure the period (in TIMx_CCR1 register) and the duty cycle (in TIMx_CCR2 register) of the PWM applied on TI1 using the following procedure (depending on CK_INT frequency and prescaler value):

- Select the active input for TIMx_CCR1: write the CC1S bits to 01 in the TIMx_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP1 (used both for capture in TIMx_CCR1 and counter clear): write the CC1P bit to '0' (active on rising edge).
- Select the active input for TIMx_CCR2: write the CC2S bits to 10 in the TIMx_CCMR1 register (TI1 selected).
- Select the active polarity for TI1FP2 (used for capture in TIMx_CCR2): write the CC2P bit to '1' (active on falling edge).
- Select the valid trigger input: write the TS bits to 101 in the TIMx_SMCR register (TI1FP1 selected).
- Configure the slave mode controller in reset mode: write the SMS bits to 100 in the TIMx_SMCR register.
- Enable the captures: write the CC1E and CC2E bits to '1' in the TIMx_CCER register.

For code example refer to the Appendix section [A.8.5: PWM input configuration code example](#).

Figure 177. PWM input mode timing



1. The PWM input mode can be used only with the TIMx_CH1/TIMx_CH2 signals due to the fact that only TI1FP1 and TI2FP2 are connected to the slave mode controller.

17.4.8 Forced output mode

In output mode (CCxS bits = 00 in the TIMx_CCMRx register), each output compare signal (OCxREF and then OCx/OCxN) can be forced to active or inactive level directly by software, independently of any comparison between the output compare register and the counter.

To force an output compare signal (OCxREF/OCx) to its active level, you just need to write 101 in the OCxM bits in the corresponding TIMx_CCMRx register. Thus OCxREF is forced high (OCxREF is always active high) and OCx get opposite value to CCxP polarity bit.

For example: CCxP=0 (OCx active high) => OCx is forced to high level.

The OCxREF signal can be forced low by writing the OCxM bits to 100 in the TIMx_CCMRx register.

Anyway, the comparison between the TIMx_CCRx shadow register and the counter is still performed and allows the flag to be set. Interrupt and DMA requests can be sent accordingly. This is described in the output compare mode section below.

17.4.9 Output compare mode

This function is used to control an output waveform or indicating when a period of time has elapsed.

When a match is found between the capture/compare register and the counter, the output compare function:

- Assigns the corresponding output pin to a programmable value defined by the output compare mode (OCxM bits in the TIMx_CCMRx register) and the output polarity (CCxP bit in the TIMx_CCER register). The output pin can keep its level (OCxM=000), be set active (OCxM=001), be set inactive (OCxM=010) or can toggle (OCxM=011) on match.
- Sets a flag in the interrupt status register (CCxIF bit in the TIMx_SR register).
- Generates an interrupt if the corresponding interrupt mask is set (CCXIE bit in the TIMx_DIER register).
- Sends a DMA request if the corresponding enable bit is set (CCxDE bit in the TIMx_DIER register, CCDS bit in the TIMx_CR2 register for the DMA request selection).

The TIMx_CCRx registers can be programmed with or without preload registers using the OCxPE bit in the TIMx_CCMRx register.

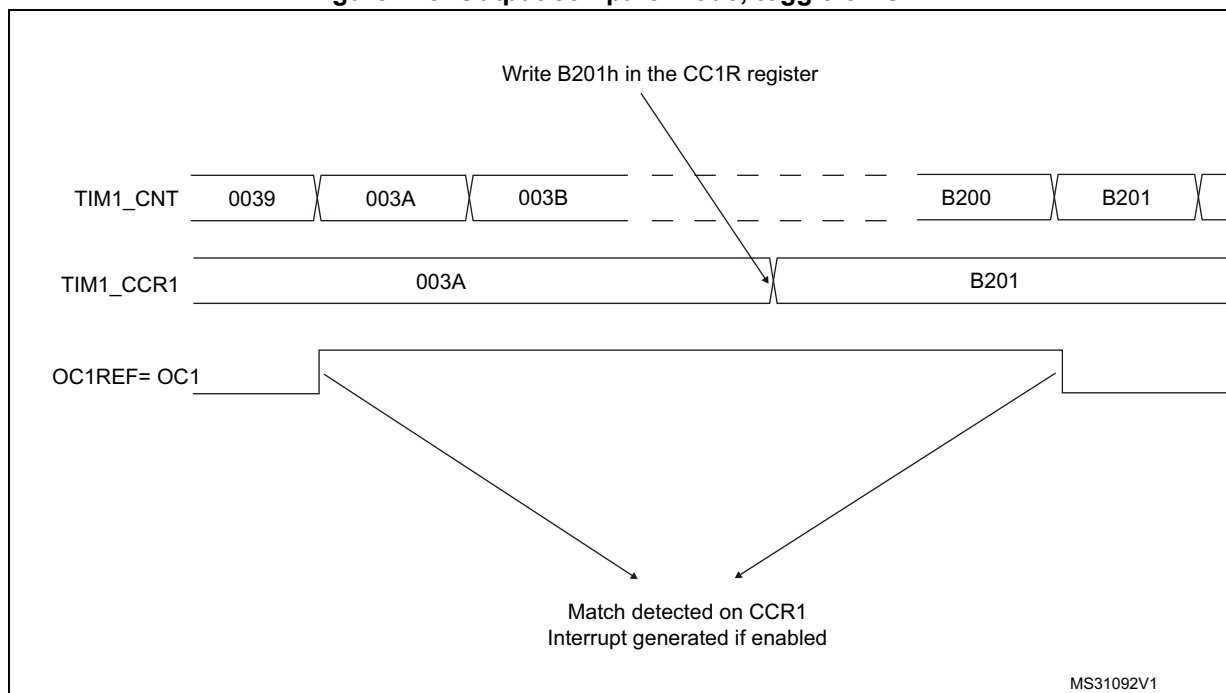
In output compare mode, the update event UEV has no effect on OCxREF and OCx output. The timing resolution is one count of the counter. Output compare mode can also be used to output a single pulse (in One-pulse mode).

Procedure:

1. Select the counter clock (internal, external, prescaler).
2. Write the desired data in the TIMx_ARR and TIMx_CCRx registers.
3. Set the CCxIE bit if an interrupt request is to be generated.
4. Select the output mode. For example:
 - Write OCxM = 011 to toggle OCx output pin when CNT matches CCRx
 - Write OCxPE = 0 to disable preload register
 - Write CCxP = 0 to select active high polarity
 - Write CCxE = 1 to enable the output
5. Enable the counter by setting the CEN bit in the TIMx_CR1 register.

For code example refer to the Appendix section [A.8.2: Up counter on each 2 ETR rising edges code example](#).

The TIMx_CCRx register can be updated at any time by software to control the output waveform, provided that the preload register is not enabled (OCxPE='0', else TIMx_CCRx shadow register is updated only at the next update event UEV). An example is given in [Figure 157](#).

Figure 178. Output compare mode, toggle on OC1

17.4.10 PWM mode

Pulse Width Modulation mode allows you to generate a signal with a frequency determined by the value of the TIMx_ARR register and a duty cycle determined by the value of the TIMx_CCRx register.

The PWM mode can be selected independently on each channel (one PWM per OCx output) by writing '110' (PWM mode 1) or '111' (PWM mode 2) in the OCxM bits in the TIMx_CCMRx register. You must enable the corresponding preload register by setting the OCxPE bit in the TIMx_CCMRx register, and eventually the auto-reload preload register (in upcounting or center-aligned modes) by setting the ARPE bit in the TIMx_CR1 register.

As the preload registers are transferred to the shadow registers only when an update event occurs, before starting the counter, you have to initialize all the registers by setting the UG bit in the TIMx_EGR register.

OCx polarity is software programmable using the CCxP bit in the TIMx_CCER register. It can be programmed as active high or active low. OCx output is enabled by a combination of the CCxE, CCxNE, MOE, OSSI and OSSR bits (TIMx_CCER and TIMx_BDTR registers). Refer to the TIMx_CCER register description for more details.

In PWM mode (1 or 2), TIMx_CNT and TIMx_CCRx are always compared to determine whether $\text{TIMx\_CCRx} \leq \text{TIMx\_CNT}$ or $\text{TIMx\_CNT} \leq \text{TIMx\_CCRx}$ (depending on the direction of the counter).

The timer is able to generate PWM in edge-aligned mode or center-aligned mode depending on the CMS bits in the TIMx_CR1 register.

PWM edge-aligned mode

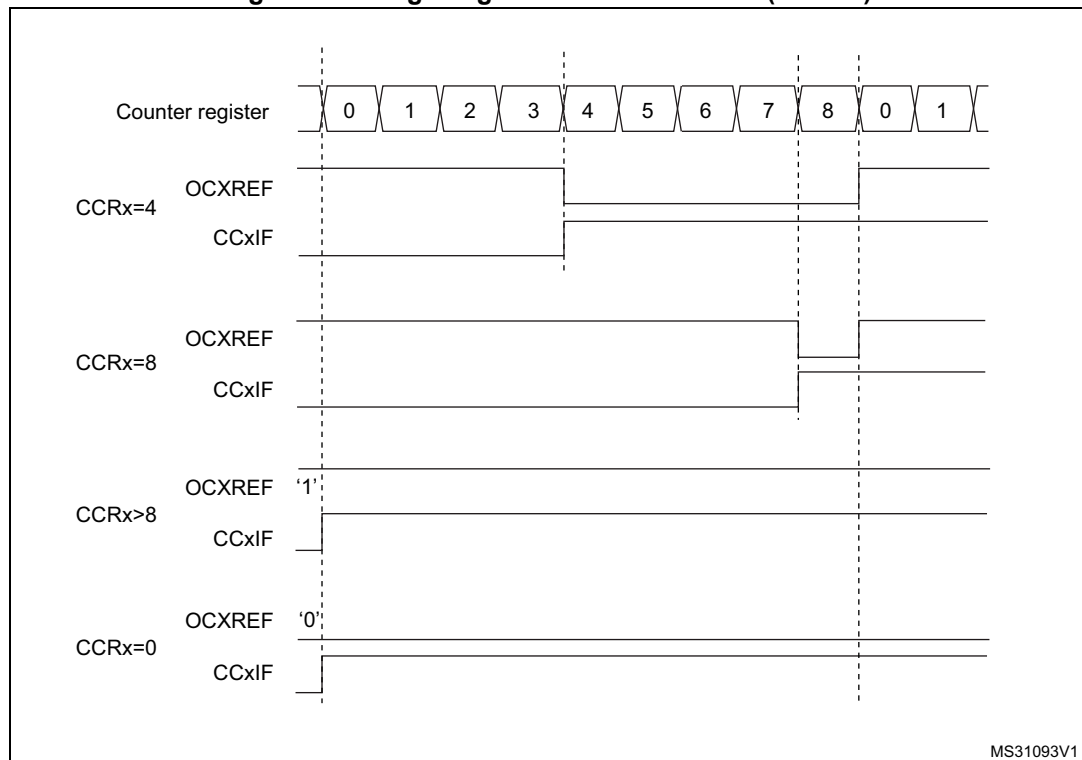
- Upcounting configuration

Upcounting is active when the DIR bit in the TIMx_CR1 register is low. Refer to the [Upcounting mode on page 377](#).

In the following example, we consider PWM mode 1. The reference PWM signal OCxREF is high as long as TIMx_CNT < TIMx_CCRx else it becomes low. If the compare value in TIMx_CCRx is greater than the auto-reload value (in TIMx_ARR) then OCxREF is held at '1'. If the compare value is 0 then OCxRef is held at '0'.

[Figure 158](#) shows some edge-aligned PWM waveforms in an example where TIMx_ARR=8.

Figure 179. Edge-aligned PWM waveforms (ARR=8)



For code example refer to the Appendix section [A.8.9: Center-aligned PWM configuration example](#).

- Downcounting configuration

Downcounting is active when DIR bit in TIMx_CR1 register is high. Refer to the [Repetition counter on page 407](#)

In PWM mode 1, the reference signal OCxRef is low as long as TIMx_CNT > TIMx_CCRx else it becomes high. If the compare value in TIMx_CCRx is greater than the auto-reload value in TIMx_ARR, then OCxREF is held at '1'. 0% PWM is not possible in this mode.

17.4.11 Complementary outputs and dead-time insertion

The TIM15/16/17 general-purpose timers can output one complementary signal and manage the switching-off and switching-on of the outputs.

This time is generally known as dead-time and you have to adjust it depending on the devices you have connected to the outputs and their characteristics (intrinsic delays of level-shifters, delays due to power switches...)

You can select the polarity of the outputs (main output OCx or complementary OCxN) independently for each output. This is done by writing to the CCxP and CCxNP bits in the TIMx_CCER register.

The complementary signals OCx and OCxN are activated by a combination of several control bits: the CCxE and CCxNE bits in the TIMx_CCER register and the MOE, OISx, OISxN, OSSI and OSSR bits in the TIMx_BDTR and TIMx_CR2 registers. Refer to [Table 56: Output control bits for complementary OCx and OCxN channels with break feature on page 442](#) for more details. In particular, the dead-time is activated when switching to the IDLE state (MOE falling down to 0).

Dead-time insertion is enabled by setting both CCxE and CCxNE bits, and the MOE bit if the break circuit is present. There is one 10-bit dead-time generator for each channel. From a reference waveform OCxREF, it generates 2 outputs OCx and OCxN. If OCx and OCxN are active high:

- The OCx output signal is the same as the reference signal except for the rising edge, which is delayed relative to the reference rising edge.
- The OCxN output signal is the opposite of the reference signal except for the rising edge, which is delayed relative to the reference falling edge.

If the delay is greater than the width of the active output (OCx or OCxN) then the corresponding pulse is not generated.

The following figures show the relationships between the output signals of the dead-time generator and the reference signal OCxREF. (we suppose CCxP=0, CCxNP=0, MOE=1, CCxE=1 and CCxNE=1 in these examples)

Figure 180. Complementary output with dead-time insertion

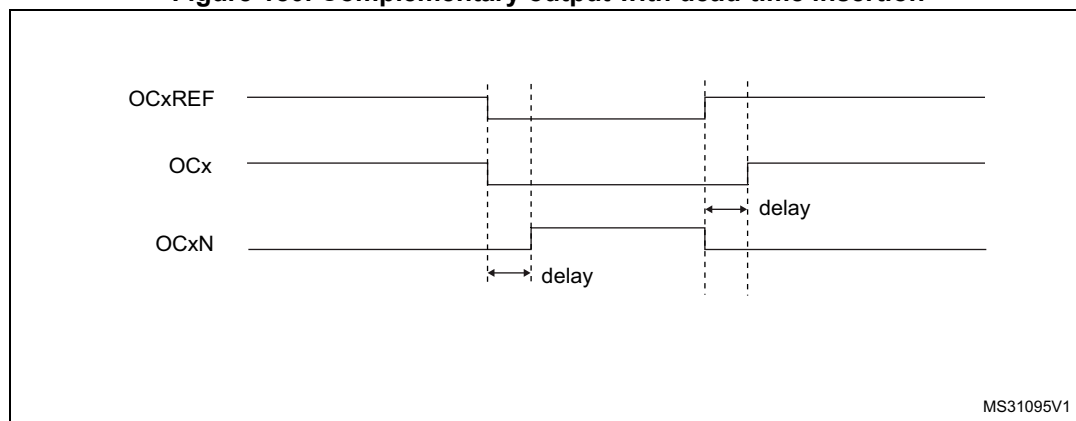
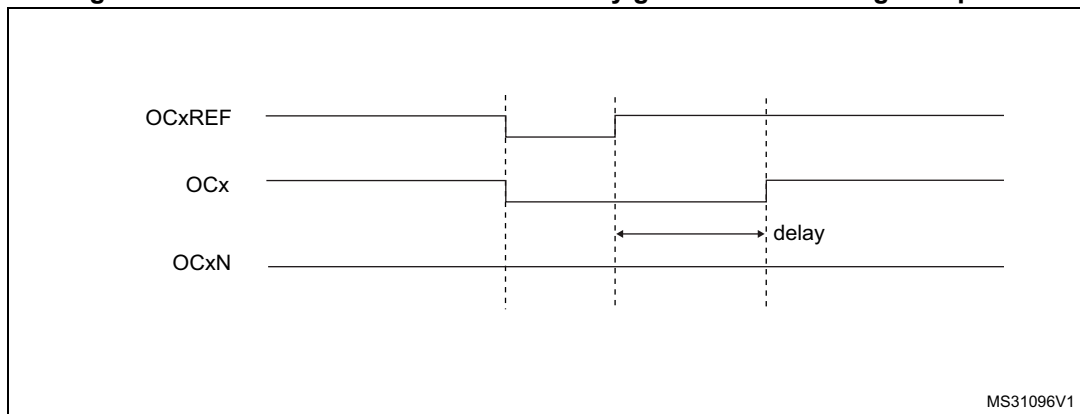
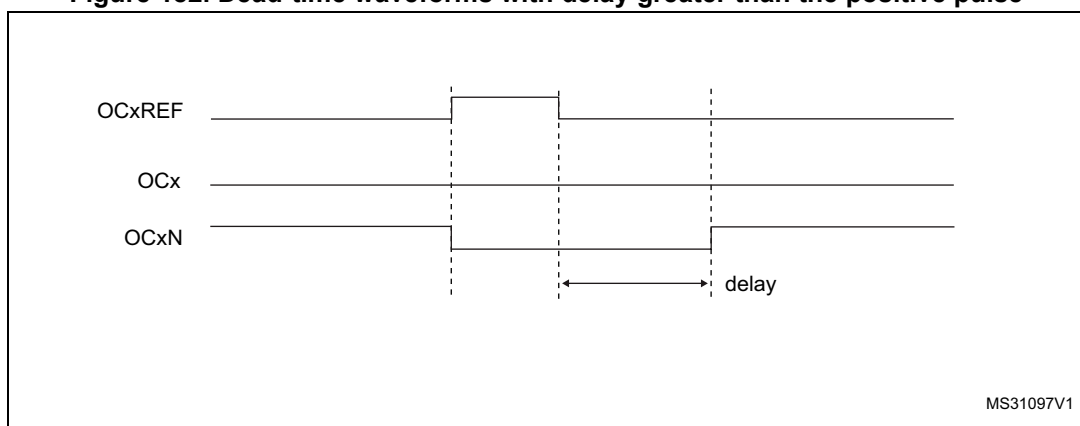


Figure 181. Dead-time waveforms with delay greater than the negative pulse**Figure 182. Dead-time waveforms with delay greater than the positive pulse**

The dead-time delay is the same for each of the channels and is programmable with the DTG bits in the TIMx_BDTR register. Refer to [Section 17.5.15: TIM15 break and dead-time register \(TIM15_BDTR\) on page 445](#) for delay calculation.

Re-directing OCxREF to OCx or OCxN

In output mode (forced, output compare or PWM), OCxREF can be re-directed to the OCx output or to OCxN output by configuring the CCxE and CCxNE bits in the TIMx_CCER register.

This allows you to send a specific waveform (such as PWM or static active level) on one output while the complementary remains at its inactive level. Other alternative possibilities are to have both outputs at inactive level or both outputs active and complementary with dead-time.

Note: When only OCxN is enabled (CCxE=0, CCxNE=1), it is not complemented and becomes active as soon as OCxREF is high. For example, if CCxNP=0 then OCxN=OCxRef. On the other hand, when both OCx and OCxN are enabled (CCxE=CCxNE=1) OCx becomes active when OCxREF is high whereas OCxN is complemented and becomes active when OCxREF is low.

17.4.12 Using the break function

When using the break function, the output enable signals and inactive levels are modified according to additional control bits (MOE, OSSI and OSSR bits in the TIMx_BDTR register, OISx and OISxN bits in the TIMx_CR2 register). In any case, the OCx and OCxN outputs cannot be set both to active level at a given time. Refer to [Table 56: Output control bits for complementary OCx and OCxN channels with break feature on page 442](#) for more details.

The source for break (BRK) channel can be an external source connected to the BKIN pin or one of the following internal sources:

- the core LOCKUP output
- the PVD output
- the SRAM parity error signal
- a clock failure event generated by the CSS detector

When exiting from reset, the break circuit is disabled and the MOE bit is low. You can enable the break function by setting the BKE bit in the TIMx_BDTR register. The break input polarity can be selected by configuring the BKP bit in the same register. BKE and BKP can be modified at the same time. When the BKE and BKP bits are written, a delay of 1 APB clock cycle is applied before the writing is effective. Consequently, it is necessary to wait 1 APB clock period to correctly read back the bit after the write operation.

Because MOE falling edge can be asynchronous, a resynchronization circuit has been inserted between the actual signal (acting on the outputs) and the synchronous control bit (accessed in the TIMx_BDTR register). It results in some delays between the asynchronous and the synchronous signals. In particular, if you write MOE to 1 whereas it was low, you must insert a delay (dummy instruction) before reading it correctly. This is because you write the asynchronous signal and read the synchronous signal.

When a break occurs (selected level on the break input):

- The MOE bit is cleared asynchronously, putting the outputs in inactive state, idle state or in reset state (selected by the OSSI bit). This feature functions even if the MCU oscillator is off.
- Each output channel is driven with the level programmed in the OISx bit in the TIMx_CR2 register as soon as MOE=0. If OSSI=0 then the timer releases the enable output else the enable output remains high.
- When complementary outputs are used:
 - The outputs are first put in reset state inactive state (depending on the polarity). This is done asynchronously so that it works even if no clock is provided to the timer.
 - If the timer clock is still present, then the dead-time generator is reactivated in order to drive the outputs with the level programmed in the OISx and OISxN bits after a dead-time. Even in this case, OCx and OCxN cannot be driven to their active level together. Note that because of the resynchronization on MOE, the dead-time duration is a bit longer than usual (around 2 ck_tim clock cycles).
 - If OSSI=0 then the timer releases the enable outputs else the enable outputs remain or become high as soon as one of the CCxE or CCxNE bits is high.
- The break status flag (BIF bit in the TIMx_SR register) is set. An interrupt can be generated if the BIE bit in the TIMx_DIER register is set.
- If the AOE bit in the TIMx_BDTR register is set, the MOE bit is automatically set again at the next update event UEV. This can be used to perform a regulation, for instance. Else, MOE remains low until you write it to '1' again. In this case, it can be used for security and you can connect the break input to an alarm from power drivers, thermal sensors or any security components.

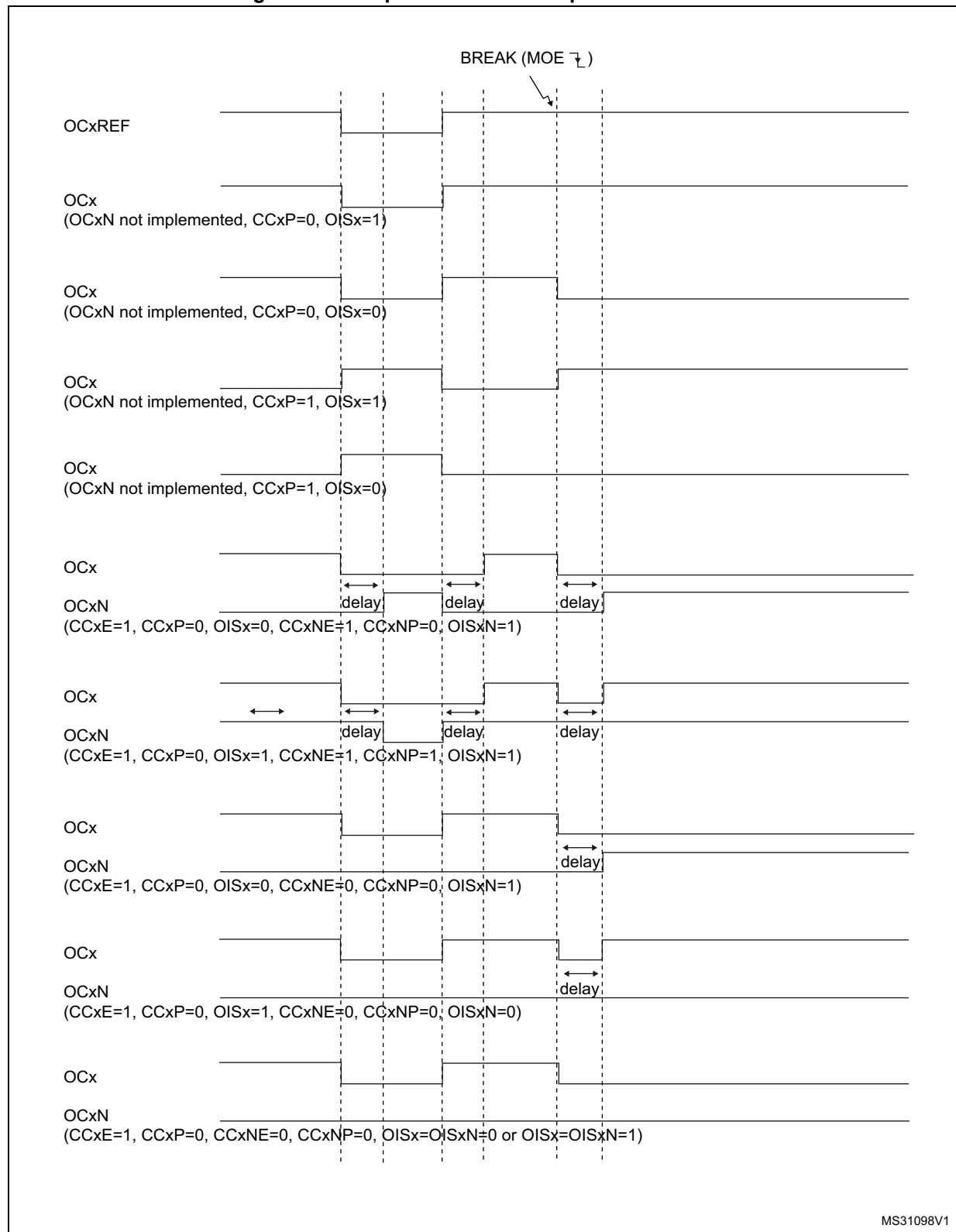
Note: The break inputs is acting on level. Thus, the MOE cannot be set while the break input is active (neither automatically nor by software). In the meantime, the status flag BIF cannot be cleared.

The break can be generated by the BRK input which has a programmable polarity and an enable bit BKE in the TIMx_BDTR Register.

In addition to the break input and the output management, a write protection has been implemented inside the break circuit to safeguard the application. It allows you to freeze the configuration of several parameters (dead-time duration, OCx/OCxN polarities and state when disabled, OCxM configurations, break enable and polarity). You can choose from 3 levels of protection selected by the LOCK bits in the TIMx_BDTR register. Refer to [Section 17.5.15: TIM15 break and dead-time register \(TIM15_BDTR\) on page 445](#). The LOCK bits can be written only once after an MCU reset.

The [Figure 183](#) shows an example of behavior of the outputs in response to a break.

Figure 183. Output behavior in response to a break



17.4.13 One-pulse mode

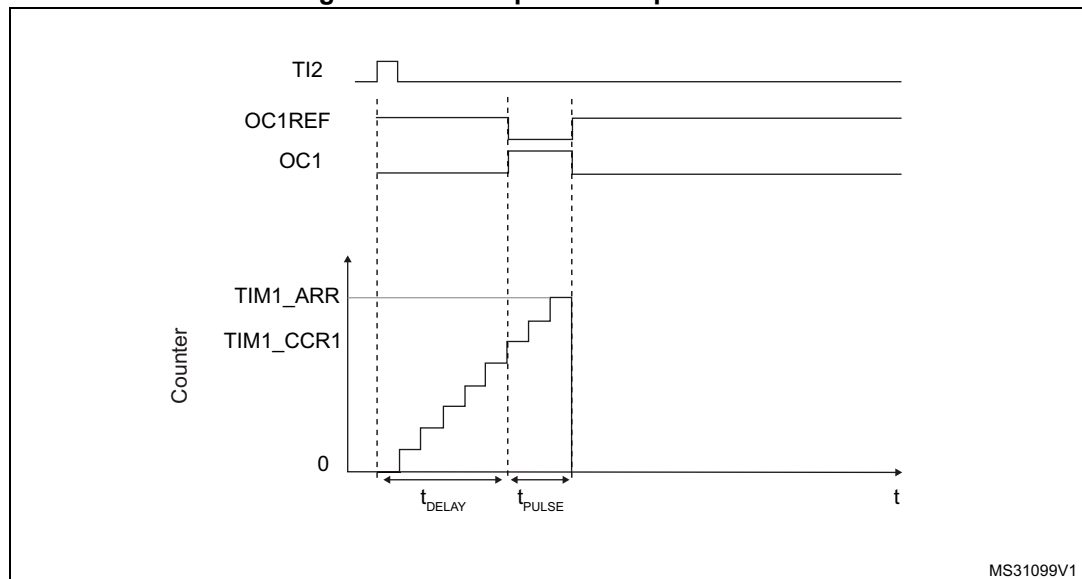
One-pulse mode (OPM) is a particular case of the previous modes. It allows the counter to be started in response to a stimulus and to generate a pulse with a programmable length after a programmable delay.

Starting the counter can be controlled through the slave mode controller. Generating the waveform can be done in output compare mode or PWM mode. You select One-pulse mode by setting the OPM bit in the TIMx_CR1 register. This makes the counter stop automatically at the next update event UEV.

A pulse can be correctly generated only if the compare value is different from the counter initial value. Before starting (when the timer is waiting for the trigger), the configuration must be:

- In upcounting: $CNT < CCRx \leq ARR$ (in particular, $0 < CCRx$)
- In downcounting: $CNT > CCRx$

Figure 184. Example of One-pulse mode



For example you may want to generate a positive pulse on OC1 with a length of t_{PULSE} and after a delay of t_{DELAY} as soon as a positive edge is detected on the TI2 input pin.

Let's use TI2FP2 as trigger 1:

- Map TI2FP2 to TI2 by writing CC2S='01' in the TIMx_CCMR1 register.
- TI2FP2 must detect a rising edge, write CC2P='0' in the TIMx_CCER register.
- Configure TI2FP2 as trigger for the slave mode controller (TRGI) by writing TS='110' in the TIMx_SMCR register.
- TI2FP2 is used to start the counter by writing SMS to '110' in the TIMx_SMCR register (trigger mode).

For code example refer to the Appendix section [A.8.16: One-Pulse mode code example](#).

The OPM waveform is defined by writing the compare registers (taking into account the clock frequency and the counter prescaler).

- The t_{DELAY} is defined by the value written in the TIMx_CCR1 register.
- The t_{PULSE} is defined by the difference between the auto-reload value and the compare value (TIMx_ARR - TIMx_CCR1).
- Let's say you want to build a waveform with a transition from '0' to '1' when a compare match occurs and a transition from '1' to '0' when the counter reaches the auto-reload value. To do this you enable PWM mode 2 by writing OC1M=111 in the TIMx_CCMR1 register. You can optionally enable the preload registers by writing OC1PE='1' in the TIMx_CCMR1 register and ARPE in the TIMx_CR1 register. In this case you have to write the compare value in the TIMx_CCR1 register, the auto-reload value in the TIMx_ARR register, generate an update by setting the UG bit and wait for external trigger event on TI2. CC1P is written to '0' in this example.

In our example, the DIR and CMS bits in the TIMx_CR1 register should be low.

You only want 1 pulse, so you write '1' in the OPM bit in the TIMx_CR1 register to stop the counter at the next update event (when the counter rolls over from the auto-reload value back to 0).

Particular case: OCx fast enable

In One-pulse mode, the edge detection on TIx input set the CEN bit which enables the counter. Then the comparison between the counter and the compare value makes the output toggle. But several clock cycles are needed for these operations and it limits the minimum delay $t_{\text{DELAY min}}$ we can get.

If you want to output a waveform with the minimum delay, you can set the OCxFE bit in the TIMx_CCMRx register. Then OCxRef (and OCx) are forced in response to the stimulus, without taking in account the comparison. Its new level is the same as if a compare match had occurred. OCxFE acts only if the channel is configured in PWM1 or PWM2 mode.

For code example refer to the part of code conditioned by PULSE_WITHOUT_DELAY > 0 in the Appendix section [A.8.16: One-Pulse mode code example](#).

17.4.14 TIM15 external trigger synchronization

This section applies to STM32F030x8, STM32F070xB and STM32F030xC devices only.

The TIM15 timer can be synchronized with an external trigger in several modes: Reset mode, Gated mode and Trigger mode.

Slave mode: Reset mode

The counter and its prescaler can be reinitialized in response to an event on a trigger input. Moreover, if the URS bit from the TIMx_CR1 register is low, an update event UEV is generated. Then all the preloaded registers (TIMx_ARR, TIMx_CCRx) are updated.

In the following example, the upcounter is cleared in response to a rising edge on TI1 input:

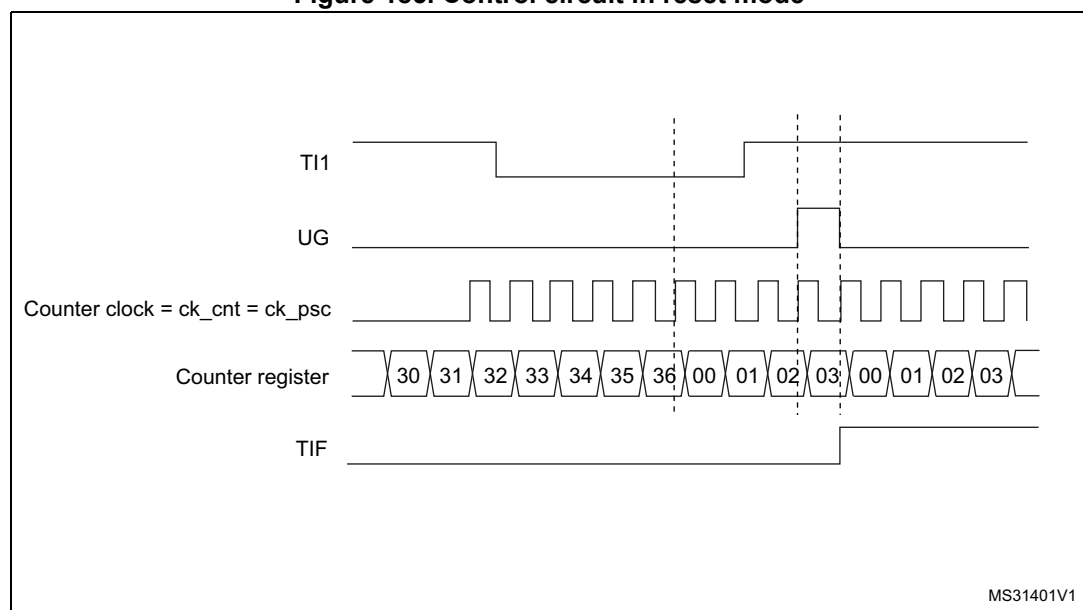
- Configure the channel 1 to detect rising edges on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S = 01 in the TIMx_CCMR1 register. Write CC1P=0 in TIMx_CCER register to validate the polarity (and detect rising edges only).
- Configure the timer in reset mode by writing SMS=100 in TIMx_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx_SMCR register.
- Start the counter by writing CEN=1 in the TIMx_CR1 register.

For code example refer to the Appendix section [A.8.12: Reset mode code example](#).

The counter starts counting on the internal clock, then behaves normally until TI1 rising edge. When TI1 rises, the counter is cleared and restarts from 0. In the meantime, the trigger flag is set (TIF bit in the TIMx_SR register) and an interrupt request, or a DMA request can be sent if enabled (depending on the TIE and TDE bits in TIMx_DIER register).

The following figure shows this behavior when the auto-reload register TIMx_ARR=0x36. The delay between the rising edge on TI1 and the actual reset of the counter is due to the resynchronization circuit on TI1 input.

Figure 185. Control circuit in reset mode



Slave mode: Gated mode

The counter can be enabled depending on the level of a selected input.

In the following example, the upcounter counts only when TI1 input is low:

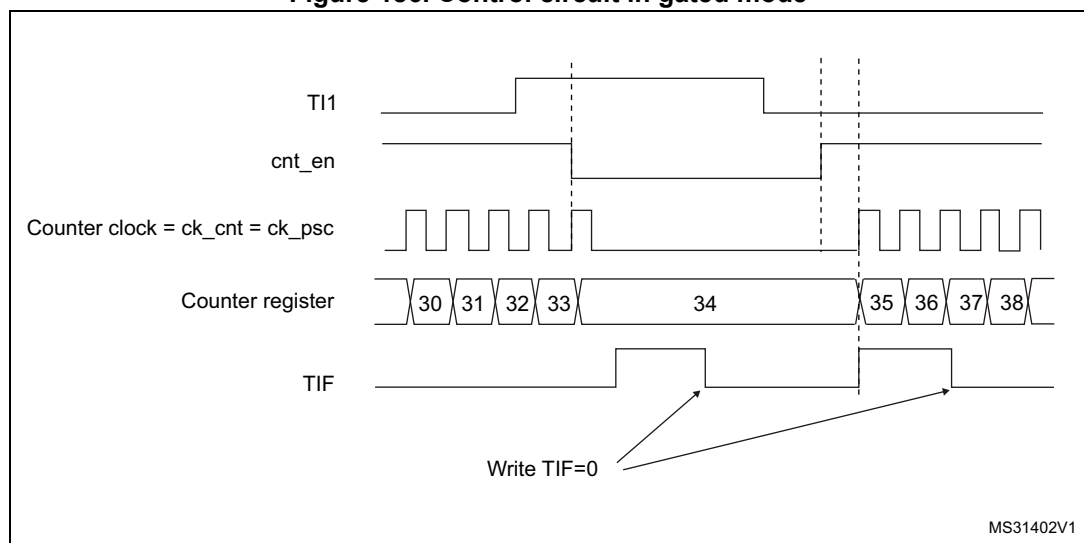
- Configure the channel 1 to detect low levels on TI1. Configure the input filter duration (in this example, we don't need any filter, so we keep IC1F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC1S bits select the input capture source only, CC1S=01 in TIMx_CCMR1 register. Write CC1P=1 in TIMx_CCER register to validate the polarity (and detect low level only).
- Configure the timer in gated mode by writing SMS=101 in TIMx_SMCR register. Select TI1 as the input source by writing TS=101 in TIMx_SMCR register.
- Enable the counter by writing CEN=1 in the TIMx_CR1 register (in gated mode, the counter doesn't start if CEN=0, whatever is the trigger input level).

For code example refer to the Appendix section [A.8.13: Gated mode code example](#).

The counter starts counting on the internal clock as long as TI1 is low and stops as soon as TI1 becomes high. The TIF flag in the TIMx_SR register is set both when the counter starts or stops.

The delay between the rising edge on TI1 and the actual stop of the counter is due to the resynchronization circuit on TI1 input.

Figure 186. Control circuit in gated mode



Slave mode: Trigger mode

The counter can start in response to an event on a selected input.

In the following example, the upcounter starts in response to a rising edge on TI2 input:

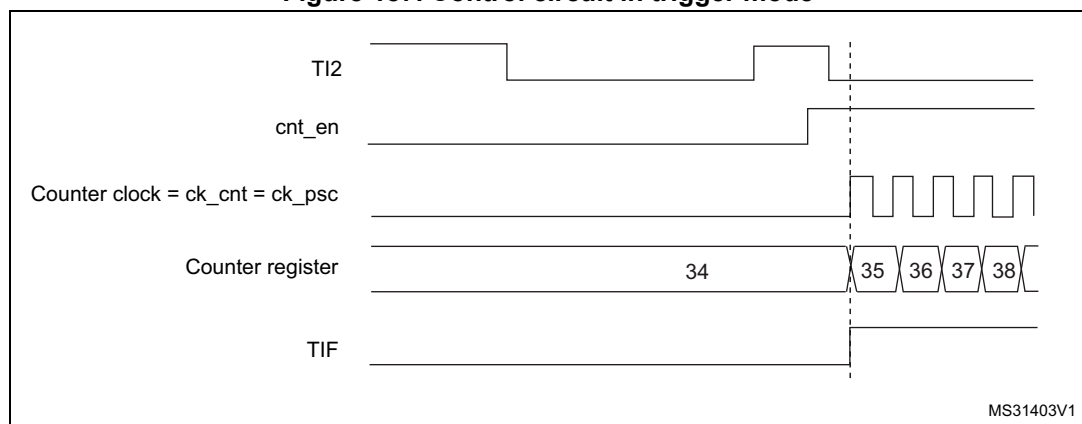
- Configure the channel 2 to detect rising edges on TI2. Configure the input filter duration (in this example, we don't need any filter, so we keep IC2F=0000). The capture prescaler is not used for triggering, so you don't need to configure it. The CC2S bits are configured to select the input capture source only, CC2S=01 in TIMx_CCMR1 register. Write CC2P=1 in TIMx_CCER register to validate the polarity (and detect low level only).
- Configure the timer in trigger mode by writing SMS=110 in TIMx_SMCR register. Select TI2 as the input source by writing TS=110 in TIMx_SMCR register.

For code example refer to the Appendix section [A.8.14: Trigger mode code example](#).

When a rising edge occurs on TI2, the counter starts counting on the internal clock and the TIF flag is set.

The delay between the rising edge on TI2 and the actual start of the counter is due to the resynchronization circuit on TI2 input.

Figure 187. Control circuit in trigger mode



The TIM timers are linked together internally for timer synchronization or chaining. Refer to [Section 14.3.15: Timer synchronization on page 331](#) for details.

17.4.15 Timer synchronization (TIM15)

This section applies to STM32F030x8 STM32F070xB and STM32F030xC devices only.

The TIM timers are linked together internally for timer synchronization or chaining. Refer to [Section 14.3.15: Timer synchronization on page 331](#) for details.

17.4.16 Debug mode

When the microcontroller enters debug mode (Cortex™-M0 core halted), the TIMx counter either continues to work normally or stops, depending on DBG_TIMx_STOP configuration bit in DBG module.

17.5 TIM15 registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

17.5.1 TIM15 control register 1 (TIM15_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	Res.	Res.	Res.	OPM	URS	UDIS	CEN
						rw	rw	rw				rw	rw	rw	rw

Bits 15:10 Reserved, always read as 0.

Bits 9:8 **CKD[1:0]**: Clock division

This bit field indicates the division ratio between the timer clock (CK_INT) frequency and the dead-time and sampling clock (t_{DTS}) used by the dead-time generators and the digital filters (TlX)

00: $t_{DTS} = t_{CK\_INT}$

01: $t_{DTS} = 2 * t_{CK\_INT}$

10: $t_{DTS} = 4 * t_{CK\_INT}$

11: Reserved, do not program this value

Bit 7 **ARPE**: Auto-reload preload enable

0: TIMx_ARR register is not buffered

1: TIMx_ARR register is buffered

Bits 6:4 Reserved, always read as 0.

Bit 3 **OPM**: One-pulse mode

0: Counter is not stopped at update event

1: Counter stops counting at the next update event (clearing the bit CEN)

Bit 2 **URS**: Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generate an update interrupt if enabled. These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt if enabled

Bit 1 **UDIS**: Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

Bit 0 **CEN**: Counter enable

0: Counter disabled

1: Counter enabled

Note: External clock and gated mode can work only if the CEN bit has been previously set by software. However trigger mode can set the CEN bit automatically by hardware.

17.5.2 TIM15 control register 2 (TIM15_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	OIS2	OIS1N	OIS1	Res.	MMS[2:0]			CCDS	CCUS	Res.	CCPC
					rw	rw	rw		rw	rw	rw	rw	rw		rw

Bit 15:11 Reserved, always read as 0.

Bit 10 **OIS2**: Output idle state 2 (OC2 output)

0: OC2=0 when MOE=0

1: OC2=1 when MOE=0

Note: This bit cannot be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in the TIMx_BKR register).

Bit 9 **OIS1N**: Output Idle state 1 (OC1N output)

0: OC1N=0 after a dead-time when MOE=0

1: OC1N=1 after a dead-time when MOE=0

Note: This bit can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BKR register).

Bit 8 **OIS1**: Output Idle state 1 (OC1 output)

0: OC1=0 (after a dead-time if OC1N is implemented) when MOE=0

1: OC1=1 (after a dead-time if OC1N is implemented) when MOE=0

Note: This bit can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BKR register).

Bit 7 Reserved, always read as 0.

Bits 6:4 **MMS[1:0]**: Master mode selection

These bits allow to select the information to be sent in master mode to slave timers for synchronization (TRGO). The combination is as follows:

000: **Reset** - the UG bit from the TIMx_EGR register is used as trigger output (TRGO). If the reset is generated by the trigger input (slave mode controller configured in reset mode) then the signal on TRGO is delayed compared to the actual reset.

001: **Enable** - the Counter Enable signal CNT_EN is used as trigger output (TRGO). It is useful to start several timers at the same time or to control a window in which a slave timer is enable. The Counter Enable signal is generated by a logic OR between CEN control bit and the trigger input when configured in gated mode. When the Counter Enable signal is controlled by the trigger input, there is a delay on TRGO, except if the master/slave mode is selected (see the MSM bit description in TIMx_SMCR register).

010: **Update** - The update event is selected as trigger output (TRGO). For instance a master timer can then be used as a prescaler for a slave timer.

011: **Compare Pulse** - The trigger output send a positive pulse when the CC1IF flag is to be set (even if it was already high), as soon as a capture or a compare match occurred. (TRGO).

100: **Compare** - OC1REF signal is used as trigger output (TRGO).

101: **Compare** - OC2REF signal is used as trigger output (TRGO).

Bit 3 **CCDS**: Capture/compare DMA selection

0: CCx DMA request sent when CCx event occurs

1: CCx DMA requests sent when update event occurs

Bit 2 **CCUS**: Capture/compare control update selection

0: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit only.

1: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit or when an rising edge occurs on TRGI.

Note: This bit acts only on channels that have a complementary output.

Bit 1 Reserved, always read as 0.

Bit 0 **CCPC**: Capture/compare preloaded control

0: CCxE, CCxNE and OCxM bits are not preloaded

1: CCxE, CCxNE and OCxM bits are preloaded, after having been written, they are updated only when COM bit is set.

Note: This bit acts only on channels that have a complementary output.

17.5.3 TIM15 slave mode control register (TIM15_SMCR)

Address offset: 0x08

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	MSM	TS[2:0]			Res.	SMS[2:0]		
								rw	rw	rw	rw		rw	rw	rw

Bits 15:8 Reserved, always read as 0.

Bit 7 **MSM**: Master/slave mode

0: No action

1: The effect of an event on the trigger input (TRGI) is delayed to allow a perfect synchronization between the current timer and its slaves (through TRGO). It is useful if we want to synchronize several timers on a single external event.

Bits 6:4 **TS[2:0]**: Trigger selection

This bit field selects the trigger input to be used to synchronize the counter.

000: Reserved

001: Internal Trigger 1 (ITR1)

010: Internal Trigger 2 (ITR2)

011: Internal Trigger 3 (ITR3)

100: TI1 Edge Detector (TI1F_ED)

101: Filtered Timer Input 1 (TI1FP1)

110: Filtered Timer Input 2 (TI2FP2)

See [Table 55: TIMx Internal trigger connection on page 432](#) for more details on ITRx meaning for each Timer.

Note: These bits must be changed only when they are not used (e.g. when SMS=000) to avoid wrong edge detections at the transition.

Bit 3 Reserved, always read as 0.

Bits 2:0 **SMS**: Slave mode selection

When external signals are selected the active edge of the trigger signal (TRGI) is linked to the polarity selected on the external input (see Input Control register and Control Register description).

000: Slave mode disabled - if CEN = '1' then the prescaler is clocked directly by the internal clock.

100: Reset Mode - Rising edge of the selected trigger input (TRGI) reinitializes the counter and generates an update of the registers.

101: Gated Mode - The counter clock is enabled when the trigger input (TRGI) is high. The counter stops (but is not reset) as soon as the trigger becomes low. Both start and stop of the counter are controlled.

110: Trigger Mode - The counter starts at a rising edge of the trigger TRGI (but it is not reset). Only the start of the counter is controlled.

111: External Clock Mode 1 - Rising edges of the selected trigger (TRGI) clock the counter.

Note: The gated mode must not be used if TI1F_ED is selected as the trigger input (TS='100'). Indeed, TI1F_ED outputs 1 pulse for each transition on TI1F, whereas the gated mode checks the level of the trigger signal.

Table 55. TIMx Internal trigger connection

Slave TIM	ITR1 (TS = 001)	ITR2 (TS = 010)	ITR3 (TS = 011)
TIM15	TIM3	TIM16_OC	TIM17_OC

17.5.4 TIM15 DMA/interrupt enable register (TIM15_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TDE	Res.	Res.	Res.	CC2DE	CC1DE	UDE	BIE	TIE	COMIE	Res.	Res.	CC2IE	CC1IE	UIE
	rw				rw	rw	rw	rw	rw	rw			rw	rw	rw

Bit 15 Reserved, always read as 0.

Bit 14 **TDE**: Trigger DMA request enable

0: Trigger DMA request disabled

1: Trigger DMA request enabled

Bits 13:11 Reserved, always read as 0.

Bit 10 **CC2DE**: Capture/Compare 2 DMA request enable

0: CC2 DMA request disabled

1: CC2 DMA request enabled

Bit 9 **CC1DE**: Capture/Compare 1 DMA request enable

0: CC1 DMA request disabled

1: CC1 DMA request enabled

Bit 8 **UDE**: Update DMA request enable

0: Update DMA request disabled

1: Update DMA request enabled

Bit 7 **BIE**: Break interrupt enable

0: Break interrupt disabled

1: Break interrupt enabled

Bit 6 **TIE**: Trigger interrupt enable

0: Trigger interrupt disabled

1: Trigger interrupt enabled

Bit 5 **COMIE**: COM interrupt enable

0: COM interrupt disabled

1: COM interrupt enabled

Bits 4:3 Reserved, always read as 0.

Bit 2 **CC2IE**: Capture/Compare 2 interrupt enable

0: CC2 interrupt disabled

1: CC2 interrupt enabled

Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable

0: CC1 interrupt disabled

1: CC1 interrupt enabled

Bit 0 **UIE**: Update interrupt enable

0: Update interrupt disabled

1: Update interrupt enabled

17.5.5 TIM15 status register (TIM15_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	CC2OF	CC1OF	Res.	BIF	TIF	COMIF	Res.	Res.	CC2IF	CC1IF	UIF
					rc_w0	rc_w0		rc_w0	rc_w0	rc_w0			rc_w0	rc_w0	rc_w0

Bits 15:11 Reserved, always read as 0.

Bit 10 **CC2OF**: Capture/Compare 2 overcapture flag
refer to CC1OF description

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

0: No overcapture has been detected

1: The counter value has been captured in TIMx_CCR1 register while CC1IF flag was already set

Bit 8 Reserved, always read as 0.

Bit 7 **BIF**: Break interrupt flag

This flag is set by hardware as soon as the break input goes active. It can be cleared by software if the break input is not active.

0: No break event occurred

1: An active level has been detected on the break input

Bit 6 **TIF**: Trigger interrupt flag

This flag is set by hardware on trigger event (active edge detected on TRGI input when the slave mode controller is enabled in all modes but gated mode, both edges in case gated mode is selected). It is cleared by software.

0: No trigger event occurred

1: Trigger interrupt pending

Bit 5 **COMIF**: COM interrupt flag

This flag is set by hardware on a COM event (once the capture/compare control bits –CCxE, CCxNE, OCxM– have been updated). It is cleared by software by writing it to '0'.

0: No COM event occurred

1: COM interrupt pending

Bits 5:3 Reserved, always read as 0.

Bit 2 **CC2IF**: Capture/Compare 2 interrupt flag
refer to CC1IF description

Bit 1 **CC1IF**: Capture/Compare 1 interrupt flag

If channel CC1 is configured as output:

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits in the TIMx_CR1 register description). It is cleared by software.

0: No match.

1: The content of the counter TIMx_CNT matches the content of the TIMx_CCR1 register. When the contents of TIMx_CCR1 are greater than the contents of TIMx_ARR, the CC1IF bit goes high on the counter overflow (in upcounting and up/down-counting modes) or underflow (in downcounting mode)

If channel CC1 is configured as input:

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx_CCR1 register.

0: No input capture occurred

1: The counter value has been captured in TIMx_CCR1 register (An edge has been detected on IC1 which matches the selected polarity)

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

–At overflow regarding the repetition counter value (update if repetition counter = 0) and if the UDIS=0 in the TIMx_CR1 register.

–When CNT is reinitialized by software using the UG bit in TIMx_EGR register, if URS=0 and UDIS=0 in the TIMx_CR1 register.

–When CNT is reinitialized by a trigger event (refer to [Section 17.5.3: TIM15 slave mode control register \(TIM15_SMCR\)](#)), if URS=0 and UDIS=0 in the TIMx_CR1 register.

17.5.6 TIM15 event generation register (TIM15_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BG	TG	COMG	Res.	Res.	CC2G	CC1G	UG
								w	w	rw			w	w	w

Bits 15:8 Reserved, always read as 0.

Bit 7 **BG**: Break generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A break event is generated. MOE bit is cleared and BIF flag is set. Related interrupt or DMA transfer can occur if enabled.

Bit 6 **TG**: Trigger generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: The TIF flag is set in TIMx_SR register. Related interrupt or DMA transfer can occur if enabled

Bit 5 **COMG**: Capture/Compare control update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: When the CCPC bit is set, it is possible to update the CCxE, CCxNE and OCxM bits

Note: This bit acts only on channels that have a complementary output.

Bits 4:3 Reserved, always read as 0.

Bit 2 **CC2G**: Capture/Compare 2 generation

Refer to CC1G description

Bit 1 **CC1G**: Capture/Compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action

1: A capture/compare event is generated on channel 1:

If channel CC1 is configured as output:

CC1IF flag is set, Corresponding interrupt or DMA request is sent if enabled.

If channel CC1 is configured as input:

The current value of the counter is captured in TIMx_CCR1 register. The CC1IF flag is set, the corresponding interrupt or DMA request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action.

1: Reinitialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared if the center-aligned mode is selected or if DIR=0 (upcounting), else it takes the auto-reload value (TIMx_ARR) if DIR=1 (downcounting).

17.5.7 TIM15 capture/compare mode register 1 (TIM15_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CCxS bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OCxx describes its function when the channel is configured in output, ICxx describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	OC2M[2:0]			OC2 PE	OC2 FE	CC2S[1:0]		Res.	OC1M[2:0]			OC1 PE	OC1 FE	CC1S[1:0]	
IC2F[3:0]				IC2PSC[1:0]				IC1F[3:0]			IC1PSC[1:0]				
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Output compare mode:

Bit 15 Reserved, always read as 0.

Bits 14:12 **OC2M[2:0]**: Output Compare 2 mode

Bit 11 **OC2PE**: Output Compare 2 preload enable

Bit 10 **OC2FE**: Output Compare 2 fast enable

Bits 9:8 **CC2S[1:0]**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output.

01: CC2 channel is configured as input, IC2 is mapped on TI2.

10: CC2 channel is configured as input, IC2 is mapped on TI1.

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through the TS bit (TIMx_SMCR register)

Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx_CCER).

Bit 7 Reserved, always read as 0.

Bits 6:4 **OC1M**: Output Compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

000: Frozen - The comparison between the output compare register TIMx_CCR1 and the counter TIMx_CNT has no effect on the outputs.

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

011: Toggle - OC1REF toggles when TIMx_CNT=TIMx_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx_CNT<TIMx_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF='0') as long as TIMx_CNT>TIMx_CCR1 else active (OC1REF='1').

111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx_CNT<TIMx_CCR1 else active. In downcounting, channel 1 is active as long as TIMx_CNT>TIMx_CCR1 else inactive.

Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S='00' (the channel is configured in output).

2: In PWM mode 1 or 2, the OCREF level changes only when the result of the comparison changes or when the output compare mode switches from "frozen" mode to "PWM" mode.

Bit 3 **OC1PE**: Output Compare 1 preload enable

0: Preload register on TIMx_CCR1 disabled. TIMx_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx_CCR1 enabled. Read/Write operations access the preload register. TIMx_CCR1 preload value is loaded in the active register at each update event.

Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S='00' (the channel is configured in output).

2: The PWM mode can be used without validating the preload register only in one pulse mode (OPM bit set in TIMx_CR1 register). Else the behavior is not guaranteed.

Bit 2 **OC1FE**: Output Compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger in input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently of the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OC1FE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output.

01: CC1 channel is configured as input, IC1 is mapped on TI1.

10: CC1 channel is configured as input, IC1 is mapped on TI2.

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx_CCER).

Input capture mode

Bits 15:12 **IC2F**: Input capture 2 filter

Bits 11:10 **IC2PSC[1:0]**: Input capture 2 prescaler

Bits 9:8 **CC2S**: Capture/Compare 2 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC2 channel is configured as output

01: CC2 channel is configured as input, IC2 is mapped on TI2

10: CC2 channel is configured as input, IC2 is mapped on TI1

11: CC2 channel is configured as input, IC2 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC2S bits are writable only when the channel is OFF (CC2E = '0' in TIMx_CCER).

Bits 7:4 **IC1F[3:0]**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N consecutive events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{DTS}

0001: $f_{SAMPLING} = f_{CK\_INT}$, N = 2

0010: $f_{SAMPLING} = f_{CK\_INT}$, N = 4

0011: $f_{SAMPLING} = f_{CK\_INT}$, N = 8

0100: $f_{SAMPLING} = f_{DTS} / 2$, N = 6

0101: $f_{SAMPLING} = f_{DTS} / 2$, N = 8

0110: $f_{SAMPLING} = f_{DTS} / 4$, N = 6

0111: $f_{SAMPLING} = f_{DTS} / 4$, N = 8

1000: $f_{SAMPLING} = f_{DTS} / 8$, N = 6

1001: $f_{SAMPLING} = f_{DTS} / 8$, N = 8

1010: $f_{SAMPLING} = f_{DTS} / 16$, N = 5

1011: $f_{SAMPLING} = f_{DTS} / 16$, N = 6

1100: $f_{SAMPLING} = f_{DTS} / 16$, N = 8

1101: $f_{SAMPLING} = f_{DTS} / 32$, N = 5

1110: $f_{SAMPLING} = f_{DTS} / 32$, N = 6

1111: $f_{SAMPLING} = f_{DTS} / 32$, N = 8

Note: Care must be taken that f_{DTS} is replaced in the formula by CK_INT when $ICx F[3:0] = 1, 2$ or 3 .

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).

The prescaler is reset as soon as CC1E='0' (TIMx_CCER register).

00: no prescaler, capture is done each time an edge is detected on the capture input

01: capture is done once every 2 events

10: capture is done once every 4 events

11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output

01: CC1 channel is configured as input, IC1 is mapped on TI1

10: CC1 channel is configured as input, IC1 is mapped on TI2

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx_CCER).

17.5.8 TIM15 capture/compare enable register (TIM15_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1NP	Res.	CC2P	CC2E	CC1NP	CC1NE	CC1P	CC1E
								rw		rw	rw	rw	rw	rw	rw

Bits 15:8 Reserved, always read as 0.

Bit 7 **CC2NP**: Capture/Compare 2 complementary output polarity
refer to CC1NP description

Bit 6 Reserved, always read as 0.

Bit 5 **CC2P**: Capture/Compare 2 output polarity
Refer to CC1P description

Bit 4 **CC2E**: Capture/Compare 2 output enable
Refer to CC1E description

Bit 3 **CC1NP**: Capture/Compare 1 complementary output polarity
0: OC1N active high
1: OC1N active low

Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S="00" (the channel is configured in output).

Bit 2 **CC1NE**: Capture/Compare 1 complementary output enable

0: Off - OC1N is not active. OC1N level is then function of MOE, OSSI, OSSR, OIS1, OIS1N and CC1E bits.

1: On - OC1N signal is output on the corresponding output pin depending on MOE, OSSI, OSSR, OIS1, OIS1N and CC1E bits.

Bit 1 **CC1P**: Capture/Compare 1 output polarity

CC1 channel configured as output:

0: OC1 active high

1: OC1 active low

CC1 channel configured as input:

The CC1NP/CC1P bits select the polarity of TI1FP1 and TI2FP1 for trigger or capture operations.

00: noninverted/rising edge: circuit is sensitive to TIxFP1's rising edge (capture, trigger in reset or trigger mode), TIxFP1 is not inverted (trigger in gated mode).

01: inverted/falling edge: circuit is sensitive to TIxFP1's falling edge (capture, trigger in reset, or trigger mode), TIxFP1 is inverted (trigger in gated mode).

10: reserved, do not use this configuration.

11: noninverted/both edges: circuit is sensitive to both the rising and falling edges of TIxFP1 (capture, trigger in reset or trigger mode), TIxFP1 is not inverted (trigger in gated mode).

Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 0 **CC1E**: Capture/Compare 1 output enable

CC1 channel configured as output:

0: Off - OC1 is not active. OC1 level is then function of MOE, OSSI, OSSR, OIS1, OIS1N and CC1NE bits.

1: On - OC1 signal is output on the corresponding output pin depending on MOE, OSSI, OSSR, OIS1, OIS1N and CC1NE bits.

CC1 channel configured as input:

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx_CCR1) or not.

0: Capture disabled

1: Capture enabled

Table 56. Output control bits for complementary OCx and OCxN channels with break feature

Control bits					Output states ⁽¹⁾	
MOE bit	OSSI bit	OSSR bit	CCxE bit	CCxNE bit	OCx output state	OCxN output state
1	X	0	0	0	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	0	1	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		0	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
		1	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
		1	0	1	Off-State (output enabled with inactive state) OCx=CCxP, OCx_EN=1	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		1	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Off-State (output enabled with inactive state) OCxN=CCxNP, OCxN_EN=1
		1	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
0	0	X	0	0	Output Disabled (not driven by the timer) Asynchronously: OCx=CCxP, OCx_EN=0, OCxN=CCxNP, OCxN_EN=0 Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCx and OCxN both in active state.	
	0		0	1		
	0		1	0		
	0		1	1		
	1		0	0	Off-State (output enabled with inactive state) Asynchronously: OCx=CCxP, OCx_EN=1, OCxN=CCxNP, OCxN_EN=1 Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCx and OCxN both in active state	
	1		0	1		
	1		1	0		
	1		1	1		

1. When both outputs of a channel are not used (CCxE = CCxNE = 0), the OISx, OISxN, CCxP and CCxNP bits must be kept cleared.

Note: The state of the external I/O pins connected to the complementary OCx and OCxN channels depends on the OCx and OCxN channel state and the GPIO and AFIO registers.

17.5.9 TIM15 counter (TIM15_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CNT[15:0]**: Counter value

17.5.10 TIM15 prescaler (TIM15_PSC)

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler value

The counter clock frequency (CK_CNT) is equal to $f_{CK\_PSC} / (PSC[15:0] + 1)$.

PSC contains the value to be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIMx_EGR register or through trigger controller when configured in “reset mode”).

17.5.11 TIM15 auto-reload register (TIM15_ARR)

Address offset: 0x2C

Reset value: 0xFFFF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 16.3.1: Time-base unit on page 375](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

17.5.12 TIM15 repetition counter register (TIM15_RCR)

Address offset: 0x30

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	REP[7:0]							
								r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w

Bits 15:8 Reserved, always read as 0.

Bits 7:0 **REP[7:0]**: Repetition counter value

These bits allow the user to set-up the update rate of the compare registers (i.e. periodic transfers from preload to active registers) when preload registers are enable, as well as the update interrupt generation rate, if this interrupt is enable.

Each time the REP_CNT related downcounter reaches zero, an update event is generated and it restarts counting from REP value. As REP_CNT is reloaded with REP value only at the repetition update event U_RC, any write to the TIMx_RCR register is not taken in account until the next repetition update event.

It means in PWM mode (REP+1) corresponds to the number of PWM periods in edge-aligned mode.

17.5.13 TIM15 capture/compare register 1 (TIM15_CCR1)

Address offset: 0x34

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w	r/w

Bits 15:0 **CCR1[15:0]**: Capture/Compare 1 value

If channel CC1 is configured as output:

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signaled on OC1 output.

If channel CC1 is configured as input:

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

17.5.14 TIM15 capture/compare register 2 (TIM15_CCR2)

Address offset: 0x38

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR2[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CCR2[15:0]**: Capture/Compare 2 value

If channel CC2 is configured as output:

CCR2 is the value to be loaded in the actual capture/compare 2 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR2 register (bit OC2PE). Else the preload value is copied in the active capture/compare 2 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signalled on OC2 output.

If channel CC2 is configured as input:

CCR2 is the counter value transferred by the last input capture 2 event (IC2).

17.5.15 TIM15 break and dead-time register (TIM15_BDTR)

Address offset: 0x44

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK[1:0]		DTG[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Note: As the bits AOE, BKP, BKE, OSSI, OSSR and DTG[7:0] can be write-locked depending on the LOCK configuration, it can be necessary to configure all of them during the first write access to the TIMx_BDTR register.

Bit 15 **MOE**: Main output enable

This bit is cleared asynchronously by hardware as soon as the break input is active. It is set by software or automatically depending on the AOE bit. It is acting only on the channels which are configured in output.

0: OC and OCN outputs are disabled or forced to idle state

1: OC and OCN outputs are enabled if their respective enable bits are set (CCxE, CCxNE in TIMx_CCER register)

See OC/OCN enable description for more details ([Section 17.5.8: TIM15 capture/compare enable register \(TIM15_CCER\) on page 440](#)).

Bit 14 **AOE**: Automatic output enable

0: MOE can be set only by software

1: MOE can be set by software or automatically at the next update event (if the break input is not be active)

Note: This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 13 **BKP**: Break polarity

0: Break input BRK is active low

1: Break input BRK is active high

Note: This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.

Bit 12 **BKE**: Break enable

0: Break inputs (BRK and CCS clock failure event) disabled

1: Break inputs (BRK and CCS clock failure event) enabled

Note: This bit cannot be modified when LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.

Bit 11 **OSSR**: Off-state selection for Run mode

This bit is used when MOE=1 on channels having a complementary output which are configured as outputs. OSSR is not implemented if no complementary output is implemented in the timer.

See OC/OCN enable description for more details ([Section 17.5.8: TIM15 capture/compare enable register \(TIM15_CCER\) on page 440](#)).

0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0)

1: When inactive, OC/OCN outputs are enabled with their inactive level as soon as CCxE=1 or CCxNE=1. Then, OC/OCN enable output signal=1

Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 10 **OSSI**: Off-state selection for Idle mode

This bit is used when MOE=0 on channels configured as outputs.

See OC/OCN enable description for more details ([Section 17.5.8: TIM15 capture/compare enable register \(TIM15_CCER\) on page 440](#)).

0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0)

1: When inactive, OC/OCN outputs are forced first with their idle level as soon as CCxE=1 or CCxNE=1. OC/OCN enable output signal=1)

Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx_BDTR register).

Bits 9:8 **LOCK[1:0]**: Lock configuration

These bits offer a write protection against software errors.

00: LOCK OFF - No bit is write protected

01: LOCK Level 1 = DTG bits in TIMx_BDTR register, OISx and OISxN bits in TIMx_CR2 register and BKE/BKP/AOE bits in TIMx_BDTR register can no longer be written

10: LOCK Level 2 = LOCK Level 1 + CC Polarity bits (CCxP/CCxNP bits in TIMx_CCER register, as long as the related channel is configured in output through the CCxS bits) as well as OSSR and OSSI bits can no longer be written.

11: LOCK Level 3 = LOCK Level 2 + CC Control bits (OCxM and OCxPE bits in TIMx_CCMRx registers, as long as the related channel is configured in output through the CCxS bits) can no longer be written.

Note: The LOCK bits can be written only once after the reset. Once the TIMx_BDTR register has been written, their content is frozen until the next reset.

Bits 7:0 **DTG[7:0]**: Dead-time generator setup

This bit-field defines the duration of the dead-time inserted between the complementary outputs. DT correspond to this duration.

DTG[7:5]=0xx => $DT = DTG[7:0] \times t_{dtg}$ with $t_{dtg} = t_{DTS}$

DTG[7:5]=10x => $DT = (64 + DTG[5:0]) \times t_{dtg}$ with $T_{dtg} = 2 \times t_{DTS}$

DTG[7:5]=110 => $DT = (32 + DTG[4:0]) \times t_{dtg}$ with $T_{dtg} = 8 \times t_{DTS}$

DTG[7:5]=111 => $DT = (32 + DTG[4:0]) \times t_{dtg}$ with $T_{dtg} = 16 \times t_{DTS}$

Example if $T_{DTS} = 125\text{ns}$ (8MHz), dead-time possible values are:

0 to 15875 ns by 125 ns steps,

16 μs to 31750 ns by 250 ns steps,

32 μs to 63 μs by 1 μs steps,

64 μs to 126 μs by 2 μs steps

Note: This bit-field can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register).

17.5.16 TIM15 DMA control register (TIM15_DCR)

Address offset: 0x48

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBL[4:0]					Res.	Res.	Res.	DBA[4:0]				
			rw	rw	rw	rw	rw				rw	rw	rw	rw	rw

Bits 15:13 Reserved, always read as 0.

Bits 12:8 **DBL[4:0]**: DMA burst length

This 5-bit vector defines the length of DMA transfers (the timer recognizes a burst transfer when a read or a write access is done to the TIMx_DMAR address).

00000: 1 transfer,
 00001: 2 transfers,
 00010: 3 transfers,
 ...
 10001: 18 transfers.

Bits 7:5 Reserved, always read as 0.

Bits 4:0 **DBA[4:0]**: DMA base address

This 5-bits vector defines the base-address for DMA transfers (when read/write access are done through the TIMx_DMAR address). DBA is defined as an offset starting from the address of the TIMx_CR1 register.

Example:

00000: TIMx_CR1,
 00001: TIMx_CR2,
 00010: TIMx_SMCR,
 ...

17.5.17 TIM15 DMA address for full transfer (TIM15_DMAR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMAB[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DMAB[15:0]**: DMA register for burst accesses

A read or write operation to the DMAR register accesses the register located at the address
 $(\text{TIMx\_CR1 address}) + (\text{DBA} + \text{DMA index}) \times 4$

where TIMx_CR1 address is the address of the control register 1, DBA is the DMA base address configured in TIMx_DCR register, DMA index is automatically controlled by the DMA transfer, and ranges from 0 to DBL (DBL configured in TIMx_DCR).

17.5.18 TIM15 register map

TIM15 registers are mapped as 16-bit addressable registers as described in the table below:

Table 57. TIM15 register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0			
0x00	TIM15_CR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CKD [1:0]	0	0	0	ARPE	Res.	Res.	Res.	Res.	OPM	URS	UDIS	CEN
	Reset value																																			
0x04	TIM15_CR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OIS2	OIS1N	OIS1	Res.	MMS[2:0]			CCDS	CCUS	Res.	CCPC		
	Reset value																						0	0	0			0	0	0	0	0	Res.	0		
0x08	TIM15_SMCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0	0	0	MSM	TS[2:0]			Res.	SMS[2:0]				
	Reset value																											0	0	0	0	0	0	0	0	
0x0C	TIM15_DIER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	0	Res.	Res.	Res.	Res.	CC2DE	CC1DE	UDE	BIE	TIE	COMIE	Res.	Res.	CC2IE	CC1IE	UIE		
	Reset value																							0	0	0	0	0	0	0	0	0	0	0		
0x10	TIM15_SR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC2OF	CC1OF	Res.	BIF	TIF	COMIF	Res.	Res.	CC2IF	CC1IF	UIF		
	Reset value																						0	0	0	0	0	0	0	0	0	0	0	0		
0x14	TIM15_EGR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BG	TG	COMG	Res.	Res.	CC2G	CC1G	UG			
	Reset value																									0	0	0			0	0	0	0		
0x18	TIM15_CCMR1 Output compare mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OC2M [2:0]				OC2PE	OC2FE	CC2S [1:0]		OC1M [2:0]			OC1PE	OC1FE	CC1S [1:0]				
	Reset value																		0	0	0	0	0	0		0	0	0	0	0	0	0	0			
	TIM15_CCMR1 Input capture mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IC2F[3:0]				IC2PSC [1:0]	CC2S [1:0]	IC1F[3:0]			IC1PSC [1:0]	CC1PSC [1:0]	CC1S [1:0]						
	Reset value																		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x20	TIM15_CCER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC2NP	Res.	CC2P	CC2E	CC1NP	CC1NE	CC1P	CC1E		
	Reset value																									0		0	0	0	0	0	0	0		
0x24	TIM15_CNT	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CNT[15:0]																		
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x28	TIM15_PSC	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PSC[15:0]																		
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x2C	TIM15_ARR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ARR[15:0]																		
	Reset value																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1		
0x30	TIM15_RCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	REP[7:0]										
	Reset value																									0	0	0	0	0	0	0	0	0		
0x34	TIM15_CCR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CCR1[15:0]																		
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		

Table 57. TIM15 register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x38	TIM15_CCR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CCR2[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x44	TIM15_BDTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK [1:0]	DT[7:0]									
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x48	TIM15_DCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBL[4:0]				Res.	Res.	Res.	DBA[4:0]						
	Reset value																				0	0	0	0	0				0	0	0	0	0	
0x4C	TIM15_DMAR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DMAB[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

17.6 TIM16 and TIM17 registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

17.6.1 TIM16 and TIM17 control register 1 (TIM16_CR1 and TIM17_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CKD[1:0]		ARPE	Res.	Res.	Res.	OPM	URS	UDIS	CEN
						rw	rw	rw				rw	rw	rw	rw

Bits 15:10 Reserved, always read as 0.

Bits 9:8 **CKD[1:0]**: Clock division

This bit-field indicates the division ratio between the timer clock (CK_INT) frequency and the dead-time and sampling clock (t_{DTS}) used by the dead-time generators and the digital filters (Tlx),

00: $t_{DTS}=t_{CK\_INT}$

01: $t_{DTS}=2*t_{CK\_INT}$

10: $t_{DTS}=4*t_{CK\_INT}$

11: Reserved, do not program this value

Bit 7 **ARPE**: Auto-reload preload enable

0: TIMx_ARR register is not buffered

1: TIMx_ARR register is buffered

Bits 6:4 Reserved, always read as 0.

Bit 3 **OPM**: One pulse mode

0: Counter is not stopped at update event

1: Counter stops counting at the next update event (clearing the bit CEN)

Bit 2 URS: Update request source

This bit is set and cleared by software to select the UEV event sources.

0: Any of the following events generate an update interrupt or DMA request if enabled.
These events can be:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

1: Only counter overflow/underflow generates an update interrupt or DMA request if enabled.

Bit 1 UDIS: Update disable

This bit is set and cleared by software to enable/disable UEV event generation.

0: UEV enabled. The Update (UEV) event is generated by one of the following events:

- Counter overflow/underflow
- Setting the UG bit
- Update generation through the slave mode controller

Buffered registers are then loaded with their preload values.

1: UEV disabled. The Update event is not generated, shadow registers keep their value (ARR, PSC, CCRx). However the counter and the prescaler are reinitialized if the UG bit is set or if a hardware reset is received from the slave mode controller.

Bit 0 CEN: Counter enable

0: Counter disabled

1: Counter enabled

17.6.2 TIM16 and TIM17 control register 2 (TIM16_CR2 and TIM17_CR2)

Address offset: 0x04

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	OIS1N	OIS1	Res.	Res.	Res.	Res.	CCDS	CCUS	Res.	CCPC
						rw	rw					rw	rw		rw

Bits 15:10 Reserved, always read as 0.

Bit 9 OIS1N: Output Idle state 1 (OC1N output)

0: OC1N=0 after a dead-time when MOE=0

1: OC1N=1 after a dead-time when MOE=0

Note: This bit can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BKR register).

Bit 8 OIS1: Output Idle state 1 (OC1 output)

0: OC1=0 (after a dead-time if OC1N is implemented) when MOE=0

1: OC1=1 (after a dead-time if OC1N is implemented) when MOE=0

Note: This bit can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BKR register).

Bits 7:4 Reserved, always read as 0.

Bit 3 CCDS: Capture/compare DMA selection

0: CCx DMA request sent when CCx event occurs

1: CCx DMA requests sent when update event occurs

Bit 2 **CCUS**: Capture/compare control update selection

0: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit only.

1: When capture/compare control bits are preloaded (CCPC=1), they are updated by setting the COMG bit or when an rising edge occurs on TRGI.

Note: This bit acts only on channels that have a complementary output.

Bit 1 Reserved, always read as 0.

Bit 0 **CCPC**: Capture/compare preloaded control

0: CCxE, CCxNE and OCxM bits are not preloaded

1: CCxE, CCxNE and OCxM bits are preloaded, after having been written, they are updated only when COM bit is set.

Note: This bit acts only on channels that have a complementary output.

17.6.3 TIM16 and TIM17 DMA/interrupt enable register (TIM16_DIER and TIM17_DIER)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CC1DE	UDE	BIE	Res.	COMIE	Res.	Res.	Res.	CC1IE	UIE
						rw	rw	rw		rw				rw	rw

Bit 15 Reserved, always read as 0.

Bit 14 Reserved, always read as 0.

Bits 13:10 Reserved, always read as 0.

Bit 9 **CC1DE**: Capture/Compare 1 DMA request enable

0: CC1 DMA request disabled

1: CC1 DMA request enabled

Bit 8 **UDE**: Update DMA request enable

0: Update DMA request disabled

1: Update DMA request enabled

Bit 7 **BIE**: Break interrupt enable

0: Break interrupt disabled

1: Break interrupt enabled

Bit 6 Reserved, always read as 0.

Bit 5 **COMIE**: COM interrupt enable

0: COM interrupt disabled

1: COM interrupt enabled

Bits 4:2 Reserved, always read as 0.

Bit 1 **CC1IE**: Capture/Compare 1 interrupt enable

0: CC1 interrupt disabled

1: CC1 interrupt enabled

Bit 0 **UIE**: Update interrupt enable

0: Update interrupt disabled

1: Update interrupt enabled

17.6.4 TIM16 and TIM17 status register (TIM16_SR and TIM17_SR)

Address offset: 0x10

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	CC1OF	Res.	BIF	Res.	COMIF	Res.	Res.	Res.	CC1IF	UIF
						rc_w0		rc_w0		rc_w0				rc_w0	rc_w0

Bits 15:10 Reserved, always read as 0.

Bit 9 **CC1OF**: Capture/Compare 1 overcapture flag

This flag is set by hardware only when the corresponding channel is configured in input capture mode. It is cleared by software by writing it to '0'.

0: No overcapture has been detected

1: The counter value has been captured in TIMx_CCR1 register while CC1IF flag was already set

Bit 8 Reserved, always read as 0.

Bit 7 **BIF**: Break interrupt flag

This flag is set by hardware as soon as the break input goes active. It can be cleared by software if the break input is not active.

0: No break event occurred

1: An active level has been detected on the break input

Bit 6 Reserved, always read as 0.

Bit 5 **COMIF**: COM interrupt flag

This flag is set by hardware on a COM event (once the capture/compare control bits –CCxE, CCxNE, OCxM– have been updated). It is cleared by software by writing it to '0'.

0: No COM event occurred

1: COM interrupt pending

Bits 4:2 Reserved, always read as 0.

Bit 1 **CC1IF**: Capture/Compare 1 interrupt flag

If channel CC1 is configured as output:

This flag is set by hardware when the counter matches the compare value, with some exception in center-aligned mode (refer to the CMS bits in the TIMx_CR1 register description). It is cleared by software.

0: No match.

1: The content of the counter TIMx_CNT matches the content of the TIMx_CCR1 register. When the contents of TIMx_CCR1 are greater than the contents of TIMx_ARR, the CC1IF bit goes high on the counter overflow (in upcounting and up/down-counting modes) or underflow (in downcounting mode)

If channel CC1 is configured as input:

This bit is set by hardware on a capture. It is cleared by software or by reading the TIMx_CCR1 register.

0: No input capture occurred

1: The counter value has been captured in TIMx_CCR1 register (An edge has been detected on IC1 which matches the selected polarity)

Bit 0 **UIF**: Update interrupt flag

This bit is set by hardware on an update event. It is cleared by software.

0: No update occurred.

1: Update interrupt pending. This bit is set by hardware when the registers are updated:

- At overflow regarding the repetition counter value (update if repetition counter = 0) and if the UDIS=0 in the TIMx_CR1 register.
- When CNT is reinitialized by software using the UG bit in TIMx_EGR register, if URS=0 and UDIS=0 in the TIMx_CR1 register.

17.6.5 TIM16 and TIM17 event generation register (TIM16_EGR and TIM17_EGR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BG	Res.	COMG	Res.	Res.	Res.	CC1G	UG
								w		w				w	w

Bits 15:8 Reserved, always read as 0.

Bit 7 **BG**: Break generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: A break event is generated. MOE bit is cleared and BIF flag is set. Related interrupt or DMA transfer can occur if enabled.

Bit 6 Reserved, always read as 0.

Bit 5 **COMG**: Capture/Compare control update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action

1: When the CCPC bit is set, it is possible to update the CCxE, CCxNE and OCxM bits

Note: This bit acts only on channels that have a complementary output.

Bits 4:2 Reserved, always read as 0.

Bit 1 **CC1G**: Capture/Compare 1 generation

This bit is set by software in order to generate an event, it is automatically cleared by hardware.

0: No action.

1: A capture/compare event is generated on channel 1:

If channel CC1 is configured as output:

CC1IF flag is set, Corresponding interrupt or DMA request is sent if enabled.

If channel CC1 is configured as input:

The current value of the counter is captured in TIMx_CCR1 register. The CC1IF flag is set, the corresponding interrupt or DMA request is sent if enabled. The CC1OF flag is set if the CC1IF flag was already high.

Bit 0 **UG**: Update generation

This bit can be set by software, it is automatically cleared by hardware.

0: No action.

1: Reinitialize the counter and generates an update of the registers. Note that the prescaler counter is cleared too (anyway the prescaler ratio is not affected). The counter is cleared if the center-aligned mode is selected or if DIR=0 (upcounting), else it takes the auto-reload value (TIMx_ARR) if DIR=1 (downcounting).

17.6.6 TIM16 and TIM17 capture/compare mode register 1 (TIM16_CCMR1 and TIM17_CCMR1)

Address offset: 0x18

Reset value: 0x0000

The channels can be used in input (capture mode) or in output (compare mode). The direction of a channel is defined by configuring the corresponding CCxS bits. All the other bits of this register have a different function in input and in output mode. For a given bit, OCxx describes its function when the channel is configured in output, ICxx describes its function when the channel is configured in input. So you must take care that the same bit can have a different meaning for the input stage and for the output stage.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OC1M[2:0]				OC1PE	OC1FE	CC1S[1:0]	
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	IC1F[3:0]				IC1PSC[1:0]				
								rw	rw	rw	rw	rw	rw	rw	rw	

Output compare mode:

Bits 15:7 Reserved, always read as 0.

Bits 6:4 **OC1M**: Output Compare 1 mode

These bits define the behavior of the output reference signal OC1REF from which OC1 and OC1N are derived. OC1REF is active high whereas OC1 and OC1N active level depends on CC1P and CC1NP bits.

000: Frozen - The comparison between the output compare register TIMx_CCR1 and the counter TIMx_CNT has no effect on the outputs.

001: Set channel 1 to active level on match. OC1REF signal is forced high when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

010: Set channel 1 to inactive level on match. OC1REF signal is forced low when the counter TIMx_CNT matches the capture/compare register 1 (TIMx_CCR1).

011: Toggle - OC1REF toggles when TIMx_CNT=TIMx_CCR1.

100: Force inactive level - OC1REF is forced low.

101: Force active level - OC1REF is forced high.

110: PWM mode 1 - In upcounting, channel 1 is active as long as TIMx_CNT<TIMx_CCR1 else inactive. In downcounting, channel 1 is inactive (OC1REF='0') as long as TIMx_CNT>TIMx_CCR1 else active (OC1REF='1').

111: PWM mode 2 - In upcounting, channel 1 is inactive as long as TIMx_CNT<TIMx_CCR1 else active. In downcounting, channel 1 is active as long as TIMx_CNT>TIMx_CCR1 else inactive.

Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S='00' (the channel is configured in output).

2: In PWM mode 1 or 2, the OCREF level changes only when the result of the comparison changes or when the output compare mode switches from "frozen" mode to "PWM" mode.

Bit 3 **OC1PE**: Output Compare 1 preload enable

0: Preload register on TIMx_CCR1 disabled. TIMx_CCR1 can be written at anytime, the new value is taken in account immediately.

1: Preload register on TIMx_CCR1 enabled. Read/Write operations access the preload register. TIMx_CCR1 preload value is loaded in the active register at each update event.

Note: 1: These bits can not be modified as long as LOCK level 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S='00' (the channel is configured in output).

2: The PWM mode can be used without validating the preload register only in one pulse mode (OPM bit set in TIMx_CR1 register). Else the behavior is not guaranteed.

Bit 2 **OC1FE**: Output Compare 1 fast enable

This bit is used to accelerate the effect of an event on the trigger in input on the CC output.

0: CC1 behaves normally depending on counter and CCR1 values even when the trigger is ON. The minimum delay to activate CC1 output when an edge occurs on the trigger input is 5 clock cycles.

1: An active edge on the trigger input acts like a compare match on CC1 output. Then, OC is set to the compare level independently of the result of the comparison. Delay to sample the trigger input and to activate CC1 output is reduced to 3 clock cycles. OC1FE acts only if the channel is configured in PWM1 or PWM2 mode.

Bits 1:0 **CC1S**: Capture/Compare 1 selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output

01: CC1 channel is configured as input, IC1 is mapped on TI1

10: CC1 channel is configured as input, IC1 is mapped on TI2

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC1S bits are writable only when the channel is OFF (CC1E = '0' in TIMx_CCER).

Input capture mode

Bits 15:8 Reserved, always read as 0.

Bits 7:4 **IC1F[3:0]**: Input capture 1 filter

This bit-field defines the frequency used to sample TI1 input and the length of the digital filter applied to TI1. The digital filter is made of an event counter in which N events are needed to validate a transition on the output:

0000: No filter, sampling is done at f_{DTS}

0001: $f_{SAMPLING} = f_{CK\_INT}$, $N = 2$

0010: $f_{SAMPLING} = f_{CK\_INT}$, $N = 4$

0011: $f_{SAMPLING} = f_{CK\_INT}$, $N = 8$

0100: $f_{SAMPLING} = f_{DTS} / 2$, $N = 6$

0101: $f_{SAMPLING} = f_{DTS} / 2$, $N = 8$

0110: $f_{SAMPLING} = f_{DTS} / 4$, $N = 6$

0111: $f_{SAMPLING} = f_{DTS} / 4$, $N = 8$

1000: $f_{SAMPLING} = f_{DTS} / 8$, $N = 6$

1001: $f_{SAMPLING} = f_{DTS} / 8$, $N = 8$

1010: $f_{SAMPLING} = f_{DTS} / 16$, $N = 5$

1011: $f_{SAMPLING} = f_{DTS} / 16$, $N = 6$

1100: $f_{SAMPLING} = f_{DTS} / 16$, $N = 8$

1101: $f_{SAMPLING} = f_{DTS} / 32$, $N = 5$

1110: $f_{SAMPLING} = f_{DTS} / 32$, $N = 6$

1111: $f_{SAMPLING} = f_{DTS} / 32$, $N = 8$

Note: Care must be taken that f_{DTS} is replaced in the formula by CK_INT when $ICx F[3:0] = 1, 2$ or 3 .

Bits 3:2 **IC1PSC**: Input capture 1 prescaler

This bit-field defines the ratio of the prescaler acting on CC1 input (IC1).

The prescaler is reset as soon as $CC1E = '0'$ (TIMx_CCER register).

00: no prescaler, capture is done each time an edge is detected on the capture input.

01: capture is done once every 2 events

10: capture is done once every 4 events

11: capture is done once every 8 events

Bits 1:0 **CC1S**: Capture/Compare 1 Selection

This bit-field defines the direction of the channel (input/output) as well as the used input.

00: CC1 channel is configured as output

01: CC1 channel is configured as input, IC1 is mapped on TI1

10: CC1 channel is configured as input, IC1 is mapped on TI2

11: CC1 channel is configured as input, IC1 is mapped on TRC. This mode is working only if an internal trigger input is selected through TS bit (TIMx_SMCR register)

Note: CC1S bits are writable only when the channel is OFF ($CC1E = '0'$ in TIMx_CCER).

17.6.7 TIM16 and TIM17 capture/compare enable register (TIM16_CCER and TIM17_CCER)

Address offset: 0x20

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1NP	CC1NE	CC1P	CC1E
												rw	rw	rw	rw

Bits 15:4 Reserved, always read as 0.

Bit 3 **CC1NP**: Capture/Compare 1 complementary output polarity

- 0: OC1N active high
- 1: OC1N active low

Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register) and CC1S="00" (the channel is configured in output).

Bit 2 **CC1NE**: Capture/Compare 1 complementary output enable

- 0: Off - OC1N is not active. OC1N level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.
- 1: On - OC1N signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1E bits.

Bit 1 **CC1P**: Capture/Compare 1 output polarity

CC1 channel configured as output:

- 0: OC1 active high
- 1: OC1 active low

CC1 channel configured as input:

The CC1NP/CC1P bits select the polarity of TI1FP1 and TI2FP1 for capture operation.

- 00: Non-inverted/rising edge: circuit is sensitive to TlxFP1's rising edge TlxFP1 is not inverted.
- 01: Inverted/falling edge: circuit is sensitive to TlxFP1's falling edge, TlxFP1 is inverted.
- 10: Reserved, do not use this configuration.
- 11: Non-inverted/both edges: circuit is sensitive to both the rising and falling edges of TlxFP1, TlxFP1 is not inverted.

Note: This bit is not writable as soon as LOCK level 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register)

Bit 0 **CC1E**: Capture/Compare 1 output enable

CC1 channel configured as output:

- 0: Off - OC1 is not active. OC1 level is then function of MOE, OSS1, OSSR, OIS1, OIS1N and CC1NE bits.
- 1: On - OC1 signal is output on the corresponding output pin depending on MOE, OSS1, OSSR, OIS1, OIS1N and CC1NE bits.

CC1 channel configured as input:

This bit determines if a capture of the counter value can actually be done into the input capture/compare register 1 (TIMx_CCR1) or not.

- 0: Capture disabled
- 1: Capture enabled

Table 58. Output control bits for complementary OCx and OCxN channels with break feature

Control bits					Output states ⁽¹⁾	
MOE bit	OSSI bit	OSSR bit	CCxE bit	CCxNE bit	OCx output state	OCxN output state
1	X	0	0	0	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	0	1	Output Disabled (not driven by the timer) OCx=0, OCx_EN=0	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		0	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Output Disabled (not driven by the timer) OCxN=0, OCxN_EN=0
		0	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
		1	0	0	Output Disabled (not driven by the timer) OCx=CCxP, OCx_EN=0	Output Disabled (not driven by the timer) OCxN=CCxNP, OCxN_EN=0
		1	0	1	Off-State (output enabled with inactive state) OCx=CCxP, OCx_EN=1	OCxREF + Polarity OCxN=OCxREF xor CCxNP, OCxN_EN=1
		1	1	0	OCxREF + Polarity OCx=OCxREF xor CCxP, OCx_EN=1	Off-State (output enabled with inactive state) OCxN=CCxNP, OCxN_EN=1
		1	1	1	OCREF + Polarity + dead-time OCx_EN=1	Complementary to OCREF (not OCREF) + Polarity + dead-time OCxN_EN=1
0	0	X	0	0	Output Disabled (not driven by the timer) Asynchronously: OCx=CCxP, OCx_EN=0, OCxN=CCxNP, OCxN_EN=0 Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCX and OCxN both in active state.	
	0		0	1		
	0		1	0		
	0		1	1		
	1		0	0	Off-State (output enabled with inactive state) Asynchronously: OCx=CCxP, OCx_EN=1, OCxN=CCxNP, OCxN_EN=1 Then if the clock is present: OCx=OISx and OCxN=OISxN after a dead-time, assuming that OISx and OISxN do not correspond to OCX and OCxN both in active state	
	1		0	1		
	1		1	0		
	1		1	1		

1. When both outputs of a channel are not used (CCxE = CCxNE = 0), the OISx, OISxN, CCxP and CCxNP bits must be kept cleared.

Note: The state of the external I/O pins connected to the complementary OCx and OCxN channels depends on the OCx and OCxN channel state and the GPIO and AFIO registers.

17.6.8 TIM16 and TIM17 counter (TIM16_CNT and TIM17_CNT)

Address offset: 0x24

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CNT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CNT[15:0]**: Counter value**17.6.9 TIM16 and TIM17 prescaler (TIM16_PSC and TIM17_PSC)**

Address offset: 0x28

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
PSC[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **PSC[15:0]**: Prescaler valueThe counter clock frequency (CK_CNT) is equal to $f_{CK\_PSC} / (PSC[15:0] + 1)$.

PSC contains the value to be loaded in the active prescaler register at each update event (including when the counter is cleared through UG bit of TIMx_EGR register or through trigger controller when configured in “reset mode”).

17.6.10 TIM16 and TIM17 auto-reload register (TIM16_ARR and TIM17_ARR)

Address offset: 0x2C

Reset value: 0xFFFF

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ARR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **ARR[15:0]**: Auto-reload value

ARR is the value to be loaded in the actual auto-reload register.

Refer to the [Section 16.3.1: Time-base unit on page 375](#) for more details about ARR update and behavior.

The counter is blocked while the auto-reload value is null.

17.6.11 TIM16 and TIM17 repetition counter register (TIM16_RCR and TIM17_RCR)

Address offset: 0x30

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	REP[7:0]							
								rW	rW	rW	rW	rW	rW	rW	rW

Bits 15:8 Reserved, always read as 0.

Bits 7:0 **REP[7:0]**: Repetition counter value

These bits allow the user to set-up the update rate of the compare registers (i.e. periodic transfers from preload to active registers) when preload registers are enable, as well as the update interrupt generation rate, if this interrupt is enable.

Each time the REP_CNT related downcounter reaches zero, an update event is generated and it restarts counting from REP value. As REP_CNT is reloaded with REP value only at the repetition update event U_RC, any write to the TIMx_RCR register is not taken in account until the next repetition update event.

It means in PWM mode (REP+1) corresponds to the number of PWM periods in edge-aligned mode.

17.6.12 TIM16 and TIM17 capture/compare register 1 (TIM16_CCR1 and TIM17_CCR1)

Address offset: 0x34

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CCR1[15:0]															
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 15:0 **CCR1[15:0]**: Capture/Compare 1 value

If channel CC1 is configured as output:

CCR1 is the value to be loaded in the actual capture/compare 1 register (preload value).

It is loaded permanently if the preload feature is not selected in the TIMx_CCMR1 register (bit OC1PE). Else the preload value is copied in the active capture/compare 1 register when an update event occurs.

The active capture/compare register contains the value to be compared to the counter TIMx_CNT and signaled on OC1 output.

If channel CC1 is configured as input:

CCR1 is the counter value transferred by the last input capture 1 event (IC1).

17.6.13 TIM16 and TIM17 break and dead-time register (TIM16_BDTR and TIM17_BDTR)

Address offset: 0x44

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK[1:0]		DTG[7:0]							
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Note: As the bits AOE, BKP, BKE, OSSI, OSSR and DTG[7:0] can be write-locked depending on the LOCK configuration, it can be necessary to configure all of them during the first write access to the TIMx_BDTR register.

Bit 15 **MOE**: Main output enable

This bit is cleared asynchronously by hardware as soon as the break input is active. It is set by software or automatically depending on the AOE bit. It is acting only on the channels which are configured in output.

0: OC and OCN outputs are disabled or forced to idle state

1: OC and OCN outputs are enabled if their respective enable bits are set (CCxE, CCxNE in TIMx_CCER register)

See OC/OCN enable description for more details ([Section 17.5.8: TIM15 capture/compare enable register \(TIM15_CCER\) on page 440](#)).

Bit 14 **AOE**: Automatic output enable

0: MOE can be set only by software

1: MOE can be set by software or automatically at the next update event (if the break input is not be active)

Note: This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 13 **BKP**: Break polarity

0: Break input BRK is active low

1: Break input BRK is active high

Note: This bit can not be modified as long as LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.

Bit 12 **BKE**: Break enable

0: Break inputs (BRK and CCS clock failure event) disabled

1: Break inputs (BRK and CCS clock failure event) enabled

Note: This bit cannot be modified when LOCK level 1 has been programmed (LOCK bits in TIMx_BDTR register).

Note: Any write operation to this bit takes a delay of 1 APB clock cycle to become effective.

Bit 11 **OSSR**: Off-state selection for Run mode

This bit is used when MOE=1 on channels having a complementary output which are configured as outputs. OSSR is not implemented if no complementary output is implemented in the timer.

See OC/OCN enable description for more details ([Section 17.5.8: TIM15 capture/compare enable register \(TIM15_CCER\) on page 440](#)).

0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0)

1: When inactive, OC/OCN outputs are enabled with their inactive level as soon as CCxE=1 or CCxNE=1. Then, OC/OCN enable output signal=1

Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx_BDTR register).

Bit 10 **OSSI**: Off-state selection for Idle mode

This bit is used when MOE=0 on channels configured as outputs.

See OC/OCN enable description for more details ([Section 17.5.8: TIM15 capture/compare enable register \(TIM15_CCER\) on page 440](#)).

0: When inactive, OC/OCN outputs are disabled (OC/OCN enable output signal=0)

1: When inactive, OC/OCN outputs are forced first with their idle level as soon as CCxE=1 or CCxNE=1. OC/OCN enable output signal=1

Note: This bit can not be modified as soon as the LOCK level 2 has been programmed (LOCK bits in TIMx_BDTR register).

Bits 9:8 **LOCK[1:0]**: Lock configuration

These bits offer a write protection against software errors.

00: LOCK OFF - No bit is write protected

01: LOCK Level 1 = DTG bits in TIMx_BDTR register, OISx and OISxN bits in TIMx_CR2 register and BKE/BKP/AOE bits in TIMx_BDTR register can no longer be written.

10: LOCK Level 2 = LOCK Level 1 + CC Polarity bits (CCxP/CCxNP bits in TIMx_CCER register, as long as the related channel is configured in output through the CCxS bits) as well as OSSR and OSSI bits can no longer be written.

11: LOCK Level 3 = LOCK Level 2 + CC Control bits (OCxM and OCxPE bits in TIMx_CCMRx registers, as long as the related channel is configured in output through the CCxS bits) can no longer be written.

Note: The LOCK bits can be written only once after the reset. Once the TIMx_BDTR register has been written, their content is frozen until the next reset.

Bits 7:0 **DTG[7:0]**: Dead-time generator setup

This bit-field defines the duration of the dead-time inserted between the complementary outputs. DT correspond to this duration.

DTG[7:5]=0xx => $DT = DTG[7:0] \times t_{dtg}$ with $t_{dtg} = t_{DTS}$

DTG[7:5]=10x => $DT = (64 + DTG[5:0]) \times t_{dtg}$ with $t_{dtg} = 2 \times t_{DTS}$

DTG[7:5]=110 => $DT = (32 + DTG[4:0]) \times t_{dtg}$ with $t_{dtg} = 8 \times t_{DTS}$

DTG[7:5]=111 => $DT = (32 + DTG[4:0]) \times t_{dtg}$ with $t_{dtg} = 16 \times t_{DTS}$

Example if $T_{DTS} = 125\text{ns}$ (8MHz), dead-time possible values are:

0 to 15875 ns by 125 ns steps,

16 μs to 31750 ns by 250 ns steps,

32 μs to 63 μs by 1 μs steps,

64 μs to 126 μs by 2 μs steps

Note: This bit-field can not be modified as long as LOCK level 1, 2 or 3 has been programmed (LOCK bits in TIMx_BDTR register).

17.6.14 TIM16 and TIM17 DMA control register (TIM16_DCR and TIM17_DCR)

Address offset: 0x48

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBL[4:0]					Res.	Res.	Res.	DBA[4:0]				
			rw	rw	rw	rw	rw				rw	rw	rw	rw	rw

Bits 15:13 Reserved, always read as 0.

Bits 12:8 **DBL[4:0]**: DMA burst length

This 5-bit vector defines the length of DMA transfers (the timer recognizes a burst transfer when a read or a write access is done to the TIMx_DMAR address), i.e. the number of transfers. Transfers can be in half-words or in bytes (see example below).

00000: 1 transfer,
 00001: 2 transfers,
 00010: 3 transfers,
 ...
 10001: 18 transfers.

Bits 7:5 Reserved, always read as 0.

Bits 4:0 **DBA[4:0]**: DMA base address

This 5-bits vector defines the base-address for DMA transfers (when read/write access are done through the TIMx_DMAR address). DBA is defined as an offset starting from the address of the TIMx_CR1 register.

Example:

00000: TIMx_CR1,
 00001: TIMx_CR2,
 00010: TIMx_SMCR,
 ...

Example: Let us consider the following transfer: DBL = 7 transfers and DBA = TIMx_CR1. In this case the transfer is done to/from 7 registers starting from the TIMx_CR1 address.

17.6.15 TIM16 and TIM17 DMA address for full transfer (TIM16_DMAR and TIM17_DMAR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DMAB[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DMAB[15:0]**: DMA register for burst accesses

A read or write access to the DMAR register accesses the register located at the address: “(TIMx_CR1 address) + DBA + (DMA index)” in which:

TIMx_CR1 address is the address of the control register 1, DBA is the DMA base address configured in TIMx_DCR register, DMA index is the offset automatically controlled by the DMA transfer, depending on the length of the transfer DBL in the TIMx_DCR register.

Example of how to use the DMA burst feature

In this example the timer DMA burst feature is used to update the contents of the CCRx registers (x = 2, 3, 4) with the DMA transferring half words into the CCRx registers.

This is done in the following steps:

1. Configure the corresponding DMA channel as follows:
 - DMA channel peripheral address is the DMAR register address
 - DMA channel memory address is the address of the buffer in the RAM containing the data to be transferred by DMA into CCRx registers.
 - Number of data to transfer = 3 (See note below).
 - Circular mode disabled.
2. Configure the DCR register by configuring the DBA and DBL bit fields as follows:
DBL = 3 transfers, DBA = 0xE.
3. Enable the TIMx update DMA request (set the UDE bit in the DIER register).
4. Enable TIMx
5. Enable the DMA channel

Note: This example is for the case where every CCRx register to be updated once. If every CCRx register is to be updated twice for example, the number of data to transfer should be 6. Let us take the example of a buffer in the RAM containing data1, data2, data3, data4, data5 and data6. The data is transferred to the CCRx registers as follows: on the first update DMA request, data1 is transferred to CCR2, data2 is transferred to CCR3, data3 is transferred to CCR4 and on the second update DMA request, data4 is transferred to CCR2, data5 is transferred to CCR3 and data6 is transferred to CCR4.

17.6.16 TIM16 and TIM17 register map

TIM16 and TIM17 registers are mapped as 16-bit addressable registers as described in the table below:

Table 59. TIM16 and TIM17 register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0							
0x00	TIM16_CR1 and TIM17_CR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CKD [1:0]		ARPE		Res.	Res.		OPM	URS	UDIS	CEN						
	Reset value																							0	0	0				0	0	0	0							
0x04	TIM16_CR2 and TIM17_CR2	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	OIS1N	OIS1	Res.	Res.	Res.		CCDS	CCUS	Res.	CCPC							
	Reset value																							OIS1N	OIS1	0	0	0	0	0	0	0	0							
0x0C	TIM16_DIER and TIM17_DIER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1DE	UDE	BIE		COMIE		Res.	Res.	CC1IE	UIE							
	Reset value																		0					0	0	0	0	0	0	0	0	0	0							
0x10	TIM16_SR and TIM17_SR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1OF	Res.	BIF		COMIF		Res.	Res.	CC1IF	UIF							
	Reset value																							0	0	0	0	0	0	0	0	0	0							
0x14	TIM16_EGR and TIM17_EGR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BG	Res.	COMG		Res.	Res.	CC1G	UG							
	Reset value																									0	0	0				0	0							
0x18	TIM16_CCMR1 and TIM17_CCMR1 Output compare mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.			OC1M [2:0]		OC1PE	OC1FE	CC1S [1:0]									
	Reset value																									0	0	0	0	0	0	0	0							
	TIM16_CCMR1 and TIM17_CCMR1 Input capture mode	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.		IC1F[3:0]		IC1 PSC [1:0]	CC1S [1:0]											
	Reset value																									0	0	0	0	0	0	0	0							
0x20	TIM16_CCER and TIM17_CCER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CC1NP	CC1NE	CC1P	CC1E								
	Reset value																												0	0	0	0								
0x24	TIM16_CNT and TIM17_CNT	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CNT[15:0]																						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
0x28	TIM16_PSC and TIM17_PSC	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PSC[15:0]																						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
0x2C	TIM16_ARR and TIM17_ARR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ARR[15:0]																						
	Reset value																	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1								
0x30	TIM16_RCR and TIM17_RCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	REP[7:0]															
	Reset value																									0	0	0	0	0	0	0	0							
0x34	TIM16_CCR1 and TIM17_CCR1	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CCR1[15:0]																						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								
0x44	TIM16_BDTR and TIM17_BDTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	MOE	AOE	BKP	BKE	OSSR	OSSI	LOCK [1:0]	DT[7:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0								

Table 59. TIM16 and TIM17 register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x48	TIM16_DCR and TIM17_DCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBL[4:0]				Res.	Res.	Res.	DBA[4:0]					
	Reset value																				0	0	0	0	0				0	0	0	0	0
0x4C	TIM16_DMAR and TIM17_DMAR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DMAB[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

18 Infrared interface (IRTIM)

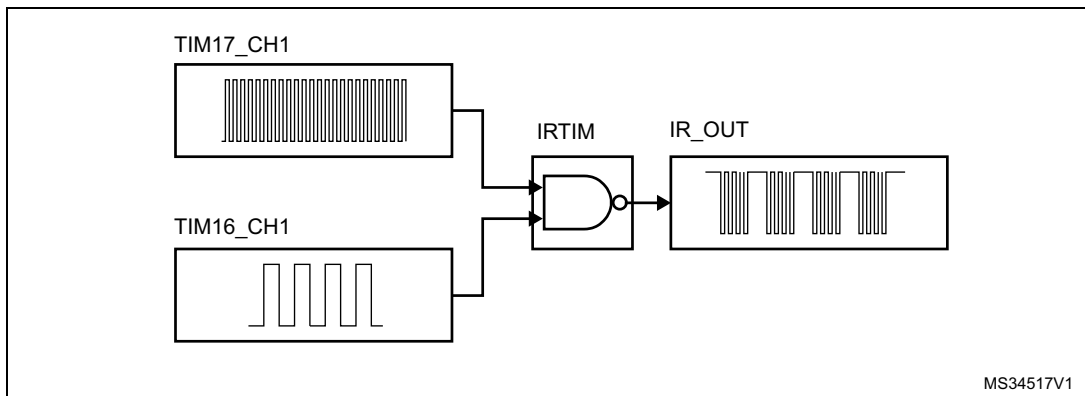
An infrared interface (IRTIM) for remote control is available on the device. It can be used with an infrared LED to perform remote control functions.

It uses internal connections with TIM16 as shown in [Figure 188](#).

To generate the infrared remote control signals, the IR interface must be enabled and TIM16 channel 1 (TIM16_OC1) must be properly configured to generate correct waveforms.

The infrared receiver can be implemented easily through a basic input capture mode.

Figure 188. IR internal hardware connections with TIM16



All standard IR pulse modulation modes can be obtained by programming the two timer output compare channels.

is used to generate the high frequency carrier signal, while TIM16 generates the modulation envelope.

The infrared function is output on the IR_OUT pin. The activation of this function is done through the GPIOx_AFRx register by enabling the related alternate function bit.

The high sink LED driver capability (only available on the PB9 pin) can be activated through the I2C_PB9_FMP bit in the SYSCFG_CFGR1 register and used to sink the high current needed to directly control an infrared LED.

For code example refer to the Appendix section [A.9.1: TIM16 and TIM17 configuration code example](#).

19 Independent watchdog (IWDG)

19.1 Introduction

The devices feature an embedded watchdog peripheral that offers a combination of high safety level, timing accuracy and flexibility of use. The Independent watchdog peripheral detects and solves malfunctions due to software failure, and triggers system reset when the counter reaches a given timeout value.

The independent watchdog (IWDG) is clocked by its own dedicated low-speed clock (LSI) and thus stays active even if the main clock fails.

The IWDG is best suited for applications that require the watchdog to run as a totally independent process outside the main application, but have lower timing accuracy constraints. For further information on the window watchdog, refer to [Section 20 on page 480](#).

19.2 IWDG main features

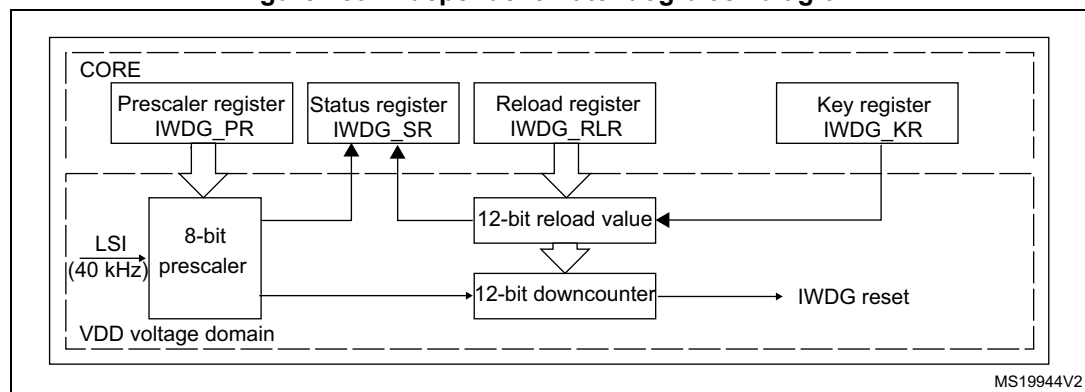
- Free-running downcounter
- Clocked from an independent RC oscillator (can operate in Standby and Stop modes)
- Conditional Reset
 - Reset (if watchdog activated) when the downcounter value becomes lower than 0x000
 - Reset (if watchdog activated) if the downcounter is reloaded outside the window

19.3 IWDG functional description

19.3.1 IWDG block diagram

[Figure 189](#) shows the functional blocks of the independent watchdog module.

Figure 189. Independent watchdog block diagram



1. The watchdog function is implemented in the CORE voltage domain that is still functional in Stop and Standby modes.

When the independent watchdog is started by writing the value 0x0000 CCCC in the Key register (IWDG_KR), the counter starts counting down from the reset value of 0xFFFF. When it reaches the end of count value (0x000) a reset signal is generated (IWDG reset).

Whenever the key value 0x0000 AAAA is written in the IWDG_KR register, the IWDG_RLR value is reloaded in the counter and the watchdog reset is prevented.

19.3.2 Window option

The IWDG can also work as a window watchdog by setting the appropriate window in the IWDG_WINR register.

If the reload operation is performed while the counter is greater than the value stored in the window register (IWDG_WINR), then a reset is provided.

The default value of the IWDG_WINR is 0x0000 0FFF, so if it is not updated, the window option is disabled.

As soon as the window value is changed, a reload operation is performed in order to reset the downcounter to the IWDG_RLR value and ease the cycle number calculation to generate the next reload.

Configuring the IWDG when the window option is enabled

1. Enable the IWDG by writing 0x0000 CCCC in the IWDG_KR register.
2. Enable register access by writing 0x0000 5555 in the IWDG_KR register.
3. Write the IWDG prescaler by programming IWDG_PR from 0 to 7.
4. Write the reload register (IWDG_RLR).
5. Wait for the registers to be updated (IWDG_SR = 0x0000 0000).
6. Write to the window register IWDG_WINR. This automatically refreshes the counter value IWDG_RLR.

Note: Writing the window value allows to refresh the Counter value by the RLR when IWDG_SR is set to 0x0000 0000.

For code example refer to the Appendix section [A.12.2: IWDG configuration with window code example](#).

Configuring the IWDG when the window option is disabled

When the window option it is not used, the IWDG can be configured as follows:

1. Enable the IWDG by writing 0x0000 CCCC in the IWDG_KR register.
2. Enable register access by writing 0x0000 5555 in the IWDG_KR register.
3. Write the IWDG prescaler by programming IWDG_PR from 0 to 7.
4. Write the reload register (IWDG_RLR).
5. Wait for the registers to be updated (IWDG_SR = 0x0000 0000).
6. Refresh the counter value with IWDG_RLR (IWDG_KR = 0x0000 AAAA)

For code example refer to the Appendix section [A.12.1: IWDG configuration code example](#).

19.3.3 Hardware watchdog

If the “Hardware watchdog” feature is enabled through the device option bits, the watchdog is automatically enabled at power-on, and generates a reset unless the Key register is written by the software before the counter reaches end of count or if the downcounter is reloaded inside the window.

19.3.4 Behavior in Stop and Standby modes

Once running, the IWDG cannot be stopped.

19.3.5 Register access protection

Write access to the IWDG_PR, IWDG_RLR and IWDG_WINR registers is protected. To modify them, you must first write the code 0x0000 5555 in the IWDG_KR register. A write access to this register with a different value will break the sequence and register access will be protected again. This implies that it is the case of the reload operation (writing 0x0000 AAAA).

A status register is available to indicate that an update of the prescaler or the down-counter reload value or the window value is on going.

For code example refer to the Appendix section [A.12.1: IWDG configuration code example](#).

19.3.6 Debug mode

When the microcontroller enters debug mode (core halted), the IWDG counter either continues to work normally or stops, depending on DBG_IWDG_STOP configuration bit in DBG module.

19.4 IWDG registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

19.4.1 Key register (IWDG_KR)

Address offset: 0x00

Reset value: 0x0000 0000 (reset by Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
KEY[15:0]															
w	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:0 **KEY[15:0]**: Key value (write only, read 0x0000)

These bits must be written by software at regular intervals with the key value 0xAAAA, otherwise the watchdog generates a reset when the counter reaches 0.

Writing the key value 0x5555 to enable access to the IWDG_PR, IWDG_RLR and IWDG_WINR registers (see [Section 19.3.5: Register access protection](#))

Writing the key value 0xCCCC starts the watchdog (except if the hardware watchdog option is selected)

19.4.2 Prescaler register (IWDG_PR)

Address offset: 0x04

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PR[2:0]		
													rw	rw	rw

Bits 31:3 Reserved, must be kept at reset value.

Bits 2:0 **PR[2:0]**: Prescaler divider

These bits are write access protected see [Section 19.3.5: Register access protection](#). They are written by software to select the prescaler divider feeding the counter clock. PVU bit of IWDG_SR must be reset in order to be able to change the prescaler divider.

000: divider /4
 001: divider /8
 010: divider /16
 011: divider /32
 100: divider /64
 101: divider /128
 110: divider /256
 111: divider /256

Note: Reading this register returns the prescaler value from the VDD voltage domain. This value may not be up to date/valid if a write operation to this register is ongoing. For this reason the value read from this register is valid only when the PVU bit in the IWDG_SR register is reset.

19.4.3 Reload register (IWDG_RLR)

Address offset: 0x08

Reset value: 0x0000 0FFF (reset by Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	RL[11:0]											
				rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:12 Reserved, must be kept at reset value.

Bits11:0 **RL[11:0]**: Watchdog counter reload value

These bits are write access protected see [Section 19.3.5](#). They are written by software to define the value to be loaded in the watchdog counter each time the value 0xAAAA is written in the IWDG_KR register. The watchdog counter counts down from this value. The timeout period is a function of this value and the clock prescaler. Refer to the datasheet for the timeout information.

The RVU bit in the IWDG_SR register must be reset in order to be able to change the reload value.

Note: Reading this register returns the reload value from the VDD voltage domain. This value may not be up to date/valid if a write operation to this register is ongoing on this register. For this reason the value read from this register is valid only when the RVU bit in the IWDG_SR register is reset.

19.4.4 Status register (IWDG_SR)

Address offset: 0x0C

Reset value: 0x0000 0000 (not reset by Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	WVU	RVU	PVU
													r	r	r

Bits 31:3 Reserved, must be kept at reset value.

Bit 2 WVU: Watchdog counter window value update

This bit is set by hardware to indicate that an update of the window value is ongoing. It is reset by hardware when the reload value update operation is completed in the V_{DD} voltage domain (takes up to 5 RC 40 kHz cycles).

Window value can be updated only when WVU bit is reset.

Bit 1 RVU: Watchdog counter reload value update

This bit is set by hardware to indicate that an update of the reload value is ongoing. It is reset by hardware when the reload value update operation is completed in the V_{DD} voltage domain (takes up to 5 RC 40 kHz cycles).

Reload value can be updated only when RVU bit is reset.

Bit 0 PVU: Watchdog prescaler value update

This bit is set by hardware to indicate that an update of the prescaler value is ongoing. It is reset by hardware when the prescaler update operation is completed in the V_{DD} voltage domain (takes up to 5 RC 40 kHz cycles).

Prescaler value can be updated only when PVU bit is reset.

Note: *If several reload, prescaler, or window values are used by the application, it is mandatory to wait until RVU bit is reset before changing the reload value, to wait until PVU bit is reset before changing the prescaler value, and to wait until WVU bit is reset before changing the window value. However, after updating the prescaler and/or the reload/window value it is not necessary to wait until RVU or PVU or WVU is reset before continuing code execution except in case of low-power mode entry.*

19.4.5 Window register (IWDG_WINR)

Address offset: 0x10

Reset value: 0x0000 0FFF (reset by Standby mode)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	WIN[11:0]											
				rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:12 Reserved, must be kept at reset value.

Bits11:0 **WIN[11:0]**: Watchdog counter window value

These bits are write access protected see [Section 19.3.5](#). These bits contain the high limit of the window value to be compared to the downcounter.

To prevent a reset, the downcounter must be reloaded when its value is lower than the window register value and greater than 0x0

The WVU bit in the IWDG_SR register must be reset in order to be able to change the reload value.

Note: Reading this register returns the reload value from the V_{DD} voltage domain. This value may not be valid if a write operation to this register is ongoing. For this reason the value read from this register is valid only when the WVU bit in the IWDG_SR register is reset.

19.4.6 IWDG register map

The following table gives the IWDG register map and reset values.

Table 60. IWDG register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x00	IWDG_KR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	KEY[15:0]																
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x04	IWDG_PR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	PR[2:0]		
	Reset value																														0	0	0	
0x08	IWDG_RLR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	RL[11:0]												
	Reset value																					1	1	1	1	1	1	1	1	1	1	1	1	
0x0C	IWDG_SR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	WVU	RVU	PVU
	Reset value																														0	0	0	
0x10	IWDG_WINR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	WIN[11:0]												
	Reset value																					1	1	1	1	1	1	1	1	1	1	1	1	

Refer to [Section 2.2.2: Memory map and register boundary addresses](#) for the register boundary addresses.

20 System window watchdog (WWDG)

20.1 Introduction

The system window watchdog (WWDG) is used to detect the occurrence of a software fault, usually generated by external interference or by unforeseen logical conditions, which causes the application program to abandon its normal sequence. The watchdog circuit generates an MCU reset on expiry of a programmed time period, unless the program refreshes the contents of the downcounter before the T6 bit becomes cleared. An MCU reset is also generated if the 7-bit downcounter value (in the control register) is refreshed before the downcounter has reached the window register value. This implies that the counter must be refreshed in a limited window.

The WWDG clock is prescaled from the APB clock and has a configurable time-window that can be programmed to detect abnormally late or early application behavior.

The WWDG is best suited for applications which require the watchdog to react within an accurate timing window.

20.2 WWDG main features

- Programmable free-running downcounter
- Conditional reset
 - Reset (if watchdog activated) when the downcounter value becomes less than 0x40
 - Reset (if watchdog activated) if the downcounter is reloaded outside the window (see [Figure 191](#))
- Early wakeup interrupt (EWI): triggered (if enabled and the watchdog activated) when the downcounter is equal to 0x40.

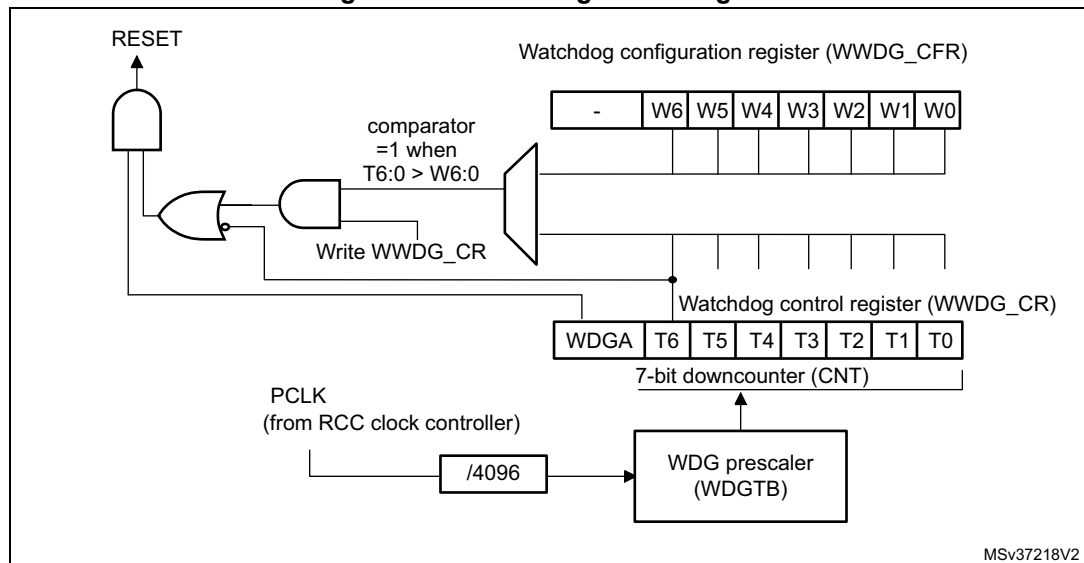
20.3 WWDG functional description

If the watchdog is activated (the WDGA bit is set in the WWDG_CR register) and when the 7-bit downcounter (T[6:0] bits) is decremented from 0x40 to 0x3F (T6 becomes cleared), it initiates a reset. If the software reloads the counter while the counter is greater than the value stored in the window register, then a reset is generated.

The application program must write in the WWDG_CR register at regular intervals during normal operation to prevent an MCU reset. This operation must occur only when the counter value is lower than the window register value and higher than 0x3F. The value to be stored in the WWDG_CR register must be between 0xFF and 0xC0.

Refer to [Figure 190](#) for WWDG block diagram.

Figure 190. Watchdog block diagram



20.3.1 Enabling the watchdog

The watchdog is always disabled after a reset. It is enabled by setting the WDGA bit in the WWDG_CR register, then it cannot be disabled again except by a reset.

20.3.2 Controlling the downcounter

This downcounter is free-running, counting down even if the watchdog is disabled. When the watchdog is enabled, the T6 bit must be set to prevent generating an immediate reset.

The T[5:0] bits contain the number of increments which represents the time delay before the watchdog produces a reset. The timing varies between a minimum and a maximum value due to the unknown status of the prescaler when writing to the WWDG_CR register (see [Figure 191](#)). The Configuration register (WWDG_CFR) contains the high limit of the window: To prevent a reset, the downcounter must be reloaded when its value is lower than the window register value and greater than 0x3F. [Figure 191](#) describes the window watchdog process.

Note: The T6 bit can be used to generate a software reset (the WDGA bit is set and the T6 bit is cleared).

20.3.3 Advanced watchdog interrupt feature

The Early Wakeup Interrupt (EWI) can be used if specific safety operations or data logging must be performed before the actual reset is generated. The EWI interrupt is enabled by setting the EWI bit in the WWDG_CFR register. When the downcounter reaches the value 0x40, an EWI interrupt is generated and the corresponding interrupt service routine (ISR) can be used to trigger specific actions (such as communications or data logging), before resetting the device.

In some applications, the EWI interrupt can be used to manage a software system check and/or system recovery/graceful degradation, without generating a WWDG reset. In this case, the corresponding interrupt service routine (ISR) should reload the WWDG counter to avoid the WWDG reset, then trigger the required actions.

The EWI interrupt is cleared by writing '0' to the EWIF bit in the WWDG_SR register.

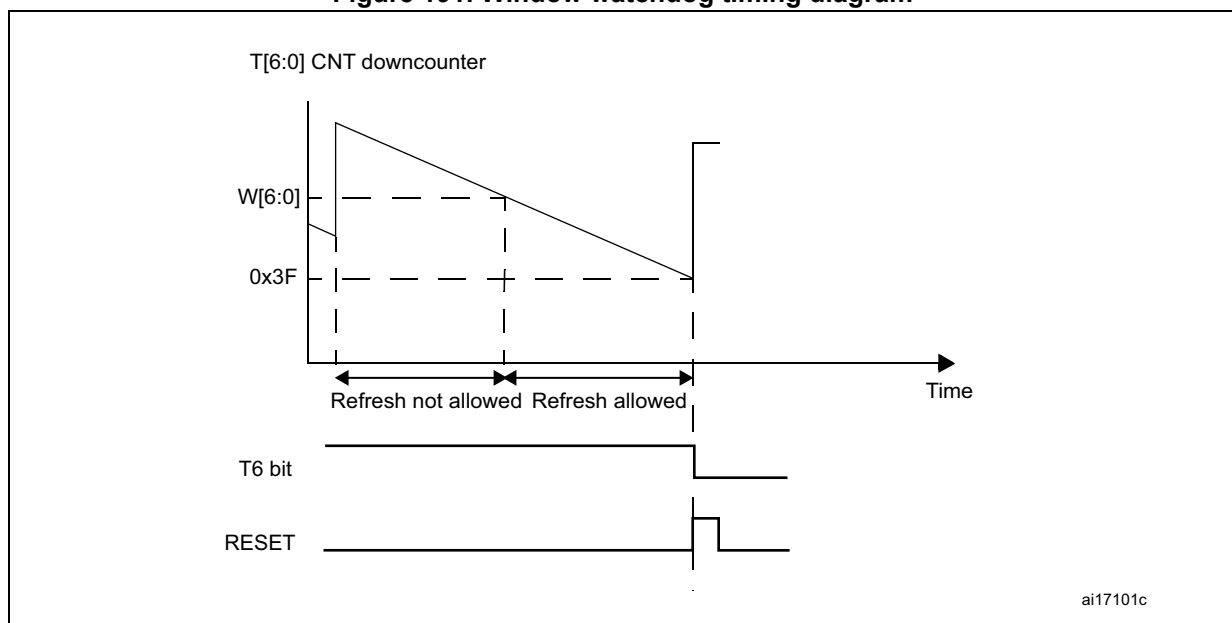
Note: When the EWI interrupt cannot be served, e.g. due to a system lock in a higher priority task, the WWDG reset will eventually be generated.

20.3.4 How to program the watchdog timeout

You can use the formula in [Figure 191](#) to calculate the WWDG timeout.

Warning: When writing to the WWDG_CR register, always write 1 in the T6 bit to avoid generating an immediate reset.

Figure 191. Window watchdog timing diagram



The formula to calculate the timeout value is given by:

$$t_{\text{WWDG}} = t_{\text{PCLK}} \times 4096 \times 2^{\text{WDGTB}[1:0]} \times (T[5:0] + 1) \quad (\text{ms})$$

where:

t_{WWDG} : WWDG timeout

t_{PCLK} : APB clock period measured in ms

4096: value corresponding to internal divider

As an example, let's assume APB frequency is equal to 48 MHz, WDGTB[1:0] is set to 3 and T[5:0] is set to 63:

$$t_{\text{WWDG}} = 1/48000 \times 4096 \times 2^3 \times (63 + 1) = 43.69 \text{ ms}$$

Refer to the datasheet for the minimum and maximum values of the t_{WWDG} .

20.3.5 Debug mode

When the microcontroller enters debug mode (ARM® Cortex®-M0 core halted), the WWDG counter either continues to work normally or stops, depending on DBG_WWDG_STOP configuration bit in DBG module. For more details, refer to [Section 26.9.2: Debug support for timers, watchdog and I²C](#).

20.4 WWDG registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

20.4.1 Control register (WWDG_CR)

Address offset: 0x00

Reset value: 0x0000 007F

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	WDGA	T[6:0]						
								rs	rw						

Bits 31:8 Reserved, must be kept at reset value.

Bit 7 **WDGA**: Activation bit

This bit is set by software and only cleared by hardware after a reset. When WDGA = 1, the watchdog can generate a reset.

0: Watchdog disabled

1: Watchdog enabled

Bits 6:0 **T[6:0]**: 7-bit counter (MSB to LSB)

These bits contain the value of the watchdog counter. It is decremented every $(4096 \times 2^{\text{WDGTB}[1:0]})$ PCLK cycles. A reset is produced when it is decremented from 0x40 to 0x3F (T6 becomes cleared).

20.4.2 Configuration register (WWDG_CFR)

Address offset: 0x04

Reset value: 0x0000 007F

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	EWI	WDGTB[1:0]		W[6:0]						
						rs	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:10 Reserved, must be kept at reset value.

Bit 9 **EWI**: Early wakeup interrupt

When set, an interrupt occurs whenever the counter reaches the value 0x40. This interrupt is only cleared by hardware after a reset.

Bits 8:7 **WDGTB[1:0]**: Timer base

The time base of the prescaler can be modified as follows:

00: CK Counter Clock (PCLK div 4096) div 1

01: CK Counter Clock (PCLK div 4096) div 2

10: CK Counter Clock (PCLK div 4096) div 4

11: CK Counter Clock (PCLK div 4096) div 8

Bits 6:0 **W[6:0]**: 7-bit window value

These bits contain the window value to be compared to the downcounter.

20.4.3 Status register (WWDG_SR)

Address offset: 0x08

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EWIF
															rc_w0

Bits 31:1 Reserved, must be kept at reset value.

Bit 0 **EWIF**: Early wakeup interrupt flag

This bit is set by hardware when the counter has reached the value 0x40. It must be cleared by software by writing '0'. A write of '1' has no effect. This bit is also set if the interrupt is not enabled.

20.4.4 WWDG register map

The following table gives the WWDG register map and reset values.

Table 61. WWDG register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0				
0x00	WWDG_CR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	WDGA	T[6:0]											
	Reset value																								0	1	1	1	1	1	1	1	1				
0x04	WWDG_CFR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	EWI	WDGTB1	WDGTB0	W[6:0]										
	Reset value																							0	0	0	1	1	1	1	1	1	1				
0x08	WWDG_SR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	EWIF				
	Reset value																								0	0	0	0	0	0	0	0	0				

Refer to [Section 2.2.2: Memory map and register boundary addresses](#) for the register boundary addresses.

21 Real-time clock (RTC)

21.1 Introduction

The RTC provides an automatic wakeup to manage all low-power modes.

The real-time clock (RTC) is an independent BCD timer/counter. The RTC provides a time-of-day clock/calendar with programmable alarm interrupt.

The RTC includes also a periodic programmable wakeup flag with interrupt capability.

Two 32-bit registers contain the seconds, minutes, hours (12- or 24-hour format), day (day of week), date (day of month), month, and year, expressed in binary coded decimal format (BCD). The sub-seconds value is also available in binary format.

Compensations for 28-, 29- (leap year), 30-, and 31-day months are performed automatically. Daylight saving time compensation can also be performed.

Additional 32-bit registers contain the programmable alarm subseconds, seconds, minutes, hours, day, and date.

A digital calibration feature is available to compensate for any deviation in crystal oscillator accuracy.

After RTC domain reset, all RTC registers are protected against possible parasitic write accesses.

As long as the supply voltage remains in the operating range, the RTC never stops, regardless of the device status (Run mode, low-power mode or under reset).

21.2 RTC main features

The RTC unit main features are the following (see [Figure 192: RTC block diagram in STM32F030x4/6, STM32F070x6 and STM32F030x8 devices](#) and [Figure 193: RTC block diagram for STM32F070xB and STM32F030xC devices](#)):

- Calendar with subseconds, seconds, minutes, hours (12 or 24 format), day (day of week), date (day of month), month, and year.
- Daylight saving compensation programmable by software.
- Programmable alarm with interrupt function. The alarm can be triggered by any combination of the calendar fields.
- Automatic wakeup unit generating a periodic flag that triggers an automatic wakeup interrupt.
- Reference clock detection: a more precise second source clock (50 or 60 Hz) can be used to enhance the calendar precision.
- Accurate synchronization with an external clock using the subsecond shift feature.
- Digital calibration circuit (periodic counter correction): 0.95 ppm accuracy, obtained in a calibration window of several seconds
- Time-stamp function for event saving
- Tamper detection event with configurable filter and internal pull-up
- Maskable interrupts/events:
 - Alarm A
 - Wakeup interrupt
 - Time-stamp
 - Tamper detection

21.3 RTC implementation

Table 62. STM32F0x0 RTC implementation⁽¹⁾

RTC Features	STM32F030x4, STM32F030x6 STM32F070x6 STM32F030x8	STM32F070xB STM32F030xC
Periodic wakeup timer	-	X
RTC_TAMP1	X	X
RTC_TAMP2	X	X
RTC_TAMP3	-	-
Alarm A	X	X

1. X = supported, '-' = not supported.

21.4 RTC functional description

21.4.1 RTC block diagram

Figure 192. RTC block diagram in STM32F030x4/6, STM32F070x6 and STM32F030x8 devices

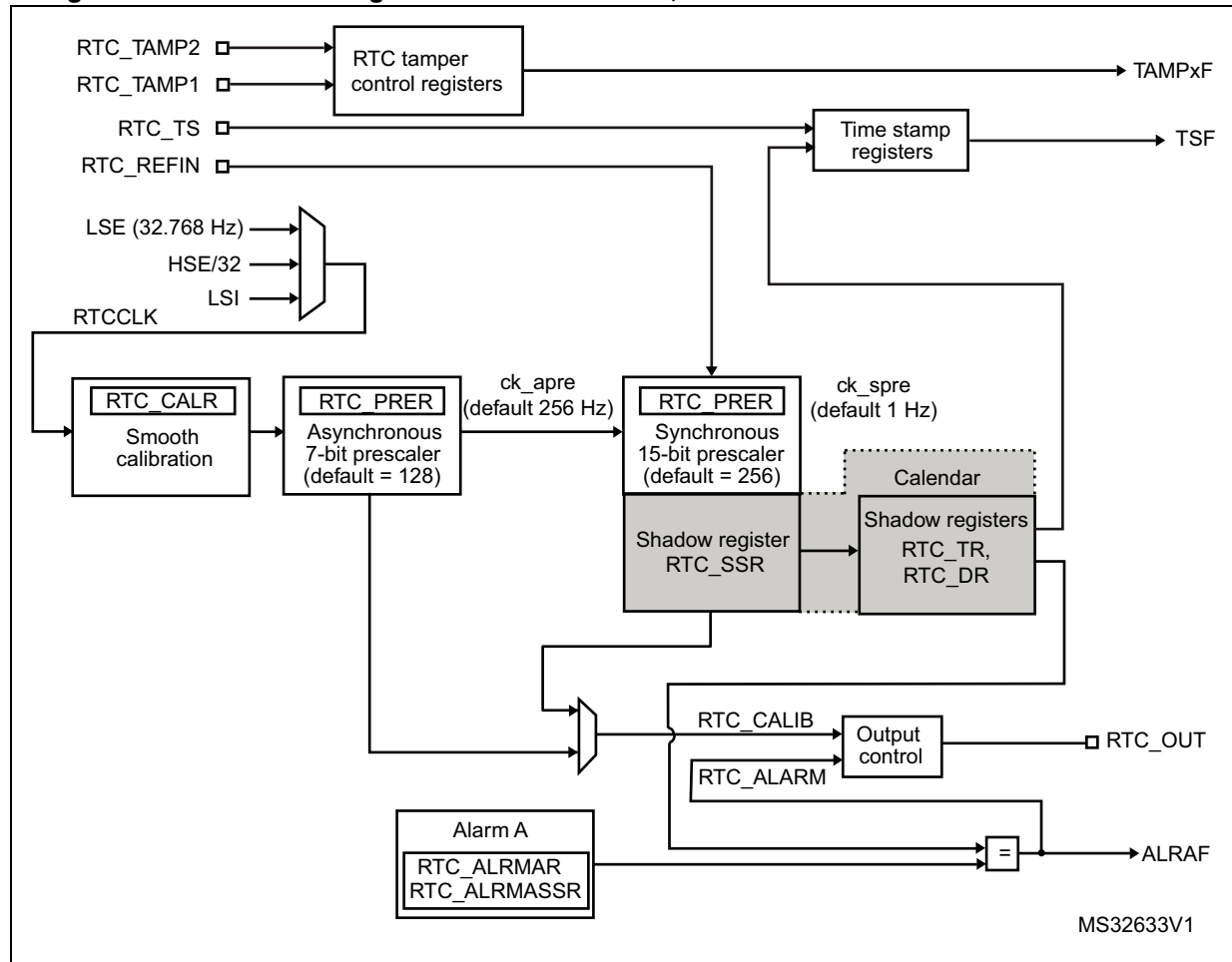
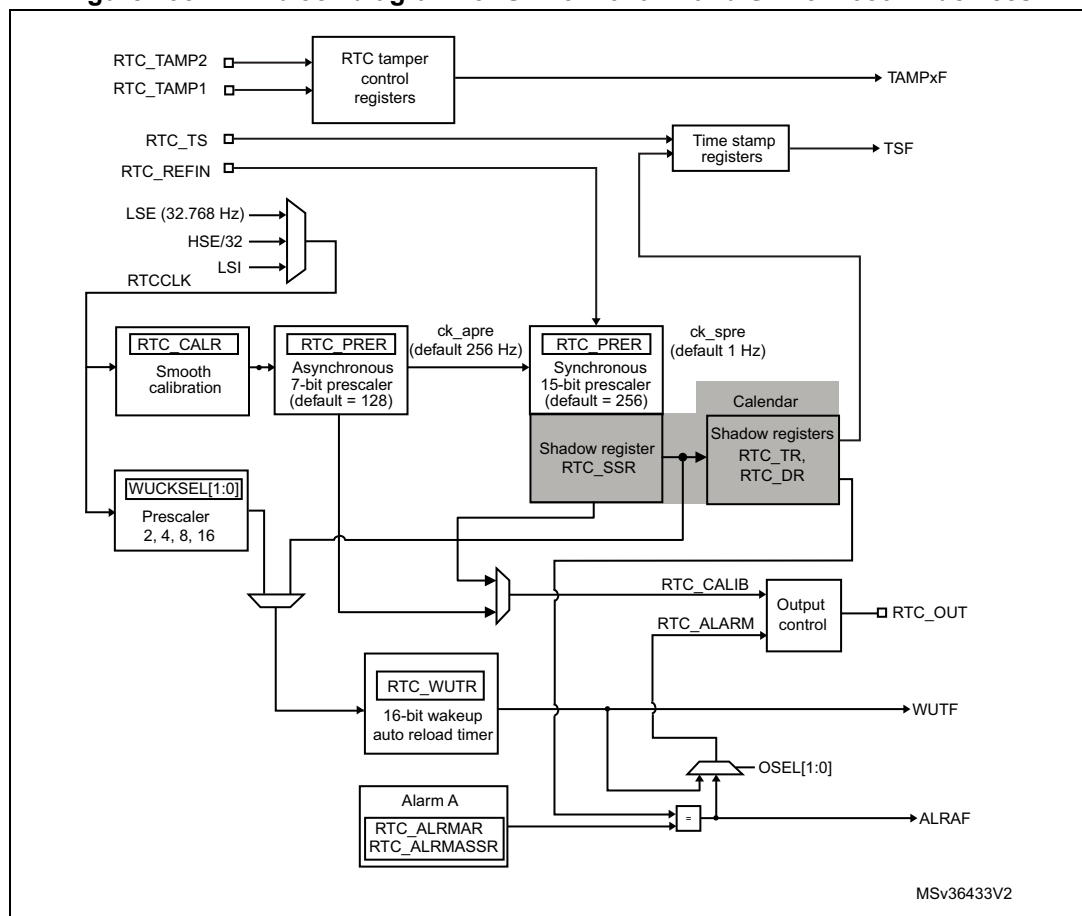


Figure 193. RTC block diagram for STM32F070xB and STM32F030xC devices



The RTC includes:

- One alarm
- Two tamper events from I/Os
 - Tamper detection erases the backup registers.
- One timestamp event from I/O
- Tamper event detection can generate a timestamp event
- Alternate function outputs: RTC_OUT which selects one of the following two outputs:
 - RTC_CALIB: 512 Hz or 1Hz clock output (with an LSE frequency of 32.768 kHz). This output is enabled by setting the COE bit in the RTC_CR register.
 - RTC_ALARM: Alarm A. This output is selected by configuring the OSEL[1:0] bits in the RTC_CR register.
- Alternate function inputs:
 - RTC_TS: timestamp event
 - RTC_TAMP1: tamper1 event detection
 - RTC_TAMP2: tamper2 event detection
 - RTC_REFIN: 50 or 60 Hz reference clock input

21.4.2 GPIOs controlled by the RTC

RTC_OUT, RTC_TS and RTC_TAMP1 are mapped on the same pin (PC13).

The selection of the RTC_ALARM output is performed through the RTC_TAFCR register as follows: the PC13VALUE bit is used to select whether the RTC_ALARM output is configured in push-pull or open drain mode.

When PC13 is not used as RTC alternate function, it can be forced in output push-pull mode by setting the PC13MODE bit in the RTC_TAFCR. The output data value is then given by the PC13VALUE bit. In this case, PC13 output push-pull state and data are preserved in Standby mode.

The output mechanism follows the priority order shown in [Table 63](#).

When PC14 and PC15 are not used as LSE oscillator, they can be forced in output push-pull mode by setting the PC14MODE and PC15MODE bits in the RTC_TAFCR register respectively. The output data values are then given by PC14VALUE and PC15VALUE. In this case, the PC14 and PC15 output push-pull states and data values are preserved in Standby mode.

The output mechanism follows the priority order shown in [Table 64](#) and [Table 65](#).

Table 63. RTC pin PC13 configuration⁽¹⁾

Pin configuration and function	RTC_ALARM output enabled	RTC_CALIB output enabled	RTC_TAMP1 input enabled	RTC_TS input enabled	PC13MODE bit	PC13VALUE bit
RTC_ALARM output OD	1	Don't care	Don't care	Don't care	Don't care	0
RTC_ALARM output PP	1	Don't care	Don't care	Don't care	Don't care	1
RTC_CALIB output PP	0	1	Don't care	Don't care	Don't care	Don't care
RTC_TAMP1 input floating	0	0	1	0	Don't care	Don't care
RTC_TS and RTC_TAMP1 input floating	0	0	1	1	Don't care	Don't care
RTC_TS input floating	0	0	0	1	Don't care	Don't care
Output PP forced	0	0	0	0	1	PC13 output data value
Wakeup pin or Standard GPIO	0	0	0	0	0	Don't care

1. OD: open drain; PP: push-pull.

Table 64. LSE pin PC14 configuration ⁽¹⁾

Pin configuration and function	LSEON bit in RCC_BDCR register	LSEBYP bit in RCC_BDCR register	PC14MODE bit	PC14VALUE bit
LSE oscillator	1	0	Don't care	Don't care
LSE bypass	1	1	Don't care	Don't care
Output PP forced	0	Don't care	1	PC14 output data value
Standard GPIO	0	Don't care	0	Don't care

1. OD: open drain; PP: push-pull.

Table 65. LSE pin PC15 configuration ⁽¹⁾

Pin configuration and function	LSEON bit in RCC_BDCR register	LSEBYP bit in RCC_BDCR register	PC15MODE bit	PC15VALUE bit
LSE oscillator	1	0	Don't care	Don't care
Output PP forced	1	1	1	PC15 output data value
	0	Don't care		
Standard GPIO	0	Don't care	0	Don't care

1. OD: open drain; PP: push-pull.

21.4.3 Clock and prescalers

The RTC clock source (RTCCLK) is selected through the clock controller among the LSE clock, the LSI oscillator clock, and the HSE clock. For more information on the RTC clock source configuration, refer to .

A programmable prescaler stage generates a 1 Hz clock which is used to update the calendar. To minimize power consumption, the prescaler is split into 2 programmable prescalers (see [Figure 192: RTC block diagram in STM32F030x4/6, STM32F070x6 and STM32F030x8 devices](#)):

- A 7-bit asynchronous prescaler configured through the PREDIV_A bits of the RTC_PRER register.
- A 15-bit synchronous prescaler configured through the PREDIV_S bits of the RTC_PRER register.

Note: When both prescalers are used, it is recommended to configure the asynchronous prescaler to a high value to minimize consumption.

The asynchronous prescaler division factor is set to 128, and the synchronous division factor to 256, to obtain an internal clock frequency of 1 Hz (ck_spre) with an LSE frequency of 32.768 kHz.

The minimum division factor is 1 and the maximum division factor is 2^{22} .

This corresponds to a maximum input frequency of around 4 MHz.

f_{ck_apre} is given by the following formula:

$$f_{CK\_APRE} = \frac{f_{RTCCLK}}{PREDIV\_A + 1}$$

The ck_apre clock is used to clock the binary RTC_SSR subseconds downcounter. When it reaches 0, RTC_SSR is reloaded with the content of PREDIV_S.

f_{ck_spre} is given by the following formula:

$$f_{CK\_SPRE} = \frac{f_{RTCCLK}}{(PREDIV\_S + 1) \times (PREDIV\_A + 1)}$$

The ck_spre clock can be used either to update the calendar or as timebase for the 16-bit wakeup auto-reload timer. To obtain short timeout periods, the 16-bit wakeup auto-reload timer can also run with the RTCCLK divided by the programmable 4-bit asynchronous prescaler (see [Section 21.4.6: Periodic auto-wakeup](#) for details).

21.4.4 Real-time clock and calendar

The RTC calendar time and date registers are accessed through shadow registers which are synchronized with PCLK (APB clock). They can also be accessed directly in order to avoid waiting for the synchronization duration.

- RTC_SSR for the subseconds
- RTC_TR for the time
- RTC_DR for the date

Every two RTCCLK periods, the current calendar value is copied into the shadow registers, and the RSF bit of RTC_ISR register is set (see [Section 21.7.4: RTC initialization and status register \(RTC_ISR\)](#)). The copy is not performed in Stop and Standby mode. When exiting these modes, the shadow registers are updated after up to 2 RTCCLK periods.

When the application reads the calendar registers, it accesses the content of the shadow registers. It is possible to make a direct access to the calendar registers by setting the BYPSHAD control bit in the RTC_CR register. By default, this bit is cleared, and the user accesses the shadow registers.

When reading the RTC_SSR, RTC_TR or RTC_DR registers in BYPSHAD=0 mode, the frequency of the APB clock (f_{APB}) must be at least 7 times the frequency of the RTC clock (f_{RTCCLK}).

The shadow registers are reset by system reset.

21.4.5 Programmable alarm

The RTC unit provides programmable alarm: Alarm A.

The programmable alarm function is enabled through the ALRAE bit in the RTC_CR register. The ALRAF is set to 1 if the calendar subseconds, seconds, minutes, hours, date or day match the values programmed in the alarm registers RTC_ALRMASSR and RTC_ALRMAR. Each calendar field can be independently selected through the MSKx bits of the RTC_ALRMAR register, and through the MASKSSx bits of the RTC_ALRMASSR register. The alarm interrupt is enabled through the ALRAIE bit in the RTC_CR register.

Caution: If the seconds field is selected (MSK1 bit reset in RTC_ALRMAR), the synchronous prescaler division factor set in the RTC_PRER register must be at least 3 to ensure correct behavior.

Alarm A (if enabled by bits OSEL[1:0] in RTC_CR register) can be routed to the RTC_ALARM output. RTC_ALARM output polarity can be configured through bit POL the RTC_CR register.

21.4.6 Periodic auto-wakeup

The periodic wakeup flag is generated by a 16-bit programmable auto-reload down-counter. The wakeup timer range can be extended to 17 bits.

The wakeup function is enabled through the WUTE bit in the RTC_CR register.

The wakeup timer clock input can be:

- RTC clock (RTCCLK) divided by 2, 4, 8, or 16.
When RTCCLK is LSE(32.768kHz), this allows to configure the wakeup interrupt period from 122 μ s to 32 s, with a resolution down to 61 μ s.
- ck_spre (usually 1 Hz internal clock)
When ck_spre frequency is 1Hz, this allows to achieve a wakeup time from 1 s to around 36 hours with one-second resolution. This large programmable time range is divided in 2 parts:
 - from 1s to 18 hours when WUCKSEL [2:1] = 10
 - and from around 18h to 36h when WUCKSEL[2:1] = 11. In this last case 2¹⁶ is added to the 16-bit counter current value. When the initialization sequence is complete (see [Programming the wakeup timer on page 495](#)), the timer starts counting down. When the wakeup function is enabled, the down-counting remains active in low-power modes. In addition, when it reaches 0, the WUTF flag is set in the RTC_ISR register, and the wakeup counter is automatically reloaded with its reload value (RTC_WUTR register value).

The WUTF flag must then be cleared by software.

When the periodic wakeup interrupt is enabled by setting the WUTIE bit in the RTC_CR2 register, it can exit the device from low-power modes.

The periodic wakeup flag can be routed to the RTC_ALARM output provided it has been enabled through bits OSEL[1:0] of RTC_CR register. RTC_ALARM output polarity can be configured through the POL bit in the RTC_CR register.

System reset, as well as low-power modes (Sleep, Stop and Standby) have no influence on the wakeup timer.

21.4.7 RTC initialization and configuration

RTC register access

The RTC registers are 32-bit registers. The APB interface introduces 2 wait-states in RTC register accesses except on read accesses to calendar shadow registers when BYPSHAD=0.

RTC register write protection

After system reset, the RTC registers are protected against parasitic write access by clearing the DBP bit in the PWR_CR register (refer to the power control section). DBP bit must be set in order to enable RTC registers write access.

After RTC domain reset, all the RTC registers are write-protected. Writing to the RTC registers is enabled by writing a key into the Write Protection register, RTC_WPR.

The following steps are required to unlock the write protection on all the RTC registers except for RTC_TAFCR and RTC_ISR[13:8].

1. Write '0xCA' into the RTC_WPR register.
2. Write '0x53' into the RTC_WPR register.

Writing a wrong key reactivates the write protection.

The protection mechanism is not affected by system reset.

Calendar initialization and configuration

To program the initial time and date calendar values, including the time format and the prescaler configuration, the following sequence is required:

1. Set INIT bit to 1 in the RTC_ISR register to enter initialization mode. In this mode, the calendar counter is stopped and its value can be updated.
2. Poll INITF bit of in the RTC_ISR register. The initialization phase mode is entered when INITF is set to 1. It takes around 2 RTCCLK clock cycles (due to clock synchronization).
3. To generate a 1 Hz clock for the calendar counter, program both the prescaler factors in RTC_PRER register.
4. Load the initial time and date values in the shadow registers (RTC_TR and RTC_DR), and configure the time format (12 or 24 hours) through the FMT bit in the RTC_CR register.
5. Exit the initialization mode by clearing the INIT bit. The actual calendar counter value is then automatically loaded and the counting restarts after 4 RTCCLK clock cycles.

When the initialization sequence is complete, the calendar starts counting.

Note: After a system reset, the application can read the INITS flag in the RTC_ISR register to check if the calendar has been initialized or not. If this flag equals 0, the calendar has not been initialized since the year field is set at its RTC domain reset default value (0x00).
To read the calendar after initialization, the software must first check that the RSF flag is set in the RTC_ISR register.

For code example refer to the Appendix section [A.13.1: RTC calendar configuration code example](#).

Daylight saving time

The daylight saving time management is performed through bits SUB1H, ADD1H, and BKP of the RTC_CR register.

Using SUB1H or ADD1H, the software can subtract or add one hour to the calendar in one single operation without going through the initialization procedure.

In addition, the software can use the BKP bit to memorize this operation.

Programming the alarm

A similar procedure must be followed to program or update the programmable alarms.

1. Clear ALRAE in RTC_CR to disable Alarm A.
2. Program the Alarm A registers (RTC_ALRMASSR/RTC_ALRMAR).
3. Set ALRAE in the RTC_CR register to enable Alarm A again.

Note: Each change of the RTC_CR register is taken into account after around 2 RTCCLK clock cycles due to clock synchronization.

For code example refer to the Appendix section [A.13.2: RTC alarm configuration code example](#).

Programming the wakeup timer

The following sequence is required to configure or change the wakeup timer auto-reload value (WUT[15:0] in RTC_WUTR):

1. Clear WUTE in RTC_CR to disable the wakeup timer.
2. Poll WUTWF until it is set in RTC_ISR to make sure the access to wakeup auto-reload counter and to WUCKSEL[2:0] bits is allowed. It takes around 2 RTCCLK clock cycles (due to clock synchronization).
3. Program the wakeup auto-reload value WUT[15:0], and the wakeup clock selection (WUCKSEL[2:0] bits in RTC_CR). Set WUTE in RTC_CR to enable the timer again. The wakeup timer restarts down-counting. The WUTWF bit is cleared up to 2 RTCCLK clock cycles after WUTE is cleared, due to clock synchronization.

For code example refer to the Appendix section [A.13.3: RTC WUT configuration code example](#).

21.4.8 Reading the calendar

When BYPSHAD control bit is cleared in the RTC_CR register

To read the RTC calendar registers (RTC_SSR, RTC_TR and RTC_DR) properly, the APB clock frequency (f_{PCLK}) must be equal to or greater than seven times the RTC clock frequency (f_{RTCCLK}). This ensures a secure behavior of the synchronization mechanism.

If the APB clock frequency is less than seven times the RTC clock frequency, the software must read the calendar time and date registers twice. If the second read of the RTC_TR gives the same result as the first read, this ensures that the data is correct. Otherwise a third read access must be done. In any case the APB clock frequency must never be lower than the RTC clock frequency.

The RSF bit is set in RTC_ISR register each time the calendar registers are copied into the RTC_SSR, RTC_TR and RTC_DR shadow registers. The copy is performed every two RTCCLK cycles. To ensure consistency between the 3 values, reading either RTC_SSR or RTC_TR locks the values in the higher-order calendar shadow registers until RTC_DR is read. In case the software makes read accesses to the calendar in a time interval smaller than 2 RTCCLK periods: RSF must be cleared by software after the first calendar read, and then the software must wait until RSF is set before reading again the RTC_SSR, RTC_TR and RTC_DR registers.

After waking up from low-power mode (Stop or Standby), RSF must be cleared by software. The software must then wait until it is set again before reading the RTC_SSR, RTC_TR and RTC_DR registers.

The RSF bit must be cleared after wakeup and not before entering low-power mode.

After a system reset, the software must wait until RSF is set before reading the RTC_SSR, RTC_TR and RTC_DR registers. Indeed, a system reset resets the shadow registers to their default values.

After an initialization (refer to [Calendar initialization and configuration on page 494](#)): the software must wait until RSF is set before reading the RTC_SSR, RTC_TR and RTC_DR registers.

After synchronization (refer to [Section 21.4.10: RTC synchronization](#)): the software must wait until RSF is set before reading the RTC_SSR, RTC_TR and RTC_DR registers.

For code example refer to the Appendix section [A.13.4: RTC read calendar code example](#).

When the BYPSHAD control bit is set in the RTC_CR register (bypass shadow registers)

Reading the calendar registers gives the values from the calendar counters directly, thus eliminating the need to wait for the RSF bit to be set. This is especially useful after exiting from low-power modes (STOP or Standby), since the shadow registers are not updated during these modes.

When the BYPSHAD bit is set to 1, the results of the different registers might not be coherent with each other if an RTCCLK edge occurs between two read accesses to the registers. Additionally, the value of one of the registers may be incorrect if an RTCCLK edge occurs during the read operation. The software must read all the registers twice, and then compare the results to confirm that the data is coherent and correct. Alternatively, the software can just compare the two results of the least-significant calendar register.

Note: While BYPSHAD=1, instructions which read the calendar registers require one extra APB cycle to complete.

21.4.9 Resetting the RTC

The calendar shadow registers (RTC_SSR, RTC_TR and RTC_DR) and some bits of the RTC status register (RTC_ISR) are reset to their default values by all available system reset sources.

On the contrary, the following registers are reset to their default values by a RTC domain reset and are not affected by a system reset: the RTC current calendar registers, the RTC control register (RTC_CR), the prescaler register (RTC_PRER), the RTC calibration register (RTC_CALR), the RTC shift register (RTC_SHIFTR), the RTC timestamp registers (RTC_TSSSR, RTC_TSTR and RTC_TSDR), the RTC tamper and alternate function configuration register (RTC_TAFCR), the wakeup timer register (RTC_WUTR), the Alarm A registers (RTC_ALRMASR/RTC_ALRMAR).

In addition, when it is clocked by the LSE, the RTC keeps on running under system reset if the reset source is different from the RTC domain reset one (refer to the RTC clock section of the Reset and clock controller for details on the list of RTC clock sources not affected by system reset). When a RTC domain reset occurs, the RTC is stopped and all the RTC registers are set to their reset values.

21.4.10 RTC synchronization

The RTC can be synchronized to a remote clock with a high degree of precision. After reading the sub-second field (RTC_SSR or RTC_TSSSR), a calculation can be made of the

precise offset between the times being maintained by the remote clock and the RTC. The RTC can then be adjusted to eliminate this offset by “shifting” its clock by a fraction of a second using RTC_SHIFTR.

RTC_SSR contains the value of the synchronous prescaler counter. This allows one to calculate the exact time being maintained by the RTC down to a resolution of $1 / (\text{PREDIV\_S} + 1)$ seconds. As a consequence, the resolution can be improved by increasing the synchronous prescaler value (PREDIV_S[14:0]). The maximum resolution allowed (30.52 μ s with a 32768 Hz clock) is obtained with PREDIV_S set to 0x7FFF.

However, increasing PREDIV_S means that PREDIV_A must be decreased in order to maintain the synchronous prescaler output at 1 Hz. In this way, the frequency of the asynchronous prescaler output increases, which may increase the RTC dynamic consumption.

The RTC can be finely adjusted using the RTC shift control register (RTC_SHIFTR). Writing to RTC_SHIFTR can shift (either delay or advance) the clock by up to a second with a resolution of $1 / (\text{PREDIV\_S} + 1)$ seconds. The shift operation consists of adding the SUBFS[14:0] value to the synchronous prescaler counter SS[15:0]: this will delay the clock. If at the same time the ADD1S bit is set, this results in adding one second and at the same time subtracting a fraction of second, so this will advance the clock.

Caution: Before initiating a shift operation, the user must check that SS[15] = 0 in order to ensure that no overflow will occur.

As soon as a shift operation is initiated by a write to the RTC_SHIFTR register, the SHPF flag is set by hardware to indicate that a shift operation is pending. This bit is cleared by hardware as soon as the shift operation has completed.

Caution: This synchronization feature is not compatible with the reference clock detection feature: firmware must not write to RTC_SHIFTR when REFCKON=1.

21.4.11 RTC reference clock detection

The update of the RTC calendar can be synchronized to a reference clock, RTC_REFIN, which is usually the mains frequency (50 or 60 Hz). The precision of the RTC_REFIN reference clock should be higher than the 32.768 kHz LSE clock. When the RTC_REFIN detection is enabled (REFCKON bit of RTC_CR set to 1), the calendar is still clocked by the LSE, and RTC_REFIN is used to compensate for the imprecision of the calendar update frequency (1 Hz).

Each 1 Hz clock edge is compared to the nearest RTC_REFIN clock edge (if one is found within a given time window). In most cases, the two clock edges are properly aligned. When the 1 Hz clock becomes misaligned due to the imprecision of the LSE clock, the RTC shifts the 1 Hz clock a bit so that future 1 Hz clock edges are aligned. Thanks to this mechanism, the calendar becomes as precise as the reference clock.

The RTC detects if the reference clock source is present by using the 256 Hz clock (ck_apre) generated from the 32.768 kHz quartz. The detection is performed during a time window around each of the calendar updates (every 1 s). The window equals 7 ck_apre periods when detecting the first reference clock edge. A smaller window of 3 ck_apre periods is used for subsequent calendar updates.

Each time the reference clock is detected in the window, the asynchronous prescaler which outputs the ck_apre clock is forced to reload. This has no effect when the reference clock and the 1 Hz clock are aligned because the prescaler is being reloaded at the same

moment. When the clocks are not aligned, the reload shifts future 1 Hz clock edges a little for them to be aligned with the reference clock.

If the reference clock halts (no reference clock edge occurred during the 3 `ck_apre` window), the calendar is updated continuously based solely on the LSE clock. The RTC then waits for the reference clock using a large 7 `ck_apre` period detection window centered on the `ck_spre` edge.

When the `RTC_REFIN` detection is enabled, `PREDIV_A` and `PREDIV_S` must be set to their default values:

- `PREDIV_A` = 0x007F
- `PREDIV_S` = 0x00FF

Note: `RTC_REFIN` clock detection is not available in Standby mode.

21.4.12 RTC smooth digital calibration

The RTC frequency can be digitally calibrated with a resolution of about 0.954 ppm with a range from -487.1 ppm to +488.5 ppm. The correction of the frequency is performed using series of small adjustments (adding and/or subtracting individual `RTCCLK` pulses). These adjustments are fairly well distributed so that the RTC is well calibrated even when observed over short durations of time.

The smooth digital calibration is performed during a cycle of about 2^{20} `RTCCLK` pulses, or 32 seconds when the input frequency is 32768 Hz. This cycle is maintained by a 20-bit counter, `cal_cnt[19:0]`, clocked by `RTCCLK`.

The smooth calibration register (`RTC_CALR`) specifies the number of `RTCCLK` clock cycles to be masked during the 32-second cycle:

- Setting the bit `CALM[0]` to 1 causes exactly one pulse to be masked during the 32-second cycle.
- Setting `CALM[1]` to 1 causes two additional cycles to be masked
- Setting `CALM[2]` to 1 causes four additional cycles to be masked
- and so on up to `CALM[8]` set to 1 which causes 256 clocks to be masked.

Note: `CALM[8:0]` (`RTC_CALR`) specifies the number of `RTCCLK` pulses to be masked during the 32-second cycle. Setting the bit `CALM[0]` to '1' causes exactly one pulse to be masked during the 32-second cycle at the moment when `cal_cnt[19:0]` is 0x80000; `CALM[1]=1` causes two other cycles to be masked (when `cal_cnt` is 0x40000 and 0xC0000); `CALM[2]=1` causes four other cycles to be masked (`cal_cnt` = 0x20000/0x60000/0xA0000/ 0xE0000); and so on up to `CALM[8]=1` which causes 256 clocks to be masked (`cal_cnt` = 0xXX800).

While `CALM` allows the RTC frequency to be reduced by up to 487.1 ppm with fine resolution, the bit `CALP` can be used to increase the frequency by 488.5 ppm. Setting `CALP` to '1' effectively inserts an extra `RTCCLK` pulse every 2^{11} `RTCCLK` cycles, which means that 512 clocks are added during every 32-second cycle.

Using `CALM` together with `CALP`, an offset ranging from -511 to +512 `RTCCLK` cycles can be added during the 32-second cycle, which translates to a calibration range of -487.1 ppm to +488.5 ppm with a resolution of about 0.954 ppm.

The formula to calculate the effective calibrated frequency (`FCAL`) given the input frequency (`FRTCCLK`) is as follows:

$$F_{\text{CAL}} = F_{\text{RTCCLK}} \times [1 + (\text{CALP} \times 512 - \text{CALM}) / (2^{20} + \text{CALM} - \text{CALP} \times 512)]$$

Calibration when PREDIV_A < 3

The CALP bit can not be set to 1 when the asynchronous prescaler value (PREDIV_A bits in RTC_PRER register) is less than 3. If CALP was already set to 1 and PREDIV_A bits are set to a value less than 3, CALP is ignored and the calibration operates as if CALP was equal to 0.

To perform a calibration with PREDIV_A less than 3, the synchronous prescaler value (PREDIV_S) should be reduced so that each second is accelerated by 8 RTCCLK clock cycles, which is equivalent to adding 256 clock cycles every 32 seconds. As a result, between 255 and 256 clock pulses (corresponding to a calibration range from 243.3 to 244.1 ppm) can effectively be added during each 32-second cycle using only the CALM bits.

With a nominal RTCCLK frequency of 32768 Hz, when PREDIV_A equals 1 (division factor of 2), PREDIV_S should be set to 16379 rather than 16383 (4 less). The only other interesting case is when PREDIV_A equals 0, PREDIV_S should be set to 32759 rather than 32767 (8 less).

If PREDIV_S is reduced in this way, the formula given the effective frequency of the calibrated input clock is as follows:

$$F_{\text{CAL}} = F_{\text{RTCCLK}} \times [1 + (256 - \text{CALM}) / (2^{20} + \text{CALM} - 256)]$$

In this case, CALM[7:0] equals 0x100 (the midpoint of the CALM range) is the correct setting if RTCCLK is exactly 32768.00 Hz.

Verifying the RTC calibration

RTC precision is ensured by measuring the precise frequency of RTCCLK and calculating the correct CALM value and CALP values. An optional 1 Hz output is provided to allow applications to measure and verify the RTC precision.

Measuring the precise frequency of the RTC over a limited interval can result in a measurement error of up to 2 RTCCLK clock cycles over the measurement period, depending on how the digital calibration cycle is aligned with the measurement period.

However, this measurement error can be eliminated if the measurement period is the same length as the calibration cycle period. In this case, the only error observed is the error due to the resolution of the digital calibration.

- By default, the calibration cycle period is 32 seconds.

Using this mode and measuring the accuracy of the 1 Hz output over exactly 32 seconds guarantees that the measure is within 0.477 ppm (0.5 RTCCLK cycles over 32 seconds, due to the limitation of the calibration resolution).

- CALW16 bit of the RTC_CALR register can be set to 1 to force a 16- second calibration cycle period.

In this case, the RTC precision can be measured during 16 seconds with a maximum error of 0.954 ppm (0.5 RTCCLK cycles over 16 seconds). However, since the calibration resolution is reduced, the long term RTC precision is also reduced to 0.954 ppm: CALM[0] bit is stuck at 0 when CALW16 is set to 1.

- CALW8 bit of the RTC_CALR register can be set to 1 to force a 8- second calibration cycle period.

In this case, the RTC precision can be measured during 8 seconds with a maximum error of 1.907 ppm (0.5 RTCCLK cycles over 8s). The long term RTC precision is also reduced to 1.907 ppm: CALM[1:0] bits are stuck at 00 when CALW8 is set to 1.

Re-calibration on-the-fly

The calibration register (RTC_CALR) can be updated on-the-fly while RTC_ISR/INITF=0, by using the follow process:

1. Poll the RTC_ISR/RECALPF (re-calibration pending flag).
2. If it is set to 0, write a new value to RTC_CALR, if necessary. RECALPF is then automatically set to 1
3. Within three ck_apre cycles after the write operation to RTC_CALR, the new calibration settings take effect.

For code example refer to the Appendix section [A.13.5: RTC calibration code example](#).

21.4.13 Time-stamp function

Time-stamp is enabled by setting the TSE bit of RTC_CR register to 1.

The calendar is saved in the time-stamp registers (RTC_TSSSR, RTC_TSTR, RTC_TSDR) when a time-stamp event is detected on the RTC_TS pin.

When a time-stamp event occurs, the time-stamp flag bit (TSF) in RTC_ISR register is set.

By setting the TSIE bit in the RTC_CR register, an interrupt is generated when a time-stamp event occurs.

If a new time-stamp event is detected while the time-stamp flag (TSF) is already set, the time-stamp overflow flag (TSOVF) flag is set and the time-stamp registers (RTC_TSTR and RTC_TSDR) maintain the results of the previous event.

Note: *TSF is set 2 ck_apre cycles after the time-stamp event occurs due to synchronization process.*

There is no delay in the setting of TSOVF. This means that if two time-stamp events are close together, TSOVF can be seen as '1' while TSF is still '0'. As a consequence, it is recommended to poll TSOVF only after TSF has been set.

Caution: If a time-stamp event occurs immediately after the TSF bit is supposed to be cleared, then both TSF and TSOVF bits are set. To avoid masking a time-stamp event occurring at the same moment, the application must not write '0' into TSF bit unless it has already read it to '1'.

Optionally, a tamper event can cause a time-stamp to be recorded. See the description of the TAMPTS control bit in [Section 21.7.15: RTC tamper and alternate function configuration register \(RTC_TAFCR\)](#).

21.4.14 Tamper detection

The RTC_TAMPx input events can be configured either for edge detection, or for level detection with filtering.

The tamper detection can be configured for the following purpose:

- generate an interrupt, capable to wakeup from Stop and Standby modes

Tamper detection initialization

Each input can be enabled by setting the corresponding TAMPxE bits to 1 in the RTC_TAFCR register.

Each RTC_TAMPx tamper detection input is associated with a flag TAMPxF in the RTC_ISR register.

The TAMPxF flag is asserted after the tamper event on the pin, with the latency provided below:

- 3 ck_apre cycles when TAMPFLT differs from 0x0 (Level detection with filtering)
- 3 ck_apre cycles when TAMPTS=1 (Timestamp on tamper event)
- No latency when TAMPFLT=0x0 (Edge detection) and TAMPTS=0

A new tamper occurring on the same pin during this period and as long as TAMPxF is set cannot be detected.

By setting the TAMPIE bit in the RTC_TAFCR register, an interrupt is generated when a tamper detection event occurs. .

Timestamp on tamper event

With TAMPTS set to '1', any tamper event causes a timestamp to occur. In this case, either the TSF bit or the TSOVF bit are set in RTC_ISR, in the same manner as if a normal timestamp event occurs. The affected tamper flag register TAMPxF is set at the same time that TSF or TSOVF is set.

Edge detection on tamper inputs

If the TAMPFLT bits are "00", the RTC_TAMPx pins generate tamper detection events when either a rising edge or a falling edge is observed depending on the corresponding TAMPxTRG bit. The internal pull-up resistors on the RTC_TAMPx inputs are deactivated when edge detection is selected.

Caution: To avoid losing tamper detection events, the signal used for edge detection is logically ANDed with the corresponding TAMPxE bit in order to detect a tamper detection event in case it occurs before the RTC_TAMPx pin is enabled.

- When TAMPxTRG = 0: if the RTC_TAMPx alternate function is already high before tamper detection is enabled (TAMPxE bit set to 1), a tamper event is detected as soon as the RTC_TAMPx input is enabled, even if there was no rising edge on the RTC_TAMPx input after TAMPxE was set.
- When TAMPxTRG = 1: if the RTC_TAMPx alternate function is already low before tamper detection is enabled, a tamper event is detected as soon as the RTC_TAMPx input is enabled (even if there was no falling edge on the RTC_TAMPx input after TAMPxE was set).

Level detection with filtering on RTC_TAMPx inputs

Level detection with filtering is performed by setting TAMPFLT to a non-zero value. A tamper detection event is generated when either 2, 4, or 8 (depending on TAMPFLT) consecutive samples are observed at the level designated by the TAMPxTRG bits.

The RTC_TAMPx inputs are precharged through the I/O internal pull-up resistance before its state is sampled, unless disabled by setting TAMPPUDIS to 1. The duration of the precharge is determined by the TAMPPRCH bits, allowing for larger capacitances on the RTC_TAMPx inputs.

The trade-off between tamper detection latency and power consumption through the pull-up can be optimized by using TAMPFREQ to determine the frequency of the sampling for level detection.

Note: Refer to the datasheets for the electrical characteristics of the pull-up resistors.

For code example refer to the Appendix sections: [A.13.6: RTC tamper and time stamp configuration code example](#) and [A.13.7: RTC tamper and time stamp code example](#).

21.4.15 Calibration clock output

When the COE bit is set to 1 in the RTC_CR register, a reference clock is provided on the RTC_CALIB device output.

If the COSEL bit in the RTC_CR register is reset and PREDIV_A = 0x7F, the RTC_CALIB frequency is $f_{\text{RTCCLK}}/64$. This corresponds to a calibration output at 512 Hz for an RTCCLK frequency at 32.768 kHz. The RTC_CALIB duty cycle is irregular: there is a light jitter on falling edges. It is therefore recommended to use rising edges.

When COSEL is set and "PREDIV_S+1" is a non-zero multiple of 256 (i.e: PREDIV_S[7:0] = 0xFF), the RTC_CALIB frequency is $f_{\text{RTCCLK}}/(256 * (\text{PREDIV\_A}+1))$. This corresponds to a calibration output at 1 Hz for prescaler default values (PREDIV_A = 0x7F, PREDIV_S = 0xFF), with an RTCCLK frequency at 32.768 kHz. The 1 Hz output is affected when a shift operation is on going and may toggle during the shift operation (SHPF=1).

Note: When the RTC_CALIB or RTC_ALARM output is selected, the RTC_OUT pin is automatically configured in output alternate function.

When COSEL bit is cleared, the RTC_CALIB output is the output of the 6th stage of the asynchronous prescaler.

When COSEL bit is set, the RTC_CALIB output is the output of the 8th stage of the synchronous prescaler.

For code example refer to the Appendix section [A.13.8: RTC clock output code example](#).

21.4.16 Alarm output

The OSEL[1:0] control bits in the RTC_CR register are used to activate the alarm alternate function output RTC_ALARM, and to select the function which is output. These functions reflect the contents of the corresponding flags in the RTC_ISR register.

The polarity of the output is determined by the POL control bit in RTC_CR so that the opposite of the selected flag bit is output when POL is set to 1.

Alarm alternate function output

The RTC_ALARM pin can be configured in output open drain or output push-pull using the control bit ALARMOUTTYPE in the RTC_TAFCR register.

Note: Once the RTC_ALARM output is enabled, it has priority over RTC_CALIB (COE bit is don't care and must be kept cleared).

When the RTC_CALIB or RTC_ALARM output is selected, the RTC_OUT pin is automatically configured in output alternate function.

21.5 RTC low-power modes

Table 66. Effect of low-power modes on RTC

Mode	Description
Sleep	No effect RTC interrupts cause the device to exit the Sleep mode.
Stop	The RTC remains active when the RTC clock source is LSE or LSI. RTC alarm, RTC tamper event, RTC timestamp event, and RTC Wakeup cause the device to exit the Stop mode.
Standby	The RTC remains active when the RTC clock source is LSE or LSI. RTC alarm, RTC tamper event, RTC timestamp event, and RTC Wakeup cause the device to exit the Standby mode.

21.6 RTC interrupts

All RTC interrupts are connected to the NVIC controller. Refer to .

To enable RTC interrupt(s), the following sequence is required:

1. Configure and enable the NVIC line(s) corresponding to the RTC event(s) in interrupt mode and select the rising edge sensitivity.
2. Configure and enable the RTC IRQ channel in the NVIC.
3. Configure the RTC to generate RTC interrupt(s).

Table 67. Interrupt control bits

Interrupt event	Event flag	Enable control bit	Exit the Sleep mode	Exit the Stop mode	Exit the Standby mode
Alarm A	ALRAF	ALRAIE	yes	yes ⁽¹⁾	yes ⁽¹⁾
RTC_TS input (timestamp)	TSF	TSIE	yes	yes ⁽¹⁾	yes ⁽¹⁾
RTC_TAMP1 input detection	TAMP1F	TAMPIE	yes	yes ⁽¹⁾	yes ⁽¹⁾
RTC_TAMP2 input detection	TAMP2F	TAMPIE	yes	yes ⁽¹⁾	yes ⁽¹⁾

1. Wakeup from STOP and Standby modes is possible only when the RTC clock source is LSE or LSI.

21.7 RTC registers

Refer to [Section 1.1 on page 33](#) of the reference manual for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by words (32-bit).

21.7.1 RTC time register (RTC_TR)

The RTC_TR is the calendar time shadow register. This register must be written in initialization mode only. Refer to [Calendar initialization and configuration on page 494](#) and [Reading the calendar on page 495](#).

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#).

Address offset: 0x00

RTC domain reset value: 0x0000 0000

System reset: 0x0000 0000 when BYPSHAD = 0. Not affected when BYPSHAD = 1.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PM	HT[1:0]		HU[3:0]			
									rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MNT[2:0]			MNU[3:0]				Res.	ST[2:0]			SU[3:0]			
	rw	rw	rw	rw	rw	rw	rw		rw	rw	rw	rw	rw	rw	rw

Bits 31-23 Reserved, must be kept at reset value

Bit 22 **PM**: AM/PM notation

0: AM or 24-hour format

1: PM

Bits 21:20 **HT[1:0]**: Hour tens in BCD format

Bits 19:16 **HU[3:0]**: Hour units in BCD format

Bit 15 Reserved, must be kept at reset value.

Bits 14:12 **MNT[2:0]**: Minute tens in BCD format

Bits 11:8 **MNU[3:0]**: Minute units in BCD format

Bit 7 Reserved, must be kept at reset value.

Bits 6:4 **ST[2:0]**: Second tens in BCD format

Bits 3:0 **SU[3:0]**: Second units in BCD format

21.7.2 RTC date register (RTC_DR)

The RTC_DR is the calendar date shadow register. This register must be written in initialization mode only. Refer to [Calendar initialization and configuration on page 494](#) and [Reading the calendar on page 495](#).

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#).

Address offset: 0x04

RTC domain reset value: 0x0000 2101

System reset: 0x0000 2101 when BYPSHAD = 0. Not affected when BYPSHAD = 1.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	YT[3:0]				YU[3:0]			
								rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
WDU[2:0]			MT	MU[3:0]				Res.	Res.	DT[1:0]		DU[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw			rw	rw	rw	rw	rw	rw

Bits 31:24 Reserved, must be kept at reset value

Bits 23:20 **YT[3:0]**: Year tens in BCD format

Bits 19:16 **YU[3:0]**: Year units in BCD format

Bits 15:13 **WDU[2:0]**: Week day units

000: forbidden

001: Monday

...

111: Sunday

Bit 12 **MT**: Month tens in BCD format

Bits 11:8 **MU**: Month units in BCD format

Bits 7:6 Reserved, must be kept at reset value.

Bits 5:4 **DT[1:0]**: Date tens in BCD format

Bits 3:0 **DU[3:0]**: Date units in BCD format

21.7.3 RTC control register (RTC_CR)

Address offset: 0x08

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	COE	OSEL[1:0]		POL	COSEL	BKP	SUB1H	ADD1H
								rw	rw	rw	rw	rw	rw	w	w
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TSIE	WUTIE	Res.	ALRAIE	TSE	WUTE	Res.	ALRAE	Res.	FMT	BYPH HAD	REFCKON	TSEDGE	WUCKSEL[2:0]		
rw	rw		rw	rw	rw		rw		rw	rw	rw	rw	rw	rw	rw

Bits 31:24 Reserved, must be kept at reset value.

Bit 23 **COE**: Calibration output enable

This bit enables the RTC_CALIB output

0: Calibration output disabled

1: Calibration output enabled

Bits 22:21 **OSEL[1:0]**: Output selection

These bits are used to select the flag to be routed to RTC_ALARM output

00: Output disabled

01: Alarm A output enabled

10: Reserved

11: Wakeup output enabled

Bit 20 **POL**: Output polarity

This bit is used to configure the polarity of RTC_ALARM output

0: The pin is high when ALRAF/WUTF is asserted (depending on OSEL[1:0])

1: The pin is low when ALRAF/WUTF is asserted (depending on OSEL[1:0]).

Bit 19 **COSEL**: Calibration output selection

When COE=1, this bit selects which signal is output on RTC_CALIB.

0: Calibration output is 512 Hz

1: Calibration output is 1 Hz

These frequencies are valid for RTCCLK at 32.768 kHz and prescalers at their default values (PREDIV_A=127 and PREDIV_S=255). Refer to [Section 21.4.15: Calibration clock output](#)

Bit 18 **BKP**: Backup

This bit can be written by the user to memorize whether the daylight saving time change has been performed or not.

Bit 17 **SUB1H**: Subtract 1 hour (winter time change)

When this bit is set, 1 hour is subtracted to the calendar time if the current hour is not 0. This bit is always read as 0.

Setting this bit has no effect when current hour is 0.

0: No effect

1: Subtracts 1 hour to the current time. This can be used for winter time change outside initialization mode.

- Bit 16 **ADD1H**: Add 1 hour (summer time change)
When this bit is set, 1 hour is added to the calendar time. This bit is always read as 0.
0: No effect
1: Adds 1 hour to the current time. This can be used for summer time change outside initialization mode.
- Bit 15 **TSIE**: Time-stamp interrupt enable
0: Time-stamp Interrupt disable
1: Time-stamp Interrupt enable
- Bit 14 **WUTIE**: Wakeup timer interrupt enable
0: Wakeup timer interrupt disabled
1: Wakeup timer interrupt enabled
- Bit 13 Reserved, must be kept at reset value
- Bit 12 **ALRAIE**: Alarm A interrupt enable
0: Alarm A interrupt disabled
1: Alarm A interrupt enabled
- Bit 11 **TSE**: timestamp enable
0: timestamp disable
1: timestamp enable
- Bit 10 **WUTE**: Wakeup timer enable
0: Wakeup timer disabled
1: Wakeup timer enabled
- Bit 9 Reserved, must be kept at reset value
- Bit 8 **ALRAE**: Alarm A enable
0: Alarm A disabled
1: Alarm A enabled
- Bit 7 Reserved, must be kept at reset value.
- Bit 6 **FMT**: Hour format
0: 24 hour/day format
1: AM/PM hour format
- Bit 5 **BYPHAD**: Bypass the shadow registers
0: Calendar values (when reading from RTC_SSR, RTC_TR, and RTC_DR) are taken from the shadow registers, which are updated once every two RTCCLK cycles.
1: Calendar values (when reading from RTC_SSR, RTC_TR, and RTC_DR) are taken directly from the calendar counters.
- Note: If the frequency of the APB clock is less than seven times the frequency of RTCCLK, BYPSHAD must be set to '1'.*

Bit 4 **REFCKON**: RTC_REFIN reference clock detection enable (50 or 60 Hz)

0: RTC_REFIN detection disabled

1: RTC_REFIN detection enabled

Note: PREDIV_S must be 0x00FF.

Bit 3 **TSEDGE**: Time-stamp event active edge

0: RTC_TS input rising edge generates a time-stamp event

1: RTC_TS input falling edge generates a time-stamp event

TSE must be reset when TSEDGE is changed to avoid unwanted TSF setting.

Bits 2:0 **WUCKSEL[2:0]**: Wakeup clock selection

000: RTC/16 clock is selected

001: RTC/8 clock is selected

010: RTC/4 clock is selected

011: RTC/2 clock is selected

10x: ck_spre (usually 1 Hz) clock is selected

11x: ck_spre (usually 1 Hz) clock is selected and 2^{16} is added to the WUT counter value
(see note below)

Note: Bits 7, 6 and 4 of this register can be written in initialization mode only (RTC_ISR/INITF = 1).

WUT = Wakeup unit counter value. WUT = (0x0000 to 0xFFFF) + 0x10000 added when WUCKSEL[2:1 = 11].

Bits 2 to 0 of this register can be written only when RTC_CR WUTE bit = 0 and RTC_ISR WUTWF bit = 1.

It is recommended not to change the hour during the calendar hour increment as it could mask the incrementation of the calendar hour.

ADD1H and SUB1H changes are effective in the next second.

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#).

Caution: TSE must be reset when TSEDGE is changed to avoid spuriously setting of TSF.

21.7.4 RTC initialization and status register (RTC_ISR)

This register is write protected (except for RTC_ISR[13:8] bits). The write access procedure is described in [RTC register write protection on page 494](#).

Address offset: 0x0C

RTC domain reset value: 0x0000 0007

System reset: not affected except INIT, INITF, and RSF bits which are cleared to '0'

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RECALPF
															r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	TAMP2F	TAMP1F	TSOVF	TSF	WUTF	Res.	ALRAF	INIT	INITF	RSF	INITS	SHPF	WUTWF	Res.	ALRAWF
	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0		rc_w0	rw	r	rc_w0	r	r	r		r

Bits 31:17 Reserved, must be kept at reset value

Bit 16 **RECALPF**: Recalibration pending Flag

The RECALPF status flag is automatically set to '1' when software writes to the RTC_CALR register, indicating that the RTC_CALR register is blocked. When the new calibration settings are taken into account, this bit returns to '0'. Refer to [Re-calibration on-the-fly](#).

Bit 15 Reserved, must be kept at reset value

Bit 14 **TAMP2F**: RTC_TAMP2 detection flag

This flag is set by hardware when a tamper detection event is detected on the RTC_TAMP2 input.

It is cleared by software writing 0

Bit 13 **TAMP1F**: RTC_TAMP1 detection flag

This flag is set by hardware when a tamper detection event is detected on the RTC_TAMP1 input.

It is cleared by software writing 0

Bit 12 **TSOVF**: Time-stamp overflow flag

This flag is set by hardware when a time-stamp event occurs while TSF is already set.

This flag is cleared by software by writing 0. It is recommended to check and then clear TSOVF only after clearing the TSF bit. Otherwise, an overflow might not be noticed if a time-stamp event occurs immediately before the TSF bit is cleared.

Bit 11 **TSF**: Time-stamp flag

This flag is set by hardware when a time-stamp event occurs.

This flag is cleared by software by writing 0.

Bit 10 **WUTF**: Wakeup timer flag

This flag is set by hardware when the wakeup auto-reload counter reaches 0.

This flag is cleared by software by writing 0.

This flag must be cleared by software at least 1.5 RTCCLK periods before WUTF is set to 1 again.

Bit 9 Reserved, must be kept at reset value.

- Bit 8 **ALRAF**: Alarm A flag
 This flag is set by hardware when the time/date registers (RTC_TR and RTC_DR) match the Alarm A register (RTC_ALRMAR).
 This flag is cleared by software by writing 0.
- Bit 7 **INIT**: Initialization mode
 0: Free running mode
 1: Initialization mode used to program time and date register (RTC_TR and RTC_DR), and prescaler register (RTC_PRER). Counters are stopped and start counting from the new value when INIT is reset.
- Bit 6 **INITF**: Initialization flag
 When this bit is set to 1, the RTC is in initialization state, and the time, date and prescaler registers can be updated.
 0: Calendar registers update is not allowed
 1: Calendar registers update is allowed
- Bit 5 **RSF**: Registers synchronization flag
 This bit is set by hardware each time the calendar registers are copied into the shadow registers (RTC_SSRx, RTC_TRx and RTC_DRx). This bit is cleared by hardware in initialization mode, while a shift operation is pending (SHPF=1), or when in bypass shadow register mode (BYPSHAD=1). This bit can also be cleared by software.
 It is cleared either by software or by hardware in initialization mode.
 0: Calendar shadow registers not yet synchronized
 1: Calendar shadow registers synchronized
- Bit 4 **INITS**: Initialization status flag
 This bit is set by hardware when the calendar year field is different from 0 (RTC domain reset state).
 0: Calendar has not been initialized
 1: Calendar has been initialized
- Bit 3 **SHPF**: Shift operation pending
 0: No shift operation is pending
 1: A shift operation is pending
 This flag is set by hardware as soon as a shift operation is initiated by a write to the RTC_SHIFTR register. It is cleared by hardware when the corresponding shift operation has been executed. Writing to the SHPF bit has no effect.
- Bit 2 **WUTWF**: Wakeup timer write flag
 This bit is set by hardware up to 2 RTCCLK cycles after the WUTE bit has been set to 0 in RTC_CR, and is cleared up to 2 RTCCLK cycles after the WUTE bit has been set to 1. The wakeup timer values can be changed when WUTE bit is cleared and WUTWF is set.
 0: Wakeup timer configuration update not allowed
 1: Wakeup timer configuration update allowed
- Bit 1 Reserved, must be kept at reset value.
- Bit 0 **ALRAWF**: Alarm A write flag
 This bit is set by hardware when Alarm A values can be changed, after the ALRAE bit has been set to 0 in RTC_CR.
 It is cleared by hardware in initialization mode.
 0: Alarm A update not allowed
 1: Alarm A update allowed

Note: The bits **ALRAF**, **WUTF** and **TSF** are cleared 2 APB clock cycles after programming them to 0.

21.7.5 RTC prescaler register (RTC_PRER)

This register must be written in initialization mode only. The initialization must be performed in two separate write accesses. Refer to [Calendar initialization and configuration on page 494](#).

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#).

Address offset: 0x10

RTC domain reset value: 0x007F 00FF

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PREDIV_A[6:0]						
									rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	PREDIV_S[14:0]														
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:23 Reserved, must be kept at reset value

Bits 22:16 **PREDIV_A[6:0]**: Asynchronous prescaler factor

This is the asynchronous division factor:

$ck_{apre} \text{ frequency} = RTCCLK \text{ frequency} / (PREDIV\_A + 1)$

Bit 15 Reserved, must be kept at reset value.

Bits 14:0 **PREDIV_S[14:0]**: Synchronous prescaler factor

This is the synchronous division factor:

$ck_{spre} \text{ frequency} = ck_{apre} \text{ frequency} / (PREDIV\_S + 1)$

21.7.6 RTC wakeup timer register (RTC_WUTR)

This register can be written only when WUTWF is set to 1 in RTC_ISR.

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#).

Address offset: 0x14

RTC domain reset value: 0x0000 FFFF

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
WUT[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value

Bits 15:0 **WUT[15:0]**: Wakeup auto-reload value bits

When the wakeup timer is enabled (WUTE set to 1), the WUTF flag is set every (WUT[15:0] + 1) ck_wut cycles. The ck_wut period is selected through WUCKSEL[2:0] bits of the RTC_CR register

When WUCKSEL[2] = 1, the wakeup timer becomes 17-bits and WUCKSEL[1] effectively becomes WUT[16] the most-significant bit to be reloaded into the timer.

The first assertion of WUTF occurs (WUT+1) ck_wut cycles after WUTE is set. Setting WUT[15:0] to 0x0000 with WUCKSEL[2:0] = 011 (RTCCLK/2) is forbidden.

21.7.7 RTC alarm A register (RTC_ALRMAR)

This register can be written only when ALRAWF is set to 1 in RTC_ISR, or in initialization mode.

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#).

Address offset: 0x1C

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
MSK4	WDSEL	DT[1:0]		DU[3:0]				MSK3	PM	HT[1:0]		HU[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
MSK2	MNT[2:0]			MNU[3:0]				MSK1	ST[2:0]			SU[3:0]			
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 31 **MSK4**: Alarm A date mask

- 0: Alarm A set if the date/day match
- 1: Date/day don't care in Alarm A comparison

Bit 30 **WDSEL**: Week day selection

- 0: DU[3:0] represents the date units
- 1: DU[3:0] represents the week day. DT[1:0] is don't care.

Bits 29:28 **DT[1:0]**: Date tens in BCD format.

Bits 27:24 **DU[3:0]**: Date units or day in BCD format.

Bit 23 **MSK3**: Alarm A hours mask

- 0: Alarm A set if the hours match
- 1: Hours don't care in Alarm A comparison

Bit 22 **PM**: AM/PM notation

- 0: AM or 24-hour format
- 1: PM

Bits 21:20 **HT[1:0]**: Hour tens in BCD format.

Bits 19:16 **HU[3:0]**: Hour units in BCD format.

Bit 15 **MSK2**: Alarm A minutes mask

- 0: Alarm A set if the minutes match
- 1: Minutes don't care in Alarm A comparison

Bits 14:12 **MNT[2:0]**: Minute tens in BCD format.

Bits 11:8 **MNU[3:0]**: Minute units in BCD format.

Bit 7 **MSK1**: Alarm A seconds mask

- 0: Alarm A set if the seconds match
- 1: Seconds don't care in Alarm A comparison

Bits 6:4 **ST[2:0]**: Second tens in BCD format.

Bits 3:0 **SU[3:0]**: Second units in BCD format.

21.7.8 RTC write protection register (RTC_WPR)

Address offset: 0x24

Reset value: 0x0000 0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	KEY							
								w	w	w	w	w	w	w	w

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **KEY**: Write protection key

This byte is written by software.

Reading this byte always returns 0x00.

Refer to [RTC register write protection](#) for a description of how to unlock RTC register write protection.

21.7.9 RTC sub second register (RTC_SSR)

Address offset: 0x28

RTC domain reset value: 0x0000 0000

System reset: 0x0000 0000 when BYPSHAD = 0. Not affected when BYPSHAD = 1.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SS[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits31:16 Reserved, must be kept at reset value

Bits 15:0 **SS**: Sub second value

SS[15:0] is the value in the synchronous prescaler counter. The fraction of a second is given by the formula below:

Second fraction = (PREDIV_S - SS) / (PREDIV_S + 1)

Note: SS can be larger than PREDIV_S only after a shift operation. In that case, the correct time/date is one second less than as indicated by RTC_TR/RTC_DR.

21.7.10 RTC shift control register (RTC_SHIFTR)

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#).

Address offset: 0x2C

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ADD1S	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
w															
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SUBFS[14:0]														
	w	w	w	w	w	w	w	w	w	w	w	w	w	w	w

Bit 31 **ADD1S**: Add one second

0: No effect

1: Add one second to the clock/calendar

This bit is write only and is always read as zero. Writing to this bit has no effect when a shift operation is pending (when SHPF=1, in RTC_ISR).

This function is intended to be used with SUBFS (see description below) in order to effectively add a fraction of a second to the clock in an atomic operation.

Bits 30:15 Reserved, must be kept at reset value

Bits 14:0 **SUBFS**: Subtract a fraction of a second

These bits are write only and is always read as zero. Writing to this bit has no effect when a shift operation is pending (when SHPF=1, in RTC_ISR).

The value which is written to SUBFS is added to the synchronous prescaler counter. Since this counter counts down, this operation effectively subtracts from (delays) the clock by:

Delay (seconds) = SUBFS / (PREDIV_S + 1)

A fraction of a second can effectively be added to the clock (advancing the clock) when the ADD1S function is used in conjunction with SUBFS, effectively advancing the clock by:

Advance (seconds) = (1 - (SUBFS / (PREDIV_S + 1))).

Note: Writing to SUBFS causes RSF to be cleared. Software can then wait until RSF=1 to be sure that the shadow registers have been updated with the shifted time.

21.7.11 RTC timestamp time register (RTC_TSTR)

The content of this register is valid only when TSF is set to 1 in RTC_ISR. It is cleared when TSF bit is reset.

Address offset: 0x30

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PM	HT[1:0]		HU[3:0]			
									r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	MNT[2:0]			MNU[3:0]				Res.	ST[2:0]			SU[3:0]			
	r	r	r	r	r	r	r		r	r	r	r	r	r	r

Bits 31:23 Reserved, must be kept at reset value

Bit 22 **PM**: AM/PM notation

0: AM or 24-hour format

1: PM

Bits 21:20 **HT[1:0]**: Hour tens in BCD format.

Bits 19:16 **HU[3:0]**: Hour units in BCD format.

Bit 15 Reserved, must be kept at reset value

Bits 14:12 **MNT[2:0]**: Minute tens in BCD format.

Bits 11:8 **MNU[3:0]**: Minute units in BCD format.

Bit 7 Reserved, must be kept at reset value

Bits 6:4 **ST[2:0]**: Second tens in BCD format.

Bits 3:0 **SU[3:0]**: Second units in BCD format.

21.7.12 RTC timestamp date register (RTC_TSDR)

The content of this register is valid only when TSF is set to 1 in RTC_ISR. It is cleared when TSF bit is reset.

Address offset: 0x34

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
WDU[1:0]			MT	MU[3:0]				Res.	Res.	DT[1:0]		DU[3:0]			
r	r	r	r	r	r	r	r			r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value

Bits 15:13 **WDU[1:0]**: Week day units

Bit 12 **MT**: Month tens in BCD format

Bits 11:8 **MU[3:0]**: Month units in BCD format

Bits 7:6 Reserved, must be kept at reset value

Bits 5:4 **DT[1:0]**: Date tens in BCD format

Bits 3:0 **DU[3:0]**: Date units in BCD format

21.7.13 RTC time-stamp sub second register (RTC_TSSSR)

The content of this register is valid only when RTC_ISR/TSF is set. It is cleared when the RTC_ISR/TSF bit is reset.

Address offset: 0x38

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SS[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 Reserved, must be kept at reset value

Bits 15:0 **SS**: Sub second value
SS[15:0] is the value of the synchronous prescaler counter when the timestamp event occurred.



21.7.14 RTC calibration register (RTC_CALR)

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#).

Address offset: 0x3C

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CALP	CALW8	CALW16	Res.	Res.	Res.	Res.	CALM[8:0]								
rw	rw	rw					rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value

Bit 15 **CALP**: Increase frequency of RTC by 488.5 ppm

0: No RTCCLK pulses are added.

1: One RTCCLK pulse is effectively inserted every 2^{11} pulses (frequency increased by 488.5 ppm).

This feature is intended to be used in conjunction with CALM, which lowers the frequency of the calendar with a fine resolution. If the input frequency is 32768 Hz, the number of RTCCLK pulses added during a 32-second window is calculated as follows: $(512 * CALP) - CALM$.

Refer to [Section 21.4.12: RTC smooth digital calibration](#).

Bit 14 **CALW8**: Use an 8-second calibration cycle period

When CALW8 is set to '1', the 8-second calibration cycle period is selected.

Note: *CALM[1:0] are stuck at "00" when CALW8='1'. Refer to [Section 21.4.12: RTC smooth digital calibration](#).*

Bit 13 **CALW16**: Use a 16-second calibration cycle period

When CALW16 is set to '1', the 16-second calibration cycle period is selected. This bit must not be set to '1' if CALW8=1.

Note: *CALM[0] is stuck at '0' when CALW16='1'. Refer to [Section 21.4.12: RTC smooth digital calibration](#).*

Bits 12:9 Reserved, must be kept at reset value

Bits 8:0 **CALM[8:0]**: Calibration minus

The frequency of the calendar is reduced by masking CALM out of 2^{20} RTCCLK pulses (32 seconds if the input frequency is 32768 Hz). This decreases the frequency of the calendar with a resolution of 0.9537 ppm.

To increase the frequency of the calendar, this feature should be used in conjunction with CALP. See [Section 21.4.12: RTC smooth digital calibration on page 498](#).

21.7.15 RTC tamper and alternate function configuration register (RTC_TAFCR)

Address offset: 0x40

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PC15 MODE	PC15 VALUE	PC14 MODE	PC14 VALUE	PC13 MODE	PC13 VALUE	Res.	Res.
								rw	rw	rw	rw	rw	rw		
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TAMPP UDIS	TAMPPRCH [1:0]		TAMPFLT[1:0]		TAMPFREQ[2:0]			TAMPT S	Res.	Res.	TAMP2 TRG	TAMP2 E	TAMPIE	TAMP1 TRG	TAMP1 E
rw	rw	rw	rw	rw	rw	rw	rw	rw			rw	rw	rw	rw	rw

Bits 31:24 Reserved, must be kept at reset value.

Bit 23 **PC15MODE**: PC15 mode

0: PC15 is controlled by the GPIO configuration registers. Consequently PC15 is floating in Standby mode.

1: PC15 is forced to push-pull output if LSE is disabled.

Bit 22 **PC15VALUE**: PC15 value

If the LSE is disabled and PC15MODE = 1, PC15VALUE configures the PC15 output data.

Bit 21 **PC14MODE**: PC14 mode

0: PC14 is controlled by the GPIO configuration registers. Consequently PC14 is floating in Standby mode.

1: PC14 is forced to push-pull output if LSE is disabled.

Bit 20 **PC14VALUE**: PC14 value

If the LSE is disabled and PC14MODE = 1, PC14VALUE configures the PC14 output data.

Bit 19 **PC13MODE**: PC13 mode

0: PC13 is controlled by the GPIO configuration registers. Consequently PC13 is floating in Standby mode.

1: PC13 is forced to push-pull output if all RTC alternate functions are disabled.

Bit 18 **PC13VALUE**: RTC_ALARM output type/PC13 value

If PC13 is used to output RTC_ALARM, PC13VALUE configures the output configuration:

0: RTC_ALARM is an open-drain output

1: RTC_ALARM is a push-pull output

If all RTC alternate functions are disabled and PC13MODE = 1, PC13VALUE configures the PC13 output data.

Bits 17:16 Reserved, must be kept at reset value.

Bit 15 **TAMPPUDIS**: RTC_TAMPx pull-up disable

This bit determines if each of the RTC_TAMPx pins are pre-charged before each sample.

0: Precharge RTC_TAMPx pins before sampling (enable internal pull-up)

1: Disable precharge of RTC_TAMPx pins.

Bits 14:13 **TAMPPRCH[1:0]**: RTC_TAMPx precharge duration

These bits determine the duration of time during which the pull-up is activated before each sample. TAMPPRCH is valid for each of the RTC_TAMPx inputs.

- 0x0: 1 RTCCLK cycle
- 0x1: 2 RTCCLK cycles
- 0x2: 4 RTCCLK cycles
- 0x3: 8 RTCCLK cycles

Bits 12:11 **TAMPFLT[1:0]**: RTC_TAMPx filter count

These bits determine the number of consecutive samples at the specified level (TAMP*TRG) needed to activate a Tamper event. TAMPFLT is valid for each of the RTC_TAMPx inputs.

- 0x0: Tamper event is activated on edge of RTC_TAMPx input transitions to the active level (no internal pull-up on RTC_TAMPx input).
- 0x1: Tamper event is activated after 2 consecutive samples at the active level.
- 0x2: Tamper event is activated after 4 consecutive samples at the active level.
- 0x3: Tamper event is activated after 8 consecutive samples at the active level.

Bits 10:8 **TAMPFREQ[2:0]**: Tamper sampling frequency

Determines the frequency at which each of the RTC_TAMPx inputs are sampled.

- 0x0: RTCCLK / 32768 (1 Hz when RTCCLK = 32768 Hz)
- 0x1: RTCCLK / 16384 (2 Hz when RTCCLK = 32768 Hz)
- 0x2: RTCCLK / 8192 (4 Hz when RTCCLK = 32768 Hz)
- 0x3: RTCCLK / 4096 (8 Hz when RTCCLK = 32768 Hz)
- 0x4: RTCCLK / 2048 (16 Hz when RTCCLK = 32768 Hz)
- 0x5: RTCCLK / 1024 (32 Hz when RTCCLK = 32768 Hz)
- 0x6: RTCCLK / 512 (64 Hz when RTCCLK = 32768 Hz)
- 0x7: RTCCLK / 256 (128 Hz when RTCCLK = 32768 Hz)

Bit 7 **TAMPTS**: Activate timestamp on tamper detection event

- 0: Tamper detection event does not cause a timestamp to be saved
- 1: Save timestamp on tamper detection event

TAMPTS is valid even if TSE=0 in the RTC_CR register.

Bits 6:5 Reserved, must be kept at reset value.

Bit 4 **TAMP2TRG**: Active level for RTC_TAMP2 input

- if TAMPFLT != 00:
 - 0: RTC_TAMP2 input staying low triggers a tamper detection event.
 - 1: RTC_TAMP2 input staying high triggers a tamper detection event.
- if TAMPFLT = 00:
 - 0: RTC_TAMP2 input rising edge triggers a tamper detection event.
 - 1: RTC_TAMP2 input falling edge triggers a tamper detection event.

Bit 3 **TAMP2E**: RTC_TAMP2 input detection enable

- 0: RTC_TAMP2 detection disabled
- 1: RTC_TAMP2 detection enabled

Bit 2 **TAMPIE**: Tamper interrupt enable

0: Tamper interrupt disabled

1: Tamper interrupt enabled.

Bit 1 **TAMP1TRG**: Active level for RTC_TAMP1 input

If TAMPFLT != 00

0: RTC_TAMP1 input staying low triggers a tamper detection event.

1: RTC_TAMP1 input staying high triggers a tamper detection event.

if TAMPFLT = 00:

0: RTC_TAMP1 input rising edge triggers a tamper detection event.

1: RTC_TAMP1 input falling edge triggers a tamper detection event.

Bit 0 **TAMP1E**: RTC_TAMP1 input detection enable

0: RTC_TAMP1 detection disabled

1: RTC_TAMP1 detection enabled

Caution: When TAMPFLT = 0, TAMPxE must be reset when TAMPxTRG is changed to avoid spuriously setting TAMPxF.

21.7.16 RTC alarm A sub second register (RTC_ALRMASR)

This register can be written only when ALRAE is reset in RTC_CR register, or in initialization mode.

This register is write protected. The write access procedure is described in [RTC register write protection on page 494](#)

Address offset: 0x44

RTC domain reset value: 0x0000 0000

System reset: not affected

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	MASKSS[3:0]				Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
				rw	rw	rw	rw								
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	SS[14:0]														
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	w	rw	rw

Bits 31:28 Reserved, must be kept at reset value.

Bits 27:24 MASKSS[3:0]: Mask the most-significant bits starting at this bit

0: No comparison on sub seconds for Alarm A. The alarm is set when the seconds unit is incremented (assuming that the rest of the fields match).

1: SS[14:1] are don't care in Alarm A comparison. Only SS[0] is compared.

2: SS[14:2] are don't care in Alarm A comparison. Only SS[1:0] are compared.

3: SS[14:3] are don't care in Alarm A comparison. Only SS[2:0] are compared.

...

12: SS[14:12] are don't care in Alarm A comparison. SS[11:0] are compared.

13: SS[14:13] are don't care in Alarm A comparison. SS[12:0] are compared.

14: SS[14] is don't care in Alarm A comparison. SS[13:0] are compared.

15: All 15 SS bits are compared and must match to activate alarm.

The overflow bits of the synchronous counter (bits 15) is never compared. This bit can be different from 0 only after a shift operation.

Bits 23:15 Reserved, must be kept at reset value.

Bits 14:0 SS[14:0]: Sub seconds value

This value is compared with the contents of the synchronous prescaler counter to determine if Alarm A is to be activated. Only bits 0 up MASKSS-1 are compared.

21.7.17 RTC register map

Table 68. RTC register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	RTC_TR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PM	HT [1:0]	HU[3:0]				Res.	MNT[2:0]			MNU[3:0]			Res.	ST[2:0]			SU[3:0]					
	Reset value										0	0	0	0	0	0	0		0	0	0	0	0	0	0	0		0	0	0	0	0	0
0x04	RTC_DR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	YT[3:0]				YU[3:0]				WDU[2:0]			MT	MU[3:0]			Res.	Res.	DT [1:0]		DU[3:0]				
	Reset value										0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1			0	0	0	0

Table 68. RTC register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x08	RTC_CR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	COE	OSE L[1:0]	POL	COSEL	BKP	SUB1H	ADD1H	TSIE	WUTIE	Res.	ALRAIE	TSE	WUTE	Res.	ALRAE	Res.	FMT	BYPHAD	REFCKON	TSEDGE	WUCKSEL[2:0]			
	Reset value									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x0C	RTC_ISR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RECALPF	TAMP2F	TAMP1F	TSOVF	TSF	WUTF	Res.	ALRAF	INIT	INITF	RSF	INITS	SHPF	WUTWF	Res.	ALRAWF		
	Reset value															0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1		1
0x10	RTC_PRER	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PREDIV_A[6:0]						PREDIV_S[14:0]																	
	Reset value									1	1	1	1	1	1	1	0	0	0	0	0	0	0	0	0	1	1	1	1	1	1	1	1
0x14	RTC_WUTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	WUT[15:0]																
	Reset value																1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	
0x1C	RTC_ALRMAR	MSK4	WDSEL	DT [1:0]	DU[3:0]			MSK3	PM	HT [1:0]	HU[3:0]			MSK2	MNT[2:0]		MNU[3:0]		MSK1	ST[2:0]		SU[3:0]											
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x24	RTC_WPR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	KEY									
	Reset value																							0	0	0	0	0	0	0	0	0	
0x28	RTC_SSR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SS[15:0]																
	Reset value																0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x2C	RTC_SHIFTR	ADD1S	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SUBFS[14:0]															
	Reset value	0																0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x30	RTC_TSTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PM	HT[1:0]	HU[3:0]			Res.	MNT[2:0]		MNU[3:0]		Res.	ST[2:0]		SU[3:0]										
	Reset value									0	0	0	0	0	0	0		0	0	0	0	0	0	0		0	0	0	0	0	0	0	
0x34	RTC_TSDR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	WDU[1:0]	MT	MU[3:0]		Res.	Res.	DT [1:0]	DU[3:0]									
	Reset value																0	0	0	0	0	0	0	0			0	0	0	0	0	0	
0x38	RTC_TSSSR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SS[15:0]																
	Reset value																0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x3C	RTC_CALR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CALP	CALW8	CALW16	Res.	Res.	Res.	Res.	CALM[8:0]									
	Reset value																0	0	0					0	0	0	0	0	0	0	0	0	
0x40	RTC_TAFCR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PC15MODE	PC15MODE	PC14VALUE	PC14MODE	PC13VALUE	PC13VALUE	Res.	Res.	TAMPPUDIS	TAMPPRCH[1:0]		TAMPFLT[1:0]		TAMPFREQ[2:0]		TAMPTS	Res.	Res.	TAMP2TRG	TAMP2E	TAMPIE	TAMP1TRG	TAMP1E	
	Reset value									0	0	0	0	0	0			0	0	0	0	0	0	0	0			0	0	0	0	0	

Table 68. RTC register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x44	RTC_ALRMASSR	Res.	Res.	Res.	Res.	MASKSS [3:0]				Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	SS[14:0]														
	Reset value					0	0	0	0										0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

22 Inter-integrated circuit (I2C) interface

22.1 Introduction

The I²C (inter-integrated circuit) bus interface handles communications between the microcontroller and the serial I²C bus. It provides multimaster capability, and controls all I²C bus-specific sequencing, protocol, arbitration and timing. It supports Standard-mode (Sm), Fast-mode (Fm) and Fast-mode Plus (Fm+).

It is also SMBus (system management bus) and PMBus (power management bus) compatible.

DMA can be used to reduce CPU overload.

22.2 I2C main features

- I²C bus specification rev03 compatibility:
 - Slave and master modes
 - Multimaster capability
 - Standard-mode (up to 100 kHz)
 - Fast-mode (up to 400 kHz)
 - Fast-mode Plus (up to 1 MHz)
 - 7-bit and 10-bit addressing mode
 - Multiple 7-bit slave addresses (2 addresses, 1 with configurable mask)
 - All 7-bit addresses acknowledge mode
 - General call
 - Programmable setup and hold times
 - Easy to use event management
 - Optional clock stretching
 - Software reset
- 1-byte buffer with DMA capability
- Programmable analog and digital noise filters

The following additional features are also available depending on the product implementation (see [Section 22.3: I2C implementation](#)):

- SMBus specification rev 2.0 compatibility:
 - Hardware PEC (Packet Error Checking) generation and verification with ACK control
 - Command and data acknowledge control
 - Address resolution protocol (ARP) support
 - Host and Device support
 - SMBus alert
 - Timeouts and idle condition detection
- PMBus rev 1.1 standard compatibility
- Independent clock: a choice of independent clock sources allowing the I2C communication speed to be independent from the PCLK reprogramming

22.3 I2C implementation

This manual describes the full set of features implemented in I2C1. I2C2 supports a smaller set of features, but is otherwise identical to I2C1. The differences are listed below.

Table 69. STM32F0x0 I2C implementation

I2C features ⁽¹⁾	STM32F030x4, STM32F030x6, STM32F070x6	STM32F030x8		STM32F070xB STM32F030xC	
	I2C1	I2C1	I2C2	I2C1	I2C2
7-bit addressing mode	X	X	X	X	X
10-bit addressing mode	X	X	X	X	X
Standard mode (up to 100 kbit/s)	X	X	X	X	X
Fast mode (up to 400 kbit/s)	X	X	X	X	X
Independent clock	X	X	-	X	-
SMBus	X	X	-	X	-
Wakeup from Stop mode	-	-	-	-	-
Fast Mode Plus with extra output drive I/Os (up to 1 Mbit/s)	X	X	-	X	-

1. X = supported.

22.4 I2C functional description

In addition to receiving and transmitting data, this interface converts it from serial to parallel format and vice versa. The interrupts are enabled or disabled by software. The interface is connected to the I²C bus by a data pin (SDA) and by a clock pin (SCL). It can be connected with a standard (up to 100 kHz), Fast-mode (up to 400 kHz) or Fast-mode Plus (up to 1 MHz) I²C bus.

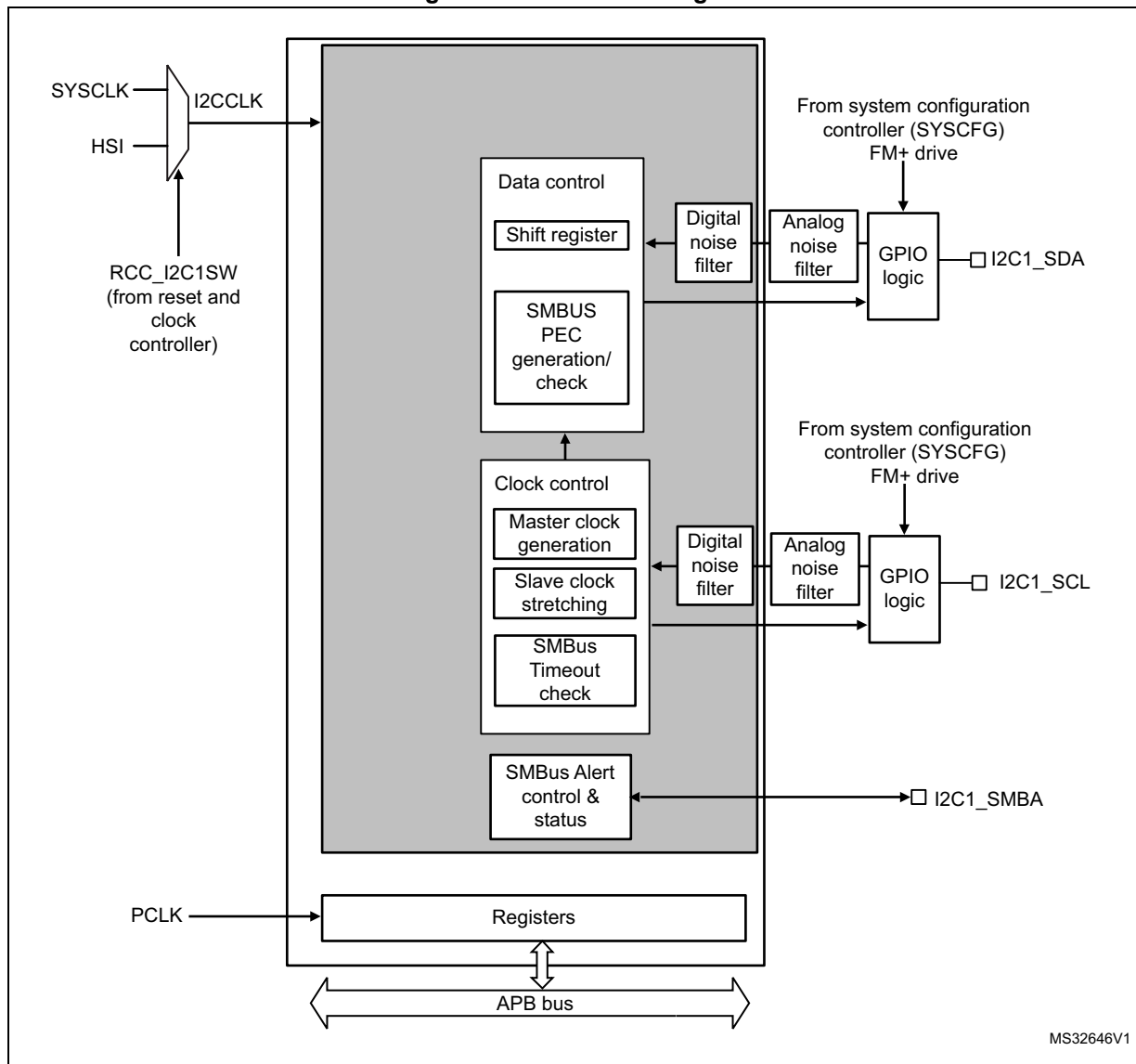
This interface can also be connected to a SMBus with the data pin (SDA) and clock pin (SCL).

If SMBus feature is supported: the additional optional SMBus Alert pin (SMBA) is also available.

22.4.1 I2C block diagram

The block diagram of the I2C interface is shown in [Figure 194](#).

Figure 194. I2C block diagram



The I2C is clocked by an independent clock source which allows to the I2C to operate independently from the PCLK frequency.

This independent clock source can be selected for either of the following clock sources:

- SYSCLK: system clock

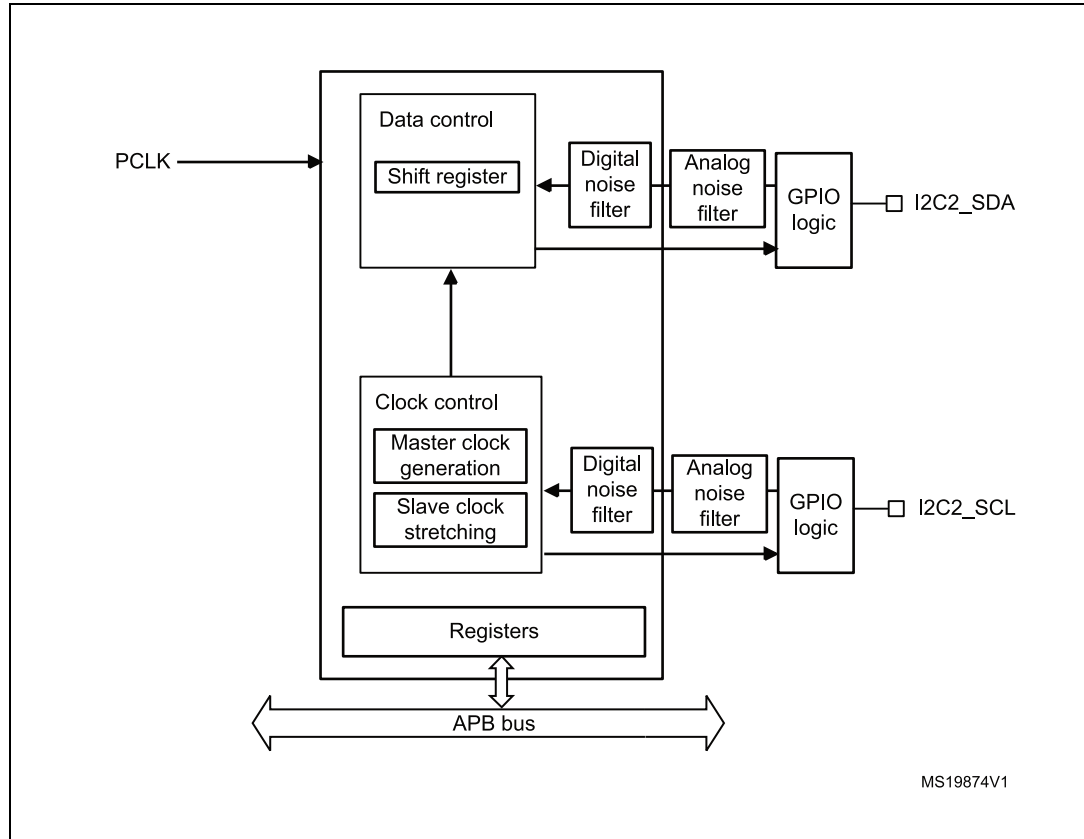
Refer to for more details.

I2C I/Os support 20 mA output current drive for Fast-mode Plus operation. This is enabled by setting the driving capability control bits for SCL and SDA in

22.4.2 I2C2 block diagram

The block diagram of the I2C2 interface is shown in [Figure 195](#).

Figure 195. I2C2 block diagram



22.4.3 I2C clock requirements

The I2C kernel is clocked by I2CCLK.

The I2CCLK period t_{I2CCLK} must respect the following conditions:

$$t_{I2CCLK} < (t_{LOW} - t_{filters}) / 4 \text{ and } t_{I2CCLK} < t_{HIGH}$$

with:

t_{LOW} : SCL low time and t_{HIGH} : SCL high time

$t_{filters}$: when enabled, sum of the delays brought by the analog filter and by the digital filter.

Analog filter delay is maximum 260 ns. Digital filter delay is $DNF \times t_{I2CCLK}$.

The PCLK clock period t_{PCLK} must respect the following condition:

$$t_{PCLK} < 4/3 t_{SCL}$$

with t_{SCL} : SCL period

Caution: When the I2C kernel is clocked by PCLK. PCLK must respect the conditions for t_{I2CCLK} .

22.4.4 Mode selection

The interface can operate in one of the four following modes:

- Slave transmitter
- Slave receiver
- Master transmitter
- Master receiver

By default, it operates in slave mode. The interface automatically switches from slave to master when it generates a START condition, and from master to slave if an arbitration loss or a STOP generation occurs, allowing multimaster capability.

Communication flow

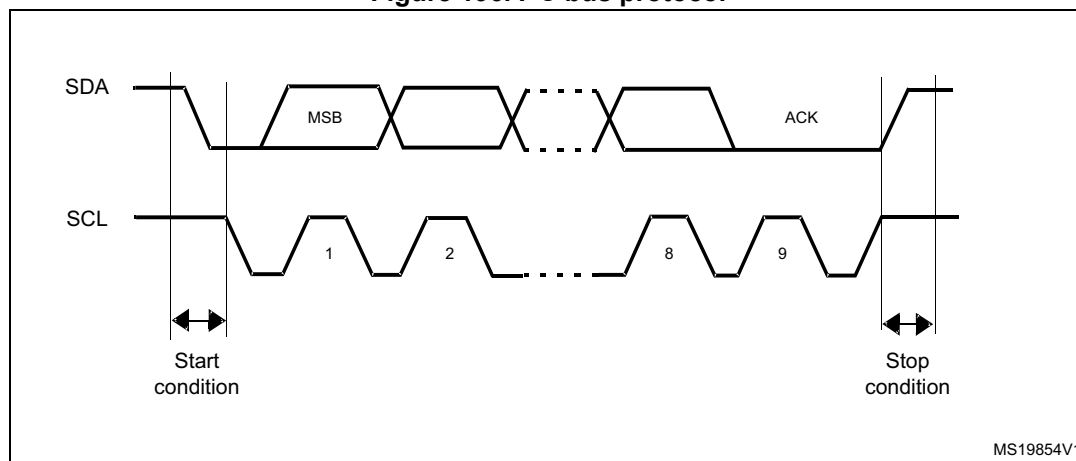
In Master mode, the I2C interface initiates a data transfer and generates the clock signal. A serial data transfer always begins with a START condition and ends with a STOP condition. Both START and STOP conditions are generated in master mode by software.

In Slave mode, the interface is capable of recognizing its own addresses (7 or 10-bit), and the General Call address. The General Call address detection can be enabled or disabled by software. The reserved SMBus addresses can also be enabled by software.

Data and addresses are transferred as 8-bit bytes, MSB first. The first byte(s) following the START condition contain the address (one in 7-bit mode, two in 10-bit mode). The address is always transmitted in Master mode.

A 9th clock pulse follows the 8 clock cycles of a byte transfer, during which the receiver must send an acknowledge bit to the transmitter. Refer to the following figure.

Figure 196. I²C bus protocol



Acknowledge can be enabled or disabled by software. The I2C interface addresses can be selected by software.

22.4.5 I2C initialization

Enabling and disabling the peripheral

The I2C peripheral clock must be configured and enabled in the clock controller (refer to).

Then the I2C can be enabled by setting the PE bit in the I2C_CR1 register.

When the I2C is disabled (PE=0), the I²C performs a software reset. Refer to [Section 22.4.6: Software reset](#) for more details.

Noise filters

Before enabling the I2C peripheral by setting the PE bit in I2C_CR1 register, the user must configure the noise filters, if needed. By default, an analog noise filter is present on the SDA and SCL inputs. This analog filter is compliant with the I²C specification which requires the suppression of spikes with a pulse width up to 50 ns in Fast-mode and Fast-mode Plus. The user can disable this analog filter by setting the ANFOFF bit, and/or select a digital filter by configuring the DNF[3:0] bit in the I2C_CR1 register.

When the digital filter is enabled, the level of the SCL or the SDA line is internally changed only if it remains stable for more than DNF x I2CCLK periods. This allows to suppress spikes with a programmable length of 1 to 15 I2CCLK periods.

Table 70. Comparison of analog vs. digital filters

	Analog filter	Digital filter
Pulse width of suppressed spikes	≥ 50 ns	Programmable length from 1 to 15 I2C peripheral clocks

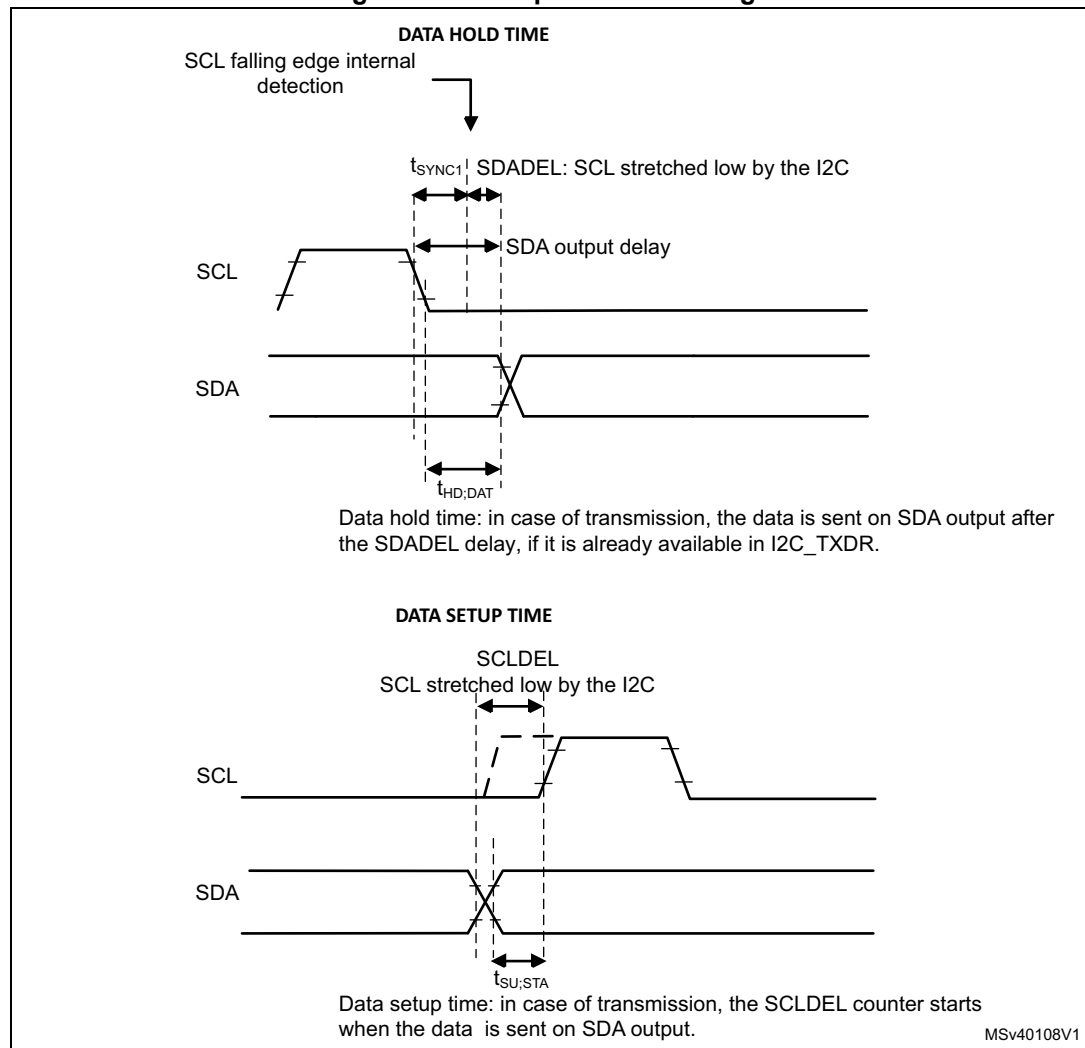
Caution: Changing the filter configuration is not allowed when the I2C is enabled.

I2C timings

The timings must be configured in order to guarantee a correct data hold and setup time, used in master and slave modes. This is done by programming the PRESC[3:0], SCLDEL[3:0] and SDADEL[3:0] bits in the I2C_TIMINGR register.

The STM32CubeMX tool calculates and provides the I2C_TIMINGR content in the I2C configuration window

Figure 197. Setup and hold timings



- When the SCL falling edge is internally detected, a delay is inserted before sending SDA output. This delay is $t_{SDADEL} = SDADEL \times t_{PRESC} + t_{I2CCLK}$ where $t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$.
 t_{SDADEL} impacts the hold time $t_{HD;DAT}$.

The total SDA output delay is:

$$t_{SYNC1} + \{[SDADEL \times (PRESC+1) + 1] \times t_{I2CCLK}\}$$

t_{SYNC1} duration depends on these parameters:

- SCL falling slope
- When enabled, input delay brought by the analog filter: $t_{AF(min)} < t_{AF} < t_{AF(max)}$ ns.
- When enabled, input delay brought by the digital filter: $t_{DNF} = DNF \times t_{I2CCLK}$
- Delay due to SCL synchronization to I2CCLK clock (2 to 3 I2CCLK periods)

In order to bridge the undefined region of the SCL falling edge, the user must program SDADEL in such a way that:

$$\{t_f(max) + t_{HD;DAT(min)} - t_{AF(min)} - [(DNF+3) \times t_{I2CCLK}]\} / \{(PRESC+1) \times t_{I2CCLK}\} \leq SDADEL$$

$$SDADEL \leq \{t_{HD;DAT(max)} - t_{AF(max)} - [(DNF+4) \times t_{I2CCLK}]\} / \{(PRESC+1) \times t_{I2CCLK}\}$$

Note: $t_{AF(min)} / t_{AF(max)}$ are part of the equation only when the analog filter is enabled. Refer to device datasheet for t_{AF} values.

The maximum $t_{HD;DAT}$ could be 3.45 μ s, 0.9 μ s and 0.45 μ s for Standard-mode, Fast-mode and Fast-mode Plus, but must be less than the maximum of $t_{VD;DAT}$ by a transition time. This maximum must only be met if the device does not stretch the LOW period (t_{LOW}) of the SCL signal. If the clock stretches the SCL, the data must be valid by the set-up time before it releases the clock.

The SDA rising edge is usually the worst case, so in this case the previous equation becomes:

$$SDADEL \leq \{t_{VD;DAT(max)} - t_r(max) - 260\text{ ns} - [(DNF+4) \times t_{I2CCLK}]\} / \{(PRESC+1) \times t_{I2CCLK}\}.$$

Note: This condition can be violated when NOSTRETCH=0, because the device stretches SCL low to guarantee the set-up time, according to the SCLDEL value.

Refer to [Table 71: I2C-SMBUS specification data setup and hold times](#) for t_f , t_r , $t_{HD;DAT}$ and $t_{VD;DAT}$ standard values.

- After t_{SDADEL} delay, or after sending SDA output in case the slave had to stretch the clock because the data was not yet written in I2C_TXDR register, SCL line is kept at low level during the setup time. This setup time is $t_{SCLDEL} = (SCLDEL+1) \times t_{PRESC}$ where $t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$.
 t_{SCLDEL} impacts the setup time $t_{SU;DAT}$.

In order to bridge the undefined region of the SDA transition (rising edge usually worst case), the user must program SCLDEL in such a way that:

$$\{[t_r(max) + t_{SU;DAT(min)}] / [(PRESC+1) \times t_{I2CCLK}]\} - 1 \leq SCLDEL$$

Refer to [Table 71: I2C-SMBUS specification data setup and hold times](#) for t_r and $t_{SU;DAT}$ standard values.

The SDA and SCL transition time values to be used are the ones in the application. Using the maximum values from the standard increases the constraints for the SDADEL and SCLDEL calculation, but ensures the feature whatever the application.

Note: At every clock pulse, after SCL falling edge detection, the I2C master or slave stretches SCL low during at least $[(SDADEL+SCLDEL+1) \times (PRESC+1) + 1] \times t_{I2CCLK}$, in both transmission and reception modes. In transmission mode, in case the data is not yet written in I2C_TXDR when SDADEL counter is finished, the I2C keeps on stretching SCL low until the next data is written. Then new data MSB is sent on SDA output, and SCLDEL counter starts, continuing stretching SCL low to guarantee the data setup time.

If NOSTRETCH=1 in slave mode, the SCL is not stretched. Consequently the SDADEL must be programmed in such a way to guarantee also a sufficient setup time.

Table 71. I²C-SMBUS specification data setup and hold times

Symbol	Parameter	Standard-mode (Sm)		Fast-mode (Fm)		Fast-mode Plus (Fm+)		SMBUS		Unit
		Min.	Max	Min.	Max	Min.	Max	Min.	Max	
$t_{HD;DAT}$	Data hold time	0	-	0	-	0	-	0.3	-	μs
$t_{VD;DAT}$	Data valid time	-	3.45	-	0.9	-	0.45	-	-	
$t_{SU;DAT}$	Data setup time	250	-	100	-	50	-	250	-	ns
t_r	Rise time of both SDA and SCL signals	-	1000	-	300	-	120	-	1000	
t_f	Fall time of both SDA and SCL signals	-	300	-	300	-	120	-	300	

Additionally, in master mode, the SCL clock high and low levels must be configured by programming the PRESC[3:0], SCLH[7:0] and SCLL[7:0] bits in the I2C_TIMINGR register.

- When the SCL falling edge is internally detected, a delay is inserted before releasing the SCL output. This delay is $t_{SCLL} = (SCLL+1) \times t_{PRESC}$ where $t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$. t_{SCLL} impacts the SCL low time t_{LOW} .
- When the SCL rising edge is internally detected, a delay is inserted before forcing the SCL output to low level. This delay is $t_{SCLH} = (SCLH+1) \times t_{PRESC}$ where $t_{PRESC} = (PRESC+1) \times t_{I2CCLK}$. t_{SCLH} impacts the SCL high time t_{HIGH} .

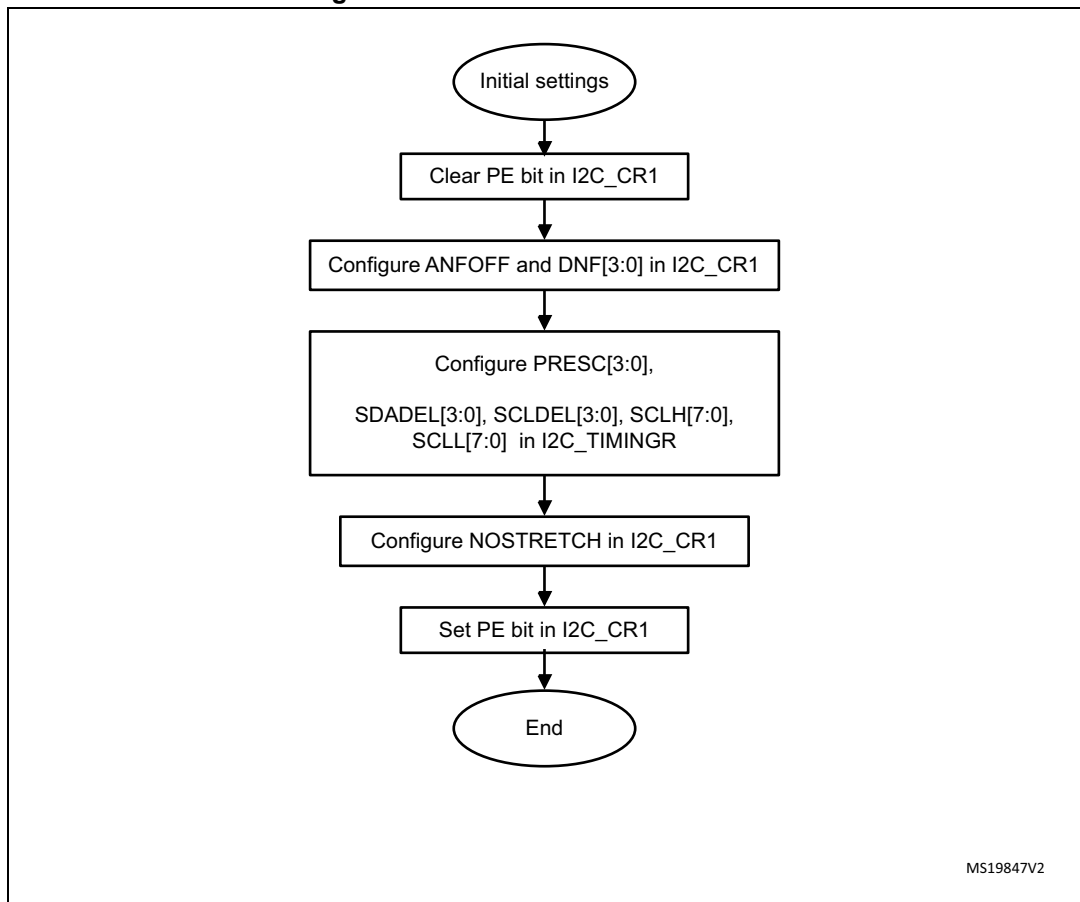
Refer to [I2C master initialization](#) for more details.

Caution: Changing the timing configuration is not allowed when the I2C is enabled.

The I2C slave NOSTRETCH mode must also be configured before enabling the peripheral. Refer to [I2C slave initialization](#) for more details.

Caution: Changing the NOSTRETCH configuration is not allowed when the I2C is enabled.

Figure 198. I2C initialization flowchart



22.4.6 Software reset

A software reset can be performed by clearing the PE bit in the I2C_CR1 register. In that case I2C lines SCL and SDA are released. Internal states machines are reset and communication control bits, as well as status bits come back to their reset value. The configuration registers are not impacted.

Here is the list of impacted register bits:

1. I2C_CR2 register: START, STOP, NACK
2. I2C_ISR register: BUSY, TXE, TXIS, RXNE, ADDR, NACKF, TCR, TC, STOPF, BERR, ARLO, OVR

and in addition when the SMBus feature is supported:

1. I2C_CR2 register: PECBYTE
2. I2C_ISR register: PECERR, TIMEOUT, ALERT

PE must be kept low during at least 3 APB clock cycles in order to perform the software reset. This is ensured by writing the following software sequence: - Write PE=0 - Check PE=0 - Write PE=1.

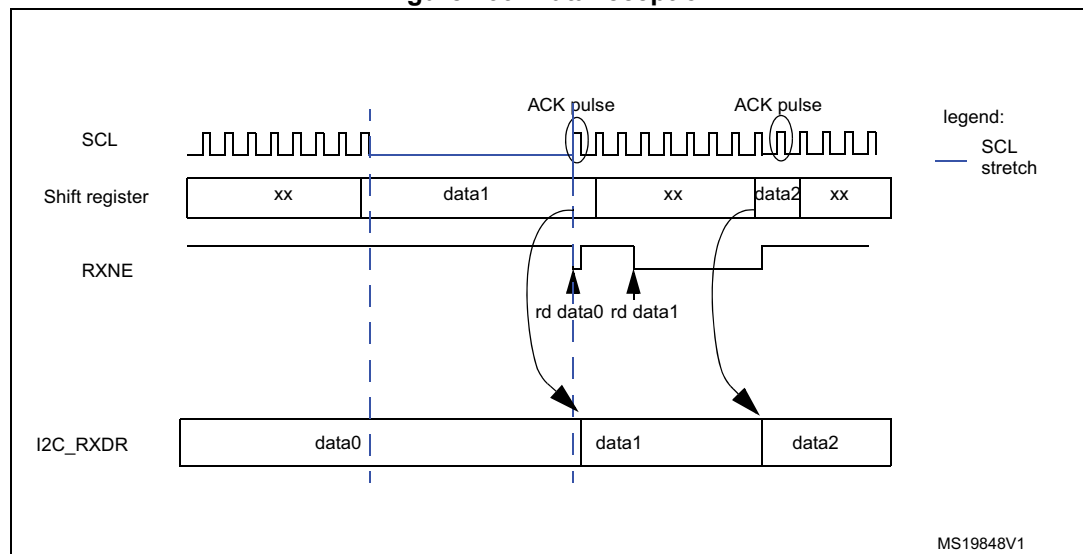
22.4.7 Data transfer

The data transfer is managed through transmit and receive data registers and a shift register.

Reception

The SDA input fills the shift register. After the 8th SCL pulse (when the complete data byte is received), the shift register is copied into I2C_RXDR register if it is empty (RXNE=0). If RXNE=1, meaning that the previous received data byte has not yet been read, the SCL line is stretched low until I2C_RXDR is read. The stretch is inserted between the 8th and 9th SCL pulse (before the Acknowledge pulse).

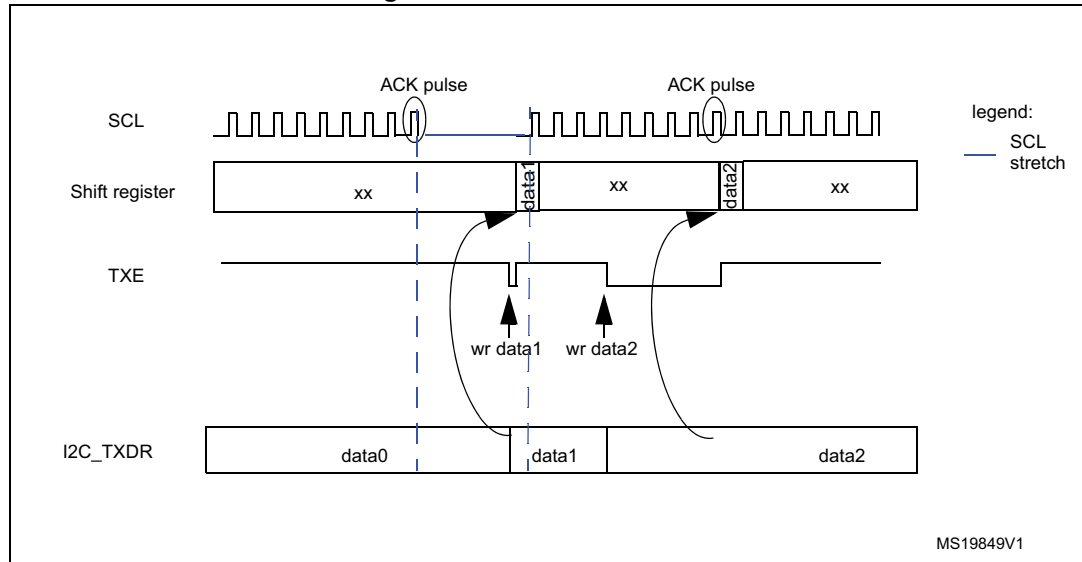
Figure 199. Data reception



Transmission

If the I2C_TXDR register is not empty (TXE=0), its content is copied into the shift register after the 9th SCL pulse (the Acknowledge pulse). Then the shift register content is shifted out on SDA line. If TXE=1, meaning that no data is written yet in I2C_TXDR, SCL line is stretched low until I2C_TXDR is written. The stretch is done after the 9th SCL pulse.

Figure 200. Data transmission



Hardware transfer management

The I2C has a byte counter embedded in hardware in order to manage byte transfer and to close the communication in various modes such as:

- NACK, STOP and ReSTART generation in master mode
- ACK control in slave receiver mode
- PEC generation/checking when SMBus feature is supported

The byte counter is always used in master mode. By default it is disabled in slave mode, but it can be enabled by software by setting the SBC (Slave Byte Control) bit in the I2C_CR2 register.

The number of bytes to be transferred is programmed in the NBYTES[7:0] bit field in the I2C_CR2 register. If the number of bytes to be transferred (NBYTES) is greater than 255, or if a receiver wants to control the acknowledge value of a received data byte, the reload mode must be selected by setting the RELOAD bit in the I2C_CR2 register. In this mode, TCR flag is set when the number of bytes programmed in NBYTES has been transferred, and an interrupt is generated if TCIE is set. SCL is stretched as long as TCR flag is set. TCR is cleared by software when NBYTES is written to a non-zero value.

When the NBYTES counter is reloaded with the last number of bytes, RELOAD bit must be cleared.

When RELOAD=0 in master mode, the counter can be used in 2 modes:

- **Automatic end mode** (AUTOEND = '1' in the I2C_CR2 register). In this mode, the master automatically sends a STOP condition once the number of bytes programmed in the NBYTES[7:0] bit field has been transferred.
- **Software end mode** (AUTOEND = '0' in the I2C_CR2 register). In this mode, software action is expected once the number of bytes programmed in the NBYTES[7:0] bit field has been transferred; the TC flag is set and an interrupt is generated if the TCIE bit is set. The SCL signal is stretched as long as the TC flag is set. The TC flag is cleared by software when the START or STOP bit is set in the I2C_CR2 register. This mode must be used when the master wants to send a RESTART condition.

Caution: The AUTOEND bit has no effect when the RELOAD bit is set.

Table 72. I2C configuration table

Function	SBC bit	RELOAD bit	AUTOEND bit
Master Tx/Rx NBYTES + STOP	x	0	1
Master Tx/Rx + NBYTES + RESTART	x	0	0
Slave Tx/Rx all received bytes ACKed	0	x	x
Slave Rx with ACK control	1	1	x

22.4.8 I2C slave mode

I2C slave initialization

In order to work in slave mode, the user must enable at least one slave address. Two registers I2C_OAR1 and I2C_OAR2 are available in order to program the slave own addresses OA1 and OA2.

- OA1 can be configured either in 7-bit mode (by default) or in 10-bit addressing mode by setting the OA1MODE bit in the I2C_OAR1 register.
OA1 is enabled by setting the OA1EN bit in the I2C_OAR1 register.
- If additional slave addresses are required, the 2nd slave address OA2 can be configured. Up to 7 OA2 LSB can be masked by configuring the OA2MSK[2:0] bits in the I2C_OAR2 register. Therefore for OA2MSK configured from 1 to 6, only OA2[7:2], OA2[7:3], OA2[7:4], OA2[7:5], OA2[7:6] or OA2[7] are compared with the received address. As soon as OA2MSK is not equal to 0, the address comparator for OA2 excludes the I2C reserved addresses (0000 XXX and 1111 XXX), which are not acknowledged. If OA2MSK=7, all received 7-bit addresses are acknowledged (except reserved addresses). OA2 is always a 7-bit address.
These reserved addresses can be acknowledged if they are enabled by the specific enable bit, if they are programmed in the I2C_OAR1 or I2C_OAR2 register with OA2MSK=0.
OA2 is enabled by setting the OA2EN bit in the I2C_OAR2 register.
- The General Call address is enabled by setting the GCEN bit in the I2C_CR1 register.

When the I2C is selected by one of its enabled addresses, the ADDR interrupt status flag is set, and an interrupt is generated if the ADDRIE bit is set.

By default, the slave uses its clock stretching capability, which means that it stretches the SCL signal at low level when needed, in order to perform software actions. If the master does not support clock stretching, the I2C must be configured with NOSTRETCH=1 in the I2C_CR1 register.

After receiving an ADDR interrupt, if several addresses are enabled the user must read the ADDCODE[6:0] bits in the I2C_ISR register in order to check which address matched. DIR flag must also be checked in order to know the transfer direction.

Slave clock stretching (NOSTRETCH = 0)

In default mode, the I2C slave stretches the SCL clock in the following situations:

- When the ADDR flag is set: the received address matches with one of the enabled slave addresses. This stretch is released when the ADDR flag is cleared by software setting the ADDRCONF bit.
- In transmission, if the previous data transmission is completed and no new data is written in I2C_TXDR register, or if the first data byte is not written when the ADDR flag is cleared (TXE=1). This stretch is released when the data is written to the I2C_TXDR register.
- In reception when the I2C_RXDR register is not read yet and a new data reception is completed. This stretch is released when I2C_RXDR is read.
- When TCR = 1 in Slave Byte Control mode, reload mode (SBC=1 and RELOAD=1), meaning that the last data byte has been transferred. This stretch is released when then TCR is cleared by writing a non-zero value in the NBYTES[7:0] field.
- After SCL falling edge detection, the I2C stretches SCL low during $[(SADDEL+SCLDEL+1) \times (PRESC+1) + 1] \times t_{I2CCLK}$.

Slave without clock stretching (NOSTRETCH = 1)

When NOSTRETCH = 1 in the I2C_CR1 register, the I2C slave does not stretch the SCL signal.

- The SCL clock is not stretched while the ADDR flag is set.
- In transmission, the data must be written in the I2C_TXDR register before the first SCL pulse corresponding to its transfer occurs. If not, an underrun occurs, the OVR flag is set in the I2C_ISR register and an interrupt is generated if the ERRIE bit is set in the I2C_CR1 register. The OVR flag is also set when the first data transmission starts and the STOPF bit is still set (has not been cleared). Therefore, if the user clears the STOPF flag of the previous transfer only after writing the first data to be transmitted in the next transfer, he ensures that the OVR status is provided, even for the first data to be transmitted.
- In reception, the data must be read from the I2C_RXDR register before the 9th SCL pulse (ACK pulse) of the next data byte occurs. If not an overrun occurs, the OVR flag is set in the I2C_ISR register and an interrupt is generated if the ERRIE bit is set in the I2C_CR1 register.

Slave Byte Control mode

In order to allow byte ACK control in slave reception mode, Slave Byte Control mode must be enabled by setting the SBC bit in the I2C_CR1 register. This is required to be compliant with SMBus standards.

Reload mode must be selected in order to allow byte ACK control in slave reception mode (RELOAD=1). To get control of each byte, NBYTES must be initialized to 0x1 in the ADDR interrupt subroutine, and reloaded to 0x1 after each received byte. When the byte is received, the TCR bit is set, stretching the SCL signal low between the 8th and 9th SCL pulses. The user can read the data from the I2C_RXDR register, and then decide to acknowledge it or not by configuring the ACK bit in the I2C_CR2 register. The SCL stretch is released by programming NBYTES to a non-zero value: the acknowledge or not-acknowledge is sent and next byte can be received.

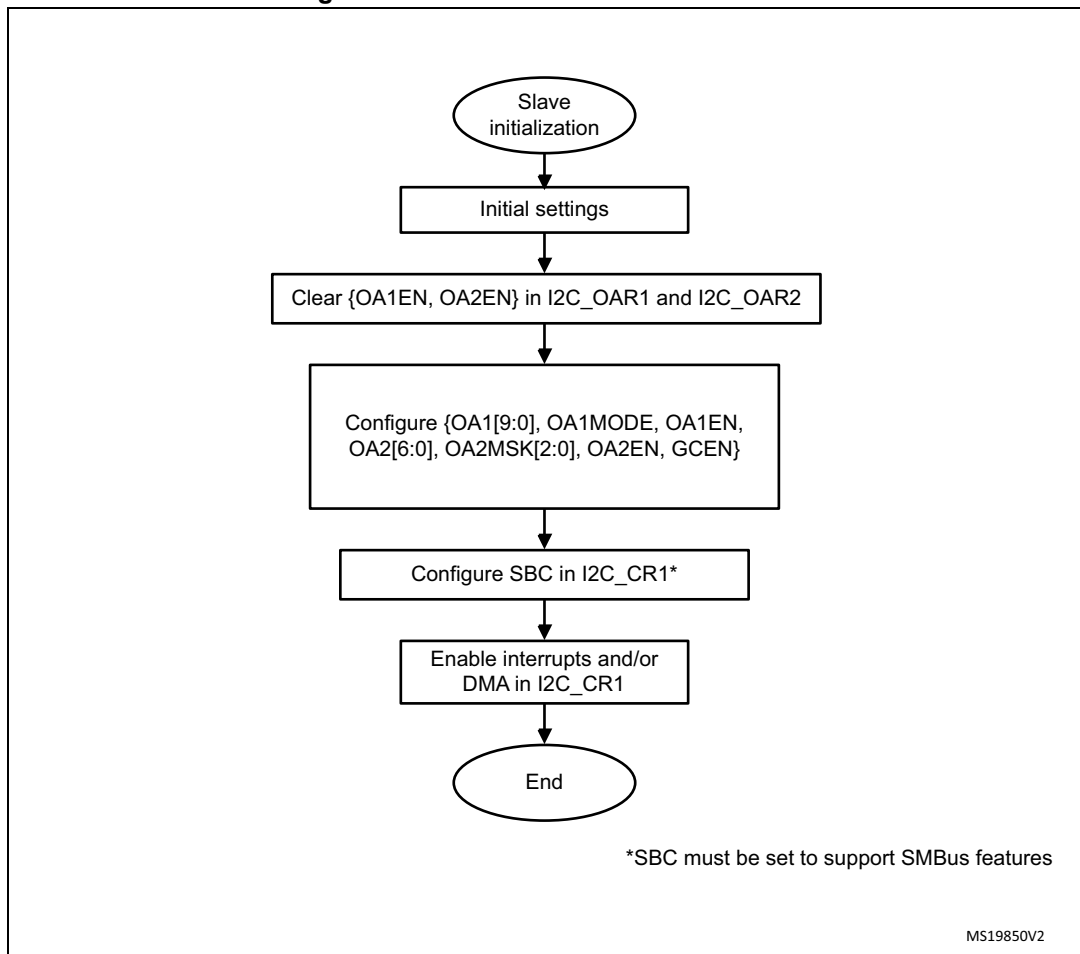
NBYTES can be loaded with a value greater than 0x1, and in this case, the reception flow is continuous during NBYTES data reception.

Note: *The SBC bit must be configured when the I2C is disabled, or when the slave is not addressed, or when ADDR=1.*

The RELOAD bit value can be changed when ADDR=1, or when TCR=1.

Caution: Slave Byte Control mode is not compatible with NOSTRETCH mode. Setting SBC when NOSTRETCH=1 is not allowed.

Figure 201. Slave initialization flowchart



For code example refer to the Appendix section [A.11.3: I2C configured in slave mode code example](#).

Slave transmitter

A transmit interrupt status (TXIS) is generated when the I2C_TXDR register becomes empty. An interrupt is generated if the TXIE bit is set in the I2C_CR1 register.

The TXIS bit is cleared when the I2C_TXDR register is written with the next data byte to be transmitted.

When a NACK is received, the NACKF bit is set in the I2C_ISR register and an interrupt is generated if the NACKIE bit is set in the I2C_CR1 register. The slave automatically releases the SCL and SDA lines in order to let the master perform a STOP or a RESTART condition. The TXIS bit is not set when a NACK is received.

When a STOP is received and the STOPIE bit is set in the I2C_CR1 register, the STOPF flag is set in the I2C_ISR register and an interrupt is generated. In most applications, the SBC bit is usually programmed to '0'. In this case, If TXE = 0 when the slave address is received (ADDR=1), the user can choose either to send the content of the I2C_TXDR register as the first data byte, or to flush the I2C_TXDR register by setting the TXE bit in order to program a new data byte.

In Slave Byte Control mode (SBC=1), the number of bytes to be transmitted must be programmed in NBYTES in the address match interrupt subroutine (ADDR=1). In this case, the number of TXIS events during the transfer corresponds to the value programmed in NBYTES.

Caution: When NOSTRETCH=1, the SCL clock is not stretched while the ADDR flag is set, so the user cannot flush the I2C_TXDR register content in the ADDR subroutine, in order to program the first data byte. The first data byte to be sent must be previously programmed in the I2C_TXDR register:

- This data can be the data written in the last TXIS event of the previous transmission message.
- If this data byte is not the one to be sent, the I2C_TXDR register can be flushed by setting the TXE bit in order to program a new data byte. The STOPF bit must be cleared only after these actions, in order to guarantee that they are executed before the first data transmission starts, following the address acknowledge.

If STOPF is still set when the first data transmission starts, an underrun error will be generated (the OVR flag is set).

If a TXIS event is needed, (Transmit Interrupt or Transmit DMA request), the user must set the TXIS bit in addition to the TXE bit, in order to generate a TXIS event.

Figure 202. Transfer sequence flowchart for I2C slave transmitter, NOSTRETCH=0

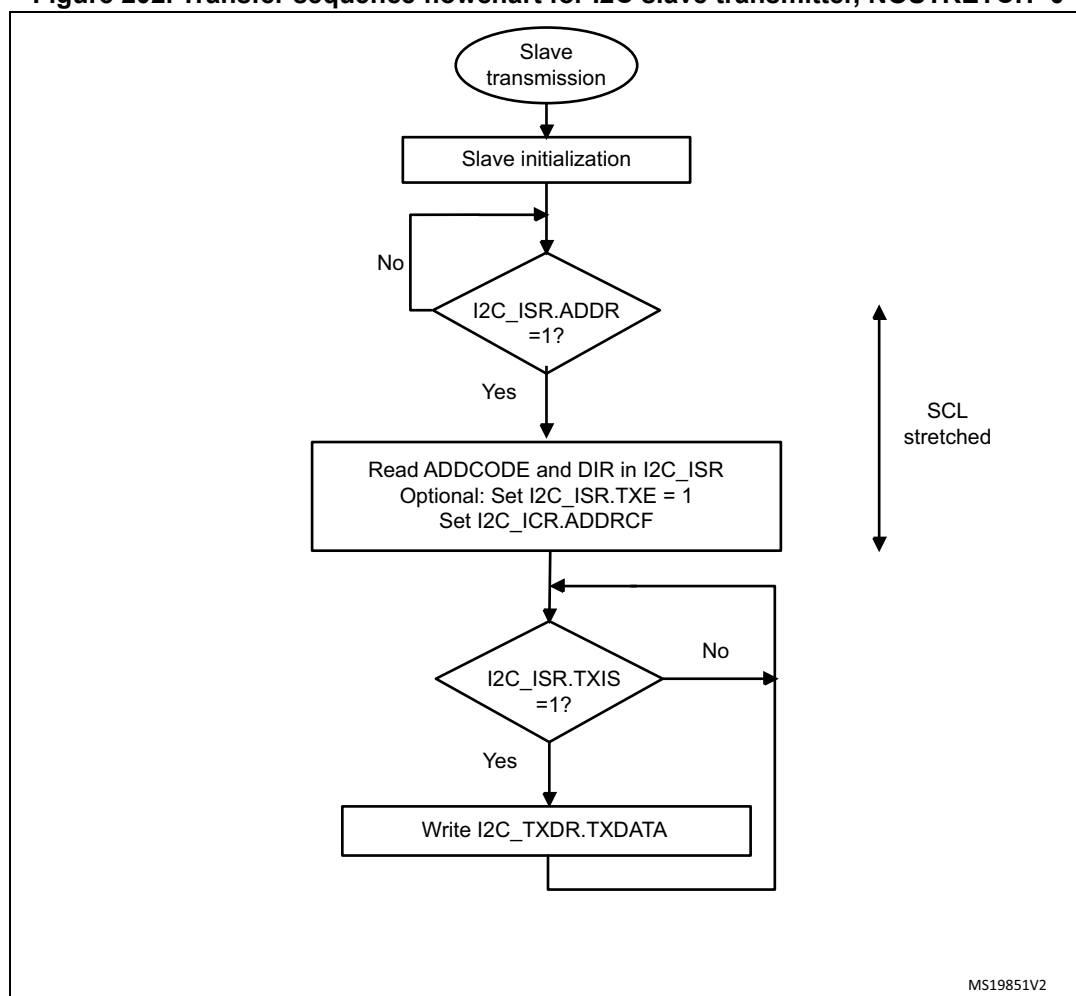


Figure 203. Transfer sequence flowchart for I2C slave transmitter, NOSTRETCH=1

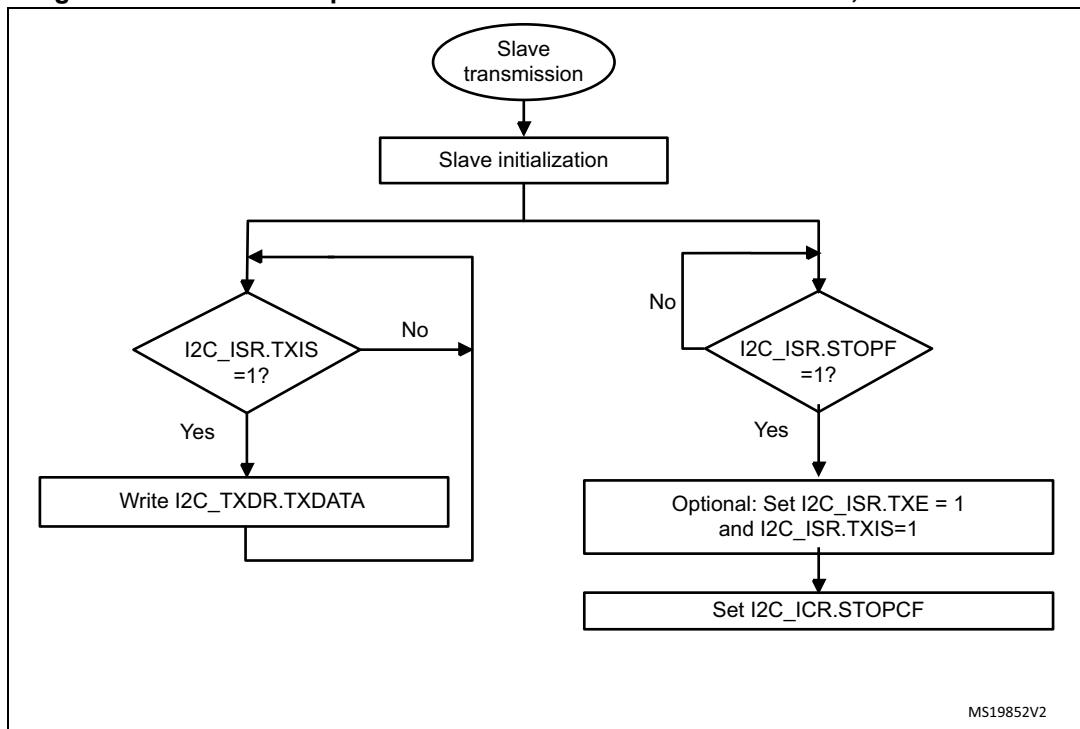
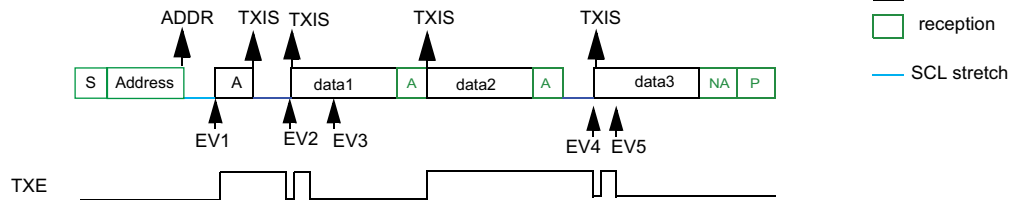


Figure 204. Transfer bus diagrams for I2C slave transmitter

Example I2C slave transmitter 3 bytes with 1st data flushed, NOSTRETCH=0:



EV1: ADDR ISR: check ADDCODE and DIR, set TXE, set ADDRCONF

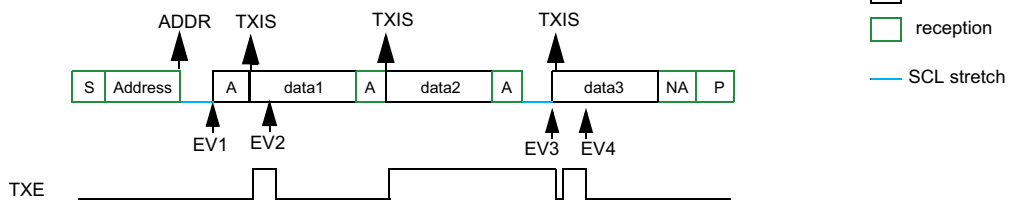
EV2: TXIS ISR: wr data1

EV3: TXIS ISR: wr data2

EV4: TXIS ISR: wr data3

EV5: TXIS ISR: wr data4 (not sent)

Example I2C slave transmitter 3 bytes without 1st data flush, NOSTRETCH=0:



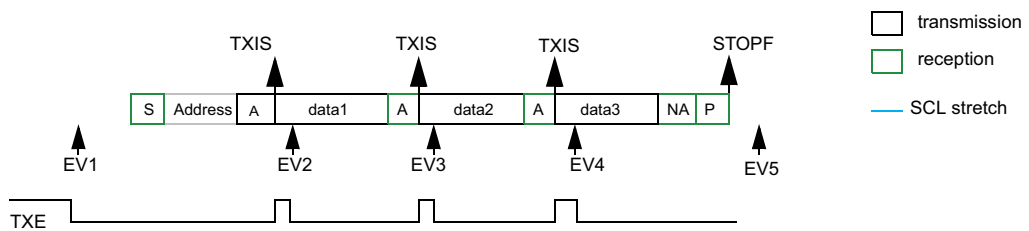
EV1: ADDR ISR: check ADDCODE and DIR, set ADDRCONF

EV2: TXIS ISR: wr data2

EV3: TXIS ISR: wr data3

EV4: TXIS ISR: wr data4 (not sent)

Example I2C slave transmitter 3 bytes, NOSTRETCH=1:



EV1: wr data1

EV2: TXIS ISR: wr data2

EV3: TXIS ISR: wr data3

EV4: TXIS ISR: wr data4 (not sent)

EV5: STOPF ISR: (optional: set TXE and TXIS), set STOPCONF

MS19853V1

For code example refer to the Appendix section [A.11.6: I2C slave transmitter code example](#).

Slave receiver

RXNE is set in I2C_ISR when the I2C_RXDR is full, and generates an interrupt if RXIE is set in I2C_CR1. RXNE is cleared when I2C_RXDR is read.

When a STOP is received and STOPIE is set in I2C_CR1, STOPF is set in I2C_ISR and an interrupt is generated.

Figure 205. Transfer sequence flowchart for slave receiver with NOSTRETCH=0

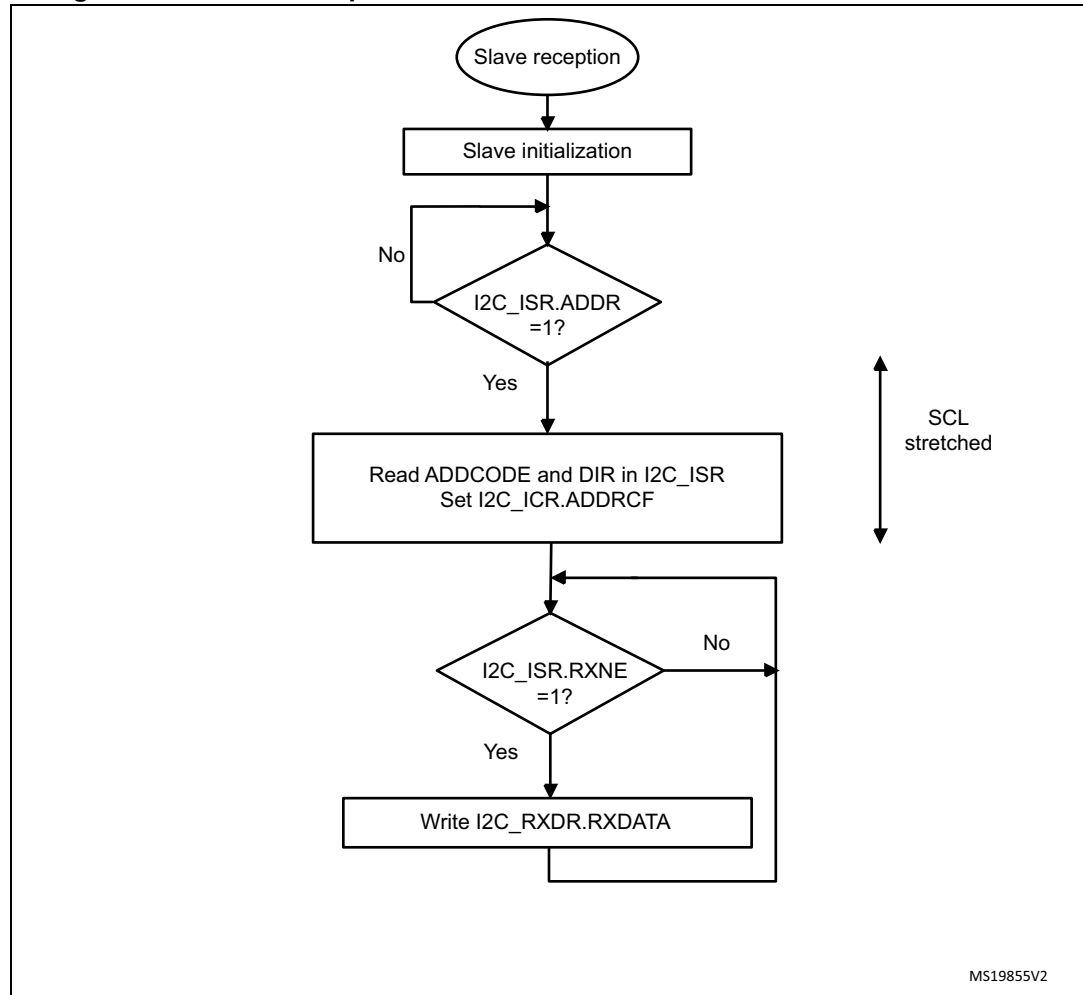


Figure 206. Transfer sequence flowchart for slave receiver with NOSTRETCH=1

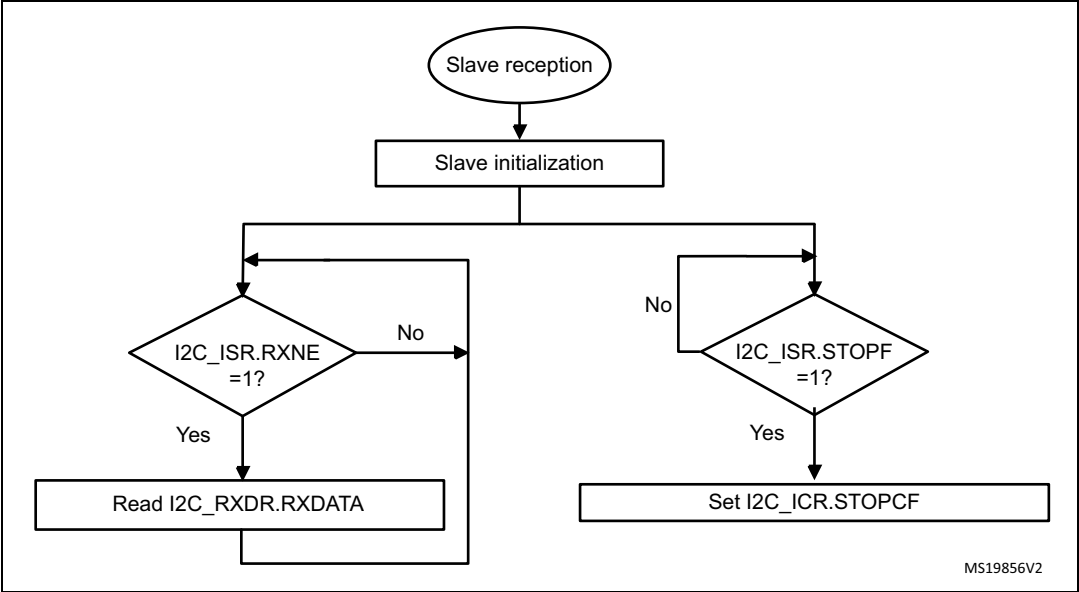
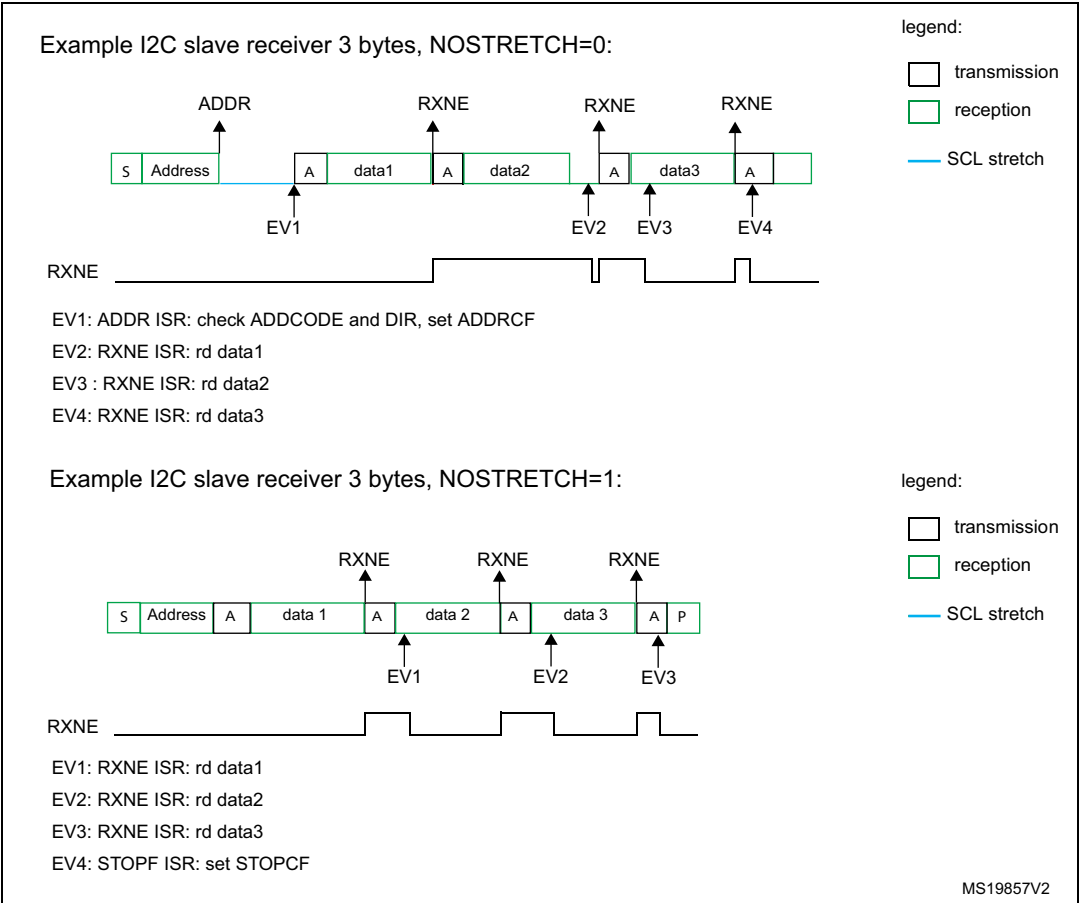


Figure 207. Transfer bus diagrams for I2C slave receiver



For code example refer to the Appendix section [A.11.7: I2C slave receiver code example](#).

22.4.9 I2C master mode

I2C master initialization

Before enabling the peripheral, the I2C master clock must be configured by setting the SCLH and SCLL bits in the I2C_TIMINGR register.

The STM32CubeMX tool calculates and provides the I2C_TIMINGR content in the I2C Configuration window.

A clock synchronization mechanism is implemented in order to support multi-master environment and slave clock stretching.

In order to allow clock synchronization:

- The low level of the clock is counted using the SCLL counter, starting from the SCL low level internal detection.
- The high level of the clock is counted using the SCLH counter, starting from the SCL high level internal detection.

The I2C detects its own SCL low level after a t_{SYNC1} delay depending on the SCL falling edge, SCL input noise filters (analog + digital) and SCL synchronization to the I2CxCLK clock. The I2C releases SCL to high level once the SCLL counter reaches the value programmed in the SCLL[7:0] bits in the I2C_TIMINGR register.

The I2C detects its own SCL high level after a t_{SYNC2} delay depending on the SCL rising edge, SCL input noise filters (analog + digital) and SCL synchronization to I2CxCLK clock. The I2C ties SCL to low level once the SCLH counter is reached reaches the value programmed in the SCLH[7:0] bits in the I2C_TIMINGR register.

Consequently the master clock period is:

$$t_{\text{SCL}} = t_{\text{SYNC1}} + t_{\text{SYNC2}} + \{[(\text{SCLH}+1) + (\text{SCLL}+1)] \times (\text{PRESC}+1) \times t_{\text{I2CCLK}}\}$$

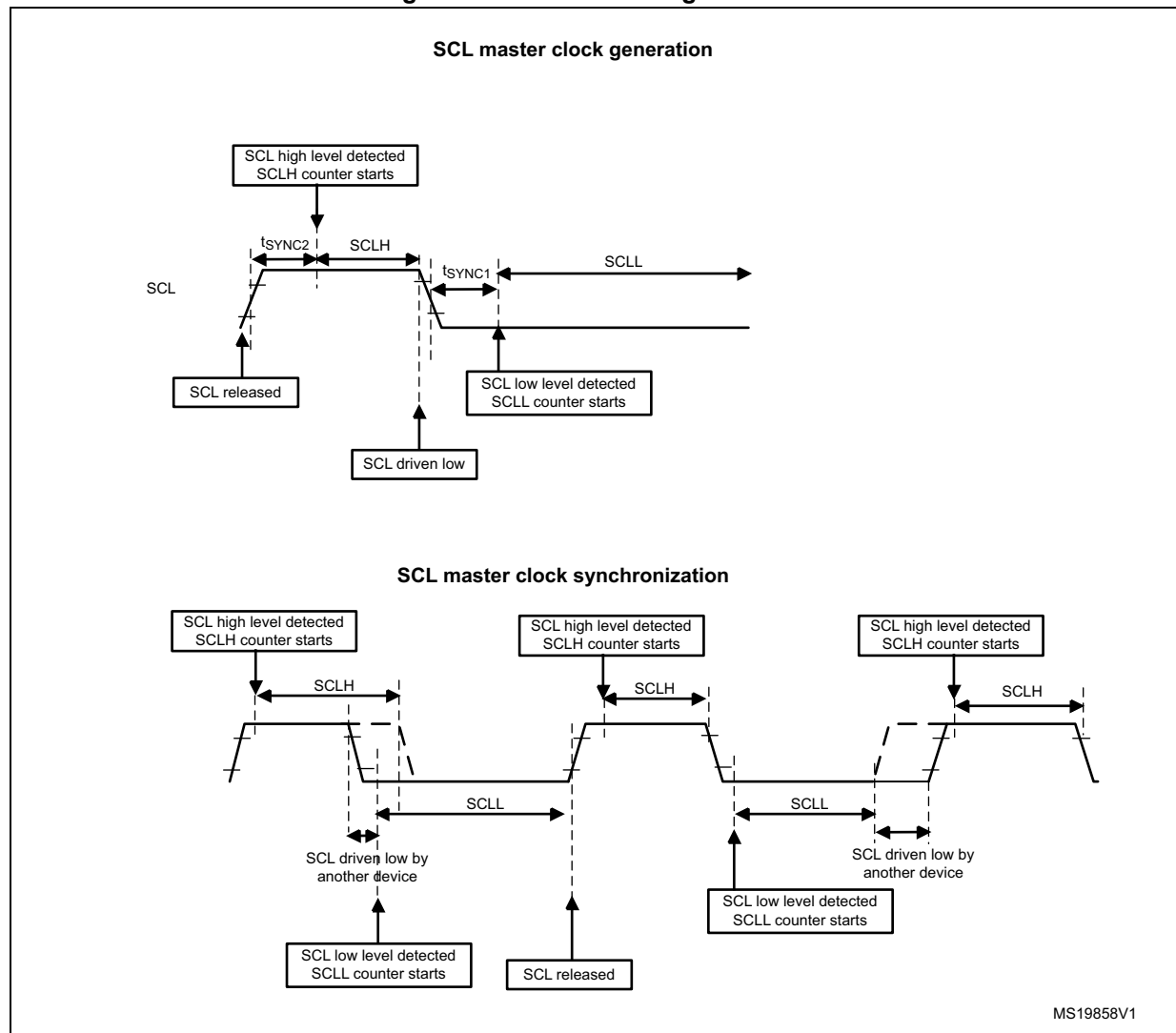
The duration of t_{SYNC1} depends on these parameters:

- SCL falling slope
- When enabled, input delay induced by the analog filter.
- When enabled, input delay induced by the digital filter: $\text{DNF} \times t_{\text{I2CCLK}}$
- Delay due to SCL synchronization with I2CCLK clock (2 to 3 I2CCLK periods)

The duration of t_{SYNC2} depends on these parameters:

- SCL rising slope
- When enabled, input delay induced by the analog filter.
- When enabled, input delay induced by the digital filter: $\text{DNF} \times t_{\text{I2CCLK}}$
- Delay due to SCL synchronization with I2CCLK clock (2 to 3 I2CCLK periods)

Figure 208. Master clock generation



Caution: In order to be I²C or SMBus compliant, the master clock must respect the timings given below:

Table 73. I²C-SMBUS specification clock timings

Symbol	Parameter	Standard-mode (Sm)		Fast-mode (Fm)		Fast-mode Plus (Fm+)		SMBUS		Unit
		Min	Max	Min	Max	Min	Max	Min	Max	
f_{SCL}	SCL clock frequency	-	100	-	400	-	1000	-	100	kHz
$t_{HD:STA}$	Hold time (repeated) START condition	4.0	-	0.6	-	0.26	-	4.0	-	μ s
$t_{SU:STA}$	Set-up time for a repeated START condition	4.7	-	0.6	-	0.26	-	4.7	-	μ s
$t_{SU:STO}$	Set-up time for STOP condition	4.0	-	0.6	-	0.26	-	4.0	-	μ s
t_{BUF}	Bus free time between a STOP and START condition	4.7	-	1.3	-	0.5	-	4.7	-	μ s
t_{LOW}	Low period of the SCL clock	4.7	-	1.3	-	0.5	-	4.7	-	μ s
t_{HIGH}	Period of the SCL clock	4.0	-	0.6	-	0.26	-	4.0	50	μ s
t_r	Rise time of both SDA and SCL signals	-	1000	-	300	-	120	-	1000	ns
t_f	Fall time of both SDA and SCL signals	-	300	-	300	-	120	-	300	ns

Note: $SCLL$ is also used to generate the t_{BUF} and $t_{SU:STA}$ timings.

$SCLH$ is also used to generate the $t_{HD:STA}$ and $t_{SU:STO}$ timings.

Refer to [Section 22.4.10: I2C_TIMINGR register configuration examples](#) for examples of I2C_TIMINGR settings vs. I2CCLK frequency.

Master communication initialization (address phase)

In order to initiate the communication, the user must program the following parameters for the addressed slave in the I2C_CR2 register:

- Addressing mode (7-bit or 10-bit): ADD10
- Slave address to be sent: SADD[9:0]
- Transfer direction: RD_WRN
- In case of 10-bit address read: HEAD10R bit. HEAD10R must be configured to indicate if the complete address sequence must be sent, or only the header in case of a direction change.
- The number of bytes to be transferred: NBYTES[7:0]. If the number of bytes is equal to or greater than 255 bytes, NBYTES[7:0] must initially be filled with 0xFF.

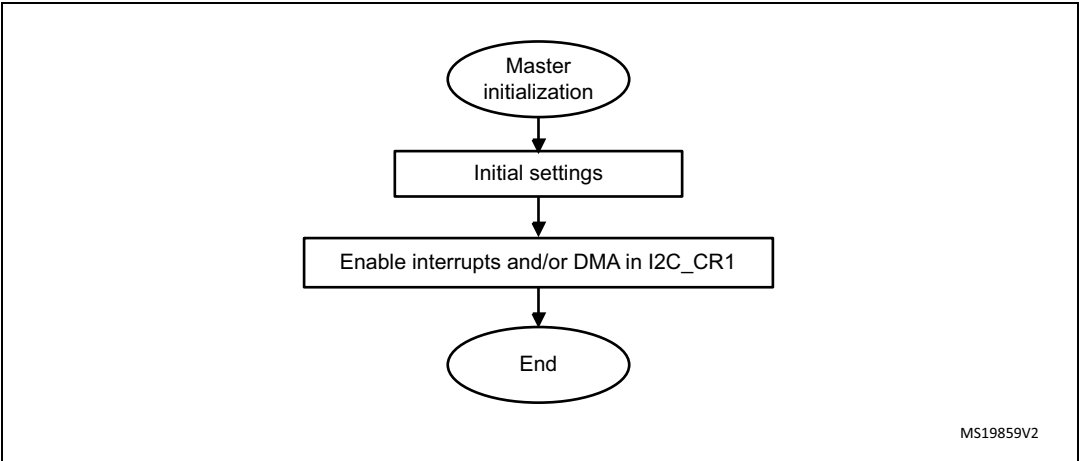
The user must then set the START bit in I2C_CR2 register. Changing all the above bits is not allowed when START bit is set.

Then the master automatically sends the START condition followed by the slave address as soon as it detects that the bus is free (BUSY = 0) and after a delay of t_{BUF} .

In case of an arbitration loss, the master automatically switches back to slave mode and can acknowledge its own address if it is addressed as a slave.

- Note:* The START bit is reset by hardware when the slave address has been sent on the bus, whatever the received acknowledge value. The START bit is also reset by hardware if an arbitration loss occurs.
- In 10-bit addressing mode, when the Slave Address first 7 bits is NACKed by the slave, the master will re-launch automatically the slave address transmission until ACK is received. In this case ADDRCF must be set if a NACK is received from the slave, in order to stop sending the slave address.*
- If the I2C is addressed as a slave (ADDR=1) while the START bit is set, the I2C switches to slave mode and the START bit is cleared when the ADDRCF bit is set.*
- Note:* The same procedure is applied for a Repeated Start condition. In this case BUSY=1.

Figure 209. Master initialization flowchart

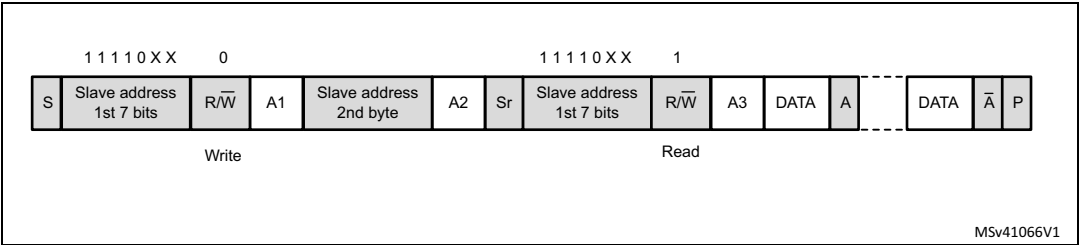


For code examples refer to the Appendix section [A.11.1: I2C configured in master mode to receive code example](#) and the Appendix section [A.11.2: I2C configured in master mode to transmit code example](#).

Initialization of a master receiver addressing a 10-bit address slave

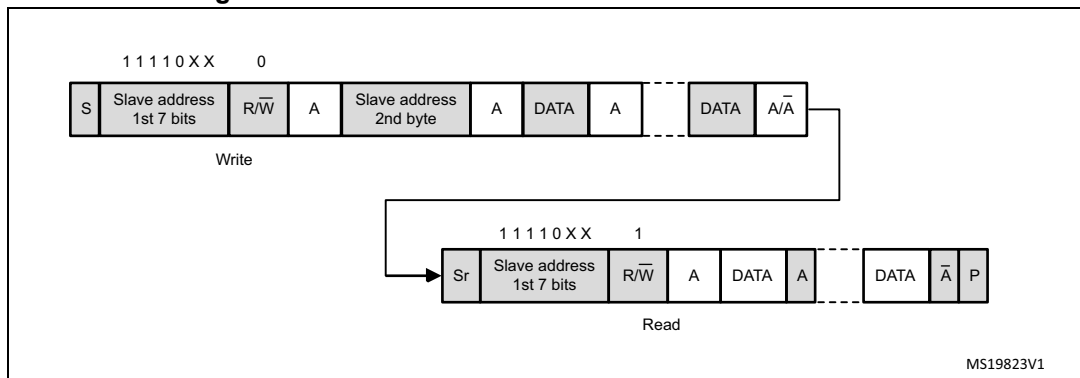
- If the slave address is in 10-bit format, the user can choose to send the complete read sequence by clearing the HEAD10R bit in the I2C_CR2 register. In this case the master automatically sends the following complete sequence after the START bit is set: (Re)Start + Slave address 10-bit header Write + Slave address 2nd byte + A2 + Sr + Slave address 1st 7 bits + R/W + A3 + DATA + A --- DATA + $\bar{A}$ + P

Figure 210. 10-bit address read access with HEAD10R=0



- If the master addresses a 10-bit address slave, transmits data to this slave and then reads data from the same slave, a master transmission flow must be done first. Then a repeated start is set with the 10 bit slave address configured with HEAD10R=1. In this case the master sends this sequence: ReStart + Slave address 10-bit header Read.

Figure 211. 10-bit address read access with HEAD10R=1



Master transmitter

In the case of a write transfer, the TXIS flag is set after each byte transmission, after the 9th SCL pulse when an ACK is received.

A TXIS event generates an interrupt if the TXIE bit is set in the I2C_CR1 register. The flag is cleared when the I2C_TXDR register is written with the next data byte to be transmitted.

The number of TXIS events during the transfer corresponds to the value programmed in NBYTES[7:0]. If the total number of data bytes to be sent is greater than 255, reload mode must be selected by setting the RELOAD bit in the I2C_CR2 register. In this case, when NBYTES data have been transferred, the TCR flag is set and the SCL line is stretched low until NBYTES[7:0] is written to a non-zero value.

The TXIS flag is not set when a NACK is received.

- When RELOAD=0 and NBYTES data have been transferred:
 - In automatic end mode (AUTOEND=1), a STOP is automatically sent.
 - In software end mode (AUTOEND=0), the TC flag is set and the SCL line is stretched low in order to perform software actions:

A RESTART condition can be requested by setting the START bit in the I2C_CR2 register with the proper slave address configuration, and number of bytes to be transferred. Setting the START bit clears the TC flag and the START condition is sent on the bus.

A STOP condition can be requested by setting the STOP bit in the I2C_CR2 register. Setting the STOP bit clears the TC flag and the STOP condition is sent on the bus.
- If a NACK is received: the TXIS flag is not set, and a STOP condition is automatically sent after the NACK reception. the NACKF flag is set in the I2C_ISR register, and an interrupt is generated if the NACKIE bit is set.

Figure 212. Transfer sequence flowchart for I2C master transmitter for N≤255 bytes

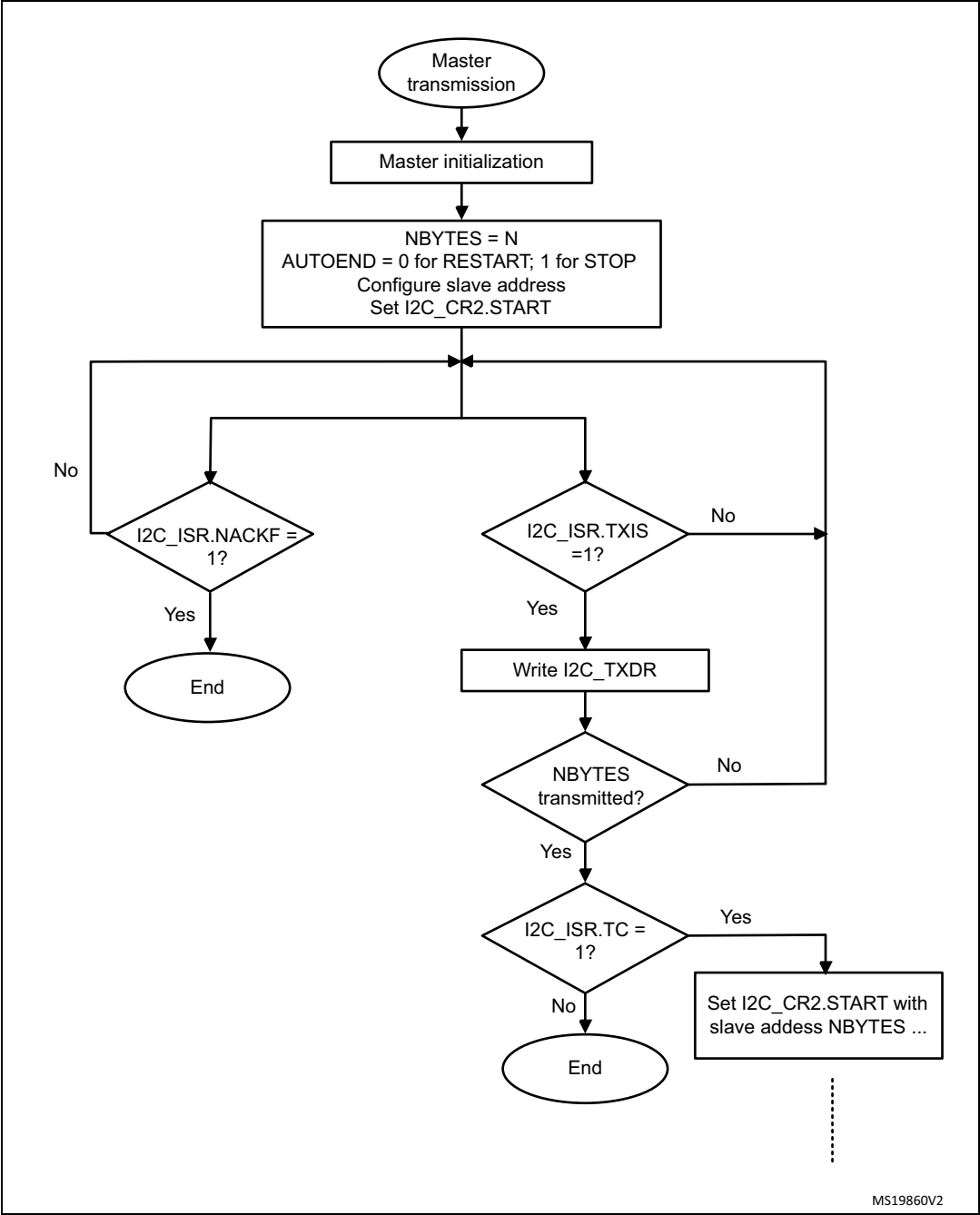


Figure 213. Transfer sequence flowchart for I2C master transmitter for N>255 bytes

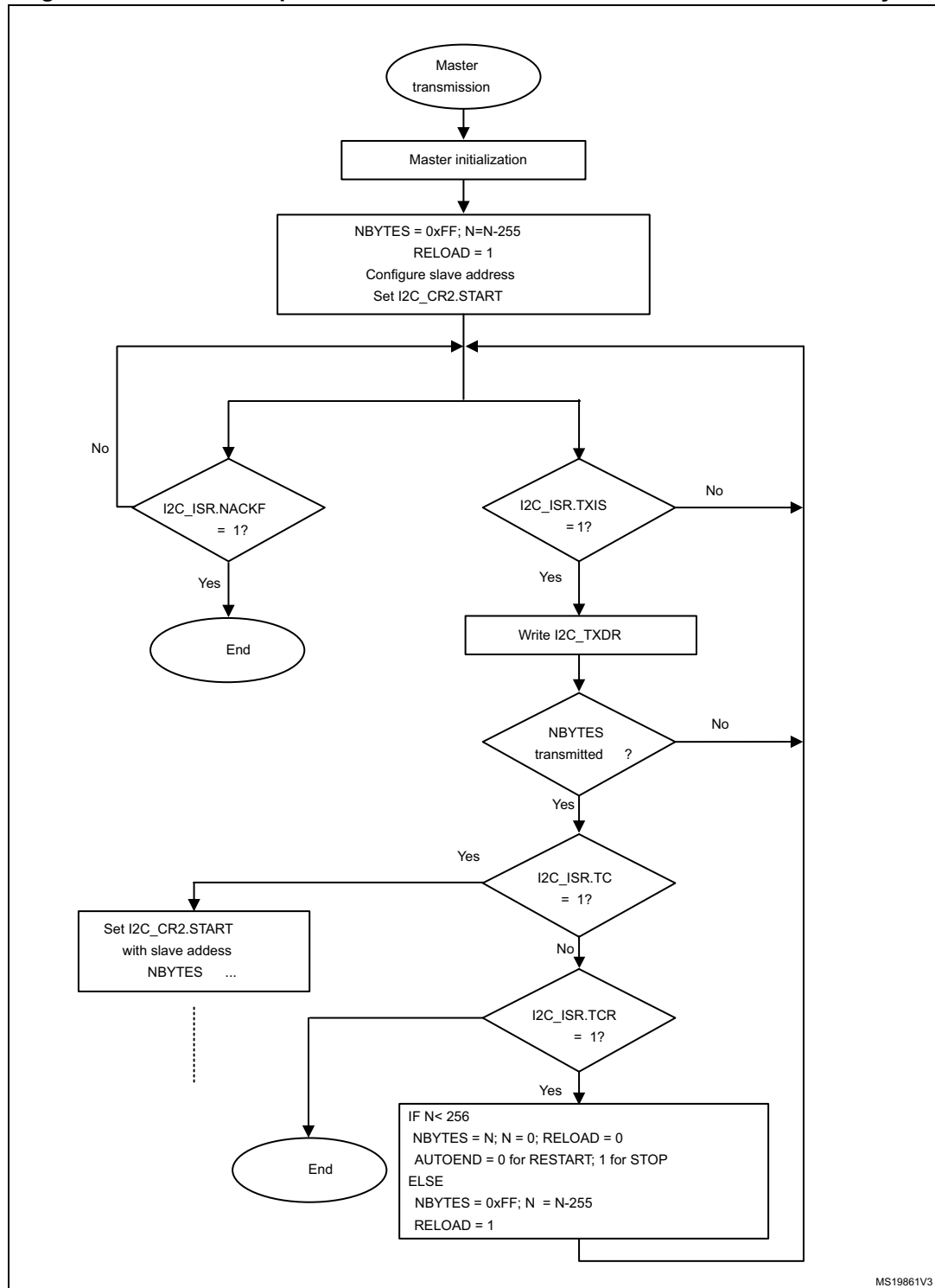
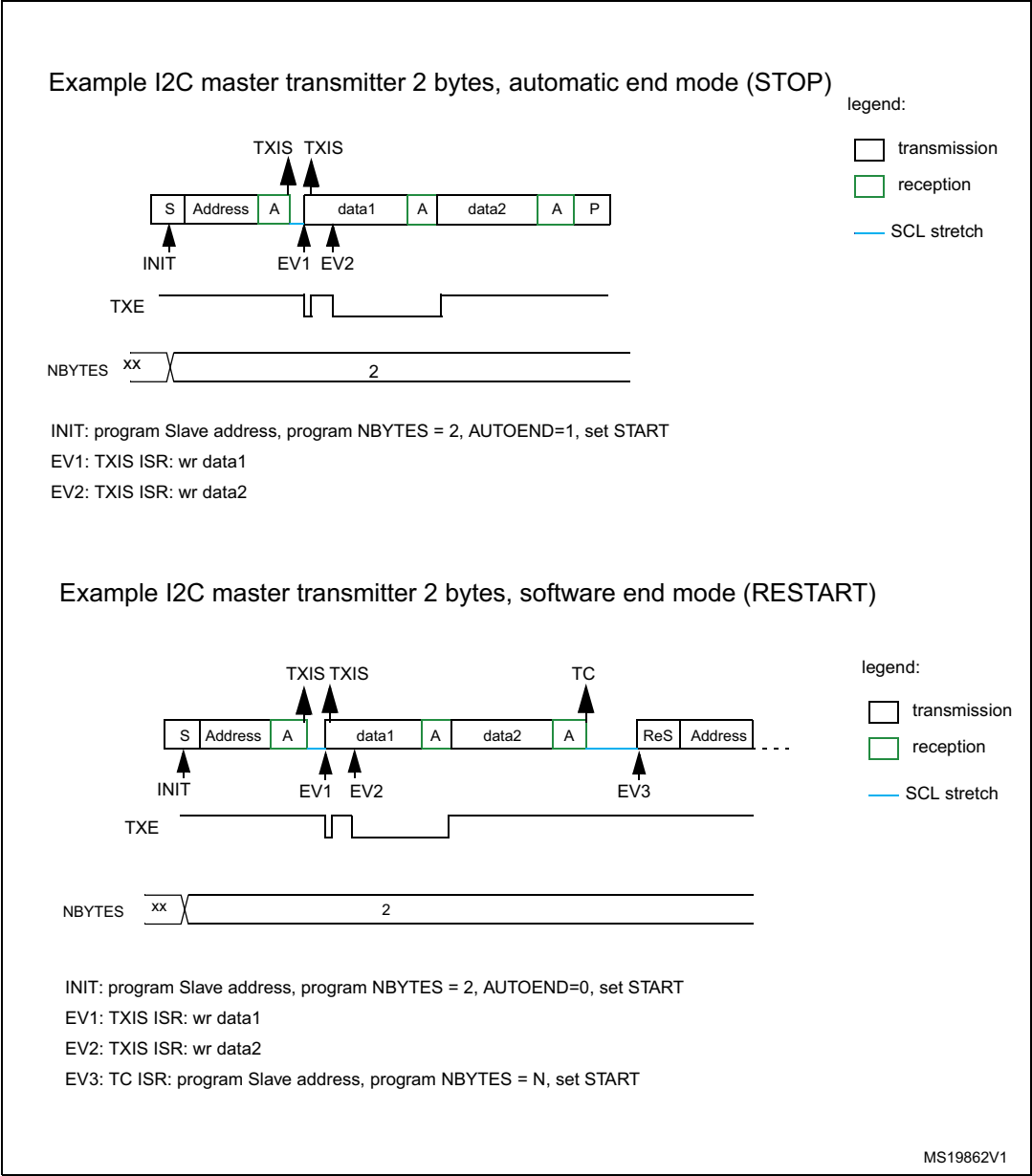


Figure 214. Transfer bus diagrams for I2C master transmitter



For code example refer to the Appendix section [A.11.4: I2C master transmitter code example](#).

Master receiver

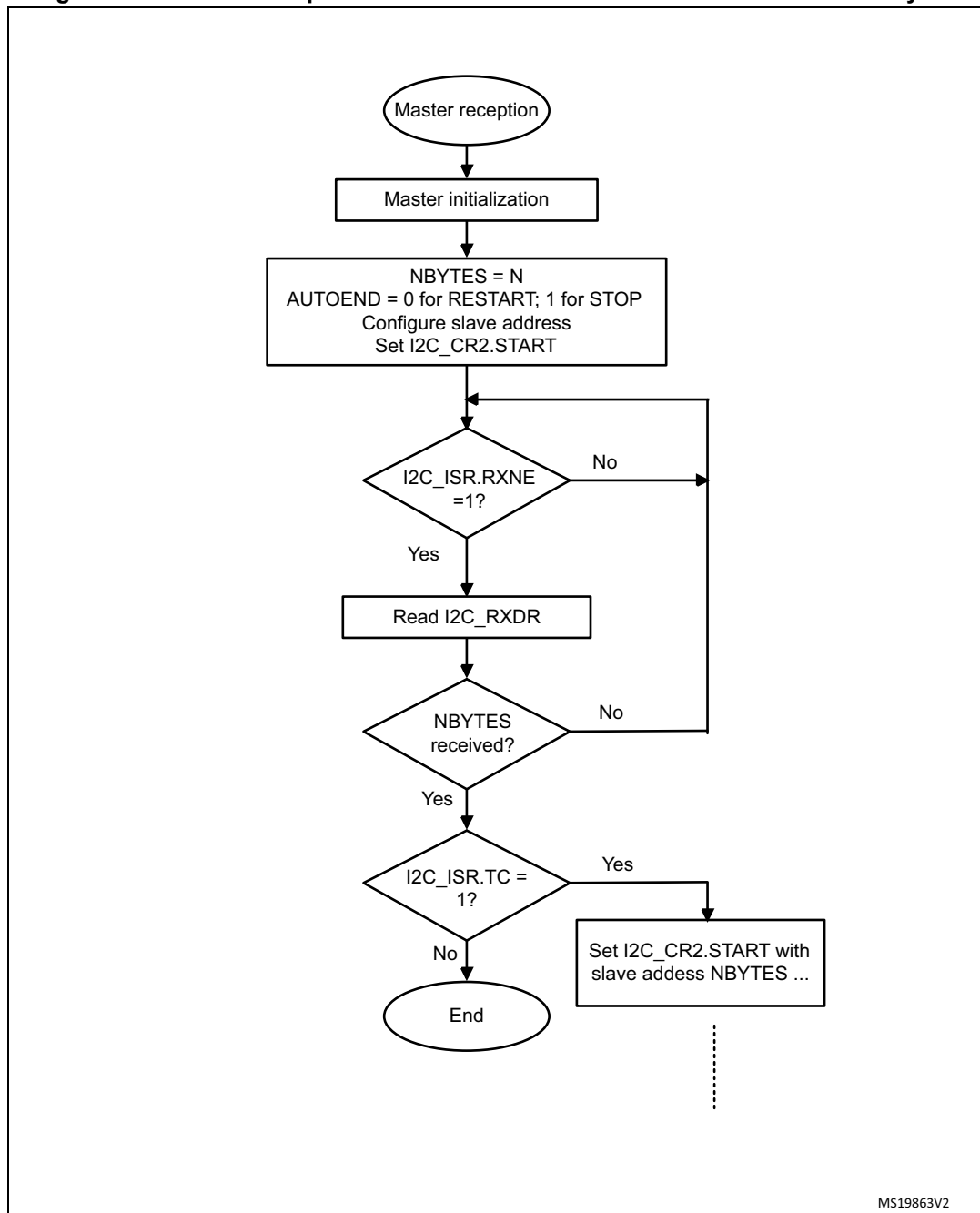
In the case of a read transfer, the RXNE flag is set after each byte reception, after the 8th SCL pulse. An RXNE event generates an interrupt if the RXIE bit is set in the I2C_CR1 register. The flag is cleared when I2C_RXDR is read.

If the total number of data bytes to be received is greater than 255, reload mode must be selected by setting the RELOAD bit in the I2C_CR2 register. In this case, when NBYTES[7:0] data have been transferred, the TCR flag is set and the SCL line is stretched low until NBYTES[7:0] is written to a non-zero value.

- When RELOAD=0 and NBYTES[7:0] data have been transferred:
 - In automatic end mode (AUTOEND=1), a NACK and a STOP are automatically sent after the last received byte.
 - In software end mode (AUTOEND=0), a NACK is automatically sent after the last received byte, the TC flag is set and the SCL line is stretched low in order to allow software actions:

A RESTART condition can be requested by setting the START bit in the I2C_CR2 register with the proper slave address configuration, and number of bytes to be transferred. Setting the START bit clears the TC flag and the START condition, followed by slave address, are sent on the bus.

A STOP condition can be requested by setting the STOP bit in the I2C_CR2 register. Setting the STOP bit clears the TC flag and the STOP condition is sent on the bus.

Figure 215. Transfer sequence flowchart for I2C master receiver for $N \leq 255$ bytes

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Figure 216. Transfer sequence flowchart for I2C master receiver for N > 255 bytes

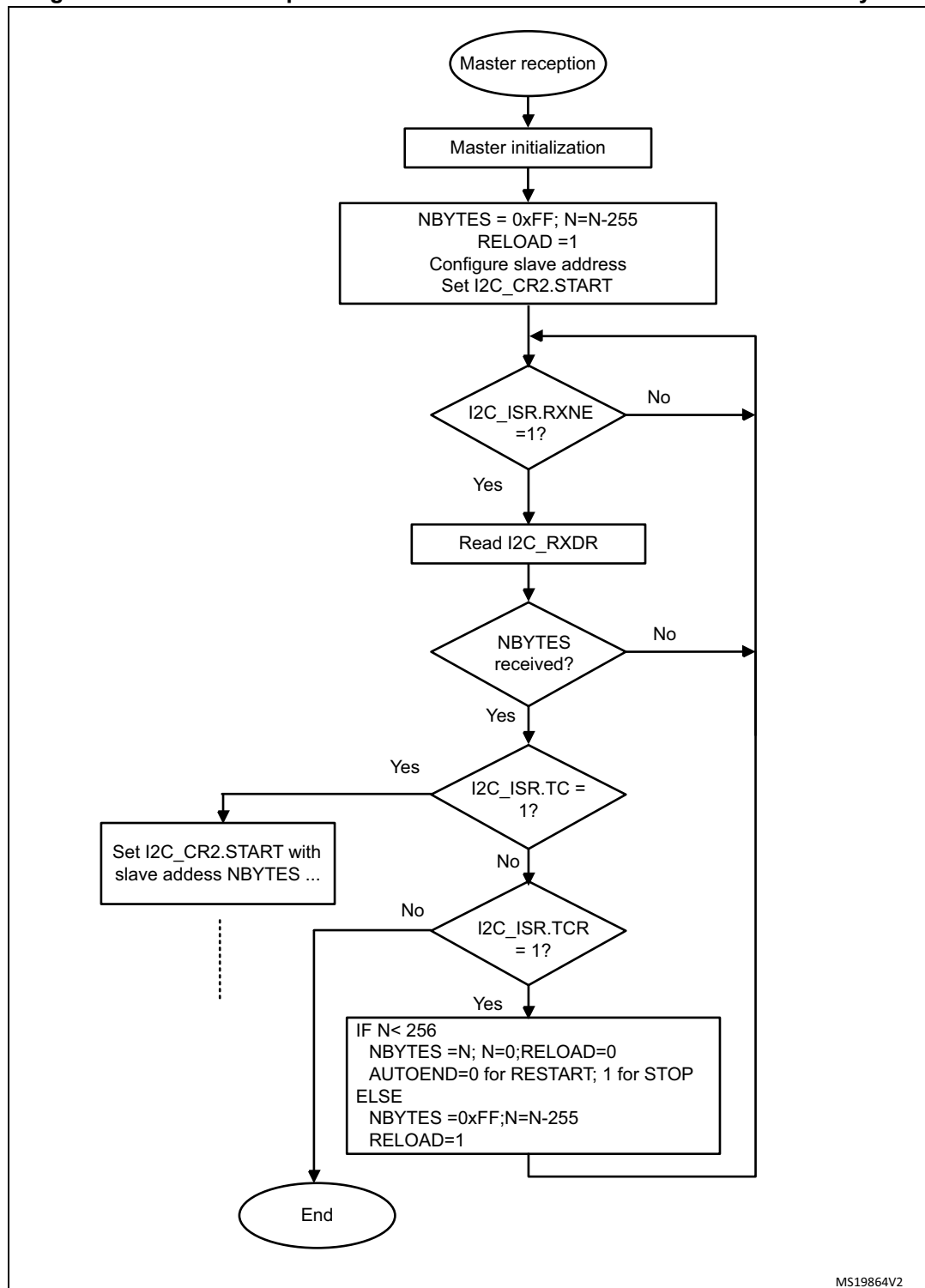
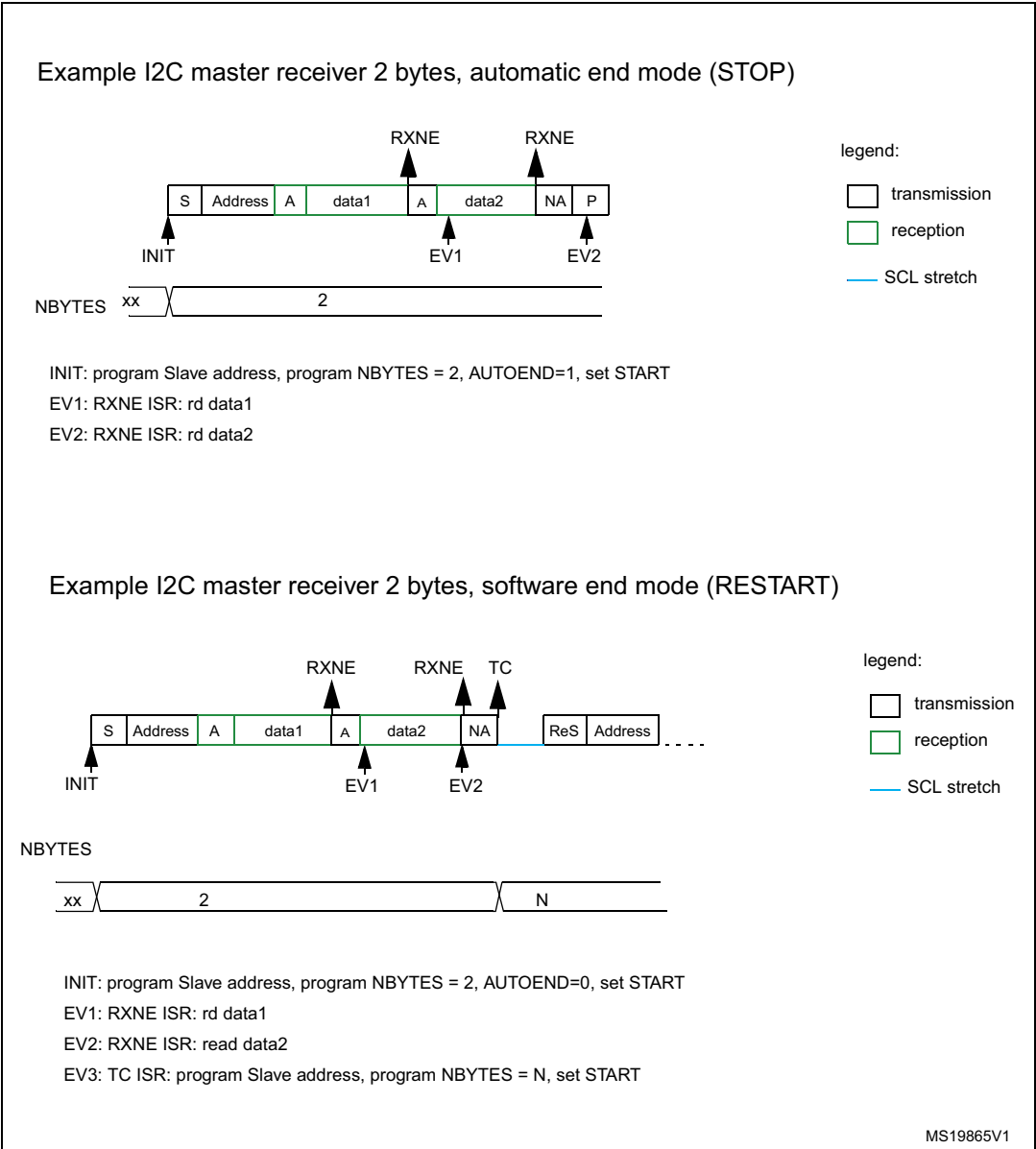


Figure 217. Transfer bus diagrams for I2C master receiver



For code example refer to the Appendix section [A.11.5: I2C master receiver code example](#).

22.4.10 I2C_TIMINGR register configuration examples

The tables below provide examples of how to program the I2C_TIMINGR to obtain timings compliant with the I²C specification. In order to get more accurate configuration values, please refer to the application note: *I²C timing configuration tool* (AN4235) and the associated software STSW-STM32126.

Table 74. Examples of timings settings for $f_{I2CCLK} = 8\text{ MHz}$

Parameter	Standard-mode (Sm)		Fast-mode (Fm)	Fast-mode Plus (Fm+)
	10 kHz	100 kHz	400 kHz	500 kHz
PRESC	1	1	0	0
SCLL	0xC7	0x13	0x9	0x6
t_{SCLL}	200x250 ns = 50 μ s	20x250 ns = 5.0 μ s	10x125 ns = 1250 ns	7x125 ns = 875 ns
SCLH	0xC3	0xF	0x3	0x3
t_{SCLH}	196x250 ns = 49 μ s	16x250 ns = 4.0 μ s	4x125ns = 500ns	4x125 ns = 500 ns
$t_{SCL}^{(1)}$	~100 μ s ⁽²⁾	~10 μ s ⁽²⁾	~2500 ns ⁽³⁾	~2000 ns ⁽⁴⁾
SDADEL	0x2	0x2	0x1	0x0
t_{SDADEL}	2x250 ns = 500 ns	2x250 ns = 500 ns	1x125 ns = 125 ns	0 ns
SCLDEL	0x4	0x4	0x3	0x1
t_{SCLDEL}	5x250 ns = 1250 ns	5x250 ns = 1250 ns	4x125 ns = 500 ns	2x125 ns = 250 ns

1. SCL period t_{SCL} is greater than $t_{SCLL} + t_{SCLH}$ due to SCL internal detection delay. Values provided for t_{SCL} are examples only.
2. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 500\text{ ns}$. Example with $t_{SYNC1} + t_{SYNC2} = 1000\text{ ns}$
3. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 500\text{ ns}$. Example with $t_{SYNC1} + t_{SYNC2} = 750\text{ ns}$
4. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 500\text{ ns}$. Example with $t_{SYNC1} + t_{SYNC2} = 655\text{ ns}$

Table 75. Examples of timings settings for $f_{I2CCLK} = 16\text{ MHz}$

Parameter	Standard-mode (Sm)		Fast-mode (Fm)	Fast-mode Plus (Fm+)
	10 kHz	100 kHz	400 kHz	1000 kHz
PRESC	3	3	1	0
SCLL	0xC7	0x13	0x9	0x4
t_{SCLL}	200 x 250 ns = 50 μ s	20 x 250 ns = 5.0 μ s	10 x 125 ns = 1250 ns	5 x 62.5 ns = 312.5 ns
SCLH	0xC3	0xF	0x3	0x2
t_{SCLH}	196 x 250 ns = 49 μ s	16 x 250 ns = 4.0 μ s	4 x 125ns = 500 ns	3 x 62.5 ns = 187.5 ns
$t_{SCL}^{(1)}$	~100 μ s ⁽²⁾	~10 μ s ⁽²⁾	~2500 ns ⁽³⁾	~1000 ns ⁽⁴⁾
SDADEL	0x2	0x2	0x2	0x0
t_{SDADEL}	2 x 250 ns = 500 ns	2 x 250 ns = 500 ns	2 x 125 ns = 250 ns	0 ns
SCLDEL	0x4	0x4	0x3	0x2
t_{SCLDEL}	5 x 250 ns = 1250 ns	5 x 250 ns = 1250 ns	4 x 125 ns = 500 ns	3 x 62.5 ns = 187.5 ns

1. SCL period t_{SCL} is greater than $t_{SCLL} + t_{SCLH}$ due to SCL internal detection delay. Values provided for t_{SCL} are examples only.
2. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 250$ ns. Example with $t_{SYNC1} + t_{SYNC2} = 1000$ ns
3. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 250$ ns. Example with $t_{SYNC1} + t_{SYNC2} = 750$ ns
4. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 250$ ns. Example with $t_{SYNC1} + t_{SYNC2} = 500$ ns

Table 76. Examples of timings settings for $f_{I2CCLK} = 48$ MHz

Parameter	Standard-mode (Sm)		Fast-mode (Fm)	Fast-mode Plus (Fm+)
	10 kHz	100 kHz	400 kHz	1000 kHz
PRESC	0xB	0xB	5	5
SCLL	0xC7	0x13	0x9	0x3
t_{SCLL}	200×250 ns = 50 μ s	20×250 ns = 5.0 μ s	10×125 ns = 1250 ns	4×125 ns = 500 ns
SCLH	0xC3	0xF	0x3	0x1
t_{SCLH}	196×250 ns = 49 μ s	16×250 ns = 4.0 μ s	4×125 ns = 500 ns	2×125 ns = 250 ns
$t_{SCL}^{(1)}$	$\sim 100 \mu$ s ⁽²⁾	$\sim 10 \mu$ s ⁽²⁾	~ 2500 ns ⁽³⁾	~ 875 ns ⁽⁴⁾
SDADEL	0x2	0x2	0x3	0x0
t_{SDADEL}	2×250 ns = 500 ns	2×250 ns = 500 ns	3×125 ns = 375 ns	0 ns
SCLDEL	0x4	0x4	0x3	0x1
t_{SCLDEL}	5×250 ns = 1250 ns	5×250 ns = 1250 ns	4×125 ns = 500 ns	2×125 ns = 250 ns

1. The SCL period t_{SCL} is greater than $t_{SCLL} + t_{SCLH}$ due to the SCL internal detection delay. Values provided for t_{SCL} are only examples.
2. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 83.3$ ns. Example with $t_{SYNC1} + t_{SYNC2} = 1000$ ns
3. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 83.3$ ns. Example with $t_{SYNC1} + t_{SYNC2} = 750$ ns
4. $t_{SYNC1} + t_{SYNC2}$ minimum value is $4 \times t_{I2CCLK} = 83.3$ ns. Example with $t_{SYNC1} + t_{SYNC2} = 250$ ns

22.4.11 SMBus specific features

This section is relevant only when SMBus feature is supported. Please refer to [Section 22.3: I2C implementation](#).

Introduction

The System Management Bus (SMBus) is a two-wire interface through which various devices can communicate with each other and with the rest of the system. It is based on I²C principles of operation. SMBus provides a control bus for system and power management related tasks.

This peripheral is compatible with the SMBUS specification rev 2.0 (<http://smbus.org>).

The System Management Bus Specification refers to three types of devices.

- A slave is a device that receives or responds to a command.
- A master is a device that issues commands, generates the clocks and terminates the transfer.
- A host is a specialized master that provides the main interface to the system's CPU. A host must be a master-slave and must support the SMBus host notify protocol. Only one host is allowed in a system.

This peripheral can be configured as master or slave device, and also as a host.

SMBUS is based on I²C specification rev 2.1.

Bus protocols

There are eleven possible command protocols for any given device. A device may use any or all of the eleven protocols to communicate. The protocols are Quick Command, Send Byte, Receive Byte, Write Byte, Write Word, Read Byte, Read Word, Process Call, Block Read, Block Write and Block Write-Block Read Process Call. These protocols should be implemented by the user software.

For more details of these protocols, refer to SMBus specification version 2.0 (<http://smbus.org>).

Address resolution protocol (ARP)

SMBus slave address conflicts can be resolved by dynamically assigning a new unique address to each slave device. In order to provide a mechanism to isolate each device for the purpose of address assignment each device must implement a unique device identifier (UDID). This 128-bit number is implemented by software.

This peripheral supports the Address Resolution Protocol (ARP). The SMBus Device Default Address (0b1100 001) is enabled by setting SMBDEN bit in I2C_CR1 register. The ARP commands should be implemented by the user software.

Arbitration is also performed in slave mode for ARP support.

For more details of the SMBus Address Resolution Protocol, refer to SMBus specification version 2.0 (<http://smbus.org>).

Received Command and Data acknowledge control

A SMBus receiver must be able to NACK each received command or data. In order to allow the ACK control in slave mode, the Slave Byte Control mode must be enabled by setting SBC bit in I2C_CR1 register. Refer to [Slave Byte Control mode on page 540](#) for more details.

Host Notify protocol

This peripheral supports the Host Notify protocol by setting the SMBHEN bit in the I2C_CR1 register. In this case the host will acknowledge the SMBus Host address (0b0001 000).

When this protocol is used, the device acts as a master and the host as a slave.

SMBus alert

The SMBus ALERT optional signal is supported. A slave-only device can signal the host through the SMBALERT# pin that it wants to talk. The host processes the interrupt and simultaneously accesses all SMBALERT# devices through the Alert Response Address (0b0001 100). Only the device(s) which pulled SMBALERT# low will acknowledge the Alert Response Address.

When configured as a slave device (SMBHEN=0), the SMBA pin is pulled low by setting the ALERTEN bit in the I2C_CR1 register. The Alert Response Address is enabled at the same time.

When configured as a host (SMBHEN=1), the ALERT flag is set in the I2C_ISR register when a falling edge is detected on the SMBA pin and ALERTEN=1. An interrupt is generated if the ERRIE bit is set in the I2C_CR1 register. When ALERTEN=0, the ALERT line is considered high even if the external SMBA pin is low.

If the SMBus ALERT pin is not needed, the SMBA pin can be used as a standard GPIO if ALERTEN=0.

Packet error checking

A packet error checking mechanism has been introduced in the SMBus specification to improve reliability and communication robustness. Packet Error Checking is implemented by appending a Packet Error Code (PEC) at the end of each message transfer. The PEC is calculated by using the $C(x) = x_8 + x^2 + x + 1$ CRC-8 polynomial on all the message bytes (including addresses and read/write bits).

The peripheral embeds a hardware PEC calculator and allows to send a Not Acknowledge automatically when the received byte does not match with the hardware calculated PEC.

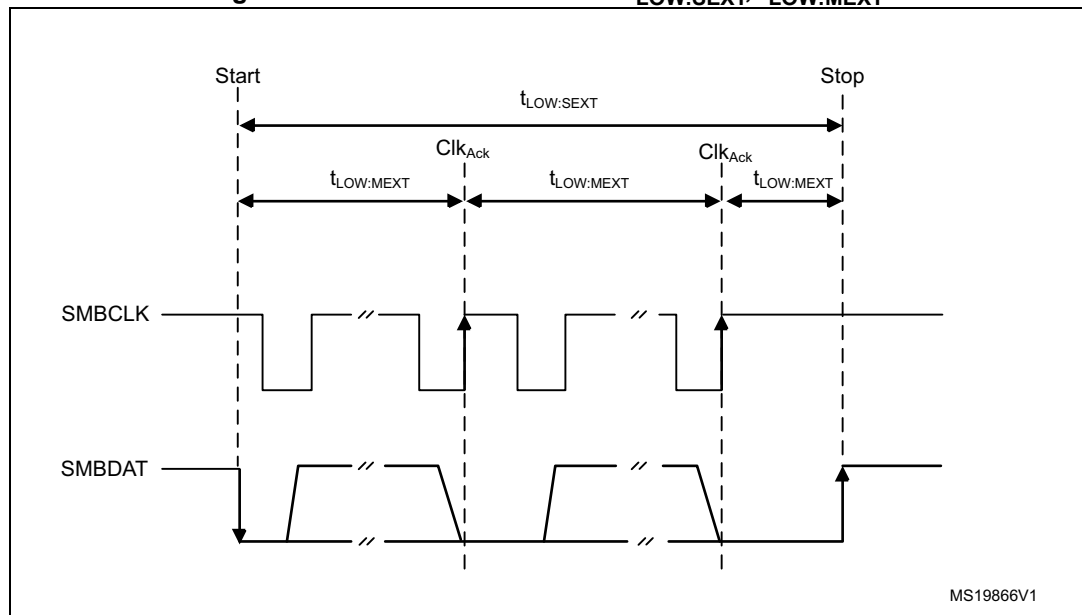
Timeouts

This peripheral embeds hardware timers in order to be compliant with the 3 timeouts defined in SMBus specification version 2.0.

Table 77. SMBus timeout specifications

Symbol	Parameter	Limits		Unit
		Min	Max	
t_{TIMEOUT}	Detect clock low timeout	25	35	ms
$t_{\text{LOW:SEXT}}^{(1)}$	Cumulative clock low extend time (slave device)	-	25	ms
$t_{\text{LOW:MEXT}}^{(2)}$	Cumulative clock low extend time (master device)	-	10	ms

1. $t_{\text{LOW:SEXT}}$ is the cumulative time a given slave device is allowed to extend the clock cycles in one message from the initial START to the STOP. It is possible that, another slave device or the master will also extend the clock causing the combined clock low extend time to be greater than $t_{\text{LOW:SEXT}}$. Therefore, this parameter is measured with the slave device as the sole target of a full-speed master.
2. $t_{\text{LOW:MEXT}}$ is the cumulative time a master device is allowed to extend its clock cycles within each byte of a message as defined from START-to-ACK, ACK-to-ACK, or ACK-to-STOP. It is possible that a slave device or another master will also extend the clock causing the combined clock low time to be greater than $t_{\text{LOW:MEXT}}$ on a given byte. Therefore, this parameter is measured with a full speed slave device as the sole target of the master.

Figure 218. Timeout intervals for $t_{\text{LOW:SEXT}}$, $t_{\text{LOW:MEXT}}$ 

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Bus idle detection

A master can assume that the bus is free if it detects that the clock and data signals have been high for t_{IDLE} greater than $t_{\text{HIGH,MAX}}$. (refer to [Table 73: I2C-SMBUS specification clock timings](#))

This timing parameter covers the condition where a master has been dynamically added to the bus and may not have detected a state transition on the SMBCLK or SMBDAT lines. In this case, the master must wait long enough to ensure that a transfer is not currently in progress. The peripheral supports a hardware bus idle detection.

22.4.12 SMBus initialization

This section is relevant only when SMBus feature is supported. Please refer to [Section 22.3: I2C implementation](#).

In addition to I2C initialization, some other specific initialization must be done in order to perform SMBus communication:

Received Command and Data Acknowledge control (Slave mode)

A SMBus receiver must be able to NACK each received command or data. In order to allow ACK control in slave mode, the Slave Byte Control mode must be enabled by setting the SBC bit in the I2C_CR1 register. Refer to [Slave Byte Control mode on page 540](#) for more details.

Specific address (Slave mode)

The specific SMBus addresses should be enabled if needed. Refer to [Bus idle detection on page 563](#) for more details.

- The SMBus Device Default address (0b1100 001) is enabled by setting the SMBDEN bit in the I2C_CR1 register.
- The SMBus Host address (0b0001 000) is enabled by setting the SMBHEN bit in the I2C_CR1 register.
- The Alert Response Address (0b0001100) is enabled by setting the ALERTEN bit in the I2C_CR1 register.

Packet error checking

PEC calculation is enabled by setting the PECEN bit in the I2C_CR1 register. Then the PEC transfer is managed with the help of a hardware byte counter: NBYTES[7:0] in the I2C_CR2 register. The PECEN bit must be configured before enabling the I2C.

The PEC transfer is managed with the hardware byte counter, so the SBC bit must be set when interfacing the SMBus in slave mode. The PEC is transferred after NBYTES-1 data have been transferred when the PECBYTE bit is set and the RELOAD bit is cleared. If RELOAD is set, PECBYTE has no effect.

Caution: Changing the PECEN configuration is not allowed when the I2C is enabled.

Table 78. SMBUS with PEC configuration

Mode	SBC bit	RELOAD bit	AUTOEND bit	PECBYTE bit
Master Tx/Rx NBYTES + PEC+ STOP	x	0	1	1
Master Tx/Rx NBYTES + PEC + ReSTART	x	0	0	1
Slave Tx/Rx with PEC	1	0	x	1

Timeout detection

The timeout detection is enabled by setting the TIMOUTEN and TEXTEN bits in the I2C_TIMEOUTR register. The timers must be programmed in such a way that they detect a timeout before the maximum time given in the SMBus specification version 2.0.

- t_{TIMEOUT} check
 In order to enable the t_{TIMEOUT} check, the 12-bit TIMEOUTA[11:0] bits must be programmed with the timer reload value in order to check the t_{TIMEOUT} parameter. The TIDLE bit must be configured to '0' in order to detect the SCL low level timeout.
 Then the timer is enabled by setting the TIMOUTEN in the I2C_TIMEOUTR register.
 If SCL is tied low for a time greater than $(\text{TIMEOUTA}+1) \times 2048 \times t_{\text{I2CCLK}}$, the TIMEOUT flag is set in the I2C_ISR register.
 Refer to [Table 79: Examples of TIMEOUTA settings for various I2CCLK frequencies \(max \$t_{\text{TIMEOUT}} = 25 \text{ ms}\$ \)](#).

Caution: Changing the TIMEOUTA[11:0] bits and TIDLE bit configuration is not allowed when the TIMOUTEN bit is set.

- $t_{\text{LOW:SEXT}}$ and $t_{\text{LOW:MEXT}}$ check
 Depending on if the peripheral is configured as a master or as a slave, The 12-bit TIMEOUTB timer must be configured in order to check $t_{\text{LOW:SEXT}}$ for a slave and

$t_{\text{LOW:MEXT}}$ for a master. As the standard specifies only a maximum, the user can choose the same value for the both.

Then the timer is enabled by setting the TEXTEN bit in the I2C_TIMEOUTR register.

If the SMBus peripheral performs a cumulative SCL stretch for a time greater than $(\text{TIMEOUTB}+1) \times 2048 \times t_{\text{I2CCLK}}$, and in the timeout interval described in [Bus idle detection on page 563](#) section, the TIMEOUT flag is set in the I2C_ISR register.

Refer to [Table 80: Examples of TIMEOUTB settings for various I2CCLK frequencies](#)

Caution: Changing the TIMEOUTB configuration is not allowed when the TEXTEN bit is set.

Bus Idle detection

In order to enable the t_{IDLE} check, the 12-bit TIMEOUTA[11:0] field must be programmed with the timer reload value in order to obtain the t_{IDLE} parameter. The TIDLE bit must be configured to '1' in order to detect both SCL and SDA high level timeout.

Then the timer is enabled by setting the TIMOUTEN bit in the I2C_TIMEOUTR register.

If both the SCL and SDA lines remain high for a time greater than $(\text{TIMEOUTA}+1) \times 4 \times t_{\text{I2CCLK}}$, the TIMEOUT flag is set in the I2C_ISR register.

Refer to [Table 81: Examples of TIMEOUTA settings for various I2CCLK frequencies \(max \$t_{\text{IDLE}} = 50 \mu\text{s}\$ \)](#)

Caution: Changing the TIMEOUTA and TIDLE configuration is not allowed when the TIMOUTEN is set.

22.4.13 SMBus: I2C_TIMEOUTR register configuration examples

This section is relevant only when SMBus feature is supported. Please refer to [Section 22.3: I2C implementation](#).

- Configuring the maximum duration of t_{TIMEOUT} to 25 ms:

Table 79. Examples of TIMEOUTA settings for various I2CCLK frequencies (max $t_{\text{TIMEOUT}} = 25 \text{ ms}$)

f_{I2CCLK}	TIMEOUTA[11:0] bits	TIDLE bit	TIMEOUTEN bit	t_{TIMEOUT}
8 MHz	0x61	0	1	$98 \times 2048 \times 125 \text{ ns} = 25 \text{ ms}$
16 MHz	0xC3	0	1	$196 \times 2048 \times 62.5 \text{ ns} = 25 \text{ ms}$
48 MHz	0x249	0	1	$586 \times 2048 \times 20.08 \text{ ns} = 25 \text{ ms}$

- Configuring the maximum duration of $t_{\text{LOW:SEXT}}$ and $t_{\text{LOW:MEXT}}$ to 8 ms:

Table 80. Examples of TIMEOUTB settings for various I2CCLK frequencies

f_{I2CCLK}	TIMEOUTB[11:0] bits	TEXTEN bit	$t_{\text{LOW:EXT}}$
8 MHz	0x1F	1	$32 \times 2048 \times 125 \text{ ns} = 8 \text{ ms}$
16 MHz	0x3F	1	$64 \times 2048 \times 62.5 \text{ ns} = 8 \text{ ms}$
48 MHz	0xBB	1	$188 \times 2048 \times 20.08 \text{ ns} = 8 \text{ ms}$

- Configuring the maximum duration of t_{IDLE} to 50 μs

Table 81. Examples of TIMEOUTA settings for various I2CCLK frequencies
(max t_{IDLE} = 50 μs)

f_{I2CCLK}	TIMEOUTA[11:0] bits	TIDLE bit	TIMEOUTEN bit	t_{TIDLE}
8 MHz	0x63	1	1	$100 \times 4 \times 125 \text{ ns} = 50 \mu s$
16 MHz	0xC7	1	1	$200 \times 4 \times 62.5 \text{ ns} = 50 \mu s$
48 MHz	0x257	1	1	$600 \times 4 \times 20.08 \text{ ns} = 50 \mu s$

22.4.14 SMBus slave mode

This section is relevant only when SMBus feature is supported. Please refer to [Section 22.3: I2C implementation](#).

In addition to 2C slave transfer management (refer to [Section 22.4.8: I2C slave mode](#)) some additional software flowcharts are provided to support SMBus.

SMBus Slave transmitter

When the IP is used in SMBus, SBC must be programmed to '1' in order to allow the PEC transmission at the end of the programmed number of data bytes. When the PECBYTE bit is set, the number of bytes programmed in NBYTES[7:0] includes the PEC transmission. In that case the total number of TXIS interrupts will be NBYTES-1 and the content of the I2C_PECR register is automatically transmitted if the master requests an extra byte after the NBYTES-1 data transfer.

Caution: The PECBYTE bit has no effect when the RELOAD bit is set.

Figure 219. Transfer sequence flowchart for SMBus slave transmitter N bytes + PEC

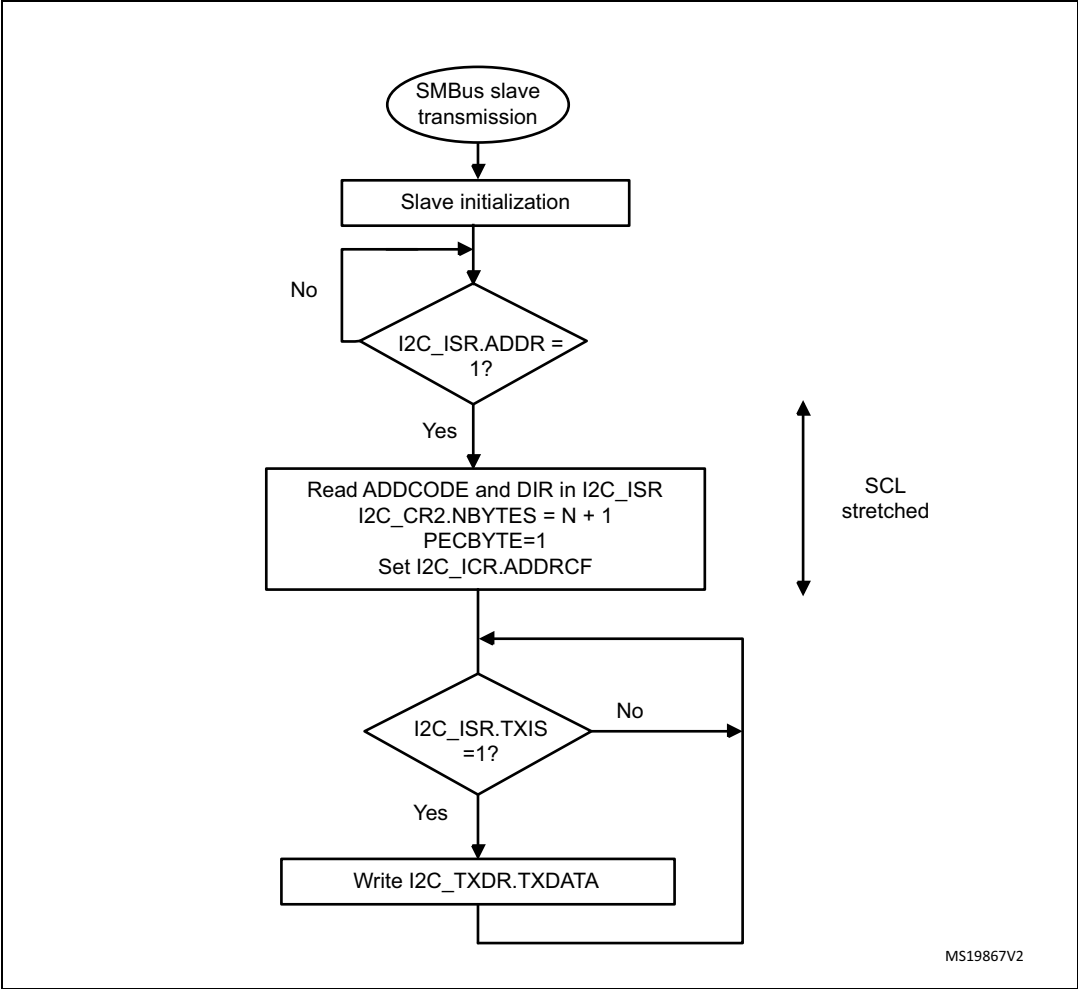
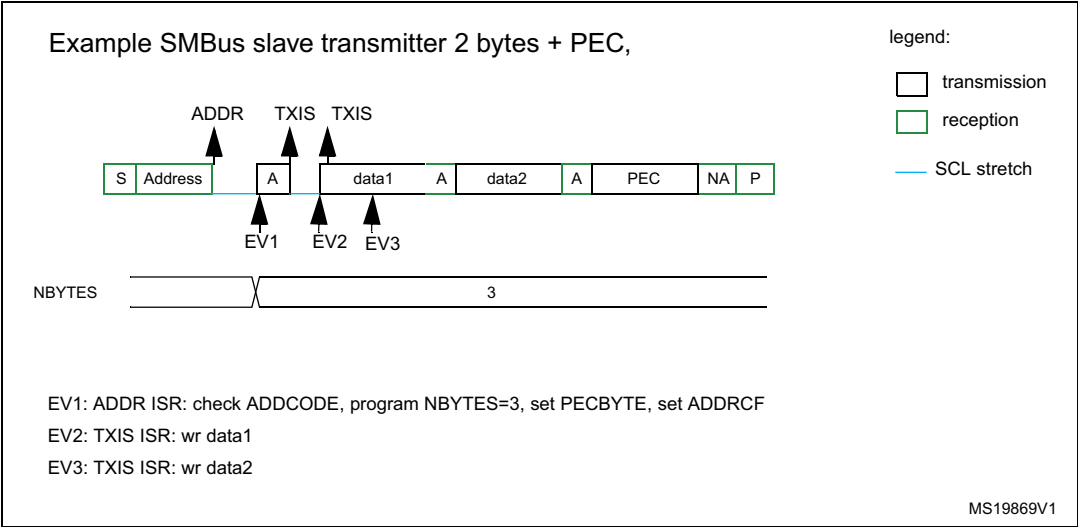


Figure 220. Transfer bus diagrams for SMBus slave transmitter (SBC=1)



SMBus Slave receiver

When the I2C is used in SMBus mode, SBC must be programmed to '1' in order to allow the PEC checking at the end of the programmed number of data bytes. In order to allow the ACK control of each byte, the reload mode must be selected (RELOAD=1). Refer to [Slave Byte Control mode on page 540](#) for more details.

In order to check the PEC byte, the RELOAD bit must be cleared and the PECBYTE bit must be set. In this case, after NBYTES-1 data have been received, the next received byte is compared with the internal I2C_PECR register content. A NACK is automatically generated if the comparison does not match, and an ACK is automatically generated if the comparison matches, whatever the ACK bit value. Once the PEC byte is received, it is copied into the I2C_RXDR register like any other data, and the RXNE flag is set.

In the case of a PEC mismatch, the PECERR flag is set and an interrupt is generated if the ERRIE bit is set in the I2C_CR1 register.

If no ACK software control is needed, the user can program PECBYTE=1 and, in the same write operation, program NBYTES with the number of bytes to be received in a continuous flow. After NBYTES-1 are received, the next received byte is checked as being the PEC.

Caution: The PECBYTE bit has no effect when the RELOAD bit is set.

Figure 221. Transfer sequence flowchart for SMBus slave receiver N Bytes + PEC

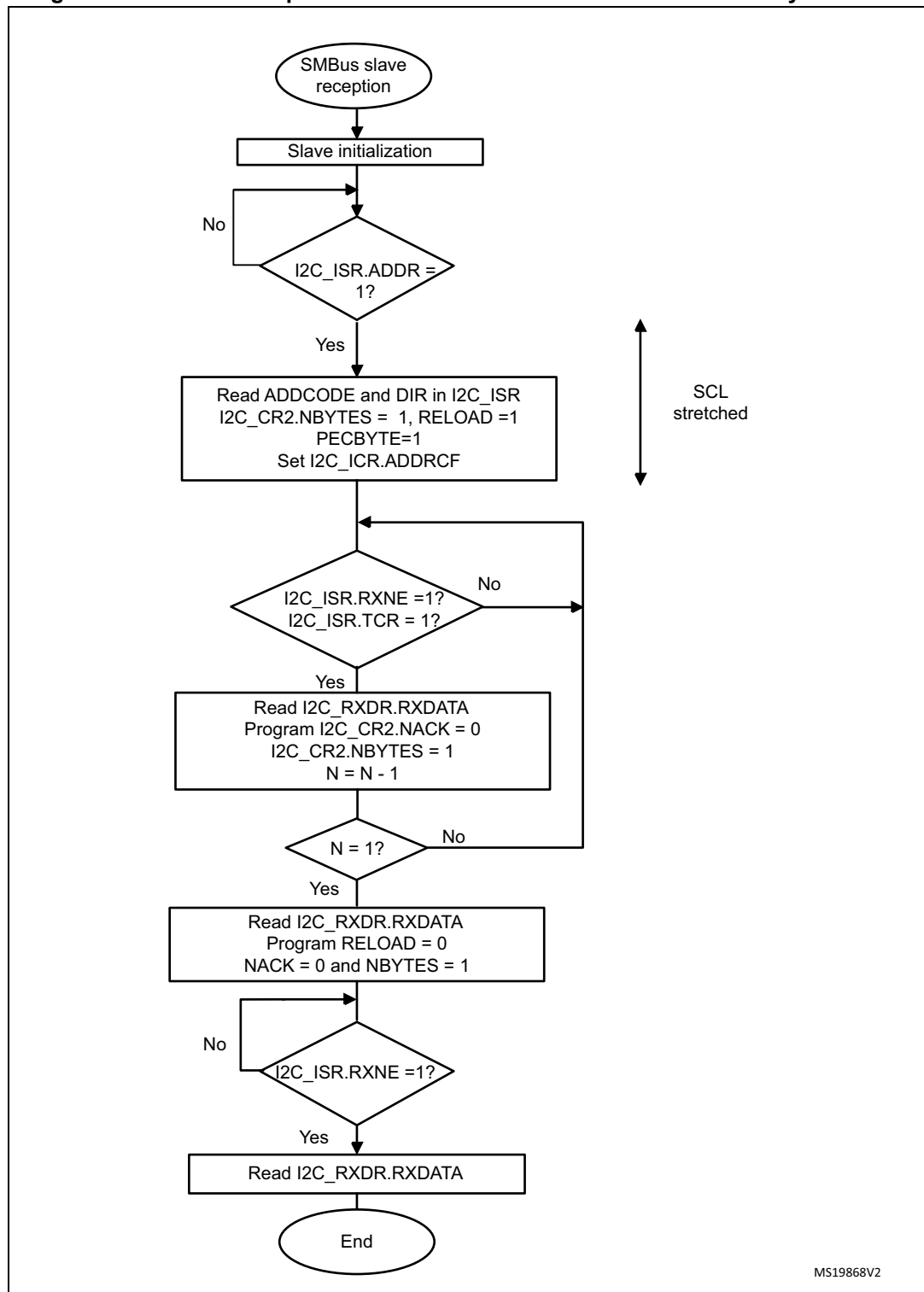
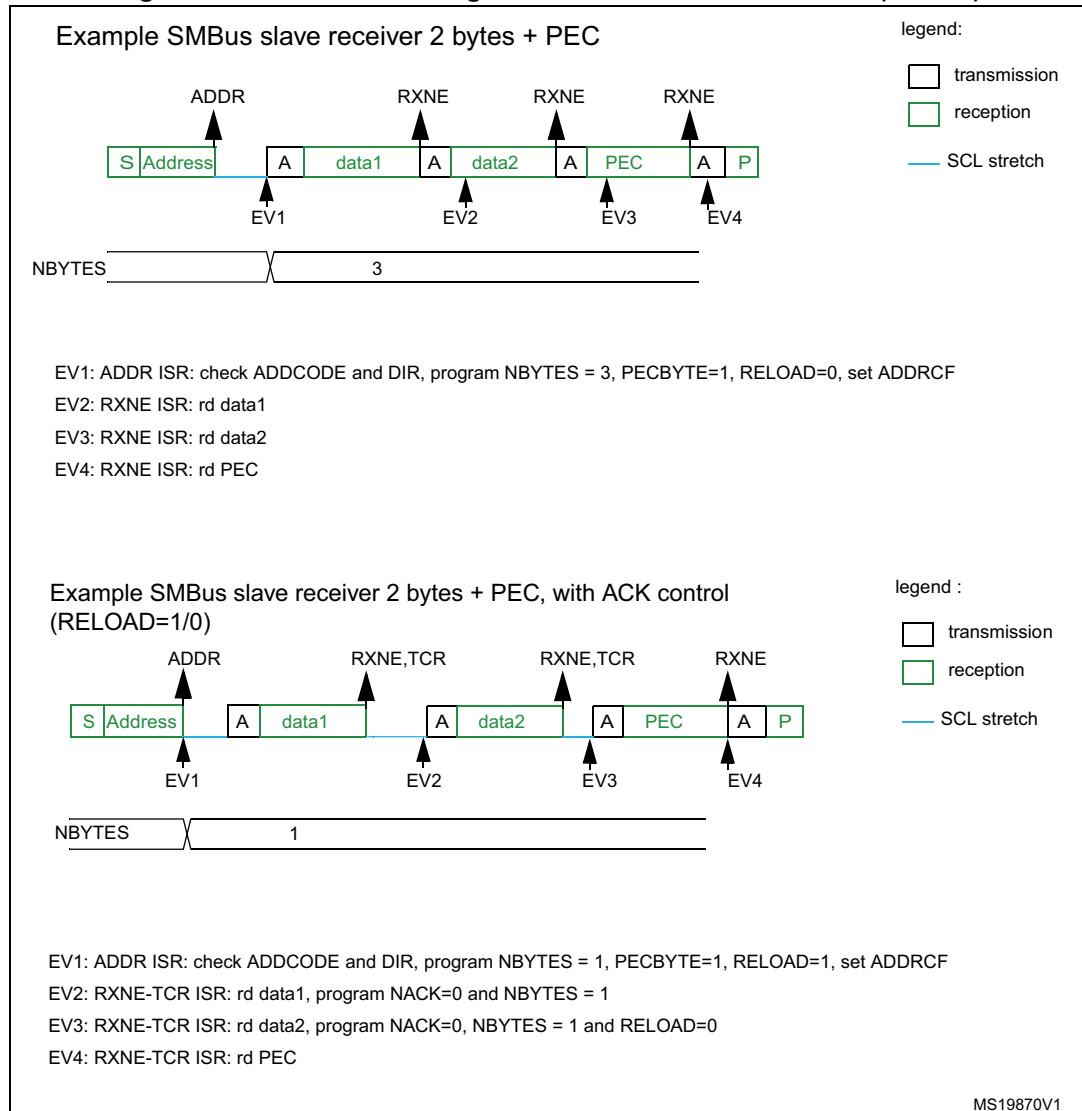


Figure 222. Bus transfer diagrams for SMBus slave receiver (SBC=1)

This section is relevant only when SMBus feature is supported. Please refer to [Section 22.3: I2C implementation](#).

In addition to I2C master transfer management (refer to [Section 22.4.9: I2C master mode](#)) some additional software flowcharts are provided to support SMBus.

SMBus Master transmitter

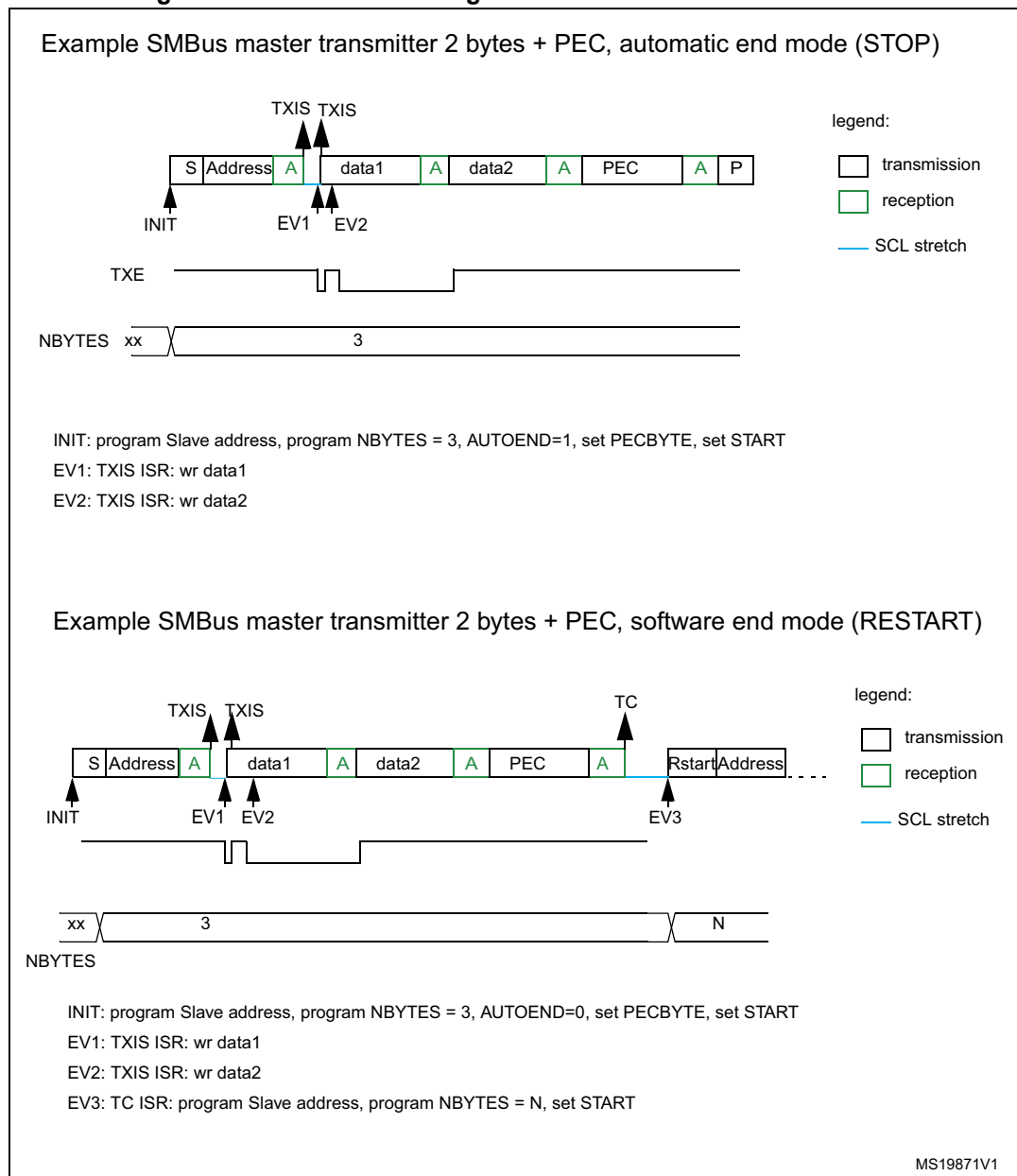
When the SMBus master wants to transmit the PEC, the PECBYTE bit must be set and the number of bytes must be programmed in the NBYTES[7:0] field, before setting the START bit. In this case the total number of TXIS interrupts will be NBYTES-1. So if the PECBYTE bit is set when NBYTES=0x1, the content of the I2C_PECR register is automatically transmitted.

If the SMBus master wants to send a STOP condition after the PEC, automatic end mode should be selected (AUTOEND=1). In this case, the STOP condition automatically follows the PEC transmission.

When the SMBus master wants to send a RESTART condition after the PEC, software mode must be selected (AUTOEND=0). In this case, once NBYTES-1 have been transmitted, the I2C_PECR register content is transmitted and the TC flag is set after the PEC transmission, stretching the SCL line low. The RESTART condition must be programmed in the TC interrupt subroutine.

Caution: The PECBYTE bit has no effect when the RELOAD bit is set.

Figure 223. Bus transfer diagrams for SMBus master transmitter

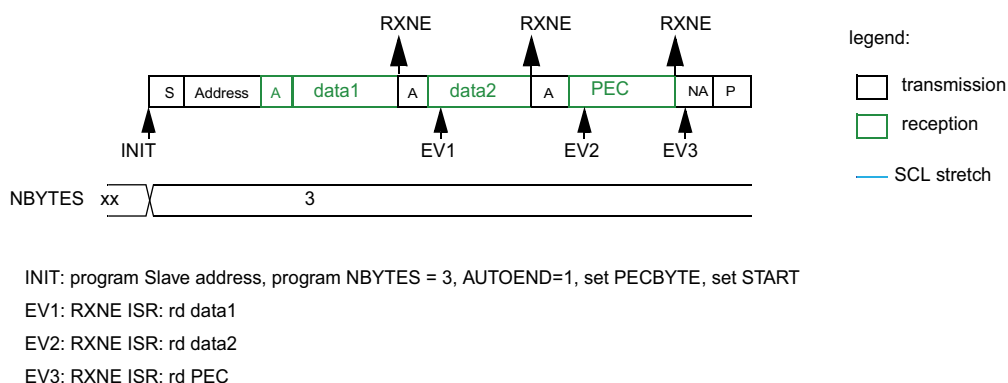
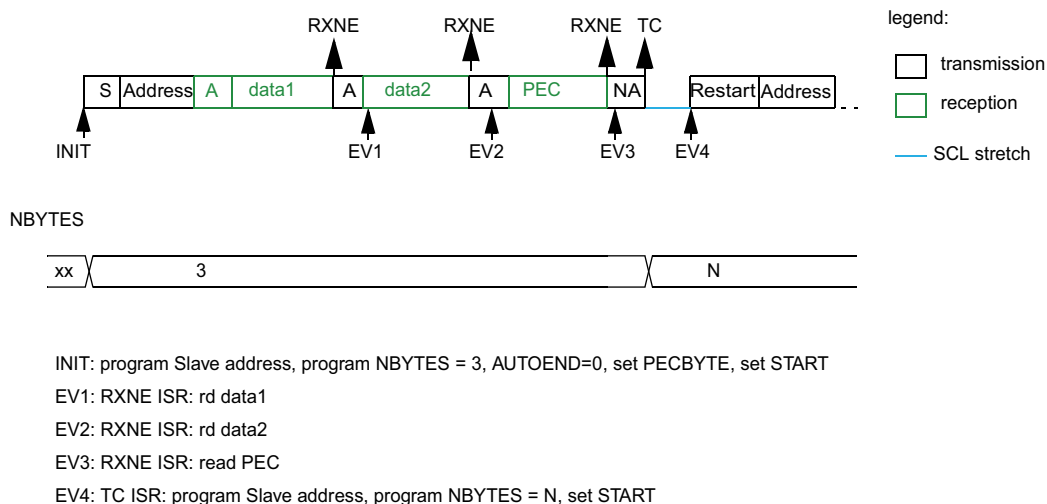


SMBus Master receiver

When the SMBus master wants to receive the PEC followed by a STOP at the end of the transfer, automatic end mode can be selected (AUTOEND=1). The PECBYTE bit must be set and the slave address must be programmed, before setting the START bit. In this case, after NBYTES-1 data have been received, the next received byte is automatically checked versus the I2C_PECR register content. A NACK response is given to the PEC byte, followed by a STOP condition.

When the SMBus master receiver wants to receive the PEC byte followed by a RESTART condition at the end of the transfer, software mode must be selected (AUTOEND=0). The PECBYTE bit must be set and the slave address must be programmed, before setting the START bit. In this case, after NBYTES-1 data have been received, the next received byte is automatically checked versus the I2C_PECR register content. The TC flag is set after the PEC byte reception, stretching the SCL line low. The RESTART condition can be programmed in the TC interrupt subroutine.

Caution: The PECBYTE bit has no effect when the RELOAD bit is set.

Figure 224. Bus transfer diagrams for SMBus master receiver**Example SMBus master receiver 2 bytes + PEC, automatic end mode (STOP)****Example SMBus master receiver 2 bytes + PEC, software end mode (RESTART)**

MS19872V1

22.4.15 Error conditions

The following are the error conditions which may cause communication to fail.

Bus error (BERR)

A bus error is detected when a START or a STOP condition is detected and is not located after a multiple of 9 SCL clock pulses. A START or a STOP condition is detected when a SDA edge occurs while SCL is high.

The bus error flag is set only if the I2C is involved in the transfer as master or addressed slave (i.e not during the address phase in slave mode).

In case of a misplaced START or RESTART detection in slave mode, the I2C enters address recognition state like for a correct START condition.

When a bus error is detected, the BERR flag is set in the I2C_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2C_CR1 register.

Arbitration lost (ARLO)

An arbitration loss is detected when a high level is sent on the SDA line, but a low level is sampled on the SCL rising edge.

- In master mode, arbitration loss is detected during the address phase, data phase and data acknowledge phase. In this case, the SDA and SCL lines are released, the START control bit is cleared by hardware and the master switches automatically to slave mode.
- In slave mode, arbitration loss is detected during data phase and data acknowledge phase. In this case, the transfer is stopped, and the SCL and SDA lines are released.

When an arbitration loss is detected, the ARLO flag is set in the I2C_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2C_CR1 register.

Overrun/underrun error (OVR)

An overrun or underrun error is detected in slave mode when NOSTRETCH=1 and:

- In reception when a new byte is received and the RXDR register has not been read yet. The new received byte is lost, and a NACK is automatically sent as a response to the new byte.
- In transmission:
 - When STOPF=1 and the first data byte should be sent. The content of the I2C_TXDR register is sent if TXE=0, 0xFF if not.
 - When a new byte should be sent and the I2C_TXDR register has not been written yet, 0xFF is sent.

When an overrun or underrun error is detected, the OVR flag is set in the I2C_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2C_CR1 register.

Packet Error Checking Error (PECERR)

This section is relevant only when the SMBus feature is supported. Please refer to [Section 22.3: I2C implementation](#).

A PEC error is detected when the received PEC byte does not match with the I2C_PECR register content. A NACK is automatically sent after the wrong PEC reception.

When a PEC error is detected, the PECERR flag is set in the I2C_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2C_CR1 register.

Timeout Error (TIMEOUT)

This section is relevant only when the SMBus feature is supported. Please refer to [Section 22.3: I2C implementation](#).

A timeout error occurs for any of these conditions:

- TIDLE=0 and SCL remained low for the time defined in the TIMEOUTA[11:0] bits: this is used to detect a SMBus timeout.
- TIDLE=1 and both SDA and SCL remained high for the time defined in the TIMEOUTA [11:0] bits: this is used to detect a bus idle condition.
- Master cumulative clock low extend time reached the time defined in the TIMEOUTB[11:0] bits (SMBus $t_{\text{LOW:MEXT}}$ parameter)
- Slave cumulative clock low extend time reached the time defined in TIMEOUTB[11:0] bits (SMBus $t_{\text{LOW:SEXT}}$ parameter)

When a timeout violation is detected in master mode, a STOP condition is automatically sent.

When a timeout violation is detected in slave mode, SDA and SCL lines are automatically released.

When a timeout error is detected, the TIMEOUT flag is set in the I2C_ISR register, and an interrupt is generated if the ERRIE bit is set in the I2C_CR1 register.

Alert (ALERT)

This section is relevant only when the SMBus feature is supported. Please refer to [Section 22.3: I2C implementation](#).

The ALERT flag is set when the I2C interface is configured as a Host (SMBHEN=1), the alert pin detection is enabled (ALERTEN=1) and a falling edge is detected on the SMBA pin. An interrupt is generated if the ERRIE bit is set in the I2C_CR1 register.

22.4.16 DMA requests

Transmission using DMA

DMA (Direct Memory Access) can be enabled for transmission by setting the TXDMAEN bit in the I2C_CR1 register. Data is loaded from an SRAM area configured using the DMA peripheral (see [Section 10: Direct memory access controller \(DMA\) on page 152](#)) to the I2C_TXDR register whenever the TXIS bit is set.

Only the data are transferred with DMA.

- In master mode: the initialization, the slave address, direction, number of bytes and START bit are programmed by software (the transmitted slave address cannot be transferred with DMA). When all data are transferred using DMA, the DMA must be initialized before setting the START bit. The end of transfer is managed with the NBYTES counter. Refer to [Master transmitter on page 551](#).

For code example refer to the Appendix section [A.11.8: I2C configured in master mode to transmit with DMA code example](#).

- In slave mode:
 - With NOSTRETCH=0, when all data are transferred using DMA, the DMA must be initialized before the address match event, or in ADDR interrupt subroutine, before clearing ADDR.
 - With NOSTRETCH=1, the DMA must be initialized before the address match event.
- For instances supporting SMBus: the PEC transfer is managed with NBYTES counter. Refer to [SMBus Slave transmitter on page 566](#) and [SMBus Master transmitter on page 570](#).

Note: If DMA is used for transmission, the TXIE bit does not need to be enabled.

Reception using DMA

DMA (Direct Memory Access) can be enabled for reception by setting the RXDMAEN bit in the I2C_CR1 register. Data is loaded from the I2C_RXDR register to an SRAM area configured using the DMA peripheral (refer to [Section 10: Direct memory access controller \(DMA\) on page 152](#)) whenever the RXNE bit is set. Only the data (including PEC) are transferred with DMA.

- In master mode, the initialization, the slave address, direction, number of bytes and START bit are programmed by software. When all data are transferred using DMA, the DMA must be initialized before setting the START bit. The end of transfer is managed with the NBYTES counter..
- In slave mode with NOSTRETCH=0, when all data are transferred using DMA, the DMA must be initialized before the address match event, or in the ADDR interrupt subroutine, before clearing the ADDR flag.
- If SMBus is supported (see [Section 22.3: I2C implementation](#)): the PEC transfer is managed with the NBYTES counter. Refer to [SMBus Slave receiver on page 568](#) and [SMBus Master receiver on page 572](#).

Note: If DMA is used for reception, the RXIE bit does not need to be enabled.

For code example refer to the Appendix section [A.11.9: I2C configured in slave mode to receive with DMA code example](#).

22.4.17 Debug mode

When the microcontroller enters debug mode (core halted), the SMBus timeout either continues to work normally or stops, depending on the DBG_I2Cx_SMBUS_TIMEOUT configuration bits in the DBG module.

22.5 I2C low-power modes

Table 82. low-power modes

Mode	Description
Sleep	No effect I2C interrupts cause the device to exit the Sleep mode.
Stop	The contents of I2C registers are kept. The I2C must be disabled before entering Stop mode.
Standby	The I2C peripheral is powered down and must be reinitialized after exiting Standby.

22.6 I2C interrupts

The table below gives the list of I2C interrupt requests.

Table 83. I2C Interrupt requests

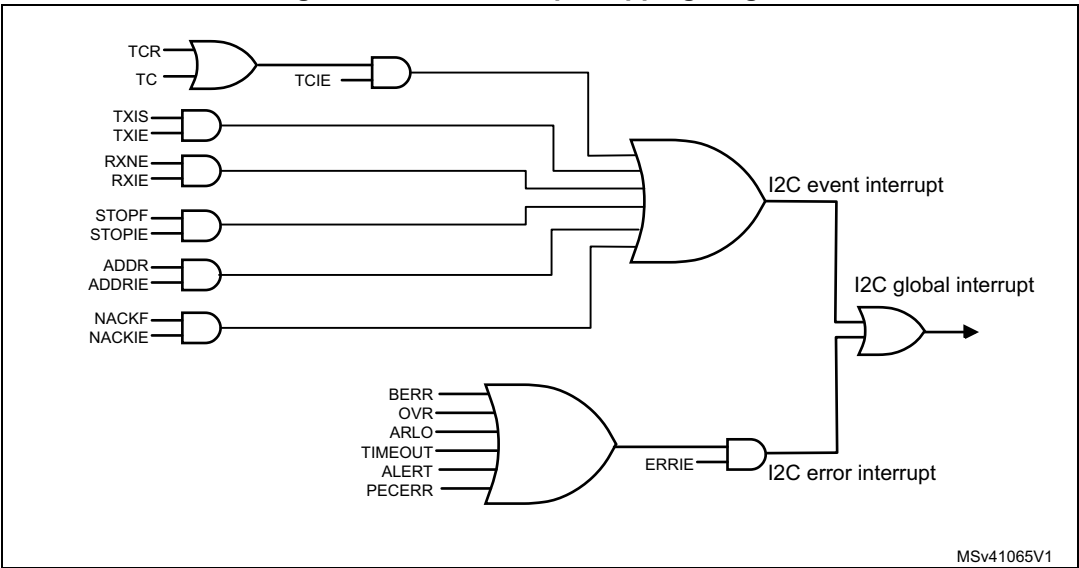
Interrupt event	Event flag	Event flag/Interrupt clearing method	Interrupt enable control bit
Receive buffer not empty	RXNE	Read I2C_RXDR register	RXIE
Transmit buffer interrupt status	TXIS	Write I2C_TXDR register	TXIE
Stop detection interrupt flag	STOPF	Write STOPCF=1	STOPIE
Transfer Complete Reload	TCR	Write I2C_CR2 with NBYTES[7:0] ≠ 0	TCIE
Transfer complete	TC	Write START=1 or STOP=1	
Address matched	ADDR	Write ADDRCONF=1	ADDRIE
NACK reception	NACKF	Write NACKCF=1	NACKIE
Bus error	BERR	Write BERRCF=1	ERRIE
Arbitration loss	ARLO	Write ARLOCF=1	
Overrun/Underrun	OVR	Write OVRCF=1	
PEC error	PECERR	Write PECERRCF=1	
Timeout/t _{LOW} error	TIMEOUT	Write TIMEOUTCF=1	
SMBus Alert	ALERT	Write ALERTCF=1	

Depending on the product implementation, all these interrupts events can either share the same interrupt vector (I2C global interrupt), or be grouped into 2 interrupt vectors (I2C event interrupt and I2C error interrupt). Refer to [Table 32: Vector table](#) for details.

In order to enable the I2C interrupts, the following sequence is required:

1. Configure and enable the I2C IRQ channel in the NVIC.
2. Configure the I2C to generate interrupts.

Figure 225. I2C interrupt mapping diagram



22.7 I2C registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

The peripheral registers are accessed by words (32-bit).

22.7.1 Control register 1 (I2C_CR1)

Address offset: 0x00

Reset value: 0x0000 0000

Access: No wait states, except if a write access occurs while a write access to this register is ongoing. In this case, wait states are inserted in the second write access until the previous one is completed. The latency of the second write access can be up to $2 \times \text{PCLK1} + 6 \times \text{I2CCLK}$.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PECEN	ALERT EN	SMBD EN	SMBH EN	GCEN	Res.	NOSTR ETCH	SBC
								rw	rw	rw	rw	rw		rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RXDMA EN	TXDMA EN	Res.	ANF OFF	DNF				ERRIE	TCIE	STOP IE	NACK IE	ADDR IE	RXIE	TXIE	PE
rw	rw		rw	rw				rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:24 Reserved, must be kept at reset value.

Bit 23 **PECEN**: PEC enable

- 0: PEC calculation disabled
- 1: PEC calculation enabled

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'.
Please refer to [Section 22.3: I2C implementation](#).*

Bit 22 **ALERTEN**: SMBus alert enable

Device mode (SMBHEN=0):

- 0: Releases SMBA pin high and Alert Response Address Header disabled: 0001100x followed by NACK.
- 1: Drives SMBA pin low and Alert Response Address Header enables: 0001100x followed by ACK.

Host mode (SMBHEN=1):

- 0: SMBus Alert pin (SMBA) not supported.
- 1: SMBus Alert pin (SMBA) supported.

Note: When ALERTEN=0, the SMBA pin can be used as a standard GPIO.

*If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'.
Please refer to [Section 22.3: I2C implementation](#).*

Bit 21 **SMBDEN**: SMBus Device Default address enable

- 0: Device default address disabled. Address 0b1100001x is NACKed.
- 1: Device default address enabled. Address 0b1100001x is ACKed.

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'.
Please refer to [Section 22.3: I2C implementation](#).*

Bit 20 **SMBHEN**: SMBus Host address enable

- 0: Host address disabled. Address 0b0001000x is NACKed.
- 1: Host address enabled. Address 0b0001000x is ACKed.

*Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'.
Please refer to [Section 22.3: I2C implementation](#).*

Bit 19 **GCEN**: General call enable

- 0: General call disabled. Address 0b00000000 is NACKed.
- 1: General call enabled. Address 0b00000000 is ACKed.

Bit 18 Reserved, must be kept at reset value.

Bit 17 **NOSTRETCH**: Clock stretching disable

This bit is used to disable clock stretching in slave mode. It must be kept cleared in master mode.

- 0: Clock stretching enabled
- 1: Clock stretching disabled

Note: This bit can only be programmed when the I2C is disabled (PE = 0).

Bit 16 **SBC**: Slave byte control

This bit is used to enable hardware byte control in slave mode.

- 0: Slave byte control disabled
- 1: Slave byte control enabled

Bit 15 **RXDMAEN**: DMA reception requests enable

- 0: DMA mode disabled for reception
- 1: DMA mode enabled for reception

Bit 14 **TXDMAEN**: DMA transmission requests enable

- 0: DMA mode disabled for transmission
- 1: DMA mode enabled for transmission

Bit 13 Reserved, must be kept at reset value.

Bit 12 **ANFOFF**: Analog noise filter OFF

0: Analog noise filter enabled

1: Analog noise filter disabled

Note: This bit can only be programmed when the I2C is disabled (PE = 0).

Bits 11:8 **DNF[3:0]**: Digital noise filter

These bits are used to configure the digital noise filter on SDA and SCL input. The digital filter will filter spikes with a length of up to $DNF[3:0] * t_{I2CCLK}$

0000: Digital filter disabled

0001: Digital filter enabled and filtering capability up to 1 t_{I2CCLK}

...
1111: digital filter enabled and filtering capability up to 15 t_{I2CCLK}

Note: If the analog filter is also enabled, the digital filter is added to the analog filter.

This filter can only be programmed when the I2C is disabled (PE = 0).

Bit 7 **ERRIE**: Error interrupts enable

0: Error detection interrupts disabled

1: Error detection interrupts enabled

Note: Any of these errors generate an interrupt:

Arbitration Loss (ARLO)

Bus Error detection (BERR)

Overrun/Underrun (OVR)

Timeout detection (TIMEOUT)

PEC error detection (PECERR)

Alert pin event detection (ALERT)

Bit 6 **TCIE**: Transfer Complete interrupt enable

0: Transfer Complete interrupt disabled

1: Transfer Complete interrupt enabled

Note: Any of these events will generate an interrupt:

Transfer Complete (TC)

Transfer Complete Reload (TCR)

Bit 5 **STOPIE**: STOP detection Interrupt enable

0: Stop detection (STOPF) interrupt disabled

1: Stop detection (STOPF) interrupt enabled

Bit 4 **NACKIE**: Not acknowledge received Interrupt enable

0: Not acknowledge (NACKF) received interrupts disabled

1: Not acknowledge (NACKF) received interrupts enabled

Bit 3 **ADDRIE**: Address match Interrupt enable (slave only)

0: Address match (ADDR) interrupts disabled

1: Address match (ADDR) interrupts enabled

Bit 2 **RXIE**: RX Interrupt enable

0: Receive (RXNE) interrupt disabled

1: Receive (RXNE) interrupt enabled

Bit 1 **TXIE**: TX Interrupt enable

0: Transmit (TXIS) interrupt disabled

1: Transmit (TXIS) interrupt enabled

Bit 0 **PE**: Peripheral enable

0: Peripheral disable

1: Peripheral enable

Note: When PE=0, the I2C SCL and SDA lines are released. Internal state machines and status bits are put back to their reset value. When cleared, PE must be kept low for at least 3 APB clock cycles.

22.7.2 Control register 2 (I2C_CR2)

Address offset: 0x04

Reset value: 0x0000 0000

Access: No wait states, except if a write access occurs while a write access to this register is ongoing. In this case, wait states are inserted in the second write access until the previous one is completed. The latency of the second write access can be up to $2 \times \text{PCLK1} + 6 \times \text{I2CCLK}$.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	PEC BYTE	AUTO END	RE LOAD	NBYTES[7:0]							
					rs	rw	rw	rw							
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
NACK	STOP	START	HEAD 10R	ADD10	RD_ WRN	SADD[9:0]									
rs	rs	rs	rw	rw	rw	rw									

Bits 31:27 Reserved, must be kept at reset value.

Bit 26 **PECBYTE**: Packet error checking byte

This bit is set by software, and cleared by hardware when the PEC is transferred, or when a STOP condition or an Address matched is received, also when PE=0.

0: No PEC transfer.

1: PEC transmission/reception is requested

Note: Writing '0' to this bit has no effect.

This bit has no effect when RELOAD is set.

This bit has no effect in slave mode when SBC=0.

If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'.

Please refer to [Section 22.3: I2C implementation](#).

Bit 25 **AUTOEND**: Automatic end mode (master mode)

This bit is set and cleared by software.

0: software end mode: TC flag is set when NBYTES data are transferred, stretching SCL low.

1: Automatic end mode: a STOP condition is automatically sent when NBYTES data are transferred.

Note: This bit has no effect in slave mode or when the RELOAD bit is set.

Bit 24 **RELOAD**: NBYTES reload mode

This bit is set and cleared by software.

0: The transfer is completed after the NBYTES data transfer (STOP or RESTART will follow).

1: The transfer is not completed after the NBYTES data transfer (NBYTES will be reloaded).

TCR flag is set when NBYTES data are transferred, stretching SCL low.

Bits 23:16 **NBYTES[7:0]**: Number of bytes

The number of bytes to be transmitted/received is programmed there. This field is don't care in slave mode with SBC=0.

Note: Changing these bits when the START bit is set is not allowed.

Bit 15 **NACK**: NACK generation (slave mode)

The bit is set by software, cleared by hardware when the NACK is sent, or when a STOP condition or an Address matched is received, or when PE=0.

0: an ACK is sent after current received byte.

1: a NACK is sent after current received byte.

Note: Writing '0' to this bit has no effect.

This bit is used in slave mode only: in master receiver mode, NACK is automatically generated after last byte preceding STOP or RESTART condition, whatever the NACK bit value.

When an overrun occurs in slave receiver NOSTRETCH mode, a NACK is automatically generated whatever the NACK bit value.

When hardware PEC checking is enabled (PECBYTE=1), the PEC acknowledge value does not depend on the NACK value.

Bit 14 **STOP**: Stop generation (master mode)

The bit is set by software, cleared by hardware when a Stop condition is detected, or when PE = 0.

In Master Mode:

0: No Stop generation.

1: Stop generation after current byte transfer.

Note: Writing '0' to this bit has no effect.

Bit 13 **START**: Start generation

This bit is set by software, and cleared by hardware after the Start followed by the address sequence is sent, by an arbitration loss, by a timeout error detection, or when PE = 0. It can also be cleared by software by writing '1' to the ADDRCONF bit in the I2C_ICR register.

0: No Start generation.

1: Restart/Start generation:

- If the I2C is already in master mode with AUTOEND = 0, setting this bit generates a Repeated Start condition when RELOAD=0, after the end of the NBYTES transfer.
- Otherwise setting this bit will generate a START condition once the bus is free.

Note: Writing '0' to this bit has no effect.

The START bit can be set even if the bus is BUSY or I2C is in slave mode.

This bit has no effect when RELOAD is set. In 10-bit addressing mode, if a NACK is received on the first part of the address, the START bit is not cleared by hardware and the master will resend the address sequence, unless the START bit is cleared by software

Bit 12 **HEAD10R**: 10-bit address header only read direction (master receiver mode)

0: The master sends the complete 10 bit slave address read sequence: Start + 2 bytes 10bit address in write direction + Restart + 1st 7 bits of the 10 bit address in read direction.

1: The master only sends the 1st 7 bits of the 10 bit address, followed by Read direction.

Note: Changing this bit when the START bit is set is not allowed.

Bit 11 **ADD10**: 10-bit addressing mode (master mode)

0: The master operates in 7-bit addressing mode,

1: The master operates in 10-bit addressing mode

Note: Changing this bit when the START bit is set is not allowed.

Bit 10 **RD_WRN**: Transfer direction (master mode)

0: Master requests a write transfer.

1: Master requests a read transfer.

Note: Changing this bit when the START bit is set is not allowed.

Bits 9:8 **SADD[9:8]**: Slave address bit 9:8 (master mode)

In 7-bit addressing mode (ADD10 = 0):

These bits are don't care

In 10-bit addressing mode (ADD10 = 1):

These bits should be written with bits 9:8 of the slave address to be sent

Note: Changing these bits when the START bit is set is not allowed.

Bits 7:1 **SADD[7:1]**: Slave address bit 7:1 (master mode)

In 7-bit addressing mode (ADD10 = 0):

These bits should be written with the 7-bit slave address to be sent

In 10-bit addressing mode (ADD10 = 1):

These bits should be written with bits 7:1 of the slave address to be sent.

Note: Changing these bits when the START bit is set is not allowed.

Bit 0 **SADD0**: Slave address bit 0 (master mode)

In 7-bit addressing mode (ADD10 = 0):

This bit is don't care

In 10-bit addressing mode (ADD10 = 1):

This bit should be written with bit 0 of the slave address to be sent

Note: Changing these bits when the START bit is set is not allowed.

22.7.3 Own address 1 register (I2C_OAR1)

Address offset: 0x08

Reset value: 0x0000 0000

Access: No wait states, except if a write access occurs while a write access to this register is ongoing. In this case, wait states are inserted in the second write access until the previous one is completed. The latency of the second write access can be up to $2 \times \text{PCLK1} + 6 \times \text{I2CCLK}$.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OA1EN	Res.	Res.	Res.	Res.	OA1 MODE	OA1[9:8]		OA1[7:1]							OA1[0]
rw					rw	rw		rw							rw

Bits 31:16 Reserved, must be kept at reset value.

Bit 15 **OA1EN**: Own Address 1 enable

0: Own address 1 disabled. The received slave address OA1 is NACKed.

1: Own address 1 enabled. The received slave address OA1 is ACKed.

Bits 14:11 Reserved, must be kept at reset value.

Bit 10 **OA1MODE** Own Address 1 10-bit mode

0: Own address 1 is a 7-bit address.

1: Own address 1 is a 10-bit address.

Note: This bit can be written only when OA1EN=0.

Bits 9:8 **OA1[9:8]**: Interface address

7-bit addressing mode: don't care

10-bit addressing mode: bits 9:8 of address

Note: These bits can be written only when OA1EN=0.

Bits 7:1 **OA1[7:1]**: Interface address

Bits 7:1 of address

Note: These bits can be written only when OA1EN=0.

Bit 0 **OA1[0]**: Interface address

7-bit addressing mode: don't care

10-bit addressing mode: bit 0 of address

Note: This bit can be written only when OA1EN=0.

22.7.4 Own address 2 register (I2C_OAR2)

Address offset: 0x0C

Reset value: 0x0000 0000

Access: No wait states, except if a write access occurs while a write access to this register is ongoing. In this case, wait states are inserted in the second write access until the previous one is completed. The latency of the second write access can be up to $2 \times \text{PCLK1} + 6 \times \text{I2CCLK}$.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OA2EN	Res.	Res.	Res.	Res.	OA2MSK[2:0]			OA2[7:1]							Res.
rw					rw			rw							

Bits 31:16 Reserved, must be kept at reset value.

Bit 15 **OA2EN**: Own Address 2 enable

0: Own address 2 disabled. The received slave address OA2 is NACKed.

1: Own address 2 enabled. The received slave address OA2 is ACKed.

Bits 14:11 Reserved, must be kept at reset value.

Bits 10:8 **OA2MSK[2:0]**: Own Address 2 masks

000: No mask

001: OA2[1] is masked and don't care. Only OA2[7:2] are compared.

010: OA2[2:1] are masked and don't care. Only OA2[7:3] are compared.

011: OA2[3:1] are masked and don't care. Only OA2[7:4] are compared.

100: OA2[4:1] are masked and don't care. Only OA2[7:5] are compared.

101: OA2[5:1] are masked and don't care. Only OA2[7:6] are compared.

110: OA2[6:1] are masked and don't care. Only OA2[7] is compared.

111: OA2[7:1] are masked and don't care. No comparison is done, and all (except reserved) 7-bit received addresses are acknowledged.

Note: These bits can be written only when OA2EN=0.

As soon as OA2MSK is not equal to 0, the reserved I2C addresses (0b0000xxx and 0b1111xxx) are not acknowledged even if the comparison matches.

Bits 7:1 **OA2[7:1]**: Interface address

bits 7:1 of address

Note: These bits can be written only when OA2EN=0.

Bit 0 Reserved, must be kept at reset value.

22.7.5 Timing register (I2C_TIMINGR)

Address offset: 0x10

Reset value: 0x0000 0000

Access: No wait states

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
PRESC[3:0]				Res.	Res.	Res.	Res.	SCLDEL[3:0]				SDADEL[3:0]			
rw								rw				rw			
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SCLH[7:0]								SCLL[7:0]							
rw								rw							

Bits 31:28 **PRESC[3:0]**: Timing prescaler

This field is used to prescale I2CCLK in order to generate the clock period t_{PRESC} used for data setup and hold counters (refer to [I2C timings on page 532](#)) and for SCL high and low level counters (refer to [I2C master initialization on page 547](#)).

$$t_{\text{PRESC}} = (\text{PRESC} + 1) \times t_{\text{I2CCLK}}$$

Bits 27:24 Reserved, must be kept at reset value.

Bits 23:20 **SCLDEL[3:0]**: Data setup time

This field is used to generate a delay t_{SCLDEL} between SDA edge and SCL rising edge. In master mode and in slave mode with NOSTRETCH = 0, the SCL line is stretched low during t_{SCLDEL} .

$$t_{\text{SCLDEL}} = (\text{SCLDEL} + 1) \times t_{\text{PRESC}}$$

Note: t_{SCLDEL} is used to generate $t_{\text{SU:DAT}}$ timing.

Bits 19:16 **SDADEL[3:0]**: Data hold time

This field is used to generate the delay t_{SDADEL} between SCL falling edge and SDA edge. In master mode and in slave mode with NOSTRETCH = 0, the SCL line is stretched low during t_{SDADEL} .

$$t_{\text{SDADEL}} = \text{SDADEL} \times t_{\text{PRESC}}$$

Note: SDADEL is used to generate $t_{\text{HD:DAT}}$ timing.

Bits 15:8 **SCLH[7:0]**: SCL high period (master mode)

This field is used to generate the SCL high period in master mode.

$$t_{\text{SCLH}} = (\text{SCLH} + 1) \times t_{\text{PRESC}}$$

Note: SCLH is also used to generate $t_{\text{SU:STO}}$ and $t_{\text{HD:STA}}$ timing.

Bits 7:0 **SCLL[7:0]**: SCL low period (master mode)

This field is used to generate the SCL low period in master mode.

$$t_{\text{SCLL}} = (\text{SCLL} + 1) \times t_{\text{PRESC}}$$

Note: SCLL is also used to generate t_{BUF} and $t_{\text{SU:STA}}$ timings.

Note: This register must be configured when the I2C is disabled ($\text{PE} = 0$).

Note: The STM32CubeMX tool calculates and provides the I2C_TIMINGR content in the I2C Configuration window.

22.7.6 Timeout register (I2C_TIMEOUTR)

Address offset: 0x14

Reset value: 0x0000 0000

Access: No wait states, except if a write access occurs while a write access to this register is ongoing. In this case, wait states are inserted in the second write access until the previous one is completed. The latency of the second write access can be up to $2 \times \text{PCLK1} + 6 \times \text{I2CCLK}$.

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
TEXTEN	Res.	Res.	Res.	TIMEOUTB [11:0]											
rw				rw											
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TIMOUTEN	Res.	Res.	TIDLE	TIMEOUTA [11:0]											
rw			rw	rw											

Bit 31 **TEXTEN**: Extended clock timeout enable

0: Extended clock timeout detection is disabled

1: Extended clock timeout detection is enabled. When a cumulative SCL stretch for more than $t_{\text{LOW:EXT}}$ is done by the I2C interface, a timeout error is detected (TIMEOUT=1).

Bits 30:28 Reserved, must be kept at reset value.

Bits 27:16 **TIMEOUTB[11:0]**: Bus timeout B

This field is used to configure the cumulative clock extension timeout:

In master mode, the master cumulative clock low extend time ($t_{\text{LOW:MEXT}}$) is detected

In slave mode, the slave cumulative clock low extend time ($t_{\text{LOW:SEXT}}$) is detected

$t_{\text{LOW:EXT}} = (\text{TIMEOUTB} + 1) \times 2048 \times t_{\text{I2CCLK}}$

Note: These bits can be written only when TEXTEN=0.

Bit 15 **TIMOUTEN**: Clock timeout enable

0: SCL timeout detection is disabled

1: SCL timeout detection is enabled: when SCL is low for more than t_{TIMEOUT} (TIDLE=0) or high for more than t_{IDLE} (TIDLE=1), a timeout error is detected (TIMEOUT=1).

Bits 14:13 Reserved, must be kept at reset value.

Bit 12 **TIDLE**: Idle clock timeout detection

0: TIMEOUTA is used to detect SCL low timeout

1: TIMEOUTA is used to detect both SCL and SDA high timeout (bus idle condition)

Note: This bit can be written only when TIMOUTEN=0.

Bits 11:0 **TIMEOUTA[11:0]**: Bus Timeout A

This field is used to configure:

– The SCL low timeout condition t_{TIMEOUT} when TIDLE=0

$t_{\text{TIMEOUT}} = (\text{TIMEOUTA} + 1) \times 2048 \times t_{\text{I2CCLK}}$

– The bus idle condition (both SCL and SDA high) when TIDLE=1

$t_{\text{IDLE}} = (\text{TIMEOUTA} + 1) \times 4 \times t_{\text{I2CCLK}}$

Note: These bits can be written only when TIMOUTEN=0.

Note: If the SMBus feature is not supported, this register is reserved and forced by hardware to "0x00000000". Please refer to [Section 22.3: I2C implementation](#).

22.7.7 Interrupt and status register (I2C_ISR)

Address offset: 0x18

Reset value: 0x0000 0001

Access: No wait states

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	ADDCODE[6:0]							DIR
								r							r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BUSY	Res.	ALERT	TIME OUT	PEC ERR	OVR	ARLO	BERR	TCR	TC	STOPF	NACKF	ADDR	RXNE	TXIS	TXE
r		r	r	r	r	r	r	r	r	r	r	r	r	rs	rs

Bits 31:24 Reserved, must be kept at reset value.

Bits 23:17 **ADDCODE[6:0]**: Address match code (Slave mode)

These bits are updated with the received address when an address match event occurs (ADDR = 1).

In the case of a 10-bit address, ADDCODE provides the 10-bit header followed by the 2 MSBs of the address.

Bit 16 **DIR**: Transfer direction (Slave mode)

This flag is updated when an address match event occurs (ADDR=1).

0: Write transfer, slave enters receiver mode.

1: Read transfer, slave enters transmitter mode.

Bit 15 **BUSY**: Bus busy

This flag indicates that a communication is in progress on the bus. It is set by hardware when a START condition is detected. It is cleared by hardware when a Stop condition is detected, or when PE=0.

Bit 14 Reserved, must be kept at reset value.

Bit 13 **ALERT**: SMBus alert

This flag is set by hardware when SMBHEN=1 (SMBus host configuration), ALERTEN=1 and a SMBALERT event (falling edge) is detected on SMBA pin. It is cleared by software by setting the ALERTCF bit.

Note: This bit is cleared by hardware when PE=0.

If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 22.3: I2C implementation](#).

Bit 12 **TIMEOUT**: Timeout or t_{LOW} detection flag

This flag is set by hardware when a timeout or extended clock timeout occurred. It is cleared by software by setting the TIMEOUTCF bit.

Note: This bit is cleared by hardware when PE=0.

If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 22.3: I2C implementation](#).

Bit 11 PECERR: PEC Error in reception

This flag is set by hardware when the received PEC does not match with the PEC register content. A NACK is automatically sent after the wrong PEC reception. It is cleared by software by setting the PECCF bit.

Note: This bit is cleared by hardware when PE=0.

If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 22.3: I2C implementation](#).

Bit 10 OVR: Overrun/Underrun (slave mode)

This flag is set by hardware in slave mode with NOSTRETCH=1, when an overrun/underrun error occurs. It is cleared by software by setting the OVRCF bit.

Note: This bit is cleared by hardware when PE=0.

Bit 9 ARLO: Arbitration lost

This flag is set by hardware in case of arbitration loss. It is cleared by software by setting the ARLOCF bit.

Note: This bit is cleared by hardware when PE=0.

Bit 8 BERR: Bus error

This flag is set by hardware when a misplaced Start or Stop condition is detected whereas the peripheral is involved in the transfer. The flag is not set during the address phase in slave mode. It is cleared by software by setting BERRCF bit.

Note: This bit is cleared by hardware when PE=0.

Bit 7 TCR: Transfer Complete Reload

This flag is set by hardware when RELOAD=1 and NBYTES data have been transferred. It is cleared by software when NBYTES is written to a non-zero value.

Note: This bit is cleared by hardware when PE=0.

This flag is only for master mode, or for slave mode when the SBC bit is set.

Bit 6 TC: Transfer Complete (master mode)

This flag is set by hardware when RELOAD=0, AUTOEND=0 and NBYTES data have been transferred. It is cleared by software when START bit or STOP bit is set.

Note: This bit is cleared by hardware when PE=0.

Bit 5 STOPF: Stop detection flag

This flag is set by hardware when a Stop condition is detected on the bus and the peripheral is involved in this transfer:

- either as a master, provided that the STOP condition is generated by the peripheral.
- or as a slave, provided that the peripheral has been addressed previously during this transfer.

It is cleared by software by setting the STOPCF bit.

Note: This bit is cleared by hardware when PE=0.

Bit 4 NACKF: Not Acknowledge received flag

This flag is set by hardware when a NACK is received after a byte transmission. It is cleared by software by setting the NACKCF bit.

Note: This bit is cleared by hardware when PE=0.

Bit 3 ADDR: Address matched (slave mode)

This bit is set by hardware as soon as the received slave address matched with one of the enabled slave addresses. It is cleared by software by setting ADDRCONF bit.

Note: This bit is cleared by hardware when PE=0.

Bit 2 **RXNE:** Receive data register not empty (receivers)

This bit is set by hardware when the received data is copied into the I2C_RXDR register, and is ready to be read. It is cleared when I2C_RXDR is read.

Note: This bit is cleared by hardware when PE=0.

Bit 1 **TXIS:** Transmit interrupt status (transmitters)

This bit is set by hardware when the I2C_TXDR register is empty and the data to be transmitted must be written in the I2C_TXDR register. It is cleared when the next data to be sent is written in the I2C_TXDR register.

This bit can be written to '1' by software when NOSTRETCH=1 only, in order to generate a TXIS event (interrupt if TXIE=1 or DMA request if TXDMAEN=1).

Note: This bit is cleared by hardware when PE=0.

Bit 0 **TXE:** Transmit data register empty (transmitters)

This bit is set by hardware when the I2C_TXDR register is empty. It is cleared when the next data to be sent is written in the I2C_TXDR register.

This bit can be written to '1' by software in order to flush the transmit data register I2C_TXDR.

Note: This bit is set by hardware when PE=0.

22.7.8 Interrupt clear register (I2C_ICR)

Address offset: 0x1C

Reset value: 0x0000 0000

Access: No wait states

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	ALERT CF	TIM OUTCF	PECCF	OVRCF	ARLO CF	BERR CF	Res.	Res.	STOP CF	NACK CF	ADDR CF	Res.	Res.	Res.
		w	w	w	w	w	w			w	w	w			

Bits 31:14 Reserved, must be kept at reset value.

Bit 13 **ALERTCF:** Alert flag clear

Writing 1 to this bit clears the ALERT flag in the I2C_ISR register.

Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 22.3: I2C implementation](#).

Bit 12 **TIMOUTCF:** Timeout detection flag clear

Writing 1 to this bit clears the TIMEOUT flag in the I2C_ISR register.

Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 22.3: I2C implementation](#).

Bit 11 **PECCF:** PEC Error flag clear

Writing 1 to this bit clears the PECERR flag in the I2C_ISR register.

Note: If the SMBus feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 22.3: I2C implementation](#).

Bit 10 **OVRCF:** Overrun/Underrun flag clear

Writing 1 to this bit clears the OVR flag in the I2C_ISR register.

Bit 9 **ARLOCF**: Arbitration Lost flag clear

Writing 1 to this bit clears the ARLO flag in the I2C_ISR register.

Bit 8 **BERRCF**: Bus error flag clear

Writing 1 to this bit clears the BERRF flag in the I2C_ISR register.

Bits 7:6 Reserved, must be kept at reset value.

Bit 5 **STOPCF**: Stop detection flag clear

Writing 1 to this bit clears the STOPF flag in the I2C_ISR register.

Bit 4 **NACKCF**: Not Acknowledge flag clear

Writing 1 to this bit clears the ACKF flag in I2C_ISR register.

Bit 3 **ADDRCF**: Address matched flag clear

Writing 1 to this bit clears the ADDR flag in the I2C_ISR register. Writing 1 to this bit also clears the START bit in the I2C_CR2 register.

Bits 2:0 Reserved, must be kept at reset value.

22.7.9 PEC register (I2C_PECR)

Address offset: 0x20

Reset value: 0x0000 0000

Access: No wait states

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PEC[7:0]							
								r							

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **PEC[7:0]** Packet error checking register

This field contains the internal PEC when PECEN=1.

The PEC is cleared by hardware when PE=0.

Note: *If the SMBus feature is not supported, this register is reserved and forced by hardware to "0x00000000". Please refer to [Section 22.3: I2C implementation](#).*

22.7.10 Receive data register (I2C_RXDR)

Address offset: 0x24

Reset value: 0x0000 0000

Access: No wait states

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RXDATA[7:0]							
								r							

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **RXDATA[7:0]** 8-bit receive dataData byte received from the I²C bus.**22.7.11 Transmit data register (I2C_TXDR)**

Address offset: 0x28

Reset value: 0x0000 0000

Access: No wait states

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TXDATA[7:0]							
								rw							

Bits 31:8 Reserved, must be kept at reset value.

Bits 7:0 **TXDATA[7:0]** 8-bit transmit dataData byte to be transmitted to the I²C bus.*Note: These bits can be written only when TXE=1.*

22.7.12 I2C register map

The table below provides the I2C register map and reset values.

Table 84. I2C register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0			
0x0	I2C_CR1	Res	Res	Res	Res	Res	Res	Res	Res	PECEN	ALERTEN	SMBDEN	SMBHEN	GCEN	Res	NOSTRETCH	SBC	RXDMAEN	TXDMAEN	Res	ANOFF	DNF[3:0]				ERRIE		TCIE	STOPIE	NACKIE	ADDRIE	RXIE	TXIE	PE		
	Reset value									0	0	0	0	0		0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0			
0x4	I2C_CR2	Res	Res	Res	Res	Res	PECBYTE	AUTOEND	RELOAD	NBYTES[7:0]							NACK	STOP	START	HEAD10R	ADD10	RD_WRN	SADD[9:0]													
	Reset value						0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x8	I2C_OAR1	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	OA1EN	Res	Res	Res	Res	OA1MODE	OA1[9:0]												
	Reset value																	0	Res	Res	Res	Res	0	0	0	0	0	0	0	0	0	0	0			
0xC	I2C_OAR2	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	OA2EN	Res	Res	Res	Res	OA2MSK [2:0]	OA2[7:1]				Res								
	Reset value																	0					0	0	0	0	0	0	0	0	0	0				
0x10	I2C_TIMINGR	PRESC[3:0]				Res	Res	Res	Res	SCLDEL[3:0]			SDADEL[3:0]			SCLH[7:0]					SCLL[7:0]															
	Reset value	0	0	0	0					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		
0x14	I2C_TIMEOUTR	TEXTEN	Res	Res	Res	TIMEOUTB[11:0]										TIMEOUTEN	Res	TIDLE	TIMEOUTA[11:0]																	
	Reset value	0				0	0	0	0	0	0	0	0	0	0	0	0	0				0	0	0	0	0	0	0	0	0	0	0	0	0		
0x18	I2C_ISR	Res	Res	Res	Res	Res	Res	Res	Res	ADDCODE[6:0]						DIR	BUSY	Res	ALERT	TIMEOUT	PECERR	OVR	ARLO	BERR	TCR	TC	STOPF	NACKF	ADDR	RXNE	TXIS	TXE				
	Reset value									0	0	0	0	0	0	0	0	0		0	0	0	0	0	0	0	0	0	0	0	0	0	1			
0x1C	I2C_ICR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	ALERTCF	TIMEOUTCF	PECCF	OVRCF	ARLOCF	BERRCF	Res	Res	STOPCF	NACKCF	ADDRCF	Res	Res	Res				
	Reset value																		0	0	0	0	0	0			0	0	0							
0x20	I2C_PECR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	PEC[7:0]													
	Reset value																					0	0	0	0	0	0	0	0	0	0	0	0			
0x24	I2C_RXDR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	RXDATA[7:0]														
	Reset value																						0	0	0	0	0	0	0	0	0	0	0			

Table 84. I2C register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x28	I2C_TXDR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TXDATA[7:0]							
	Reset value																									0	0	0	0	0	0	0	0

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.



23 Universal synchronous asynchronous receiver transmitter (USART)

23.1 Introduction

The universal synchronous asynchronous receiver transmitter (USART) offers a flexible means of Full-duplex data exchange with external equipment requiring an industry standard NRZ asynchronous serial data format. The USART offers a very wide range of baud rates using a programmable baud rate generator.

It supports synchronous one-way communication and Half-duplex Single-wire communication, as well as multiprocessor communications. It also supports Modem operations (CTS/RTS).

High speed data communication is possible by using the DMA (direct memory access) for multibuffer configuration.

23.2 USART main features

- Full-duplex asynchronous communications
- NRZ standard format (mark/space)
- Configurable oversampling method by 16 or 8 to give flexibility between speed and clock tolerance
- A common programmable transmit and receive baud rate of up to 6 Mbit/s when the clock frequency is 48 MHz and oversampling is by 8
- Convenient baud rate programming
- Auto baud rate detection
- Programmable data word length (8 or 9 bits)
- Programmable data order with MSB-first or LSB-first shifting
- Configurable stop bits (1 or 2 stop bits)
- Synchronous mode and clock output for synchronous communications
- Single-wire Half-duplex communications
- Continuous communications using DMA
- Received/transmitted bytes are buffered in reserved SRAM using centralized DMA
- Separate enable bits for transmitter and receiver
- Separate signal polarity control for transmission and reception
- Swappable Tx/Rx pin configuration
- Hardware flow control for modem and RS-485 transceiver

- Communication control/error detection flags
- Parity control:
 - Transmits parity bit
 - Checks parity of received data byte
- Fourteen interrupt sources with flags
- Multiprocessor communications

The USART enters mute mode if the address does not match.
- Wakeup from mute mode (by idle line detection or address mark detection)

23.3 USART implementation

Table 85. STM32F0x0 USART implementation⁽¹⁾

USART modes/ features	STM32F030x4, STM32F030x6	STM32F030x8		STM32F070x6		STM32F070xB			STM32F030xC			
	USART1	USART1	USART2	USART1	USART2	USART1/ USART2	USART3	USART4	USART1/ USART2/ USART3	USART4	USART5	USART6
Hardware flow control for modem	X	X	X	X	X	X	X	X	X	X	-	-
Continuous communication using DMA	X	X	X	X	X	X	X	-	X	X	X	X
Multiprocessor communication	X	X	X	X	X	X	X	X	X	X	X	X
Synchronous mode	X	X	X	X	X	X	X	X	X	X	X	-
Smartcard mode	-	-	-	-	-	-	-	-	-	-	-	-
Single-wire Half-duplex communication	X	X	X	X	X	X	X	X	X	X	X	X
IrDA SIR ENDEC block	-	-	-	-	-	-	-	-	-	-	-	-
LIN mode	-	-	-	-	-	-	-	-	-	-	-	-
Dual clock domain and wakeup from Stop mode	-	-	-	-	-	-	-	-	-	-	-	-
Receiver timeout interrupt	X	X	-	X	-	X	-	-	X	-	-	-
Modbus communication	-	-	-	-	-	-	-	-	-	-	-	-
Auto baud rate detection (supported modes)	2	2	-	4	-	4	-	-	4	-	-	-
Driver Enable	X	X	X	X	X	X	X	X	X	X	X	X
USART data length	8 and 9 bits			7, 8 and 9 bits								

1. X = supported.

23.4 USART functional description

Any USART bidirectional communication requires a minimum of two pins: Receive data In (RX) and Transmit data Out (TX):

- **RX:** Receive data Input.
This is the serial data input. Oversampling techniques are used for data recovery by discriminating between valid incoming data and noise.
- **TX:** Transmit data Output.
When the transmitter is disabled, the output pin returns to its I/O port configuration. When the transmitter is enabled and nothing is to be transmitted, the TX pin is at high level. In Single-wire, this I/O is used to transmit and receive the data.

Serial data are transmitted and received through these pins in normal USART mode. The frames are comprised of:

- An Idle Line prior to transmission or reception
- A start bit
- A data word (8 or 9 bits) least significant bit first
- 1, 2 stop bits indicating that the frame is complete
- The USART interface uses a baud rate generator
- A status register (USART_ISR)
- Receive and transmit data registers (USART_RDR, USART_TDR)
- A baud rate register (USART_BRR)

Refer to [Section 23.7: USART registers on page 625](#) for the definitions of each bit.

The following pin is required to interface in synchronous mode:

- **CK:** Clock output. This pin outputs the transmitter data clock for synchronous transmission corresponding to SPI master mode (no clock pulses on start bit and stop bit, and a software option to send a clock pulse on the last data bit). In parallel, data can be received synchronously on RX. This can be used to control peripherals that have shift registers. The clock phase and polarity are software programmable.

The following pins are required in RS232 Hardware flow control mode:

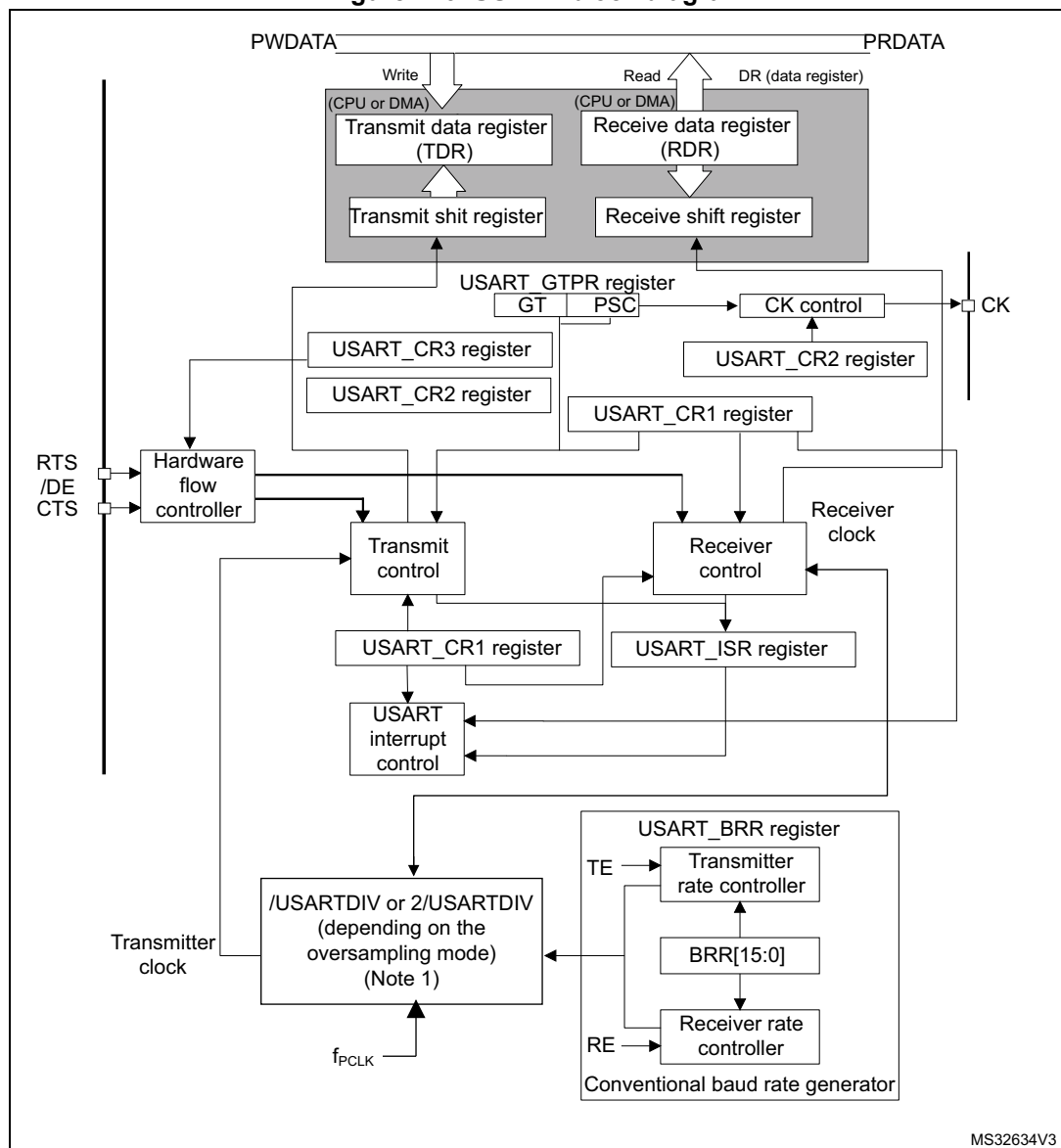
- **CTS:** Clear To Send blocks the data transmission at the end of the current transfer when high
- **RTS:** Request to send indicates that the USART is ready to receive data (when low).

The following pin is required in RS485 Hardware control mode:

- **DE:** Driver Enable activates the transmission mode of the external transceiver.

Note: DE and RTS share the same pin.

Figure 226. USART block diagram



1. For details on coding USARTDIV in the USART_BRR register, please refer to [Section 23.4.4: USART baud rate generation](#).

23.4.1 USART character description

The word length can be selected as being either 8 or 9 bits by programming the M bit (M0: bit 12) in the USART_CR1 register (see [Figure 227](#)).

- 8-bit character length: M0 = 0
- 9-bit character length: M0 = 1

By default, the signal (TX or RX) is in low state during the start bit. It is in high state during the stop bit.

These values can be inverted, separately for each signal, through polarity configuration control.

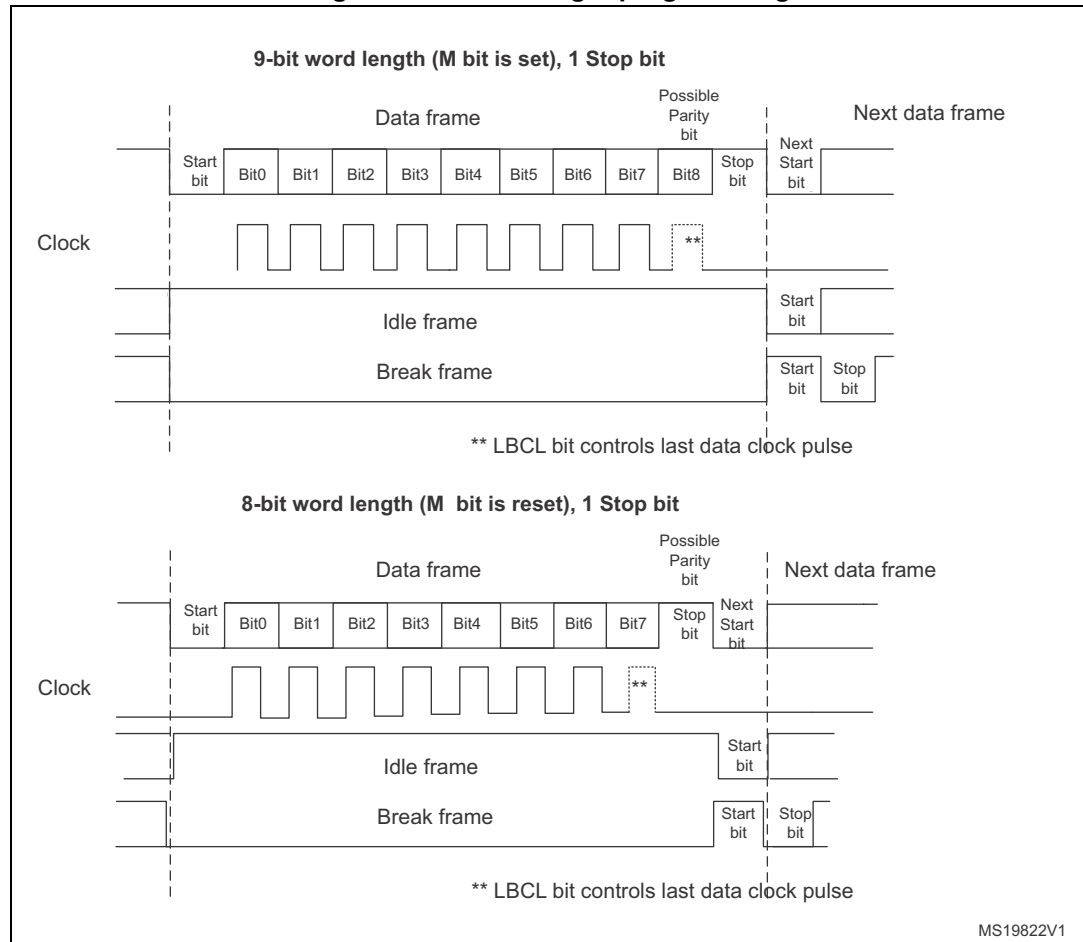
An **Idle character** is interpreted as an entire frame of “1”s (the number of “1”s includes the number of stop bits).

A **Break character** is interpreted on receiving “0”s for a frame period. At the end of the break frame, the transmitter inserts 2 stop bits.

Transmission and reception are driven by a common baud rate generator, the clock for each is generated when the enable bit is set respectively for the transmitter and receiver.

The details of each block is given below.

Figure 227. Word length programming



23.4.2 USART transmitter

The transmitter can send data words of either 8 or 9 bits depending on the M bit status. The Transmit Enable bit (TE) must be set in order to activate the transmitter function. The data in the transmit shift register is output on the TX pin and the corresponding clock pulses are output on the CK pin.

Character transmission

During an USART transmission, data shifts out least significant bit first (default configuration) on the TX pin. In this mode, the USART_TDR register consists of a buffer (TDR) between the internal bus and the transmit shift register (see [Figure 226](#)).

Every character is preceded by a start bit which is a logic level low for one bit period. The character is terminated by a configurable number of stop bits.

The following stop bits are supported by USART: 1 and 2 stop bits.

Note: *The TE bit must be set before writing the data to be transmitted to the USART_TDR.*
The TE bit should not be reset during transmission of data. Resetting the TE bit during the transmission will corrupt the data on the TX pin as the baud rate counters will get frozen.
The current data being transmitted will be lost.
An idle frame will be sent after the TE bit is enabled.

Configurable stop bits

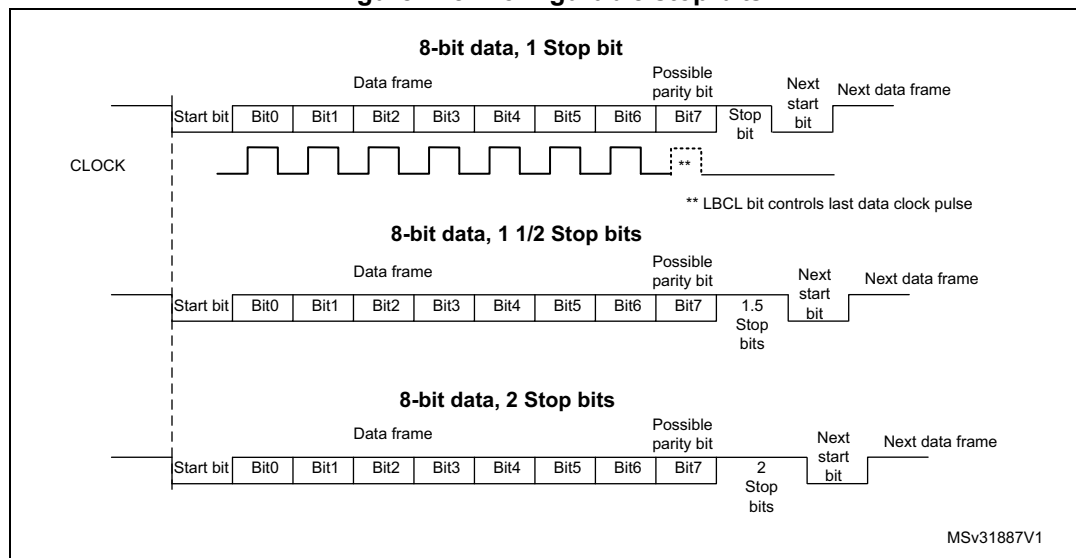
The number of stop bits to be transmitted with every character can be programmed in Control register 2, bits 13,12.

- **1 stop bit:** This is the default value of number of stop bits.
- **2 stop bits:** This will be supported by normal USART, Single-wire and Modem modes.

An idle frame transmission will include the stop bits.

A break transmission will be 10 low bits (when M0= 0) or 11 low bits (when M0= 1) followed by 2 stop bits (see [Figure 228](#)). It is not possible to transmit long breaks (break of length greater than 10/11 low bits).

Figure 228. Configurable stop bits



Character transmission procedure

1. Program the M bit in USART_CR1 to define the word length.
2. Select the desired baud rate using the USART_BRR register.
3. Program the number of stop bits in USART_CR2.
4. Enable the USART by writing the UE bit in USART_CR1 register to 1.
5. Select DMA enable (DMAT) in USART_CR3 if multibuffer communication is to take place. Configure the DMA register as explained in multibuffer communication.
6. Set the TE bit in USART_CR1 to send an idle frame as first transmission.
7. Write the data to send in the USART_TDR register (this clears the TXE bit). Repeat this for each data to be transmitted in case of single buffer.
8. After writing the last data into the USART_TDR register, wait until TC=1. This indicates that the transmission of the last frame is complete. This is required for instance when the USART is disabled or enters the Halt mode to avoid corrupting the last transmission.

For code example refer to Appendix section [A.15.1: USART transmitter configuration code example](#).

Single byte communication

Clearing the TXE bit is always performed by a write to the transmit data register.

The TXE bit is set by hardware and it indicates:

- The data has been moved from the USART_TDR register to the shift register and the data transmission has started.
- The USART_TDR register is empty.
- The next data can be written in the USART_TDR register without overwriting the previous data.

For code example refer to the Appendix section [A.15.2: USART transmit byte code example](#).

This flag generates an interrupt if the TXEIE bit is set.

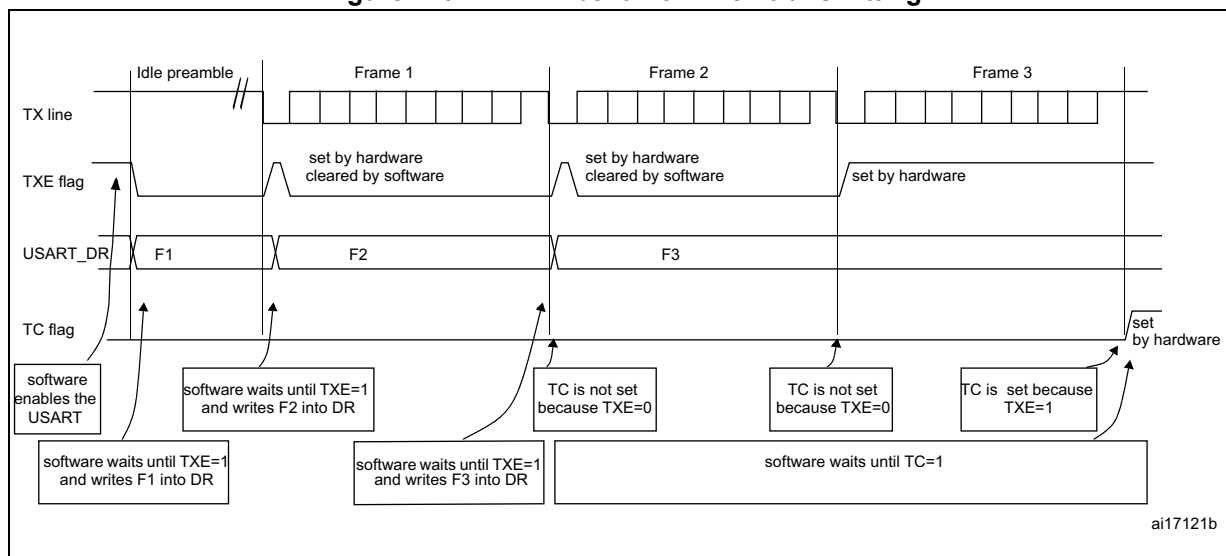
When a transmission is taking place, a write instruction to the USART_TDR register stores the data in the TDR register; next, the data is copied in the shift register at the end of the currently ongoing transmission.

When no transmission is taking place, a write instruction to the USART_TDR register places the data in the shift register, the data transmission starts, and the TXE bit is set.

If a frame is transmitted (after the stop bit) and the TXE bit is set, the TC bit goes high. An interrupt is generated if the TCIE bit is set in the USART_CR1 register.

After writing the last data in the USART_TDR register, it is mandatory to wait for TC=1 before disabling the USART or causing the microcontroller to enter the low-power mode (see [Figure 229: TC/TXE behavior when transmitting](#)).

Figure 229. TC/TXE behavior when transmitting



For code example refer to the Appendix section [A.15.3: USART transfer complete code example](#).

Break characters

Setting the SBKRQ bit transmits a break character. The break frame length depends on the M bit (see [Figure 227](#)).

If a '1' is written to the SBKRQ bit, a break character is sent on the TX line after completing the current character transmission. The SBKF bit is set by the write operation and it is reset by hardware when the break character is completed (during the stop bits after the break character). The USART inserts a logic 1 signal (STOP) for the duration of 2 bits at the end of the break frame to guarantee the recognition of the start bit of the next frame.

In the case the application needs to send the break character following all previously inserted data, including the ones not yet transmitted, the software should wait for the TXE flag assertion before setting the SBKRQ bit.

Idle characters

Setting the TE bit drives the USART to send an idle frame before the first data frame.

23.4.3 USART receiver

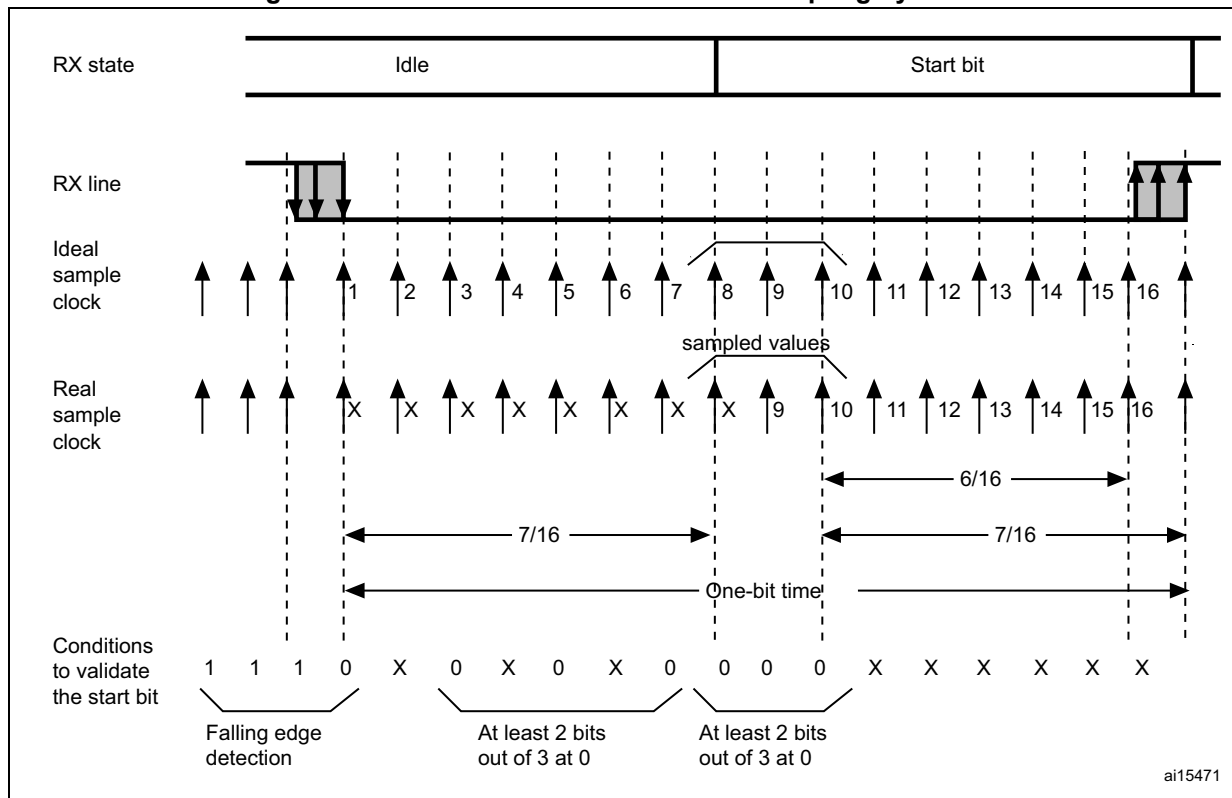
The USART can receive data words of either 8 or 9 bits depending on the M bit in the USART_CR1 register.

Start bit detection

The start bit detection sequence is the same when oversampling by 16 or by 8.

In the USART, the start bit is detected when a specific sequence of samples is recognized. This sequence is: 1 1 1 0 X 0 X 0X 0X 0 X 0X 0.

Figure 230. Start bit detection when oversampling by 16 or 8



Note: If the sequence is not complete, the start bit detection aborts and the receiver returns to the idle state (no flag is set), where it waits for a falling edge.

The start bit is confirmed (RXNE flag set, interrupt generated if RXNEIE=1) if the 3 sampled bits are at 0 (first sampling on the 3rd, 5th and 7th bits finds the 3 bits at 0 and second sampling on the 8th, 9th and 10th bits also finds the 3 bits at 0).

The start bit is validated (RXNE flag set, interrupt generated if RXNEIE=1) but the NF noise flag is set if,

- a) for both samplings, 2 out of the 3 sampled bits are at 0 (sampling on the 3rd, 5th and 7th bits and sampling on the 8th, 9th and 10th bits)
- or
- b) for one of the samplings (sampling on the 3rd, 5th and 7th bits or sampling on the 8th, 9th and 10th bits), 2 out of the 3 bits are found at 0.

If neither conditions a. or b. are met, the start detection aborts and the receiver returns to the idle state (no flag is set).

Character reception

During an USART reception, data shifts in least significant bit first (default configuration) through the RX pin. In this mode, the USART_RDR register consists of a buffer (RDR) between the internal bus and the receive shift register.

Character reception procedure

1. Program the M bit in USART_CR1 to define the word length.
2. Select the desired baud rate using the baud rate register USART_BRR
3. Program the number of stop bits in USART_CR2.
4. Enable the USART by writing the UE bit in USART_CR1 register to 1.
5. Select DMA enable (DMAR) in USART_CR3 if multibuffer communication is to take place. Configure the DMA register as explained in multibuffer communication.
6. Set the RE bit USART_CR1. This enables the receiver which begins searching for a start bit.

For code example refer to the Appendix section [A.15.4: USART receiver configuration code example](#).

When a character is received:

- The RXNE bit is set to indicate that the content of the shift register is transferred to the RDR. In other words, data has been received and can be read (as well as its associated error flags).
- An interrupt is generated if the RXNEIE bit is set.
- The error flags can be set if a frame error, noise or an overrun error has been detected during reception. PE flag can also be set with RXNE.
- In multibuffer, RXNE is set after every byte received and is cleared by the DMA read of the Receive data Register.
- In single buffer mode, clearing the RXNE bit is performed by a software read to the USART_RDR register. The RXNE flag can also be cleared by writing 1 to the RXFRQ in the USART_RQR register. The RXNE bit must be cleared before the end of the reception of the next character to avoid an overrun error.

For code example refer to the Appendix section [A.15.5: USART receive byte code example](#).

Break character

When a break character is received, the USART handles it as a framing error.

Idle character

When an idle frame is detected, there is the same procedure as for a received data character plus an interrupt if the IDLEIE bit is set.

Overrun error

An overrun error occurs when a character is received when RXNE has not been reset. Data can not be transferred from the shift register to the RDR register until the RXNE bit is cleared.

The RXNE flag is set after every byte received. An overrun error occurs if RXNE flag is set when the next data is received or the previous DMA request has not been serviced. When an overrun error occurs:

- The ORE bit is set.
- The RDR content will not be lost. The previous data is available when a read to USART_RDR is performed.
- The shift register will be overwritten. After that point, any data received during overrun is lost.
- An interrupt is generated if either the RXNEIE bit is set or EIE bit is set.
- The ORE bit is reset by setting the ORECF bit in the ICR register.

Note: The ORE bit, when set, indicates that at least 1 data has been lost. There are two possibilities:

- if $RXNE=1$, then the last valid data is stored in the receive register RDR and can be read,
- if $RXNE=0$, then it means that the last valid data has already been read and thus there is nothing to be read in the RDR. This case can occur when the last valid data is read in the RDR at the same time as the new (and lost) data is received.

Selecting the clock source and the proper oversampling method

The choice of the clock source is done through the Clock Control system (see Section Reset and clock control (RCC)). The clock source must be chosen before enabling the USART (by setting the UE bit).

The choice of the clock source must be done according to two criteria:

- Possible use of the USART in low-power mode
- Communication speed.

The clock source frequency is f_{CK} .

The communication speed range (specially the maximum communication speed) is also determined by the clock source.

The receiver implements different user-configurable oversampling techniques for data recovery by discriminating between valid incoming data and noise. This allows a trade-off between the maximum communication speed and noise/clock inaccuracy immunity.

The oversampling method can be selected by programming the OVER8 bit in the USART_CR1 register and can be either 16 or 8 times the baud rate clock ([Figure 231](#) and [Figure 232](#)).

Depending on the application:

- Select oversampling by 8 (OVER8=1) to achieve higher speed (up to $f_{CK}/8$). In this case the maximum receiver tolerance to clock deviation is reduced (refer to [Section 23.4.5: Tolerance of the USART receiver to clock deviation on page 611](#))
- Select oversampling by 16 (OVER8=0) to increase the tolerance of the receiver to clock deviations. In this case, the maximum speed is limited to maximum $f_{CK}/16$ where f_{CK} is the clock source frequency.

Programming the ONEBIT bit in the USART_CR3 register selects the method used to evaluate the logic level. There are two options:

- The majority vote of the three samples in the center of the received bit. In this case, when the 3 samples used for the majority vote are not equal, the NF bit is set
- A single sample in the center of the received bit

Depending on the application:

- select the three samples' majority vote method (ONEBIT=0) when operating in a noisy environment and reject the data when a noise is detected (refer to [Figure 86](#)) because this indicates that a glitch occurred during the sampling.
- select the single sample method (ONEBIT=1) when the line is noise-free to increase the receiver's tolerance to clock deviations (see [Section 23.4.5: Tolerance of the USART receiver to clock deviation on page 611](#)). In this case the NF bit will never be set.

When noise is detected in a frame:

- The NF bit is set at the rising edge of the RXNE bit.
- The invalid data is transferred from the Shift register to the USART_RDR register.
- No interrupt is generated in case of single byte communication. However this bit rises at the same time as the RXNE bit which itself generates an interrupt. In case of multibuffer communication an interrupt will be issued if the EIE bit is set in the USART_CR3 register.

The NF bit is reset by setting NFCF bit in ICR register.

Figure 231. Data sampling when oversampling by 16

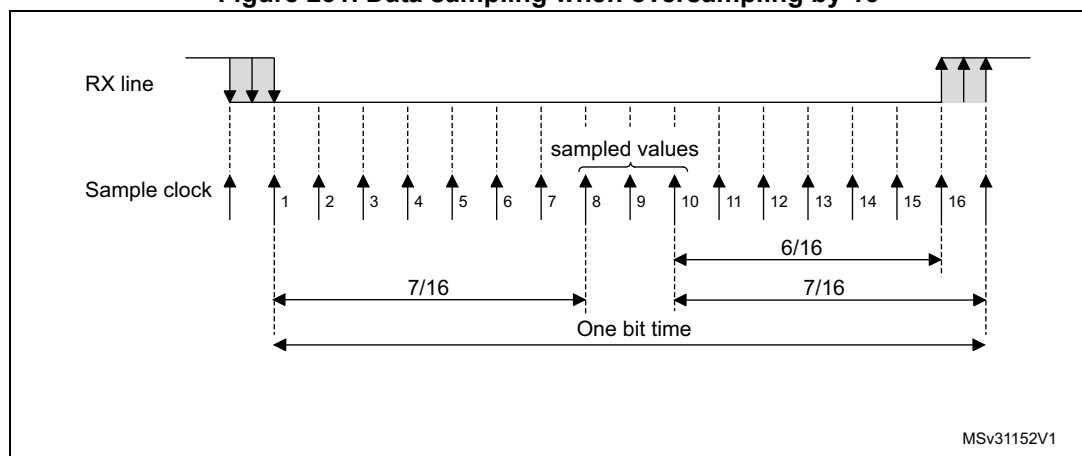
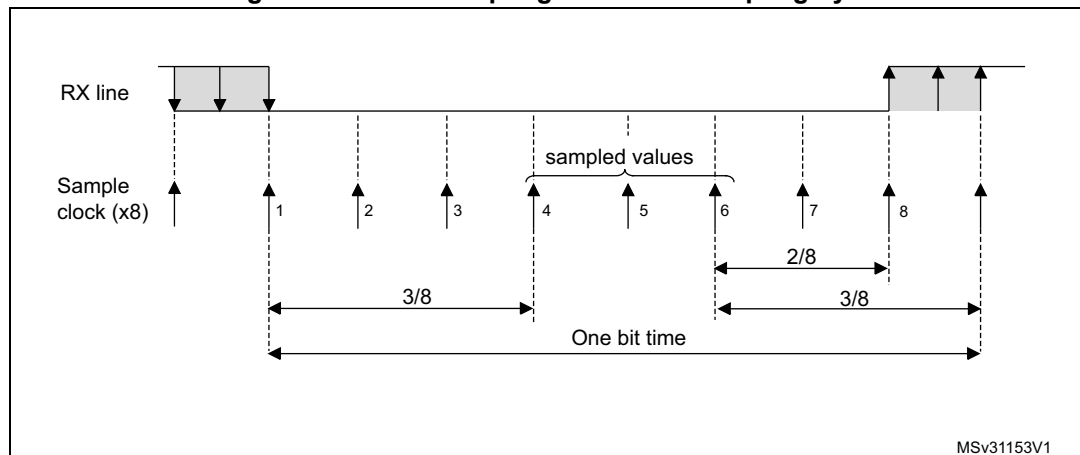


Figure 232. Data sampling when oversampling by 8



MSv31153V1

Table 86. Noise detection from sampled data

Sampled value	NE status	Received bit value
000	0	0
001	1	0
010	1	0
011	1	1
100	1	0
101	1	1
110	1	1
111	0	1

Framing error

A framing error is detected when the stop bit is not recognized on reception at the expected time, following either a de-synchronization or excessive noise.

When the framing error is detected:

- The FE bit is set by hardware
- The invalid data is transferred from the Shift register to the USART_RDR register.
- No interrupt is generated in case of single byte communication. However this bit rises at the same time as the RXNE bit which itself generates an interrupt. In case of multibuffer communication an interrupt will be issued if the EIE bit is set in the USART_CR3 register.

The FE bit is reset by writing 1 to the FECF in the USART_ICR register.

Configurable stop bits during reception

The number of stop bits to be received can be configured through the control bits of Control Register 2 - it can be either 1 or 2 in normal mode.

- **1 stop bit:** Sampling for 1 stop Bit is done on the 8th, 9th and 10th samples.
- **2 stop bits:** Sampling for 2 stop bits is done on the 8th, 9th and 10th samples of the first stop bit. If a framing error is detected during the first stop bit the framing error flag will be set. The second stop bit is not checked for framing error. The RXNE flag will be set at the end of the first stop bit.

23.4.4 USART baud rate generation

The baud rate for the receiver and transmitter (Rx and Tx) are both set to the same value as programmed in the USART_BRR register.

Equation 1: Baud rate for standard USART (SPI mode included) (OVER8 = 0 or 1)

In case of oversampling by 16, the equation is:

$$\text{Tx/Rx baud} = \frac{f_{\text{CK}}}{\text{USARTDIV}}$$

In case of oversampling by 8, the equation is:

$$\text{Tx/Rx baud} = \frac{2 \times f_{\text{CK}}}{\text{USARTDIV}}$$

USARTDIV is an unsigned fixed point number that is coded on the USART_BRR register.

- When OVER8 = 0, BRR = USARTDIV.
- When OVER8 = 1
 - BRR[2:0] = USARTDIV[3:0] shifted 1 bit to the right.
 - BRR[3] must be kept cleared.
 - BRR[15:4] = USARTDIV[15:4]

Note: The baud counters are updated to the new value in the baud registers after a write operation to USART_BRR. Hence the baud rate register value should not be changed during communication.

In case of oversampling by 16 or 8, USARTDIV must be greater than or equal to 0d16.

How to derive USARTDIV from USART_BRR register values

Example 1

To obtain 9600 baud with $f_{\text{CK}} = 8 \text{ MHz}$.

- In case of oversampling by 16:
 $\text{USARTDIV} = 8\,000\,000/9600$
 $\text{BRR} = \text{USARTDIV} = 833\text{d} = 0341\text{h}$
- In case of oversampling by 8:
 $\text{USARTDIV} = 2 * 8\,000\,000/9600$
 $\text{USARTDIV} = 1666,66 \text{ (1667d = 683h)}$
 $\text{BRR}[3:0] = 3\text{h} \ll 1 = 1\text{h}$
 $\text{BRR} = 0\text{x}681$

Example 2

To obtain 921.6 Kbaud with $f_{CK} = 48$ MHz.

- In case of oversampling by 16:
 $USARTDIV = 48\,000\,000/921\,600$
 $BRR = USARTDIV = 52d = 34h$
- In case of oversampling by 8:
 $USARTDIV = 2 * 48\,000\,000/921\,600$
 $USARTDIV = 104$ ($104d = 68h$)
 $BRR[3:0] = USARTDIV[3:0] \gg 1 = 8h \gg 1 = 4h$
 $BRR = 0x64$

Table 87. Error calculation for programmed baud rates at $f_{CK} = 48$ MHz in both cases of oversampling by 16 or by 8⁽¹⁾

Baud rate		Oversampling by 16 (OVER8 = 0)			Oversampling by 8 (OVER8 = 1)		
S.No	Desired	Actual	BRR	% Error = (Calculated - Desired)B.Rate/ Desired B.Rate	Actual	BRR	% Error
2	2.4 KBps	2.4 KBps	0x4E20	0	2.4 KBps	0x9C40	0
3	9.6 KBps	9.6 KBps	0x1388	0	9.6 KBps	0x2710	0
4	19.2 KBps	19.2 KBps	0x9C4	0	19.2 KBps	0x1384	0
5	38.4 KBps	38.4 KBps	0x4E2	0	38.4 KBps	0x9C2	0
6	57.6 KBps	57.62 KBps	0x341	0.03	57.59 KBps	0x681	0.02
7	115.2 KBps	115.11 KBps	0x1A1	0.08	115.25 KBps	0x340	0.04
8	230.4 KBps	230.76KBps	0xD0	0.16	230.21 KBps	0x1A0	0.08
9	460.8 KBps	461.54KBps	0x68	0.16	461.54KBps	0xD0	0.16
10	921.6KBps	923.07KBps	0x34	0.16	923.07KBps	0x64	0.16
11	2 MBps	2 MBps	0x18	0	2 MBps	0x30	0
12	3 MBps	3 MBps	0x10	0	3 MBps	0x20	0
13	4MBps	N.A	N.A	N.A	4MBps	0x14	0
14	5MBps	N.A	N.A	N.A	5052.63KBps	0x11	1.05
15	6MBps	N.A	N.A	N.A	6MBps	0x10	0

1. The lower the CPU clock the lower the accuracy for a particular baud rate. The upper limit of the achievable baud rate can be fixed with these data.

23.4.5 Tolerance of the USART receiver to clock deviation

The asynchronous receiver of the USART works correctly only if the total clock system deviation is less than the tolerance of the USART receiver. The causes which contribute to the total deviation are:

- DTRA: Deviation due to the transmitter error (which also includes the deviation of the transmitter's local oscillator)
- DQUANT: Error due to the baud rate quantization of the receiver
- DREC: Deviation of the receiver's local oscillator
- DTCL: Deviation due to the transmission line (generally due to the transceivers which can introduce an asymmetry between the low-to-high transition timing and the high-to-low transition timing)

$$DTRA + DQUANT + DREC + DTCL < \text{USART receiver's tolerance}$$

The USART receiver can receive data correctly at up to the maximum tolerated deviation specified in [Table 88](#) and [Table 89](#) depending on the following choices:

- 10- or 11-bit character length defined by the M bit in the USART_CR1 register
- Oversampling by 8 or 16 defined by the OVER8 bit in the USART_CR1 register
- Bits BRR[3:0] of USART_BRR register are equal to or different from 0000.
- Use of 1 bit or 3 bits to sample the data, depending on the value of the ONEBIT bit in the USART_CR3 register.

Table 88. Tolerance of the USART receiver when BRR [3:0] = 0000

M bit	OVER8 bit = 0		OVER8 bit = 1	
	ONEBIT=0	ONEBIT=1	ONEBIT=0	ONEBIT=1
0	3.75%	4.375%	2.50%	3.75%
1	3.41%	3.97%	2.27%	3.41%

Table 89. Tolerance of the USART receiver when BRR [3:0] is different from 0000

M bit	OVER8 bit = 0		OVER8 bit = 1	
	ONEBIT=0	ONEBIT=1	ONEBIT=0	ONEBIT=1
0	3.33%	3.88%	2%	3%
1	3.03%	3.53%	1.82%	2.73%

Note:

The data specified in [Table 88](#), and [Table 89](#) may slightly differ in the special case when the received frames contain some Idle frames of exactly 10-bit durations when M = 0 (11-bit durations when M = 1).

23.4.6 USART auto baud rate detection

The USART is able to detect and automatically set the USART_BRR register value based on the reception of one character. Automatic baud rate detection is useful under two circumstances:

- The communication speed of the system is not known in advance
- The system is using a relatively low accuracy clock source and this mechanism allows the correct baud rate to be obtained without measuring the clock deviation.

The clock source frequency must be compatible with the expected communication speed (Oversampling by 16 must be selected for a baud rate between $f_{CK}/65535$ and $f_{CK}/16$).

Before activating the auto baud rate detection, the auto baud rate detection mode must be chosen. There are various modes based on different character patterns.

They can be chosen through the ABRMOD[1:0] field in the USART_CR2 register. In these auto baud rate modes, the baud rate is measured several times during the synchronization data reception and each measurement is compared to the previous one.

These modes are:

- **Mode 0:** Any character starting with a bit at 1. In this case the USART measures the duration of the Start bit (falling edge to rising edge).
- **Mode 1:** Any character starting with a 10xx bit pattern. In this case, the USART measures the duration of the Start and of the 1st data bit. The measurement is done falling edge to falling edge, ensuring better accuracy in the case of slow signal slopes. In parallel, another check is performed for each intermediate transition of RX line. An error is generated if the transitions on RX are not sufficiently synchronized with the receiver (the receiver being based on the baud rate calculated on bit 0).

Prior to activating auto baud rate detection, the USART_BRR register must be initialized by writing a non-zero baud rate value.

The automatic baud rate detection is activated by setting the ABREN bit in the USART_CR2 register. The USART will then wait for the first character on the RX line. The auto baud rate operation completion is indicated by the setting of the ABRF flag in the USART_ISR register. If the line is noisy, the correct baud rate detection cannot be guaranteed. In this case the BRR value may be corrupted and the ABRE error flag will be set. This also happens if the communication speed is not compatible with the automatic baud rate detection range (bit duration not between 16 and 65536 clock periods (oversampling by 16) and not between 8 and 65536 clock periods (oversampling by 8)).

The RXNE interrupt will signal the end of the operation.

At any later time, the auto baud rate detection may be relaunched by resetting the ABRF flag (by writing a 0).

Note: If the USART is disabled (UE=0) during an auto baud rate operation, the BRR value may be corrupted.

23.4.7 Multiprocessor communication using USART

In multiprocessor communication, the following bits are to be kept cleared:

- LINEN bit in the USART_CR2 register,
- HDSEL, IREN and SCEN bits in the USART_CR3 register.

It is possible to perform multiprocessor communication with the USART (with several USARTs connected in a network). For instance one of the USARTs can be the master, its TX output connected to the RX inputs of the other USARTs. The others are slaves, their respective TX outputs are logically ANDed together and connected to the RX input of the master.

In multiprocessor configurations it is often desirable that only the intended message recipient should actively receive the full message contents, thus reducing redundant USART service overhead for all non addressed receivers.

The non addressed devices may be placed in mute mode by means of the muting function. In order to use the mute mode feature, the MME bit must be set in the USART_CR1 register.

In mute mode:

- None of the reception status bits can be set.
- All the receive interrupts are inhibited.
- The RWU bit in USART_ISR register is set to 1. RWU can be controlled automatically by hardware or by software, through the MMRQ bit in the USART_RQR register, under certain conditions.

The USART can enter or exit from mute mode using one of two methods, depending on the WAKE bit in the USART_CR1 register:

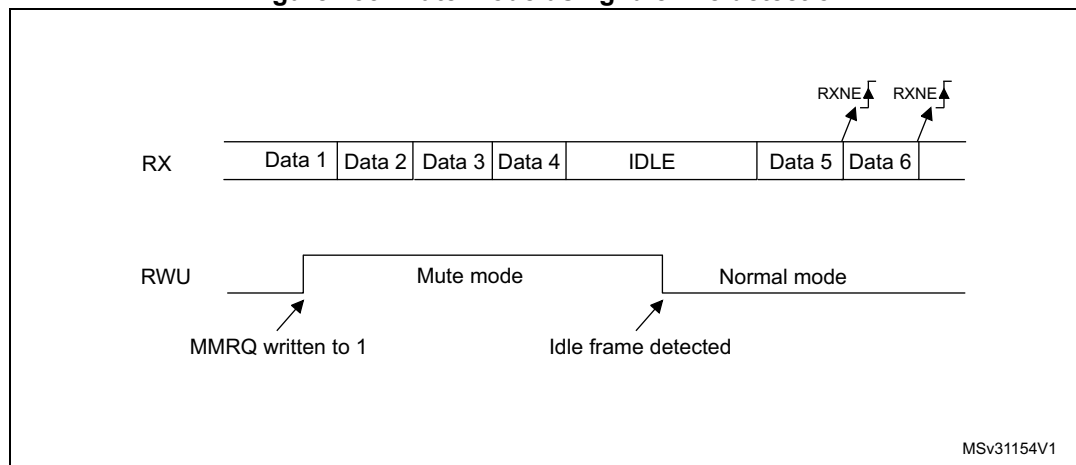
- Idle Line detection if the WAKE bit is reset,
- Address Mark detection if the WAKE bit is set.

Idle line detection (WAKE=0)

The USART enters mute mode when the MMRQ bit is written to 1 and the RWU is automatically set.

It wakes up when an Idle frame is detected. Then the RWU bit is cleared by hardware but the IDLE bit is not set in the USART_ISR register. An example of mute mode behavior using Idle line detection is given in [Figure 233](#).

Figure 233. Mute mode using Idle line detection



Note: If the MMRQ is set while the IDLE character has already elapsed, mute mode will not be entered (RWU is not set).

If the USART is activated while the line is IDLE, the idle state is detected after the duration of one IDLE frame (not only after the reception of one character frame).

4-bit/7-bit address mark detection (WAKE=1)

In this mode, bytes are recognized as addresses if their MSB is a '1' otherwise they are considered as data. In an address byte, the address of the targeted receiver is put in the 4 or 7 LSBs. The choice of 7 or 4-bit address detection is done using the ADDM7 bit. This 4-bit/7-bit word is compared by the receiver with its own address which is programmed in the ADD bits in the USART_CR2 register.

Note: In 7-bit and 9-bit data modes, address detection is done on 6-bit and 8-bit addresses (ADD[5:0] and ADD[7:0]) respectively.

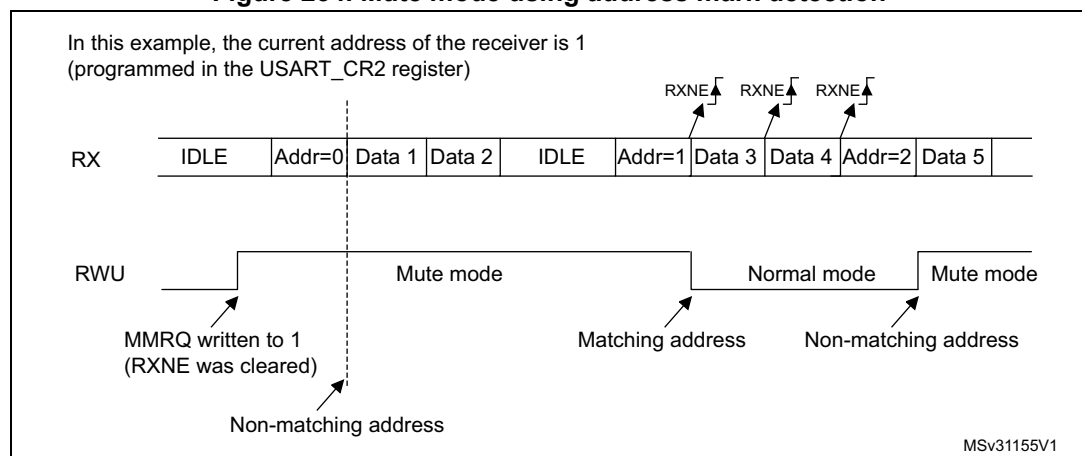
The USART enters mute mode when an address character is received which does not match its programmed address. In this case, the RWU bit is set by hardware. The RXNE flag is not set for this address byte and no interrupt or DMA request is issued when the USART enters mute mode.

The USART also enters mute mode when the MMRQ bit is written to 1. The RWU bit is also automatically set in this case.

The USART exits from mute mode when an address character is received which matches the programmed address. Then the RWU bit is cleared and subsequent bytes are received normally. The RXNE bit is set for the address character since the RWU bit has been cleared.

An example of mute mode behavior using address mark detection is given in [Figure 234](#).

Figure 234. Mute mode using address mark detection



23.4.8 USART parity control

Parity control (generation of parity bit in transmission and parity checking in reception) can be enabled by setting the PCE bit in the USART_CR1 register. Depending on the frame length defined by the M bit, the possible USART frame formats are as listed in [Table 90](#).

Table 90. Frame formats

M bit	PCE bit	USART frame ⁽¹⁾
0	0	SB 8-bit data STB
0	1	SB 7-bit data PB STB
1	0	SB 9-bit data STB
1	1	SB 8-bit data PB STB

1. Legends: SB: start bit, STB: stop bit, PB: parity bit. In the data register, the PB is always taking the MSB position (8th or 7th, depending on the M bits value).

Even parity

The parity bit is calculated to obtain an even number of “1s” inside the frame of the 7 or 8 LSB bits (depending on M bit value) and the parity bit.

As an example, if data=00110101, and 4 bits are set, then the parity bit will be 0 if even parity is selected (PS bit in USART_CR1 = 0).

Odd parity

The parity bit is calculated to obtain an odd number of “1s” inside the frame made of the 7 or 8 LSB bits (depending on M bit value) and the parity bit.

As an example, if data=00110101 and 4 bits set, then the parity bit will be 1 if odd parity is selected (PS bit in USART_CR1 = 1).

Parity checking in reception

If the parity check fails, the PE flag is set in the USART_ISR register and an interrupt is generated if PEIE is set in the USART_CR1 register. The PE flag is cleared by software writing 1 to the PECF in the USART_ICR register.

Parity generation in transmission

If the PCE bit is set in USART_CR1, then the MSB bit of the data written in the data register is transmitted but is changed by the parity bit (even number of “1s” if even parity is selected (PS=0) or an odd number of “1s” if odd parity is selected (PS=1)).

23.4.9 [A.15.6: USART synchronous mode code example](#) **USART synchronous mode**

The synchronous mode is selected by writing the CLKEN bit in the USART_CR2 register to 1. In synchronous mode, the following bits must be kept cleared:

- SCEN, HDSEL and IREN bits in the USART_CR3 register.

In this mode, the USART can be used to control bidirectional synchronous serial communications in master mode. The CK pin is the output of the USART transmitter clock. No clock pulses are sent to the CK pin during start bit and stop bit. Depending on the state

of the LBCL bit in the USART_CR2 register, clock pulses are, or are not, generated during the last valid data bit (address mark). The CPOL bit in the USART_CR2 register is used to select the clock polarity, and the CPHA bit in the USART_CR2 register is used to select the phase of the external clock (see [Figure 235](#), [Figure 236](#) and [Figure 237](#)).

During the Idle state, preamble and send break, the external CK clock is not activated.

In synchronous mode the USART transmitter works exactly like in asynchronous mode. But as CK is synchronized with TX (according to CPOL and CPHA), the data on TX is synchronous.

In this mode the USART receiver works in a different manner compared to the asynchronous mode. If RE=1, the data is sampled on CK (rising or falling edge, depending on CPOL and CPHA), without any oversampling. A setup and a hold time must be respected (which depends on the baud rate: 1/16 bit duration).

Note: The CK pin works in conjunction with the TX pin. Thus, the clock is provided only if the transmitter is enabled (TE=1) and data is being transmitted (the data register USART_TDR written). This means that it is not possible to receive synchronous data without transmitting data.

The LBCL, CPOL and CPHA bits have to be selected when the USART is disabled (UE=0) to ensure that the clock pulses function correctly.

Note: For code example refer to the Appendix [A.15.6: USART synchronous mode code example](#)

Figure 235. USART example of synchronous transmission

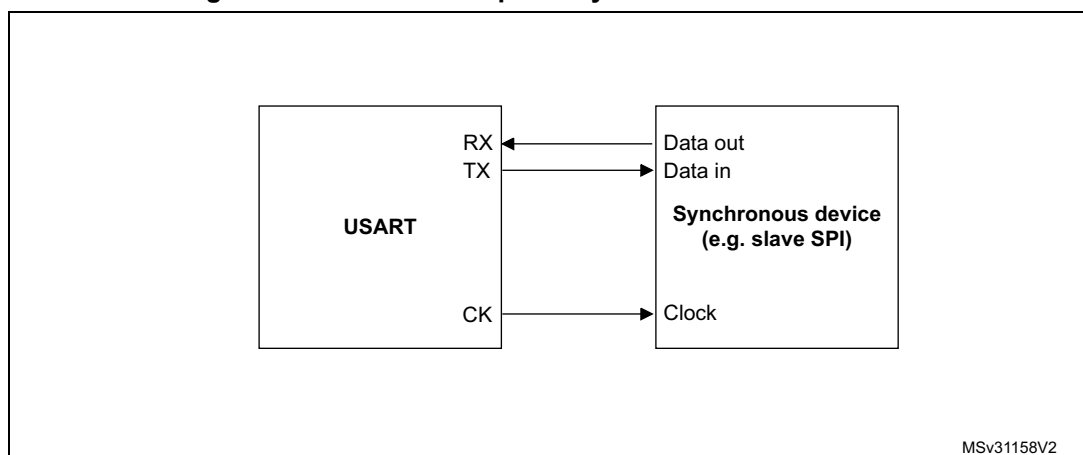


Figure 236. USART data clock timing diagram (M=0)

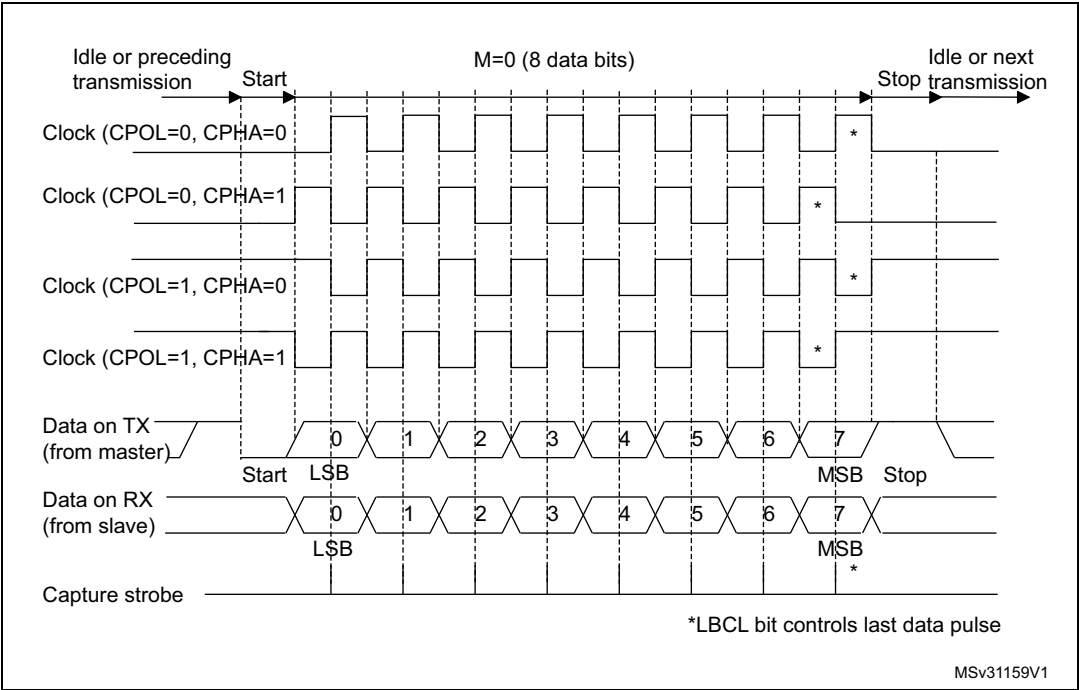


Figure 237. USART data clock timing diagram (M=1)

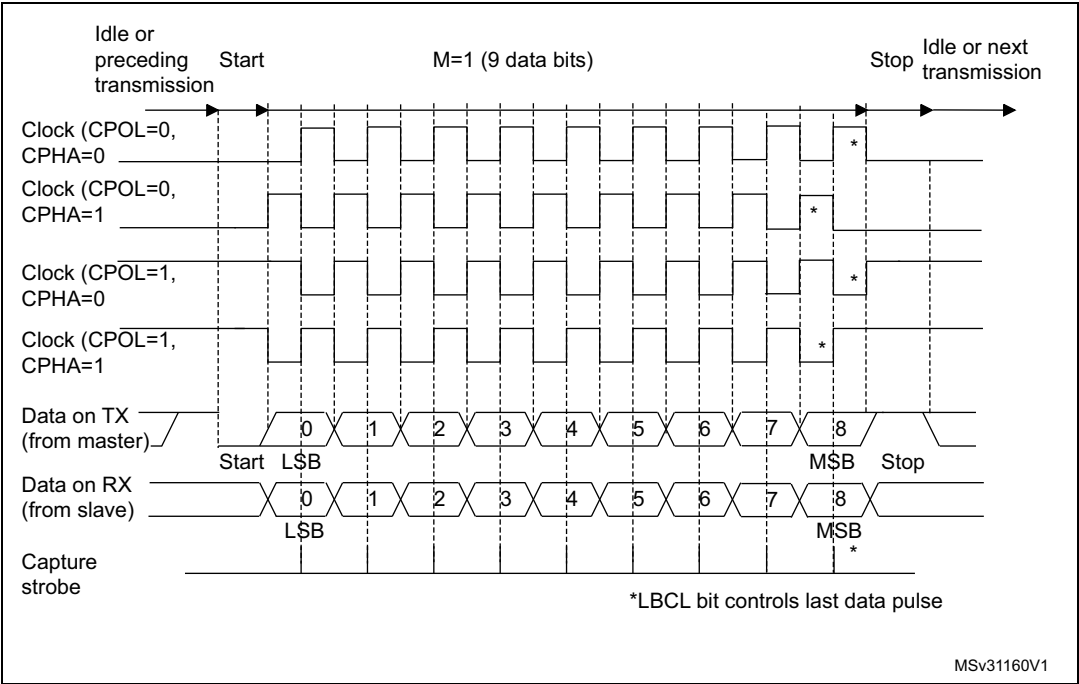
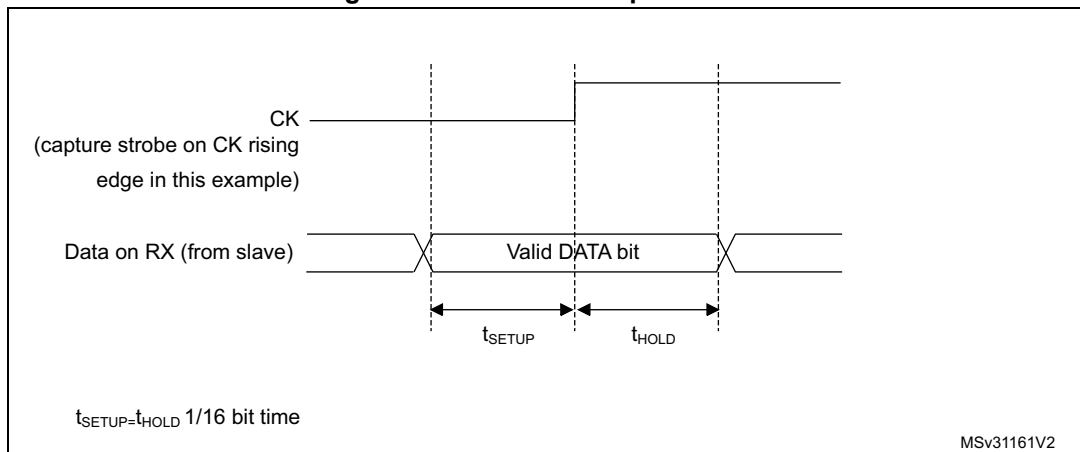


Figure 238. RX data setup/hold time



23.4.10 USART Single-wire Half-duplex communication

Single-wire Half-duplex mode is selected by setting the HDSEL bit in the USART_CR3 register. In this mode, the following bits must be kept cleared:

- CLKEN bit in the USART_CR2 register,
- SCEN and IREN bits in the USART_CR3 register.

The USART can be configured to follow a Single-wire Half-duplex protocol where the TX and RX lines are internally connected. The selection between half- and Full-duplex communication is made with a control bit HDSEL in USART_CR3.

As soon as HDSEL is written to 1:

- The TX and RX lines are internally connected
- The RX pin is no longer used
- The TX pin is always released when no data is transmitted. Thus, it acts as a standard I/O in idle or in reception. It means that the I/O must be configured so that TX is configured as alternate function open-drain with an external pull-up.

Apart from this, the communication protocol is similar to normal USART mode. Any conflicts on the line must be managed by software (by the use of a centralized arbiter, for instance). In particular, the transmission is never blocked by hardware and continues as soon as data is written in the data register while the TE bit is set.

For code example refer to the Appendix section [A.15.7: USART DMA code example](#).

23.4.11 USART continuous communication in DMA mode

The USART is capable of performing continuous communication using the DMA. The DMA requests for Rx buffer and Tx buffer are generated independently.

Note: Please refer to [Section 23.3: USART implementation on page 597](#) to determine if the DMA mode is supported. If DMA is not supported, use the USART as explained in [Section 23.4.2: USART transmitter](#) or [Section 23.4.3: USART receiver](#). To perform continuous communication, the user can clear the TXE/ RXNE flags in the USART_ISR register.

For code example refer to the Appendix section [A.15.7: USART DMA code example](#).

Transmission using DMA

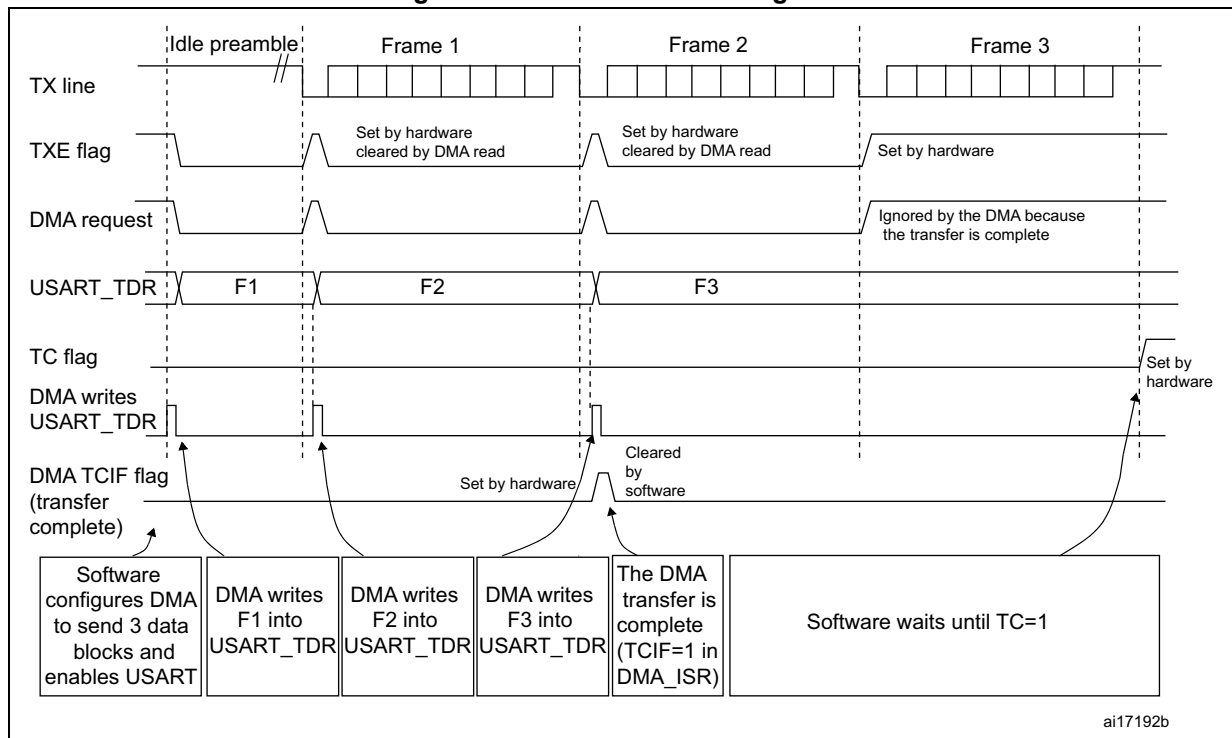
DMA mode can be enabled for transmission by setting DMAT bit in the USART_CR3 register. Data is loaded from a SRAM area configured using the DMA peripheral (refer to) to the USART_TDR register whenever the TXE bit is set. To map a DMA channel for USART transmission, use the following procedure (x denotes the channel number):

1. Write the USART_TDR register address in the DMA control register to configure it as the destination of the transfer. The data is moved to this address from memory after each TXE event.
2. Write the memory address in the DMA control register to configure it as the source of the transfer. The data is loaded into the USART_TDR register from this memory area after each TXE event.
3. Configure the total number of bytes to be transferred to the DMA control register.
4. Configure the channel priority in the DMA register
5. Configure DMA interrupt generation after half/ full transfer as required by the application.
6. Clear the TC flag in the USART_ISR register by setting the TCCF bit in the USART_ICR register.
7. Activate the channel in the DMA register.

When the number of data transfers programmed in the DMA Controller is reached, the DMA controller generates an interrupt on the DMA channel interrupt vector.

In transmission mode, once the DMA has written all the data to be transmitted (the TCIF flag is set in the DMA_ISR register), the TC flag can be monitored to make sure that the USART communication is complete. This is required to avoid corrupting the last transmission before disabling the USART or entering Stop mode. Software must wait until TC=1. The TC flag remains cleared during all data transfers and it is set by hardware at the end of transmission of the last frame.

Figure 239. Transmission using DMA



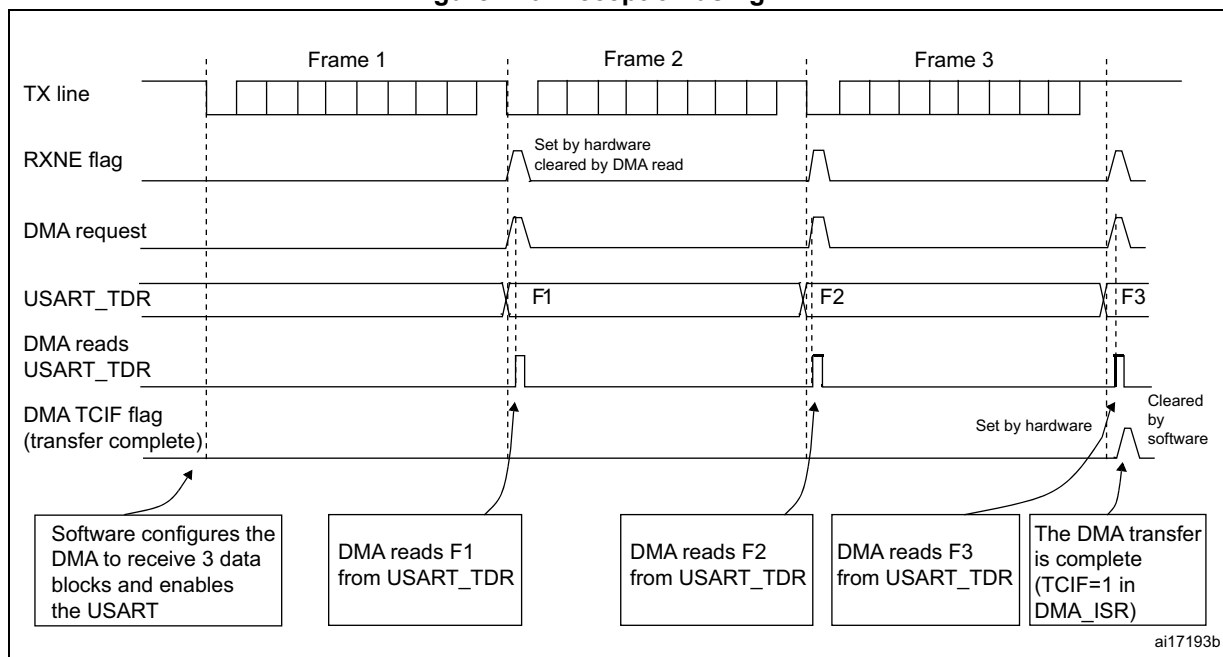
Reception using DMA

DMA mode can be enabled for reception by setting the DMAR bit in USART_CR3 register. Data is loaded from the USART_RDR register to a SRAM area configured using the DMA peripheral (refer to [Section 10: Direct memory access controller \(DMA\) on page 152](#)) whenever a data byte is received. To map a DMA channel for USART reception, use the following procedure:

1. Write the USART_RDR register address in the DMA control register to configure it as the source of the transfer. The data is moved from this address to the memory after each RXNE event.
2. Write the memory address in the DMA control register to configure it as the destination of the transfer. The data is loaded from USART_RDR to this memory area after each RXNE event.
3. Configure the total number of bytes to be transferred to the DMA control register.
4. Configure the channel priority in the DMA control register.
5. Configure interrupt generation after half/ full transfer as required by the application.
6. Activate the channel in the DMA control register.

When the number of data transfers programmed in the DMA Controller is reached, the DMA controller generates an interrupt on the DMA channel interrupt vector.

Figure 240. Reception using DMA



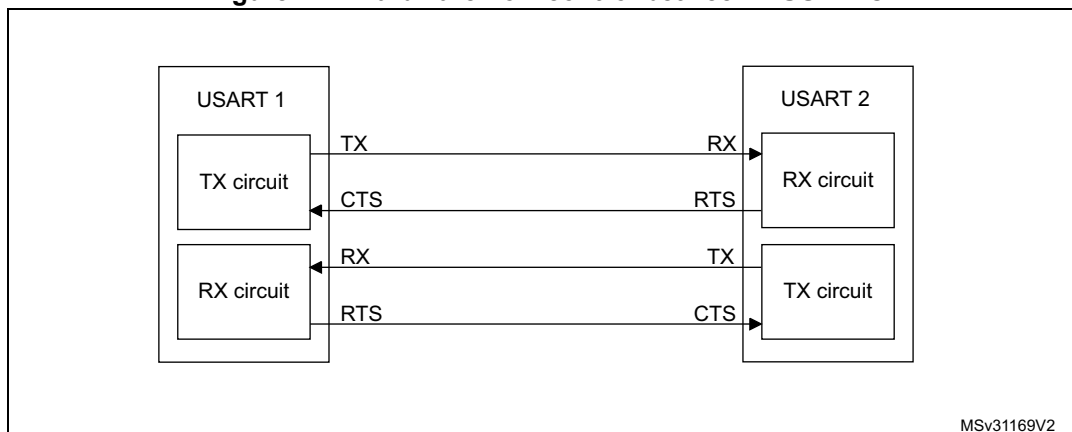
Error flagging and interrupt generation in multibuffer communication

In multibuffer communication if any error occurs during the transaction the error flag is asserted after the current byte. An interrupt is generated if the interrupt enable flag is set. For framing error, overrun error and noise flag which are asserted with RXNE in single byte reception, there is a separate error flag interrupt enable bit (EIE bit in the USART_CR3 register), which, if set, enables an interrupt after the current byte if any of these errors occur.

23.4.12 RS232 hardware flow control and RS485 driver enable using USART

It is possible to control the serial data flow between 2 devices by using the CTS input and the RTS output. The [Figure 241](#) shows how to connect 2 devices in this mode:

Figure 241. Hardware flow control between 2 USARTs

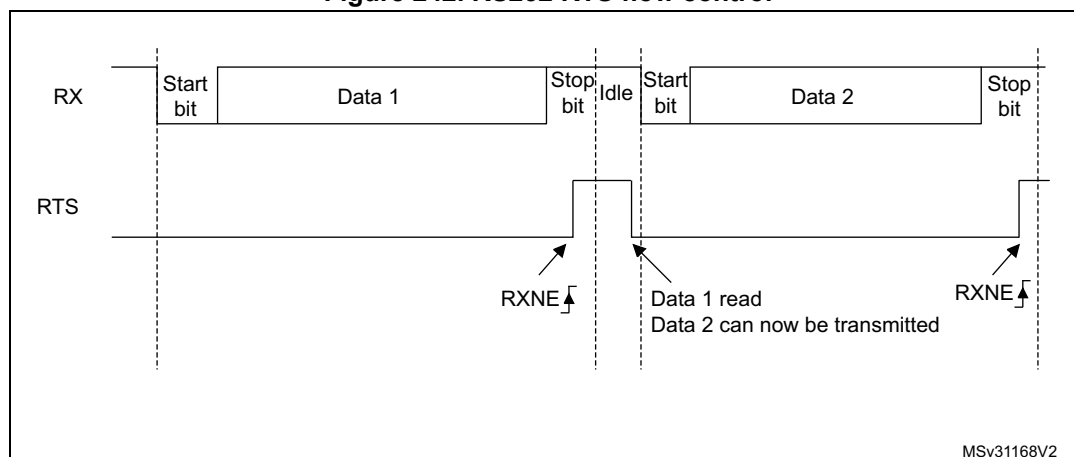


RS232 RTS and CTS flow control can be enabled independently by writing the RTSE and CTSE bits respectively to 1 (in the USART_CR3 register).

RS232 RTS flow control

If the RTS flow control is enabled (RTSE=1), then RTS is asserted (tied low) as long as the USART receiver is ready to receive a new data. When the receive register is full, RTS is de-asserted, indicating that the transmission is expected to stop at the end of the current frame. [Figure 242](#) shows an example of communication with RTS flow control enabled.

Figure 242. RS232 RTS flow control

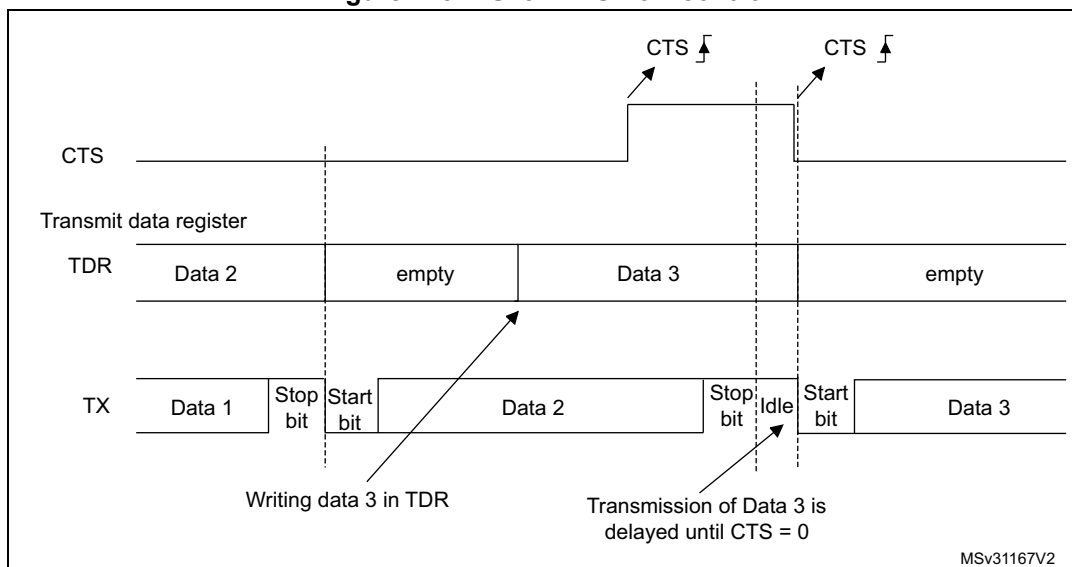


RS232 CTS flow control

If the CTS flow control is enabled (CTSE=1), then the transmitter checks the CTS input before transmitting the next frame. If CTS is asserted (tied low), then the next data is transmitted (assuming that data is to be transmitted, in other words, if TXE=0), else the transmission does not occur. When CTS is de-asserted during a transmission, the current transmission is completed before the transmitter stops.

When CTSE=1, the CTSIF status bit is automatically set by hardware as soon as the CTS input toggles. It indicates when the receiver becomes ready or not ready for communication. An interrupt is generated if the CTSIE bit in the USART_CR3 register is set. [Figure 243](#) shows an example of communication with CTS flow control enabled.

Figure 243. RS232 CTS flow control



Note: For correct behavior, CTS must be asserted at least 3 USART clock source periods before the end of the current character. In addition it should be noted that the CTSCF flag may not be set for pulses shorter than 2 x PCLK periods.

For code example refer to the Appendix section [A.15.8: USART hardware flow control code example](#).

RS485 Driver Enable

The driver enable feature is enabled by setting bit DEM in the USART_CR3 control register. This allows the user to activate the external transceiver control, through the DE (Driver Enable) signal. The assertion time is the time between the activation of the DE signal and the beginning of the START bit. It is programmed using the DEAT [4:0] bit fields in the USART_CR1 control register. The de-assertion time is the time between the end of the last stop bit, in a transmitted message, and the de-activation of the DE signal. It is programmed using the DEDT [4:0] bit fields in the USART_CR1 control register. The polarity of the DE signal can be configured using the DEP bit in the USART_CR3 control register.

In USART, the DEAT and DEDT are expressed in sample time units (1/8 or 1/16 bit duration, depending on the oversampling rate).

23.5 USART low-power modes

Table 91. Effect of low-power modes on the USART

Mode	Description
Sleep	No effect. USART interrupt causes the device to exit Sleep mode.
Stop	The USART is not clocked. It is not functional in Stop mode but its configuration is kept upon wakeup.
Standby	The USART is powered down and must be reinitialized when the device has exited from Standby mode.

23.6 USART interrupts

Table 92. USART interrupt requests

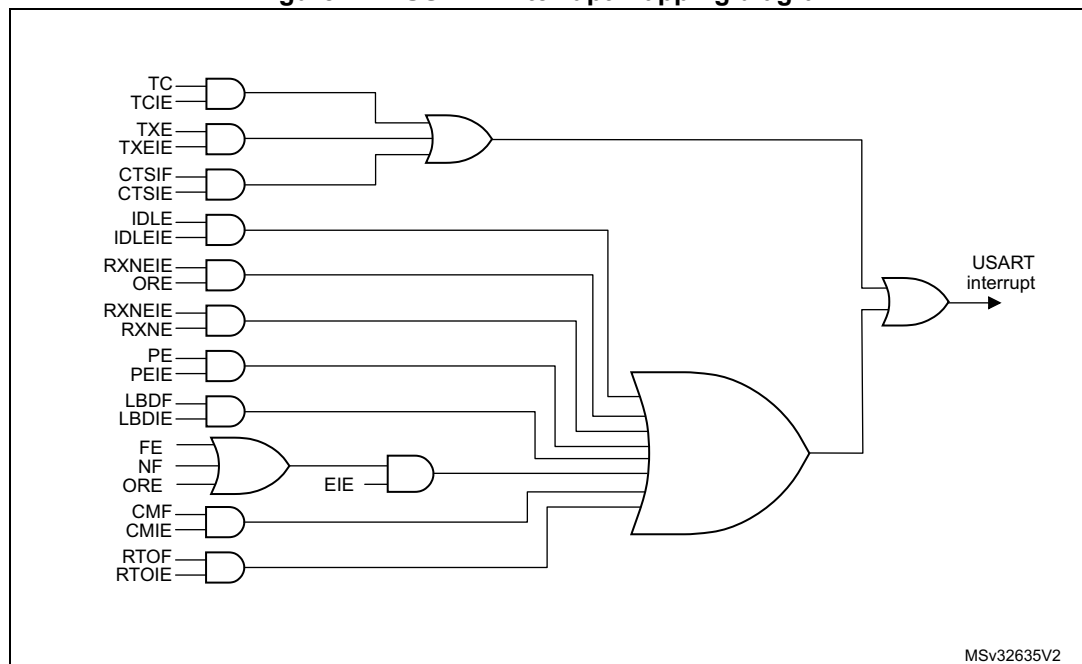
Interrupt event	Event flag	Enable Control bit
Transmit data register empty	TXE	TXEIE
CTS interrupt	CTSIF	CTSIE
Transmission Complete	TC	TCIE
Receive data register not empty (data ready to be read)	RXNE	RXNEIE
Overrun error detected	ORE	
Idle line detected	IDLE	IDLEIE
Parity error	PE	PEIE
Noise Flag, Overrun error and Framing Error in multibuffer communication.	NF or ORE or FE	EIE
Character match	CMF	CMIE
Receiver timeout	RTOF	RTOIE

The USART interrupt events are connected to the same interrupt vector (see [Figure 244](#)).

- During transmission: Transmission Complete, Clear to Send, Transmit data Register empty interrupt.
- During reception: Idle Line detection, Overrun error, Receive data register not empty, Parity error, Noise Flag, Framing Error, Character match, etc.

These events generate an interrupt if the corresponding Enable Control Bit is set.

Figure 244. USART interrupt mapping diagram



23.7 USART registers

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

23.7.1 Control register 1 (USART_CR1)

Address offset: 0x00

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	M1	Res.	RTOIE	DEAT[4:0]					DEDT[4:0]				
			rw		rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
OVER8	CMIE	MME	M0	WAKE	PCE	PS	PEIE	TXEIE	TCIE	RXNEIE	IDLEIE	TE	RE	Res.	UE
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw		rw

Bits 31:29 Reserved, must be kept at reset value

Bit 28 **M1**: Word length

This bit, with bit 12 (M0), determines the word length. It is set or cleared by software.

M[1:0] = 00: 1 Start bit, 8 data bits, n stop bits

M[1:0] = 01: 1 Start bit, 9 data bits, n stop bits

M[1:0] = 10: 1 Start bit, 7 data bits, n stop bits

This bit can only be written when the USART is disabled (UE=0).

Bit 27 Reserved, must be kept at reset value

Bit 26 **RTOIE**: Receiver timeout interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: An USART interrupt is generated when the RTOF bit is set in the USART_ISR register.

Note: If the USART does not support the Receiver timeout feature, this bit is reserved and forced by hardware to '0'. [Section 23.3: USART implementation on page 597](#).

Bits 25:21 **DEAT[4:0]**: Driver Enable assertion time

This 5-bit value defines the time between the activation of the DE (Driver Enable) signal and the beginning of the start bit. It is expressed in sample time units (1/8 or 1/16 bit duration, depending on the oversampling rate).

This bit field can only be written when the USART is disabled (UE=0).

Note: If the Driver Enable feature is not supported, this bit is reserved and must be kept cleared. Please refer to [Section 23.3: USART implementation on page 597](#).

Bits 20:16 **DEDT[4:0]**: Driver Enable de-assertion time

This 5-bit value defines the time between the end of the last stop bit, in a transmitted message, and the de-activation of the DE (Driver Enable) signal. It is expressed in sample time units (1/8 or 1/16 bit duration, depending on the oversampling rate).

If the USART_TDR register is written during the DEDT time, the new data is transmitted only when the DEDT and DEAT times have both elapsed.

This bit field can only be written when the USART is disabled (UE=0).

Note: If the Driver Enable feature is not supported, this bit is reserved and must be kept cleared. Please refer to [Section 23.3: USART implementation on page 597](#).

- Bit 15 **OVER8**: Oversampling mode
0: Oversampling by 16
1: Oversampling by 8
This bit can only be written when the USART is disabled (UE=0).
- Bit 14 **CMIE**: Character match interrupt enable
This bit is set and cleared by software.
0: Interrupt is inhibited
1: A USART interrupt is generated when the CMF bit is set in the USART_ISR register.
- Bit 13 **MME**: Mute mode enable
This bit activates the mute mode function of the USART. when set, the USART can switch between the active and mute modes, as defined by the WAKE bit. It is set and cleared by software.
0: Receiver in active mode permanently
1: Receiver can switch between mute mode and active mode.
- Bit 12 **M0**: Word length
This bit determines the word length. It is set or cleared by software.
0: 1 Start bit, 8 data bits, n stop bits
1: 1 Start bit, 9 data bits, n stop bits
- Bit 11 **WAKE**: Receiver wakeup method
This bit determines the USART wakeup method from Mute mode. It is set or cleared by software.
0: Idle line
1: Address mark
This bit field can only be written when the USART is disabled (UE=0).
- Bit 10 **PCE**: Parity control enable
This bit selects the hardware parity control (generation and detection). When the parity control is enabled, the computed parity is inserted at the MSB position (9th bit if M=1; 8th bit if M=0) and parity is checked on the received data. This bit is set and cleared by software. Once it is set, PCE is active after the current byte (in reception and in transmission).
0: Parity control disabled
1: Parity control enabled
This bit field can only be written when the USART is disabled (UE=0).
- Bit 9 **PS**: Parity selection
This bit selects the odd or even parity when the parity generation/detection is enabled (PCE bit set). It is set and cleared by software. The parity will be selected after the current byte.
0: Even parity
1: Odd parity
This bit field can only be written when the USART is disabled (UE=0).
- Bit 8 **PEIE**: PE interrupt enable
This bit is set and cleared by software.
0: Interrupt is inhibited
1: A USART interrupt is generated whenever PE=1 in the USART_ISR register
- Bit 7 **TXEIE**: interrupt enable
This bit is set and cleared by software.
0: Interrupt is inhibited
1: A USART interrupt is generated whenever TXE=1 in the USART_ISR register

Bit 6 **TCIE**: Transmission complete interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated whenever TC=1 in the USART_ISR register

Bit 5 **RXNEIE**: RXNE interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated whenever ORE=1 or RXNE=1 in the USART_ISR register

Bit 4 **IDLEIE**: IDLE interrupt enable

This bit is set and cleared by software.

0: Interrupt is inhibited

1: A USART interrupt is generated whenever IDLE=1 in the USART_ISR register

Bit 3 **TE**: Transmitter enable

This bit enables the transmitter. It is set and cleared by software.

0: Transmitter is disabled

1: Transmitter is enabled

During transmission, a "0" pulse on the TE bit ("0" followed by "1") sends a preamble (idle line) after the current word. In order to generate an idle character, the TE must not be immediately written to 1.

Bit 2 **RE**: Receiver enable

This bit enables the receiver. It is set and cleared by software.

0: Receiver is disabled

1: Receiver is enabled and begins searching for a start bit

Bit 1 Reserved, must be kept at reset value.

Bit 0 **UE**: USART enable

When this bit is cleared, the USART prescalers and outputs are stopped immediately, and current operations are discarded. The configuration of the USART is kept, but all the status flags, in the USART_ISR are set to their default values. This bit is set and cleared by software.

0: USART prescaler and outputs disabled, low-power mode

1: USART enabled

Note: In order to go into low-power mode without generating errors on the line, the TE bit must be reset before and the software must wait for the TC bit in the USART_ISR to be set before resetting the UE bit.

The DMA requests are also reset when UE = 0 so the DMA channel must be disabled before resetting the UE bit.

23.7.2 Control register 2 (USART_CR2)

Address offset: 0x04

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
ADD[7:4]				ADD[3:0]				RTOEN	ABRMOD[1:0]		ABREN	MSBFIRST	DATAINV	TXINV	RXINV
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
SWAP	Res.	STOP[1:0]		CLKEN	CPOL	CPHA	LBCL	Res.	Res.	Res.	ADDM7	Res.	Res.	Res.	Res.
rw		rw	rw	rw	rw	rw	rw				rw				

Bits 31:28 **ADD[7:4]**: Address of the USART node

This bit-field gives the address of the USART node or a character code to be recognized.

This is used in multiprocessor communication during Mute mode or Stop mode, for wakeup with 7-bit address mark detection. The MSB of the character sent by the transmitter should be equal to 1. It may also be used for character detection during normal reception, Mute mode inactive. In this case, the whole received character (8-bit) is compared to the ADD[7:0] value and CMF flag is set on match.

This bit field can only be written when reception is disabled (RE = 0) or the USART is disabled (UE=0)

Bits 27:24 **ADD[3:0]**: Address of the USART node

This bit-field gives the address of the USART node or a character code to be recognized.

This is used in multiprocessor communication during Mute mode or Stop mode, for wakeup with address mark detection.

This bit field can only be written when reception is disabled (RE = 0) or the USART is disabled (UE=0)

Bit 23 **RTOEN**: Receiver timeout enable

This bit is set and cleared by software.

0: Receiver timeout feature disabled.

1: Receiver timeout feature enabled.

When this feature is enabled, the RTOF flag in the USART_ISR register is set if the RX line is idle (no reception) for the duration programmed in the RTOR (receiver timeout register).

Note: If the USART does not support the Receiver timeout feature, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

Bits 22:21 **ABRMOD[1:0]**: Auto baud rate mode

These bits are set and cleared by software.

00: Measurement of the start bit is used to detect the baud rate.

01: Falling edge to falling edge measurement. (the received frame must start with a single bit = 1 -> Frame = Start10xxxxxx)

10: 0x7F frame detection.

11: 0x55 frame detection

This bit field can only be written when ABREN = 0 or the USART is disabled (UE=0).

Note: If DATAINV=1 and/or MSBFIRST=1 the patterns must be the same on the line, for example 0xAA for MSBFIRST)

If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

Bit 20 **ABREN**: Auto baud rate enable

This bit is set and cleared by software.

0: Auto baud rate detection is disabled.

1: Auto baud rate detection is enabled.

Note: If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

Bit 19 **MSBFIRST**: Most significant bit first

This bit is set and cleared by software.

0: data is transmitted/received with data bit 0 first, following the start bit.

1: data is transmitted/received with the MSB (bit 7/8/9) first, following the start bit.

This bit field can only be written when the USART is disabled (UE=0).

Bit 18 **DATAINV**: Binary data inversion

This bit is set and cleared by software.

0: Logical data from the data register are send/received in positive/direct logic. (1=H, 0=L)

1: Logical data from the data register are send/received in negative/inverse logic. (1=L, 0=H). The parity bit is also inverted.

This bit field can only be written when the USART is disabled (UE=0).

Bit 17 **TXINV**: TX pin active level inversion

This bit is set and cleared by software.

0: TX pin signal works using the standard logic levels (V_{DD} =1/idle, Gnd=0/mark)

1: TX pin signal values are inverted. (V_{DD} =0/mark, Gnd=1/idle).

This allows the use of an external inverter on the TX line.

This bit field can only be written when the USART is disabled (UE=0).

Bit 16 **RXINV**: RX pin active level inversion

This bit is set and cleared by software.

0: RX pin signal works using the standard logic levels (V_{DD} =1/idle, Gnd=0/mark)

1: RX pin signal values are inverted. (V_{DD} =0/mark, Gnd=1/idle).

This allows the use of an external inverter on the RX line.

This bit field can only be written when the USART is disabled (UE=0).

Bit 15 **SWAP**: Swap TX/RX pins

This bit is set and cleared by software.

0: TX/RX pins are used as defined in standard pinout

1: The TX and RX pins functions are swapped. This allows to work in the case of a cross-wired connection to another USART.

This bit field can only be written when the USART is disabled (UE=0).

Bit 14 Reserved, must be kept at reset value.

Bits 13:12 **STOP[1:0]**: STOP bits

These bits are used for programming the stop bits.

00: 1 stop bit

01: Reserved

10: 2 stop bits

11: Reserved

This bit field can only be written when the USART is disabled (UE=0).

Bit 11 CLKEN: Clock enable

This bit allows the user to enable the CK pin.

0: CK pin disabled

1: CK pin enabled

This bit can only be written when the USART is disabled (UE=0).

*Note: If synchronous mode is not supported, this bit is reserved and forced by hardware to '0'.
Please refer to [Section 23.3: USART implementation on page 597](#).*

Bit 10 CPOL: Clock polarity

This bit allows the user to select the polarity of the clock output on the CK pin in synchronous mode. It works in conjunction with the CPHA bit to produce the desired clock/data relationship

0: Steady low value on CK pin outside transmission window

1: Steady high value on CK pin outside transmission window

This bit can only be written when the USART is disabled (UE=0).

*Note: If synchronous mode is not supported, this bit is reserved and forced by hardware to '0'.
Please refer to [Section 23.3: USART implementation on page 597](#).*

Bit 9 CPHA: Clock phase

This bit is used to select the phase of the clock output on the CK pin in synchronous mode. It works in conjunction with the CPOL bit to produce the desired clock/data relationship (see [Figure 236](#) and [Figure 237](#))

0: The first clock transition is the first data capture edge

1: The second clock transition is the first data capture edge

This bit can only be written when the USART is disabled (UE=0).

*Note: If synchronous mode is not supported, this bit is reserved and forced by hardware to '0'.
Please refer to [Section 23.3: USART implementation on page 597](#).*

Bit 8 LBCL: Last bit clock pulse

This bit is used to select whether the clock pulse associated with the last data bit transmitted (MSB) has to be output on the CK pin in synchronous mode.

0: The clock pulse of the last data bit is not output to the CK pin

1: The clock pulse of the last data bit is output to the CK pin

Caution: The last bit is the 7th or 8th or 9th data bit transmitted depending on the 7 or 8 or 9 bit format selected by the M bit in the USART_CR1 register.

This bit can only be written when the USART is disabled (UE=0).

*Note: If synchronous mode is not supported, this bit is reserved and forced by hardware to '0'.
Please refer to [Section 23.3: USART implementation on page 597](#).*

Bits 7:5 Reserved, must be kept at reset value.

Bit 4 ADDM7: 7-bit Address Detection/4-bit Address Detection

This bit is for selection between 4-bit address detection or 7-bit address detection.

0: 4-bit address detection

1: 7-bit address detection (in 8-bit data mode)

This bit can only be written when the USART is disabled (UE=0)

Note: In 7-bit and 9-bit data modes, the address detection is done on 6-bit and 8-bit address (ADD[5:0] and ADD[7:0]) respectively.

Bits 3:0 Reserved, must be kept at reset value.

Note: The 3 bits (CPOL, CPHA, LBCL) should not be written while the transmitter is enabled.

23.7.3 Control register 3 (USART_CR3)

Address offset: 0x08

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DEP	DEM	DDRE	OVR DIS	ONE BIT	CTSIE	CTSE	RTSE	DMAT	DMAR	Res.	Res.	HDSEL	Res.	Res.	EIE
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw			rw			rw

Bits 31:25 Reserved, must be kept at reset value.

Bit 24 Reserved, must be kept at reset value.

Bit 23 Reserved, must be kept at reset value.

Bits 19:17 Reserved, must be kept at reset value.

Bit 16 Reserved, must be kept at reset value.

Bit 15 **DEP**: Driver enable polarity selection

0: DE signal is active high.

1: DE signal is active low.

This bit can only be written when the USART is disabled (UE=0).

Note: If the Driver Enable feature is not supported, this bit is reserved and must be kept cleared. Please refer to [Section 23.3: USART implementation on page 597](#).

Bit 14 **DEM**: Driver enable mode

This bit allows the user to activate the external transceiver control, through the DE signal.

0: DE function is disabled.

1: DE function is enabled. The DE signal is output on the RTS pin.

This bit can only be written when the USART is disabled (UE=0).

Note: If the Driver Enable feature is not supported, this bit is reserved and must be kept cleared. [Section 23.3: USART implementation on page 597](#).

Bit 13 **DDRE**: DMA Disable on Reception Error

0: DMA is not disabled in case of reception error. The corresponding error flag is set but RXNE is kept 0 preventing from overrun. As a consequence, the DMA request is not asserted, so the erroneous data is not transferred (no DMA request), but next correct received data will be transferred.

1: DMA is disabled following a reception error. The corresponding error flag is set, as well as RXNE. The DMA request is masked until the error flag is cleared. This means that the software must first disable the DMA request (DMAR = 0) or clear RXNE before clearing the error flag.

This bit can only be written when the USART is disabled (UE=0).

Note: The reception errors are: parity error, framing error or noise error.

Bit 12 **OVRDIS**: Overrun Disable

This bit is used to disable the receive overrun detection.

0: Overrun Error Flag, ORE, is set when received data is not read before receiving new data.

1: Overrun functionality is disabled. If new data is received while the RXNE flag is still set the ORE flag is not set and the new received data overwrites the previous content of the USART_RDR register.

This bit can only be written when the USART is disabled (UE=0).

Note: This control bit allows checking the communication flow without reading the data.

Bit 11 ONEBIT: One sample bit method enable

This bit allows the user to select the sample method. When the one sample bit method is selected the noise detection flag (NF) is disabled.

0: Three sample bit method

1: One sample bit method

This bit can only be written when the USART is disabled (UE=0).

Note: ONEBIT feature applies only to data bits, It does not apply to Start bit.

Bit 10 CTSIE: CTS interrupt enable

0: Interrupt is inhibited

1: An interrupt is generated whenever CTSIF=1 in the USART_ISR register

Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

Bit 9 CTSE: CTS enable

0: CTS hardware flow control disabled

1: CTS mode enabled, data is only transmitted when the CTS input is asserted (tied to 0). If the CTS input is de-asserted while data is being transmitted, then the transmission is completed before stopping. If data is written into the data register while CTS is de-asserted, the transmission is postponed until CTS is asserted.

This bit can only be written when the USART is disabled (UE=0)

Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

Bit 8 RTSE: RTS enable

0: RTS hardware flow control disabled

1: RTS output enabled, data is only requested when there is space in the receive buffer. The transmission of data is expected to cease after the current character has been transmitted. The RTS output is asserted (pulled to 0) when data can be received.

This bit can only be written when the USART is disabled (UE=0).

Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

Bit 7 DMAT: DMA enable transmitter

This bit is set/reset by software

1: DMA mode is enabled for transmission

0: DMA mode is disabled for transmission

Bit 6 DMAR: DMA enable receiver

This bit is set/reset by software

1: DMA mode is enabled for reception

0: DMA mode is disabled for reception

Bits 5:4 Reserved, must be kept at reset value.

Bit 3 **HDSEL**: Half-duplex selection

Selection of Single-wire Half-duplex mode

0: Half duplex mode is not selected

1: Half duplex mode is selected

This bit can only be written when the USART is disabled (UE=0).

Bits 2:1 Reserved, must be kept at reset value.

Bit 0 **EIE**: Error interrupt enable

Error Interrupt Enable Bit is required to enable interrupt generation in case of a framing error, overrun error or noise flag (FE=1 or ORE=1 or NF=1 in the USART_ISR register).

0: Interrupt is inhibited

1: An interrupt is generated when FE=1 or ORE=1 or NF=1 in the USART_ISR register.

23.7.4 Baud rate register (USART_BRR)

This register can only be written when the USART is disabled (UE=0). It may be automatically updated by hardware in auto baud rate detection mode.

Address offset: 0x0C

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BRR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:16 Reserved, must be kept at reset value.

Bits 15:4 **BRR[15:4]**

BRR[15:4] = USARTDIV[15:4]

Bits 3:0 **BRR[3:0]**

When OVER8 = 0, BRR[3:0] = USARTDIV[3:0].

When OVER8 = 1:

BRR[2:0] = USARTDIV[3:0] shifted 1 bit to the right.

BRR[3] must be kept cleared.

23.7.5 Receiver timeout register (USART_RTOR)

Address offset: 0x14

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RTO[23:16]							
								rw	rw	rw	rw	rw	rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RTO[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 31:24 Reserved, must be kept at reset value.

Bits 23:0 **RTO[23:0]**: Receiver timeout value

This bit-field gives the Receiver timeout value in terms of number of bit duration.

In standard mode, the RTOF flag is set if, after the last received character, no new start bit is detected for more than the RTO value.

Note: This value must only be programmed once per received character.

Note: RTOR can be written on the fly. If the new value is lower than or equal to the counter, the RTOF flag is set.

This register is reserved and forced by hardware to "0x00000000" when the Receiver timeout feature is not supported. Please refer to [Section 23.3: USART implementation on page 597](#).

23.7.6 Request register (USART_RQR)

Address offset: 0x18

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RXFRQ	MMRQ	SBKRQ	ABRRQ
												w	w	w	w

Bits 31:4 Reserved, must be kept at reset value

Bit 3 **RXFRQ**: Receive data flush request

Writing 1 to this bit clears the RXNE flag.

This allows to discard the received data without reading it, and avoid an overrun condition.

Bit 2 **MMRQ**: Mute mode request

Writing 1 to this bit puts the USART in mute mode and sets the RWU flag.

Bit 1 **SBKRQ**: Send break request

Writing 1 to this bit sets the SBKF flag and request to send a BREAK on the line, as soon as the transmit machine is available.

Note: In the case the application needs to send the break character following all previously inserted data, including the ones not yet transmitted, the software should wait for the TXE flag assertion before setting the SBKRQ bit.

Bit 0 **ABRRQ**: Auto baud rate request

Writing 1 to this bit resets the ABRF flag in the USART_ISR and request an automatic baud rate measurement on the next received data frame.

Note: If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

23.7.7 Interrupt and status register (USART_ISR)

Address offset: 0x1C

Reset value: 0x0200 00C0

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RWU	SBKF	CMF	BUSY
												r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ABRF	ABRE	Res.	Res.	RTOF	CTS	CTSIF	Res.	TXE	TC	RXNE	IDLE	ORE	NF	FE	PE
r	r			r	r	r		r	r	r	r	r	r	r	r

Bits 31:25 Reserved, must be kept at reset value.

Bits 24:22 Reserved, must be kept at reset value.

Bit 21 Reserved, must be kept at reset value

Bit 20 Reserved, must be kept at reset value.

Bit 19 **RWU**: Receiver wakeup from Mute mode

This bit indicates if the USART is in mute mode. It is cleared/set by hardware when a wakeup/mute sequence is recognized. The mute mode control sequence (address or IDLE) is selected by the WAKE bit in the USART_CR1 register.

When wakeup on IDLE mode is selected, this bit can only be set by software, writing 1 to the MMRQ bit in the USART_RQR register.

0: Receiver in active mode

1: Receiver in mute mode

Bit 18 **SBKF**: Send break flag

This bit indicates that a send break character was requested. It is set by software, by writing 1 to the SBKRQ bit in the USART_RQR register. It is automatically reset by hardware during the stop bit of break transmission.

0: No break character is transmitted

1: Break character will be transmitted

Bit 17 **CMF**: Character match flag

This bit is set by hardware, when the character defined by ADD[7:0] is received. It is cleared by software, writing 1 to the CMCF in the USART_ICR register.

An interrupt is generated if CMIE=1 in the USART_CR1 register.

0: No Character match detected

1: Character Match detected

Bit 16 **BUSY**: Busy flag

This bit is set and reset by hardware. It is active when a communication is ongoing on the RX line (successful start bit detected). It is reset at the end of the reception (successful or not).

0: USART is idle (no reception)

1: Reception on going

Bit 15 ABRF: Auto baud rate flag

This bit is set by hardware when the automatic baud rate has been set (RXNE will also be set, generating an interrupt if RXNEIE = 1) or when the auto baud rate operation was completed without success (ABRE=1) (ABRE, RXNE and FE are also set in this case)

It is cleared by software, in order to request a new auto baud rate detection, by writing 1 to the ABRRQ in the USART_RQR register.

Note: If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'.

Bit 14 ABRE: Auto baud rate error

This bit is set by hardware if the baud rate measurement failed (baud rate out of range or character comparison failed)

It is cleared by software, by writing 1 to the ABRRQ bit in the USART_CR3 register.

Note: If the USART does not support the auto baud rate feature, this bit is reserved and forced by hardware to '0'.

Bits 13:12 Reserved, must be kept at reset value.

Bit 11 RTOF: Receiver timeout

This bit is set by hardware when the timeout value, programmed in the RTOR register has lapsed, without any communication. It is cleared by software, writing 1 to the RTOCF bit in the USART_ICR register.

An interrupt is generated if RTOIE=1 in the USART_CR1 register.

0: Timeout value not reached

1: Timeout value reached without any data reception

Note: If a time equal to the value programmed in RTOR register separates 2 characters, RTOF is not set. If this time exceeds this value + 2 sample times (2/16 or 2/8, depending on the oversampling method), RTOF flag is set.

The counter counts even if RE = 0 but RTOF is set only when RE = 1. If the timeout has already elapsed when RE is set, then RTOF will be set.

If the USART does not support the Receiver timeout feature, this bit is reserved and forced by hardware to '0'.

Bit 10 CTS: CTS flag

This bit is set/reset by hardware. It is an inverted copy of the status of the CTS input pin.

0: CTS line set

1: CTS line reset

Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'.

Bit 9 CTSIF: CTS interrupt flag

This bit is set by hardware when the CTS input toggles, if the CTSE bit is set. It is cleared by software, by writing 1 to the CTSCF bit in the USART_ICR register.

An interrupt is generated if CTSIE=1 in the USART_CR3 register.

0: No change occurred on the CTS status line

1: A change occurred on the CTS status line

Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'.

Bit 8 Reserved, must be kept at reset value.

Bit 7 TXE: Transmit data register empty

This bit is set by hardware when the content of the USART_TDR register has been transferred into the shift register. It is cleared by a write to the USART_TDR register.

An interrupt is generated if the TXEIE bit =1 in the USART_CR1 register.

0: data is not transferred to the shift register

1: data is transferred to the shift register)

Note: This bit is used during single buffer transmission.

Bit 6 TC: Transmission complete

This bit is set by hardware if the transmission of a frame containing data is complete and if TXE is set. An interrupt is generated if TCIE=1 in the USART_CR1 register. It is cleared by software, writing 1 to the TCCF in the USART_ICR register or by a write to the USART_TDR register.

An interrupt is generated if TCIE=1 in the USART_CR1 register.

0: Transmission is not complete

1: Transmission is complete

Note: If TE bit is reset and no transmission is on going, the TC bit will be set immediately.

Bit 5 RXNE: Read data register not empty

This bit is set by hardware when the content of the RDR shift register has been transferred to the USART_RDR register. It is cleared by a read to the USART_RDR register. The RXNE flag can also be cleared by writing 1 to the RXFRQ in the USART_RQR register.

An interrupt is generated if RXNEIE=1 in the USART_CR1 register.

0: data is not received

1: Received data is ready to be read.

Bit 4 IDLE: Idle line detected

This bit is set by hardware when an Idle Line is detected. An interrupt is generated if IDLEIE=1 in the USART_CR1 register. It is cleared by software, writing 1 to the IDLECF in the USART_ICR register.

0: No Idle line is detected

1: Idle line is detected

Note: The IDLE bit will not be set again until the RXNE bit has been set (i.e. a new idle line occurs).

If mute mode is enabled (MME=1), IDLE is set if the USART is not mute (RWU=0), whatever the mute mode selected by the WAKE bit. If RWU=1, IDLE is not set.

Bit 3 ORE: Overrun error

This bit is set by hardware when the data currently being received in the shift register is ready to be transferred into the RDR register while RXNE=1. It is cleared by a software, writing 1 to the ORECF, in the USART_ICR register.

An interrupt is generated if RXNEIE=1 or EIE = 1 in the USART_CR1 register.

0: No overrun error

1: Overrun error is detected

Note: When this bit is set, the RDR register content is not lost but the shift register is overwritten. An interrupt is generated if the ORE flag is set during multibuffer communication if the EIE bit is set.

This bit is permanently forced to 0 (no overrun detection) when the OVRDIS bit is set in the USART_CR3 register.

Bit 2 NF: START bit Noise detection flag

This bit is set by hardware when noise is detected on a received frame. It is cleared by software, writing 1 to the NFCF bit in the USART_ICR register.

0: No noise is detected

1: Noise is detected

Note: This bit does not generate an interrupt as it appears at the same time as the RXNE bit which itself generates an interrupt. An interrupt is generated when the NF flag is set during multibuffer communication if the EIE bit is set.

Note: When the line is noise-free, the NF flag can be disabled by programming the ONEBIT bit to 1 to increase the USART tolerance to deviations (Refer to [Section 23.4.5: Tolerance of the USART receiver to clock deviation on page 611](#)).

Bit 1 FE: Framing error

This bit is set by hardware when a de-synchronization, excessive noise or a break character is detected. It is cleared by software, writing 1 to the FECF bit in the USART_ICR register.

An interrupt is generated if EIE = 1 in the USART_CR1 register.

0: No Framing error is detected

1: Framing error or break character is detected

Bit 0 PE: Parity error

This bit is set by hardware when a parity error occurs in receiver mode. It is cleared by software, writing 1 to the PECF in the USART_ICR register.

An interrupt is generated if PEIE = 1 in the USART_CR1 register.

0: No parity error

1: Parity error

23.7.8 Interrupt flag clear register (USART_ICR)

Address offset: 0x20

Reset value: 0x0000

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CMCF	Res.
														rc_w1	
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	RTOCF	Res.	CTSCF	Res.	Res.	TCCF	Res.	IDLECF	ORECF	NCF	FECF	PECF
				rc_w1		rc_w1			rc_w1		rc_w1	rc_w1	rc_w1	rc_w1	rc_w1

Bits 31:20 Reserved, must be kept at reset value.

Bits 19:18 Reserved, must be kept at reset value.

Bit 17 CMCF: Character match clear flag

Writing 1 to this bit clears the CMF flag in the USART_ISR register.

Bits 16:12 Reserved, must be kept at reset value.

Bit 11 RTOCF: Receiver timeout clear flag

Writing 1 to this bit clears the RTOF flag in the USART_ISR register.

Note: If the USART does not support the Receiver timeout feature, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

Bit 10 Reserved, must be kept at reset value.

Bit 9 **CTSCF**: CTS clear flag

Writing 1 to this bit clears the CTSIF flag in the USART_ISR register.

Note: If the hardware flow control feature is not supported, this bit is reserved and forced by hardware to '0'. Please refer to [Section 23.3: USART implementation on page 597](#).

Bit 8 Reserved, must be kept at reset value.

Bit 7 Reserved, must be kept at reset value.

Bit 6 **TCCF**: Transmission complete clear flag

Writing 1 to this bit clears the TC flag in the USART_ISR register.

Bit 5 Reserved, must be kept at reset value.

Bit 4 **IDLECF**: Idle line detected clear flag

Writing 1 to this bit clears the IDLE flag in the USART_ISR register.

Bit 3 **ORECF**: Overrun error clear flag

Writing 1 to this bit clears the ORE flag in the USART_ISR register.

Bit 2 **NCF**: Noise detected clear flag

Writing 1 to this bit clears the NF flag in the USART_ISR register.

Bit 1 **FE CF**: Framing error clear flag

Writing 1 to this bit clears the FE flag in the USART_ISR register.

Bit 0 **PECF**: Parity error clear flag

Writing 1 to this bit clears the PE flag in the USART_ISR register.

23.7.9 Receive data register (USART_RDR)

Address offset: 0x24

Reset value: Undefined

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	RDR[8:0]								
							r	r	r	r	r	r	r	r	r

Bits 31:9 Reserved, must be kept at reset value.

Bits 8:0 **RDR[8:0]**: Receive data value

Contains the received data character.

The RDR register provides the parallel interface between the input shift register and the internal bus (see [Figure 226](#)).

When receiving with the parity enabled, the value read in the MSB bit is the received parity bit.

23.7.10 Transmit data register (USART_TDR)

Address offset: 0x28

Reset value: Undefined

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	TDR[8:0]								
							rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 31:9 Reserved, must be kept at reset value.

Bits 8:0 **TDR[8:0]**: Transmit data value

Contains the data character to be transmitted.

The TDR register provides the parallel interface between the internal bus and the output shift register (see [Figure 226](#)).

When transmitting with the parity enabled (PCE bit set to 1 in the USART_CR1 register), the value written in the MSB (bit 7 or bit 8 depending on the data length) has no effect because it is replaced by the parity.

Note: This register must be written only when TXE=1.

23.7.11 USART register map

The table below gives the USART register map and reset values.

Table 93. USART register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	USART_CR1	Res	Res	Res	M1	Res	RTOIE	DEAT4	DEAT3	DEAT2	DEAT1	DEAT0	DEDT4	DEDT3	DEDT2	DEDT1	DEDT0	OVER8	CMIE	MME	M0	WAKE	PCE	PS	PEIE	TXEIE	TCIE	RXNEIE	IDLEIE	TE	RE	Res	UE
	Reset value				0		0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x04	USART_CR2	ADD[7:4]				ADD[3:0]				RTOEN	ABRM0D1	ABRM0D0	ABREN	MSBFIRST	DATAINV	TXINV	RXINV	SWAP	Res	STOP [1:0]		CLKEN	CPOL	CPHA	LBCL	Res	Res	Res	ADDM7	Res	Res	Res	Res
	Reset value	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0		0	0	0	0	0	0			Res	0				
0x08	USART_CR3	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	DEP	DEM	DDRE	OVRDIS	ONEBIT	CTSIE	CTSE	RTSE	DMAT	DMAR	Res	Res	Res	Res	Res	Res
	Reset value																	0	0	0	0	0	0	0	0	0	0			0			
0x0C	USART_BRR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	BRR[15:0]												Res	Res	Res	Res
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Table 93. USART register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0					
0x10	Reserved	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
0x14	USART_RTOR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RTO[23:0]																												
	Reset value									0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0					
0x18	USART_RQR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
	Reset value																																					
0x1C	USART_ISR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RWU	SBKF	CMF	BUSY	ABRF	ABRE	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
	Reset value													0	0	0	0	0	0	0	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
0x20	USART_ICR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CMCF	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.					
	Reset value															0								0														
0x24	USART_RDR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RDR[8:0]													
	Reset value																									X	X	X	X	X	X	X	X	X				
0x28	USART_TDR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	TDR[8:0]													
	Reset value																									X	X	X	X	X	X	X	X	X				

Refer to [Section 2.2 on page 36](#) for the register boundary addresses.

24 Serial peripheral interface (SPI)

24.1 Introduction

The SPI interface can be used to communicate with external devices using the SPI protocol. SPI mode is selectable by software. SPI Motorola mode is selected by default after a device reset.

The serial peripheral interface (SPI) protocol supports half-duplex, full-duplex and simplex synchronous, serial communication with external devices. The interface can be configured as master and in this case it provides the communication clock (SCK) to the external slave device. The interface is also capable of operating in multimaster configuration.

24.2 SPI main features

- Master or slave operation
- Full-duplex synchronous transfers on three lines
- Half-duplex synchronous transfer on two lines (with bidirectional data line)
- Simplex synchronous transfers on two lines (with unidirectional data line)
- 4-bit to 16-bit data size selection
- Multimaster mode capability
- 8 master mode baud rate prescalers up to $f_{PCLK}/2$.
- Slave mode frequency up to $f_{PCLK}/2$.
- NSS management by hardware or software for both master and slave: dynamic change of master/slave operations
- Programmable clock polarity and phase
- Programmable data order with MSB-first or LSB-first shifting
- Dedicated transmission and reception flags with interrupt capability
- SPI bus busy status flag
- SPI Motorola support
- Hardware CRC feature for reliable communication:
 - CRC value can be transmitted as last byte in Tx mode
 - Automatic CRC error checking for last received byte
- Master mode fault, overrun flags with interrupt capability
- CRC Error flag
- Two 32-bit embedded Rx and Tx FIFOs with DMA capability
- SPI TI mode support

24.3 SPI implementation

This manual describes the SPI implementation in STM32F0x0 devices.

Table 94. STM32F0x0 SPI implementation⁽¹⁾

SPI Features	STM32F030x4, STM32F030x6 STM32F070x6	STM32F030x8		STM32F070xB STM32F030xC	
	SPI1	SPI1	SPI2	SPI1	SPI2
Hardware CRC calculation	X	X	X	X	X
Rx/Tx FIFO	X	X	X	X	X
NSS pulse mode	X	X	X	X	X
I2S mode	-	-	-	-	-
TI mode	X	X	X	X	X

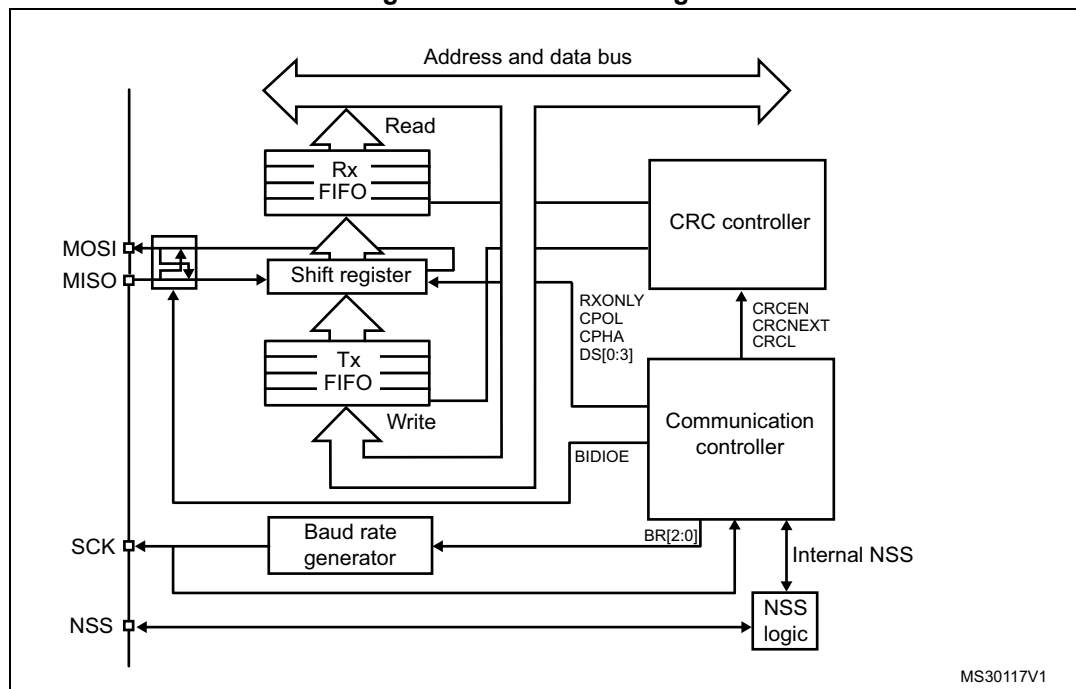
1. X = supported.

24.4 SPI functional description

24.4.1 General description

The SPI allows synchronous, serial communication between the MCU and external devices. Application software can manage the communication by polling the status flag or using dedicated SPI interrupt. The main elements of SPI and their interactions are shown in the following block diagram [Figure 245](#).

Figure 245. SPI block diagram



Four I/O pins are dedicated to SPI communication with external devices.

- **MISO:** Master In / Slave Out data. In the general case, this pin is used to transmit data in slave mode and receive data in master mode.
- **MOSI:** Master Out / Slave In data. In the general case, this pin is used to transmit data in master mode and receive data in slave mode.
- **SCK:** Serial Clock output pin for SPI masters and input pin for SPI slaves.
- **NSS:** Slave select pin. Depending on the SPI and NSS settings, this pin can be used to either:
 - select an individual slave device for communication
 - synchronize the data frame or
 - detect a conflict between multiple masters

See [Section 24.4.5: Slave select \(NSS\) pin management](#) for details.

The SPI bus allows the communication between one master device and one or more slave devices. The bus consists of at least two wires - one for the clock signal and the other for synchronous data transfer. Other signals can be added depending on the data exchange between SPI nodes and their slave select signal management.

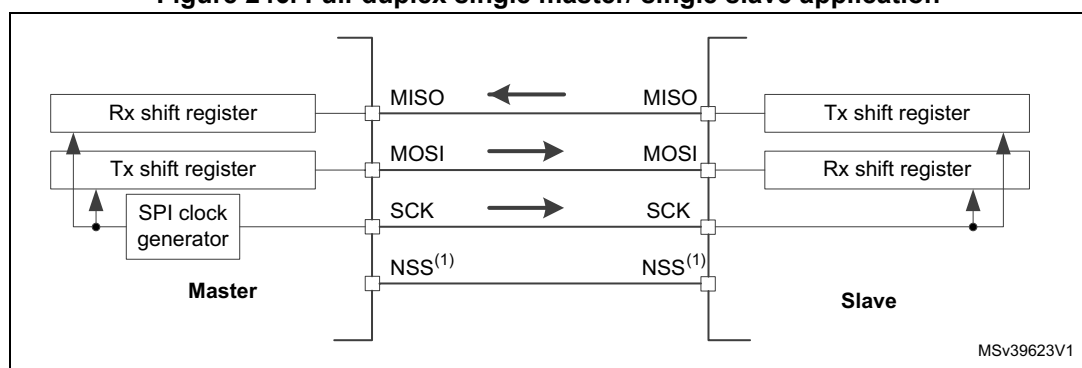
24.4.2 Communications between one master and one slave

The SPI allows the MCU to communicate using different configurations, depending on the device targeted and the application requirements. These configurations use 2 or 3 wires (with software NSS management) or 3 or 4 wires (with hardware NSS management). Communication is always initiated by the master.

Full-duplex communication

By default, the SPI is configured for full-duplex communication. In this configuration, the shift registers of the master and slave are linked using two unidirectional lines between the MOSI and the MISO pins. During SPI communication, data is shifted synchronously on the SCK clock edges provided by the master. The master transmits the data to be sent to the slave via the MOSI line and receives data from the slave via the MISO line. When the data frame transfer is complete (all the bits are shifted) the information between the master and slave is exchanged.

Figure 246. Full-duplex single master/ single slave application

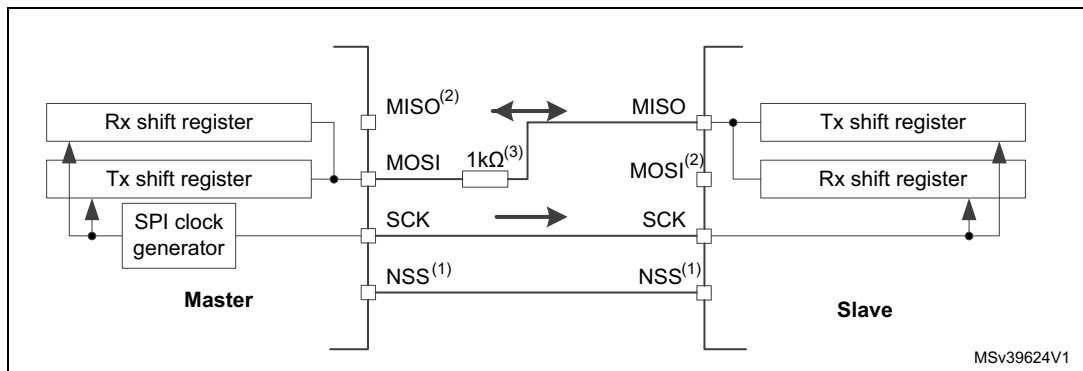


1. The NSS pins can be used to provide a hardware control flow between master and slave. Optionally, the pins can be left unused by the peripheral. Then the flow has to be handled internally for both master and slave. For more details see [Section 24.4.5: Slave select \(NSS\) pin management](#).

Half-duplex communication

The SPI can communicate in half-duplex mode by setting the BIDIMODE bit in the SPIx_CR1 register. In this configuration, one single cross connection line is used to link the shift registers of the master and slave together. During this communication, the data is synchronously shifted between the shift registers on the SCK clock edge in the transfer direction selected reciprocally by both master and slave with the BDIOE bit in their SPIx_CR1 registers. In this configuration, the master's MISO pin and the slave's MOSI pin are free for other application uses and act as GPIOs.

Figure 247. Half-duplex single master/ single slave application



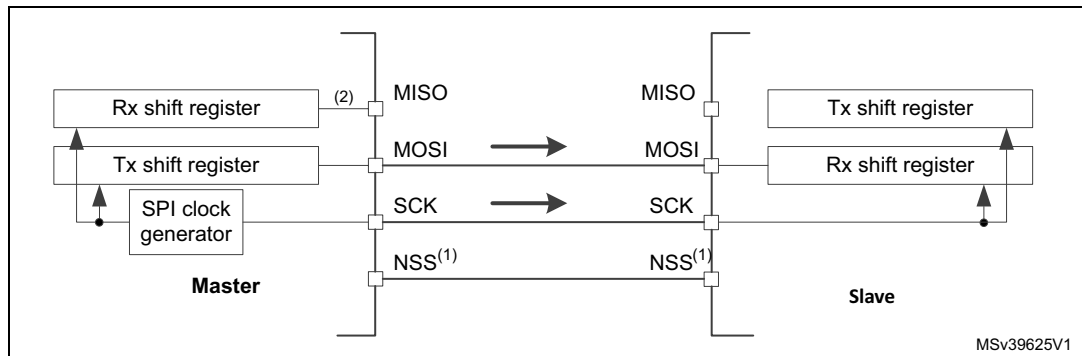
1. The NSS pins can be used to provide a hardware control flow between master and slave. Optionally, the pins can be left unused by the peripheral. Then the flow has to be handled internally for both master and slave. For more details see [Section 24.4.5: Slave select \(NSS\) pin management](#).
2. In this configuration, the master's MISO pin and the slave's MOSI pin can be used as GPIOs.
3. A critical situation can happen when communication direction is changed not synchronously between two nodes working at bidirectional mode and new transmitter accesses the common data line while former transmitter still keeps an opposite value on the line (the value depends on SPI configuration and communication data). Both nodes then fight while providing opposite output levels on the common line temporary till next node changes its direction settings correspondingly, too. It is suggested to insert a serial resistance between MISO and MOSI pins at this mode to protect the outputs and limit the current blowing between them at this situation.

Simplex communications

The SPI can communicate in simplex mode by setting the SPI in transmit-only or in receive-only using the RXONLY bit in the SPIx_CR2 register. In this configuration, only one line is used for the transfer between the shift registers of the master and slave. The remaining MISO and MOSI pins pair is not used for communication and can be used as standard GPIOs.

- **Transmit-only mode (RXONLY=0):** The configuration settings are the same as for full-duplex. The application has to ignore the information captured on the unused input pin. This pin can be used as a standard GPIO.
- **Receive-only mode (RXONLY=1):** The application can disable the SPI output function by setting the RXONLY bit. In slave configuration, the MISO output is disabled and the pin can be used as a GPIO. The slave continues to receive data from the MOSI pin while its slave select signal is active (see [24.4.5: Slave select \(NSS\) pin management](#)). Received data events appear depending on the data buffer configuration. In the master configuration, the MOSI output is disabled and the pin can be used as a GPIO. The clock signal is generated continuously as long as the SPI is enabled. The only way to stop the clock is to clear the RXONLY bit or the SPE bit and wait until the incoming pattern from the MISO pin is finished and fills the data buffer structure, depending on its configuration.

**Figure 248. Simplex single master/single slave application (master in transmit-only/
slave in receive-only mode)**



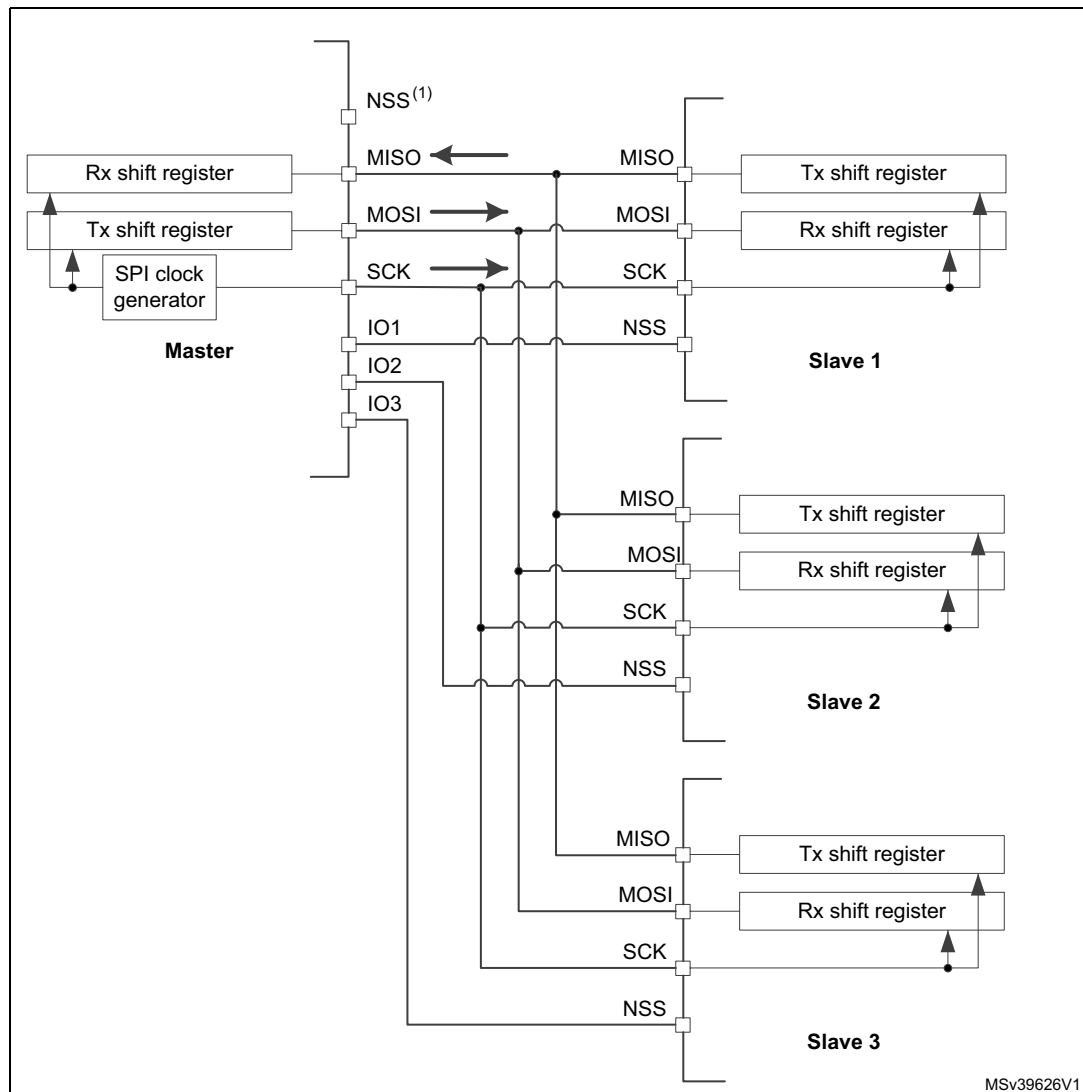
1. The NSS pins can be used to provide a hardware control flow between master and slave. Optionally, the pins can be left unused by the peripheral. Then the flow has to be handled internally for both master and slave. For more details see [Section 24.4.5: Slave select \(NSS\) pin management](#).
2. An accidental input information is captured at the input of transmitter Rx shift register. All the events associated with the transmitter receive flow must be ignored in standard transmit only mode (e.g. OVF flag).
3. In this configuration, both the MISO pins can be used as GPIOs.

Note: *Any simplex communication can be alternatively replaced by a variant of the half-duplex communication with a constant setting of the transaction direction (bidirectional mode is enabled while BDIO bit is not changed).*

24.4.3 Standard multi-slave communication

In a configuration with two or more independent slaves, the master uses GPIO pins to manage the chip select lines for each slave (see [Figure 249](#)). The master must select one of the slaves individually by pulling low the GPIO connected to the slave NSS input. When this is done, a standard master and dedicated slave communication is established.

Figure 249. Master and three independent slaves



1. NSS pin is not used on master side at this configuration. It has to be managed internally (SSM=1, SSI=1) to prevent any MODF error.
2. As MISO pins of the slaves are connected together, all slaves must have the GPIO configuration of their MISO pin set as alternate function open-drain (see [Section 8.3.7: I/O alternate function input/output on page 131](#)).

24.4.4 Multi-master communication

Unless SPI bus is not designed for a multi-master capability primarily, the user can use build in feature which detects a potential conflict between two nodes trying to master the bus at the same time. For this detection, NSS pin is used configured at hardware input mode.

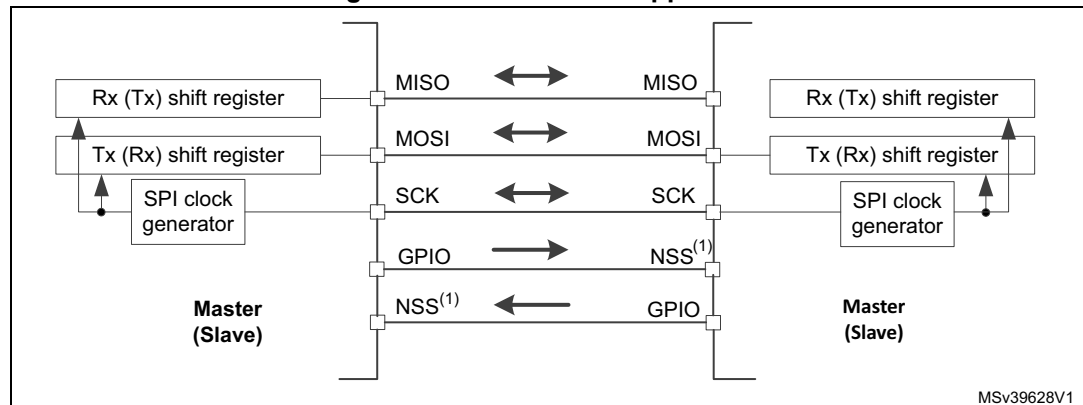
The connection of more than two SPI nodes working at this mode is impossible as only one node can apply its output on a common data line at time.

When nodes are non active, both stay at slave mode by default. Once one node wants to overtake control on the bus, it switches itself into master mode and applies active level on the slave select input of the other node via dedicated GPIO pin. After the session is

completed, the active slave select signal is released and the node mastering the bus temporarily returns back to passive slave mode waiting for next session start.

If potentially both nodes raised their mastering request at the same time a bus conflict event appears (see mode fault MODF event). Then the user can apply some simple arbitration process (e.g. to postpone next attempt by predefined different time-outs applied at both nodes).

Figure 250. Multi-master application



1. The NSS pin is configured at hardware input mode at both nodes. Its active level enables the MISO line output control as the passive node is configured as a slave.

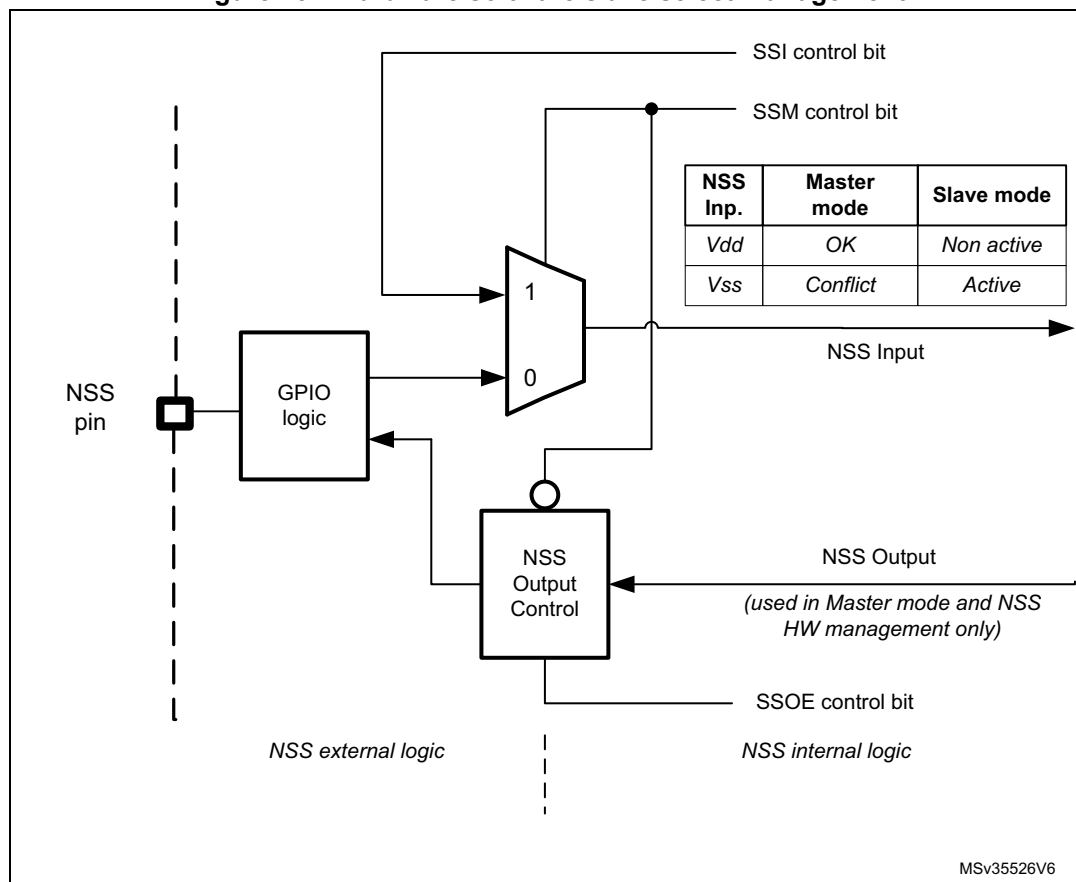
24.4.5 Slave select (NSS) pin management

In slave mode, the NSS works as a standard “chip select” input and lets the slave communicate with the master. In master mode, NSS can be used either as output or input. As an input it can prevent multimaster bus collision, and as an output it can drive a slave select signal of a single slave.

Hardware or software slave select management can be set using the SSM bit in the SPIx_CR1 register:

- **Software NSS management (SSM = 1):** in this configuration, slave select information is driven internally by the SSI bit value in register SPIx_CR1. The external NSS pin is free for other application uses.
- **Hardware NSS management (SSM = 0):** in this case, there are two possible configurations. The configuration used depends on the NSS output configuration (SSOE bit in register SPIx_CR1).
 - **NSS output enable (SSM=0, SSOE = 1):** this configuration is only used when the MCU is set as master. The NSS pin is managed by the hardware. The NSS signal is driven low as soon as the SPI is enabled in master mode (SPE=1), and is kept low until the SPI is disabled (SPE =0). A pulse can be generated between continuous communications if NSS pulse mode is activated (NSSP=1). The SPI cannot work in multimaster configuration with this NSS setting.
 - **NSS output disable (SSM=0, SSOE = 0):** if the microcontroller is acting as the master on the bus, this configuration allows multimaster capability. If the NSS pin is pulled low in this mode, the SPI enters master mode fault state and the device is automatically reconfigured in slave mode. In slave mode, the NSS pin works as a standard “chip select” input and the slave is selected while NSS line is at low level.

Figure 251. Hardware/software slave select management



24.4.6 Communication formats

During SPI communication, receive and transmit operations are performed simultaneously. The serial clock (SCK) synchronizes the shifting and sampling of the information on the data lines. The communication format depends on the clock phase, the clock polarity and the data frame format. To be able to communicate together, the master and slaves devices must follow the same communication format.

Clock phase and polarity controls

Four possible timing relationships may be chosen by software, using the CPOL and CPHA bits in the SPIx_CR1 register. The CPOL (clock polarity) bit controls the idle state value of the clock when no data is being transferred. This bit affects both master and slave modes. If CPOL is reset, the SCK pin has a low-level idle state. If CPOL is set, the SCK pin has a high-level idle state.

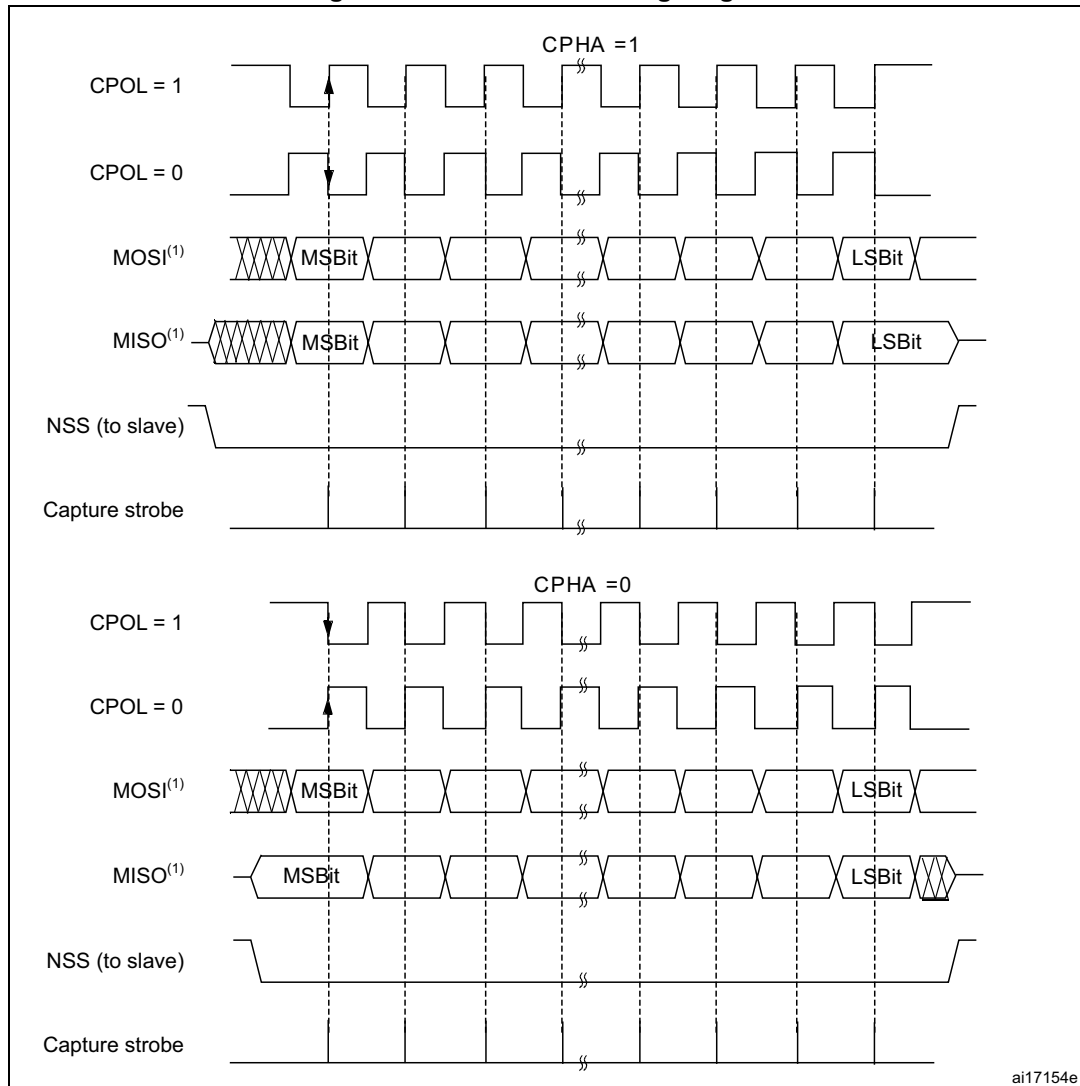
If the CPHA bit is set, the second edge on the SCK pin captures the first data bit transacted (falling edge if the CPOL bit is reset, rising edge if the CPOL bit is set). Data are latched on each occurrence of this clock transition type. If the CPHA bit is reset, the first edge on the SCK pin captures the first data bit transacted (falling edge if the CPOL bit is set, rising edge if the CPOL bit is reset). Data are latched on each occurrence of this clock transition type.

The combination of CPOL (clock polarity) and CPHA (clock phase) bits selects the data capture clock edge.

[Figure 252](#), shows an SPI full-duplex transfer with the four combinations of the CPHA and CPOL bits.

Note: Prior to changing the CPOL/CPHA bits the SPI must be disabled by resetting the SPE bit. The idle state of SCK must correspond to the polarity selected in the SPIx_CR1 register (by pulling up SCK if CPOL=1 or pulling down SCK if CPOL=0).

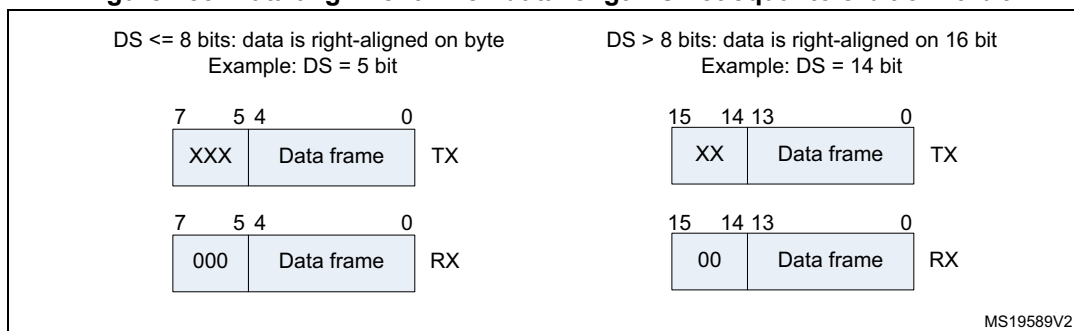
Figure 252. Data clock timing diagram



1. The order of data bits depends on LSBFIRST bit setting.

Data frame format

The SPI shift register can be set up to shift out MSB-first or LSB-first, depending on the value of the LSBFIRST bit. The data frame size is chosen by using the DS bits. It can be set from 4-bit up to 16-bit length and the setting applies for both transmission and reception. Whatever the selected data frame size, read access to the FIFO must be aligned with the FRXTH level. When the SPIx_DR register is accessed, data frames are always right-aligned into either a byte (if the data fits into a byte) or a half-word (see [Figure 253](#)). During communication, only bits within the data frame are clocked and transferred.

Figure 253. Data alignment when data length is not equal to 8-bit or 16-bit

Note: The minimum data length is 4 bits. If a data length of less than 4 bits is selected, it is forced to an 8-bit data frame size.

24.4.7 Configuration of SPI

The configuration procedure is almost the same for master and slave. For specific mode setups, follow the dedicated sections. When a standard communication is to be initialized, perform these steps:

1. Write proper GPIO registers: Configure GPIO for MOSI, MISO and SCK pins.
2. Write to the SPI_CR1 register:
 - a) Configure the serial clock baud rate using the BR[2:0] bits (Note: 4).
 - b) Configure the CPOL and CPHA bits combination to define one of the four relationships between the data transfer and the serial clock (CPHA must be cleared in NSSP mode). (Note: 2 - except the case when CRC is enabled at TI mode).
 - c) Select simplex or half-duplex mode by configuring RXONLY or BIDIMODE and BIDIOE (RXONLY and BIDIMODE can't be set at the same time).
 - d) Configure the LSBFIRST bit to define the frame format (Note: 2).
 - e) Configure the CRCL and CRCEN bits if CRC is needed (while SCK clock signal is at idle state).
 - f) Configure SSM and SSI (Notes: 2 & 3).
 - g) Configure the MSTR bit (in multimaster NSS configuration, avoid conflict state on NSS if master is configured to prevent MODF error).
3. Write to SPI_CR2 register:
 - a) Configure the DS[3:0] bits to select the data length for the transfer.
 - b) Configure SSOE (Notes: 1 & 2 & 3).
 - c) Set the FRF bit if the TI protocol is required (keep NSSP bit cleared in TI mode).
 - d) Set the NSSP bit if the NSS pulse mode between two data units is required (keep CPHA and TI bits cleared in NSSP mode).
 - e) Configure the FRXTH bit. The RXFIFO threshold must be aligned to the read access size for the SPIx_DR register.
 - f) Initialize LDMA_TX and LDMA_RX bits if DMA is used in packed mode.
4. Write to SPI_CRCPR register: Configure the CRC polynomial if needed.
5. Write proper DMA registers: Configure DMA streams dedicated for SPI Tx and Rx in DMA registers if the DMA streams are used.

- Note:
- (1) Step is not required in slave mode.
 - (2) Step is not required in TI mode.
 - (3) Step is not required in NSSP mode.
 - (4) The step is not required in slave mode except slave working at TI mode

For code example refer to the Appendix sections [A.14.1: SPI master configuration code example](#) and [A.14.2: SPI slave configuration code example](#).

24.4.8 Procedure for enabling SPI

It is recommended to enable the SPI slave before the master sends the clock. If not, undesired data transmission might occur. The data register of the slave must already contain data to be sent before starting communication with the master (either on the first edge of the communication clock, or before the end of the ongoing communication if the clock signal is continuous). The SCK signal must be settled at an idle state level corresponding to the selected polarity before the SPI slave is enabled.

The master at full-duplex (or in any transmit-only mode) starts to communicate when the SPI is enabled and TXFIFO is not empty, or with the next write to TXFIFO.

In any master receive only mode (RXONLY=1 or BIDIMODE=1 & BIDIOE=0), master starts to communicate and the clock starts running immediately after SPI is enabled.

For handling DMA, follow the dedicated section.

24.4.9 Data transmission and reception procedures

RXFIFO and TXFIFO

All SPI data transactions pass through the 32-bit embedded FIFOs. This enables the SPI to work in a continuous flow, and prevents overruns when the data frame size is short. Each direction has its own FIFO called TXFIFO and RXFIFO. These FIFOs are used in all SPI modes except for receiver-only mode (slave or master) with CRC calculation enabled (see [Section 24.4.14: CRC calculation](#)).

The handling of FIFOs depends on the data exchange mode (duplex, simplex), data frame format (number of bits in the frame), access size performed on the FIFO data registers (8-bit or 16-bit), and whether or not data packing is used when accessing the FIFOs (see [Section 24.4.13: TI mode](#)).

A read access to the SPIx_DR register returns the oldest value stored in RXFIFO that has not been read yet. A write access to the SPIx_DR stores the written data in the TXFIFO at the end of a send queue. The read access must be always aligned with the RXFIFO threshold configured by the FRXTH bit in SPIx_CR2 register. FTLVL[1:0] and FRLVL[1:0] bits indicate the current occupancy level of both FIFOs.

A read access to the SPIx_DR register must be managed by the RXNE event. This event is triggered when data is stored in RXFIFO and the threshold (defined by FRXTH bit) is reached. When RXNE is cleared, RXFIFO is considered to be empty. In a similar way, write access of a data frame to be transmitted is managed by the TXE event. This event is triggered when the TXFIFO level is less than or equal to half of its capacity. Otherwise TXE is cleared and the TXFIFO is considered as full. In this way, RXFIFO can store up to four data frames, whereas TXFIFO can only store up to three when the data frame format is not greater than 8 bits. This difference prevents possible corruption of 3x 8-bit data frames already stored in the TXFIFO when software tries to write more data in 16-bit mode into

TXFIFO. Both TXE and RXNE events can be polled or handled by interrupts. See [Figure 255](#) through [Figure 258](#).

Another way to manage the data exchange is to use DMA (see [Section 10.2: DMA main features](#)).

If the next data is received when the RXFIFO is full, an overrun event occurs (see description of OVR flag at [Section 24.4.10: SPI status flags](#)). An overrun event can be polled or handled by an interrupt.

The BSY bit being set indicates ongoing transaction of a current data frame. When the clock signal runs continuously, the BSY flag stays set between data frames at master but becomes low for a minimum duration of one SPI clock at slave between each data frame transfer.

Sequence handling

A few data frames can be passed at single sequence to complete a message. When transmission is enabled, a sequence begins and continues while any data is present in the TXFIFO of the master. The clock signal is provided continuously by the master until TXFIFO becomes empty, then it stops waiting for additional data.

In receive-only modes, half-duplex (BIDIMODE=1, BIDIOE=0) or simplex (BIDIMODE=0, RXONLY=1) the master starts the sequence immediately when both SPI is enabled and receive-only mode is activated. The clock signal is provided by the master and it does not stop until either SPI or receive-only mode is disabled by the master. The master receives data frames continuously up to this moment.

While the master can provide all the transactions in continuous mode (SCK signal is continuous) it has to respect slave capability to handle data flow and its content at anytime. When necessary, the master must slow down the communication and provide either a slower clock or separate frames or data sessions with sufficient delays. Be aware there is no underflow error signal for master or slave in SPI mode, and data from the slave is always transacted and processed by the master even if the slave could not prepare it correctly in time. It is preferable for the slave to use DMA, especially when data frames are shorter and bus rate is high.

Each sequence must be encased by the NSS pulse in parallel with the multislave system to select just one of the slaves for communication. In a single slave system it is not necessary to control the slave with NSS, but it is often better to provide the pulse here too, to synchronize the slave with the beginning of each data sequence. NSS can be managed by both software and hardware (see [Section 24.4.5: Slave select \(NSS\) pin management](#)).

When the BSY bit is set it signifies an ongoing data frame transaction. When the dedicated frame transaction is finished, the RXNE flag is raised. The last bit is just sampled and the complete data frame is stored in the RXFIFO.

Procedure for disabling the SPI

When SPI is disabled, it is mandatory to follow the disable procedures described in this paragraph. It is important to do this before the system enters a low-power mode when the peripheral clock is stopped. Ongoing transactions can be corrupted in this case. In some modes the disable procedure is the only way to stop continuous communication running.

Master in full-duplex or transmit only mode can finish any transaction when it stops providing data for transmission. In this case, the clock stops after the last data transaction. Special care must be taken in packing mode when an odd number of data frames are

transacted to prevent some dummy byte exchange (refer to [Data packing](#) section). Before the SPI is disabled in these modes, the user must follow standard disable procedure. When the SPI is disabled at the master transmitter while a frame transaction is ongoing or next data frame is stored in TXFIFO, the SPI behavior is not guaranteed.

When the master is in any receive only mode, the only way to stop the continuous clock is to disable the peripheral by SPE=0. This must occur in specific time window within last data frame transaction just between the sampling time of its first bit and before its last bit transfer starts (in order to receive a complete number of expected data frames and to prevent any additional “dummy” data reading after the last valid data frame). Specific procedure must be followed when disabling SPI in this mode.

Data received but not read remains stored in RXFIFO when the SPI is disabled, and must be processed the next time the SPI is enabled, before starting a new sequence. To prevent having unread data, ensure that RXFIFO is empty when disabling the SPI, by using the correct disabling procedure, or by initializing all the SPI registers with a software reset via the control of a specific register dedicated to peripheral reset (see the SPIiRST bits in the RCC_APB1RSTR registers).

Standard disable procedure is based on pulling BSY status together with FTLVL[1:0] to check if a transmission session is fully completed. This check can be done in specific cases, too, when it is necessary to identify the end of ongoing transactions, for example:

- When NSS signal is managed by software and master has to provide proper end of NSS pulse for slave, or
- When transactions' streams from DMA or FIFO are completed while the last data frame or CRC frame transaction is still ongoing in the peripheral bus.

The correct disable procedure is (except when receive only mode is used):

1. Wait until FTLVL[1:0] = 00 (no more data to transmit).
2. Wait until BSY=0 (the last data frame is processed).
3. Disable the SPI (SPE=0).
4. Read data until FRLVL[1:0] = 00 (read all the received data).

The correct disable procedure for certain receive only modes is:

1. Interrupt the receive flow by disabling SPI (SPE=0) in the specific time window while the last data frame is ongoing.
2. Wait until BSY=0 (the last data frame is processed).
3. Read data until FRLVL[1:0] = 00 (read all the received data).

Note: *If packing mode is used and an odd number of data frames with a format less than or equal to 8 bits (fitting into one byte) has to be received, FRXTH must be set when FRLVL[1:0] = 01, in order to generate the RXNE event to read the last odd data frame and to keep good FIFO pointer alignment.*

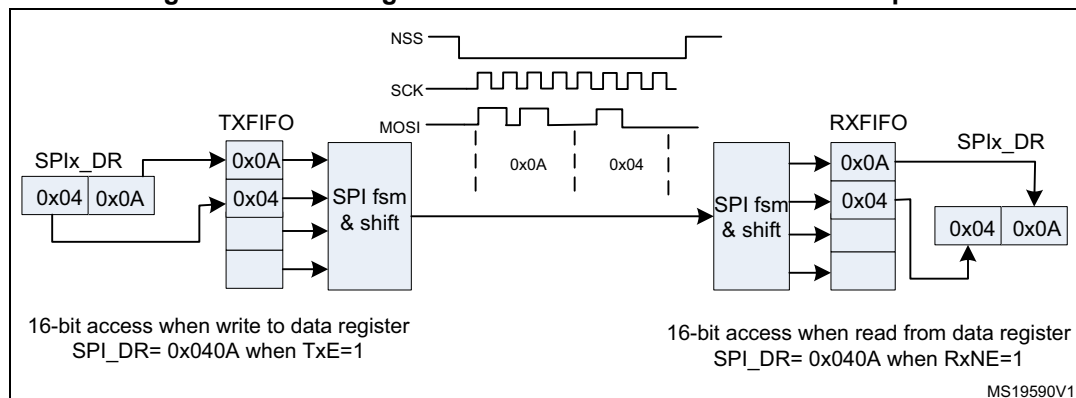
Data packing

When the data frame size fits into one byte (less than or equal to 8 bits), data packing is used automatically when any read or write 16-bit access is performed on the SPIx_DR register. The double data frame pattern is handled in parallel in this case. At first, the SPI operates using the pattern stored in the LSB of the accessed word, then with the other half stored in the MSB. [Figure 254](#) provides an example of data packing mode sequence handling. Two data frames are sent after the single 16-bit access the SPIx_DR register of the transmitter. This sequence can generate just one RXNE event in the receiver if the

RXFIFO threshold is set to 16 bits (FRXTH=0). The receiver then has to access both data frames by a single 16-bit read of SPIx_DR as a response to this single RXNE event. The Rx FIFO threshold setting and the following read access must be always kept aligned at the receiver side, as data can be lost if it is not in line.

A specific problem appears if an odd number of such “fit into one byte” data frames must be handled. On the transmitter side, writing the last data frame of any odd sequence with an 8-bit access to SPIx_DR is enough. The receiver has to change the Rx_FIFO threshold level for the last data frame received in the odd sequence of frames in order to generate the RXNE event.

Figure 254. Packing data in FIFO for transmission and reception



Communication using DMA (direct memory addressing)

To operate at its maximum speed and to facilitate the data register read/write process required to avoid overrun, the SPI features a DMA capability, which implements a simple request/acknowledge protocol.

A DMA access is requested when the TXE or RXNE enable bit in the SPIx_CR2 register is set. Separate requests must be issued to the Tx and Rx buffers.

- In transmission, a DMA request is issued each time TXE is set to 1. The DMA then writes to the SPIx_DR register.
- In reception, a DMA request is issued each time RXNE is set to 1. The DMA then reads the SPIx_DR register.

See [Figure 255](#) through [Figure 258](#).

When the SPI is used only to transmit data, it is possible to enable only the SPI Tx DMA channel. In this case, the OVR flag is set because the data received is not read. When the SPI is used only to receive data, it is possible to enable only the SPI Rx DMA channel.

In transmission mode, when the DMA has written all the data to be transmitted (the TCIF flag is set in the DMA_ISR register), the BSY flag can be monitored to ensure that the SPI communication is complete. This is required to avoid corrupting the last transmission before disabling the SPI or entering the Stop mode. The software must first wait until FTLVL[1:0]=00 and then until BSY=0.

When starting communication using DMA, to prevent DMA channel management raising error events, these steps must be followed in order:

1. Enable DMA Rx buffer in the RXDMAEN bit in the SPI_CR2 register, if DMA Rx is used.
2. Enable DMA streams for Tx and Rx in DMA registers, if the streams are used.
3. Enable DMA Tx buffer in the TXDMAEN bit in the SPI_CR2 register, if DMA Tx is used.
4. Enable the SPI by setting the SPE bit.

For code example refer to the Appendix sections [A.14.5: SPI master configuration with DMA code example](#) and [A.14.6: SPI slave configuration with DMA code example](#).

To close communication it is mandatory to follow these steps in order:

1. Disable DMA streams for Tx and Rx in the DMA registers, if the streams are used.
2. Disable the SPI by following the SPI disable procedure.
3. Disable DMA Tx and Rx buffers by clearing the TXDMAEN and RXDMAEN bits in the SPI_CR2 register, if DMA Tx and/or DMA Rx are used.

Packing with DMA

If the transfers are managed by DMA (TXDMAEN and RXDMAEN set in the SPIx_CR2 register) packing mode is enabled/disabled automatically depending on the PSIZE value configured for SPI TX and the SPI RX DMA channel. If the DMA channel PSIZE value is equal to 16-bit and SPI data size is less than or equal to 8-bit, then packing mode is enabled. The DMA then automatically manages the write operations to the SPIx_DR register.

If data packing mode is used and the number of data to transfer is not a multiple of two, the LDMA_TX/LDMA_RX bits must be set. The SPI then considers only one data for the transmission or reception to serve the last DMA transfer (for more details refer to [Data packing on page 654](#).)

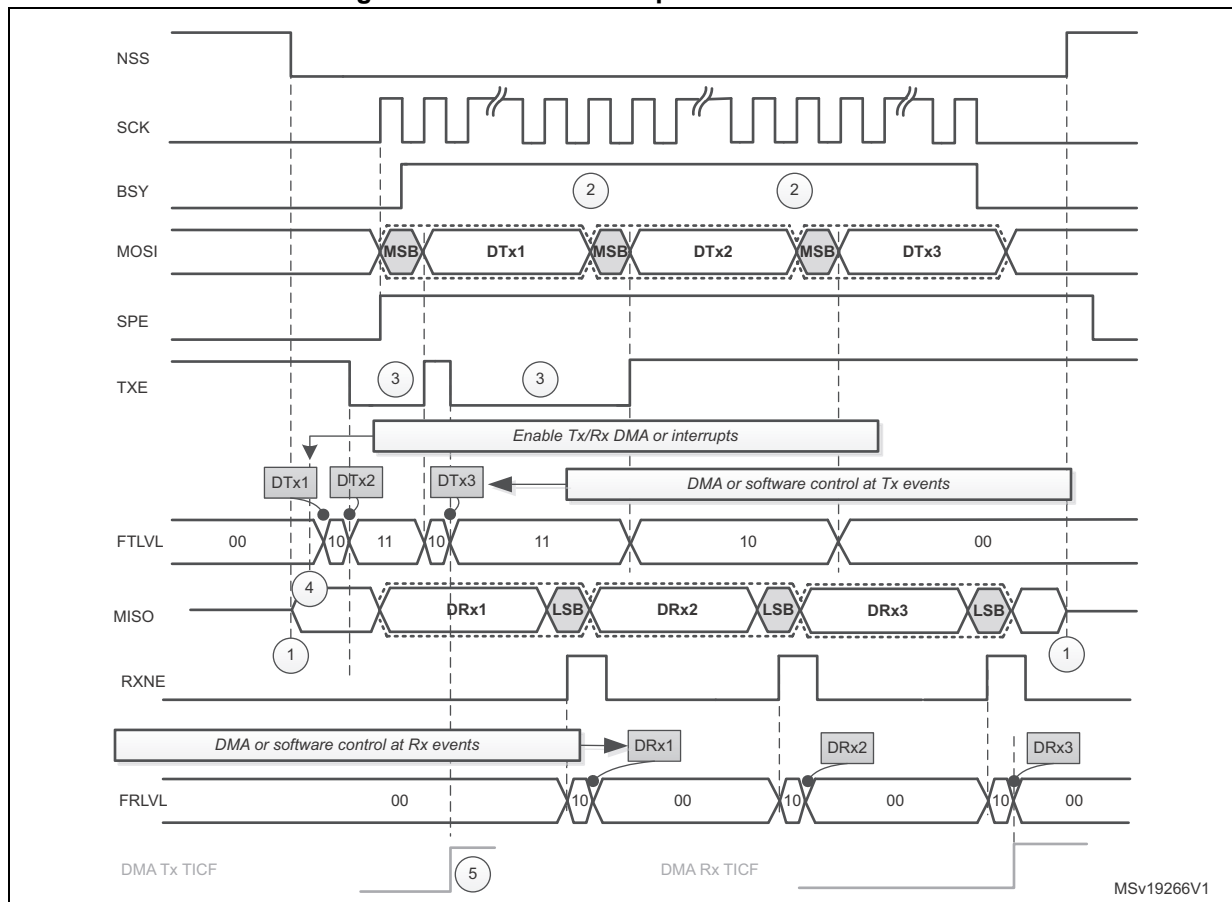
Communication diagrams

Some typical timing schemes are explained in this section. These schemes are valid no matter if the SPI events are handled by polling, interrupts or DMA. For simplicity, the LSBFIRST=0, CPOL=0 and CPHA=1 setting is used as a common assumption here. No complete configuration of DMA streams is provided.

The following numbered notes are common for [Figure 255 on page 658](#) through [Figure 258 on page 661](#).

1. The slave starts to control MISO line as NSS is active and SPI is enabled, and is disconnected from the line when one of them is released. Sufficient time must be provided for the slave to prepare data dedicated to the master in advance before its transaction starts.
At the master, the SPI peripheral takes control at MOSI and SCK signals (occasionally at NSS signal as well) only if SPI is enabled. If SPI is disabled the SPI peripheral is disconnected from GPIO logic, so the levels at these lines depends on GPIO setting exclusively.
2. At the master, BSY stays active between frames if the communication (clock signal) is continuous. At the slave, BSY signal always goes down for at least one clock cycle between data frames.
3. The TXE signal is cleared only if TXFIFO is full.
4. The DMA arbitration process starts just after the TXDMAEN bit is set. The TXE interrupt is generated just after the TXEIE is set. As the TXE signal is at an active level, data transfers to TxFIFO start, until TxFIFO becomes full or the DMA transfer completes.
5. If all the data to be sent can fit into TxFIFO, the DMA Tx TCIF flag can be raised even before communication on the SPI bus starts. This flag always rises before the SPI transaction is completed.
6. The CRC value for a package is calculated continuously frame by frame in the SPIx_TxCRCR and SPIx_RxCRCR registers. The CRC information is processed after the entire data package has completed, either automatically by DMA (Tx channel must be set to the number of data frames to be processed) or by SW (the user must handle CRCNEXT bit during the last data frame processing).
While the CRC value calculated in SPIx_TxCRCR is simply sent out by transmitter, received CRC information is loaded into RxFIFO and then compared with the SPIx_RxCRCR register content (CRC error flag can be raised here if any difference). This is why the user must take care to flush this information from the FIFO, either by software reading out all the stored content of RxFIFO, or by DMA when the proper number of data frames is preset for Rx channel (number of data frames + number of CRC frames) (see the settings at the example assumption).
7. In data packed mode, TxE and RxNE events are paired and each read/write access to the FIFO is 16 bits wide until the number of data frames are even. If the TxFIFO is $\frac{3}{4}$ full FTLVL status stays at FIFO full level. That is why the last odd data frame cannot be stored before the TxFIFO becomes $\frac{1}{2}$ full. This frame is stored into TxFIFO with an 8-bit access either by software or automatically by DMA when LDMA_TX control is set.
8. To receive the last odd data frame in packed mode, the Rx threshold must be changed to 8-bit when the last data frame is processed, either by software setting FRXTH=1 or automatically by a DMA internal signal when LDMA_RX is set.

Figure 255. Master full-duplex communication



Assumptions for master full-duplex communication example:

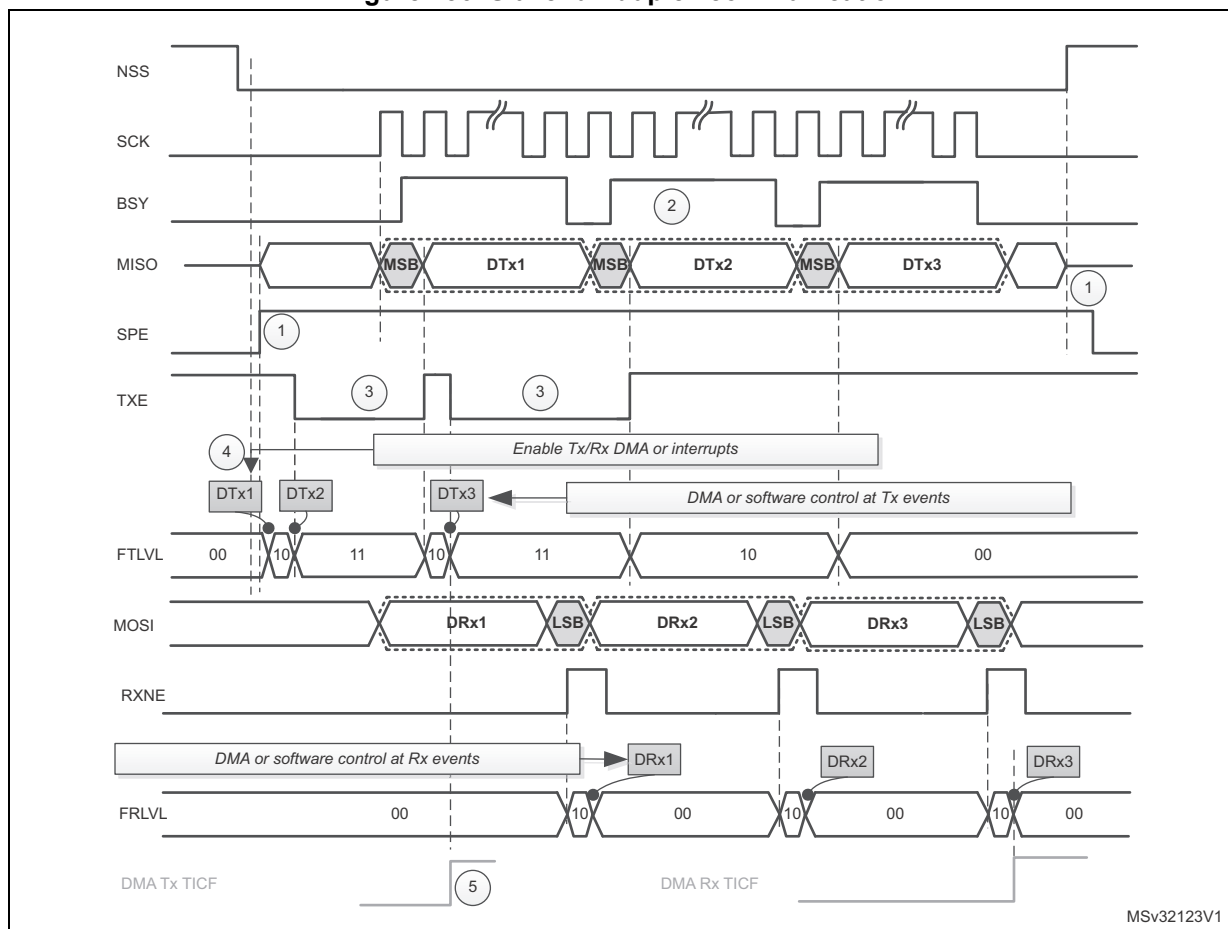
- Data size > 8 bit

If DMA is used:

- Number of Tx frames transacted by DMA is set to 3
- Number of Rx frames transacted by DMA is set to 3

See also : [Communication diagrams on page 657](#) for details about common assumptions and notes.

Figure 256. Slave full-duplex communication



Assumptions for slave full-duplex communication example:

- Data size > 8 bit

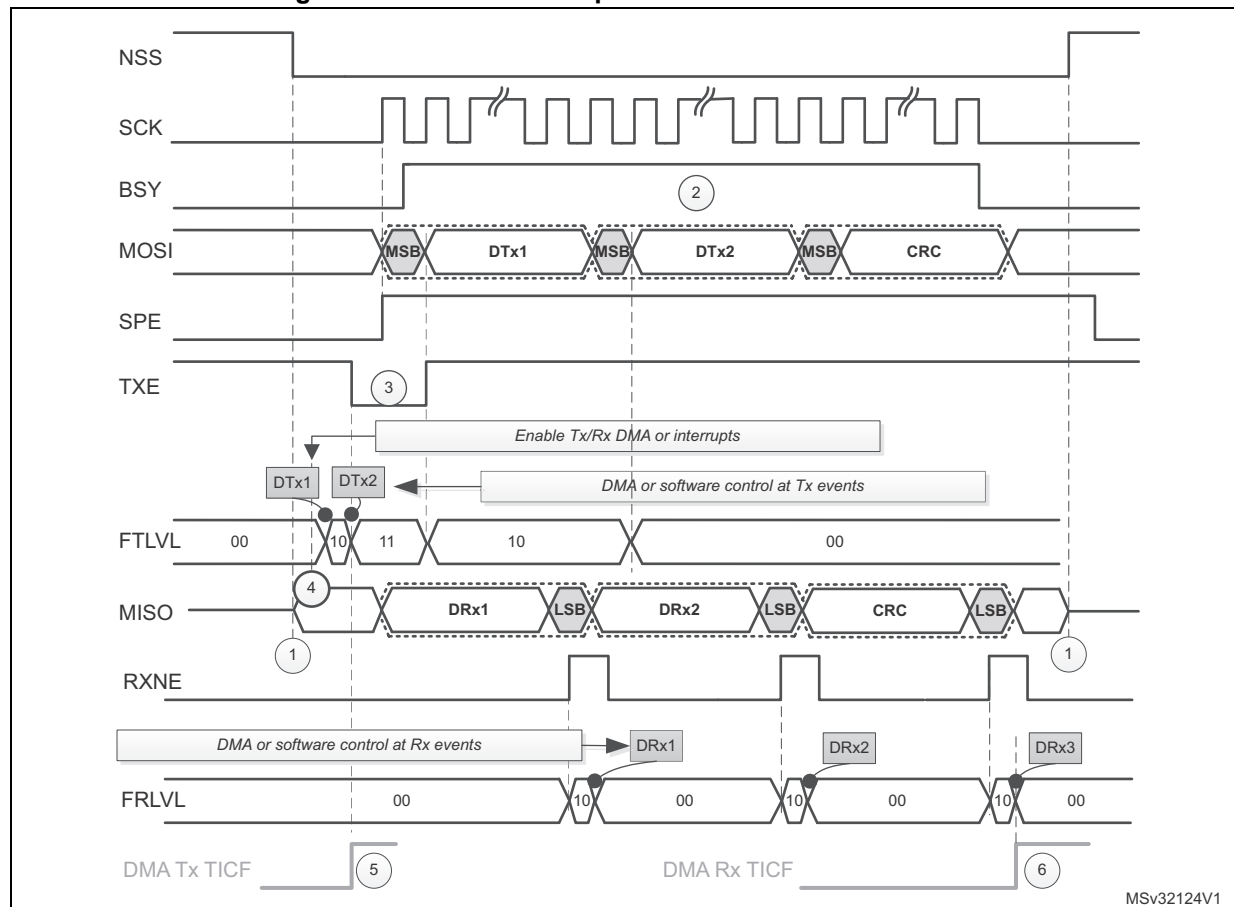
If DMA is used:

- Number of Tx frames transacted by DMA is set to 3
- Number of Rx frames transacted by DMA is set to 3

See also : [Communication diagrams on page 657](#) for details about common assumptions and notes.

For code example refer to the Appendix section [A.14.3: SPI full duplex communication code example](#).

Figure 257. Master full-duplex communication with CRC



Assumptions for master full-duplex communication with CRC example:

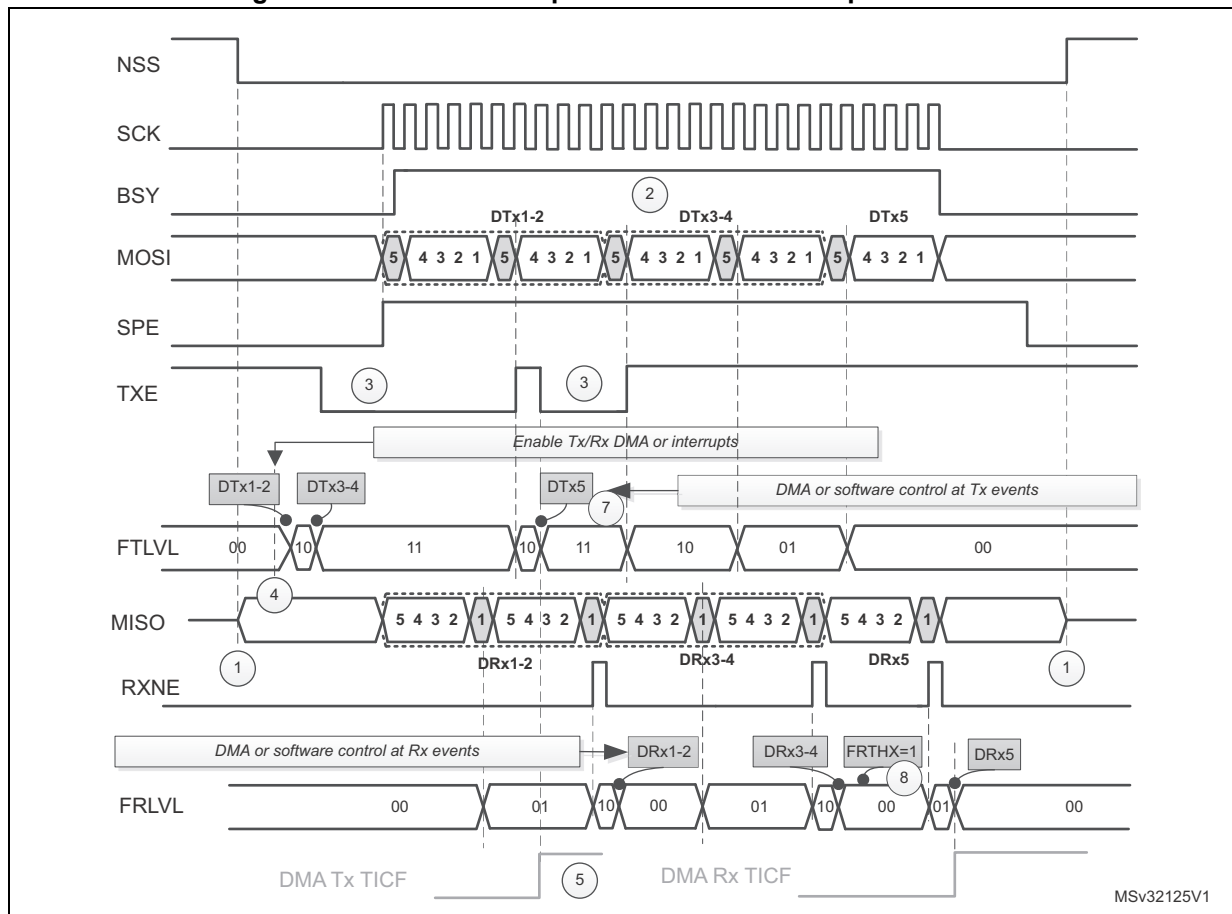
- Data size = 16 bit
- CRC enabled

If DMA is used:

- Number of Tx frames transacted by DMA is set to 2
- Number of Rx frames transacted by DMA is set to 3

See also : [Communication diagrams on page 657](#) for details about common assumptions and notes.

Figure 258. Master full-duplex communication in packed mode



Assumptions for master full-duplex communication in packed mode example:

- Data size = 5 bit
- Read/write FIFO is performed mostly by 16-bit access
- FRXTH=0

If DMA is used:

- Number of Tx frames to be transacted by DMA is set to 3
- Number of Rx frames to be transacted by DMA is set to 3
- PSIZE for both Tx and Rx DMA channel is set to 16-bit
- LDMA_TX=1 and LDMA_RX=1

See also : [Communication diagrams on page 657](#) for details about common assumptions and notes.

24.4.10 SPI status flags

Three status flags are provided for the application to completely monitor the state of the SPI bus.

Tx buffer empty flag (TXE)

The TXE flag is set when transmission TXFIFO has enough space to store data to send. TXE flag is linked to the TXFIFO level. The flag goes high and stays high until the TXFIFO level is lower or equal to 1/2 of the FIFO depth. An interrupt can be generated if the TXEIE bit in the SPIx_CR2 register is set. The bit is cleared automatically when the TXFIFO level becomes greater than 1/2.

Rx buffer not empty (RXNE)

The RXNE flag is set depending on the FRXTH bit value in the SPIx_CR2 register:

- If FRXTH is set, RXNE goes high and stays high until the RXFIFO level is greater or equal to 1/4 (8-bit).
- If FRXTH is cleared, RXNE goes high and stays high until the RXFIFO level is greater than or equal to 1/2 (16-bit).

An interrupt can be generated if the RXNEIE bit in the SPIx_CR2 register is set.

The RXNE is cleared by hardware automatically when the above conditions are no longer true.

Busy flag (BSY)

The BSY flag is set and cleared by hardware (writing to this flag has no effect).

When BSY is set, it indicates that a data transfer is in progress on the SPI (the SPI bus is busy).

The BSY flag can be used in certain modes to detect the end of a transfer so that the software can disable the SPI or its peripheral clock before entering a low-power mode which does not provide a clock for the peripheral. This avoids corrupting the last transfer.

The BSY flag is also useful for preventing write collisions in a multimaster system.

The BSY flag is cleared under any one of the following conditions:

- When the SPI is correctly disabled
- When a fault is detected in Master mode (MODF bit set to 1)
- In Master mode, when it finishes a data transmission and no new data is ready to be sent
- In Slave mode, when the BSY flag is set to '0' for at least one SPI clock cycle between each data transfer.

Note: When the next transmission can be handled immediately by the master (e.g. if the master is in Receive-only mode or its Transmit FIFO is not empty), communication is continuous and the BSY flag remains set to '1' between transfers on the master side. Although this is not the case with a slave, it is recommended to use always the TXE and RXNE flags (instead of the BSY flags) to handle data transmission or reception operations.

24.4.11 SPI error flags

An SPI interrupt is generated if one of the following error flags is set and interrupt is enabled by setting the ERRIE bit.

Overrun flag (OVR)

An overrun condition occurs when data is received by a master or slave and the RXFIFO has not enough space to store this received data. This can happen if the software or the DMA did not have enough time to read the previously received data (stored in the RXFIFO) or when space for data storage is limited e.g. the RXFIFO is not available when CRC is enabled in receive only mode so in this case the reception buffer is limited into a single data frame buffer (see [Section 24.4.14: CRC calculation](#)).

When an overrun condition occurs, the newly received value does not overwrite the previous one in the RXFIFO. The newly received value is discarded and all data transmitted subsequently is lost. Clearing the OVR bit is done by a read access to the SPI_DR register followed by a read access to the SPI_SR register.

Mode fault (MODF)

Mode fault occurs when the master device has its internal NSS signal (NSS pin in NSS hardware mode, or SSI bit in NSS software mode) pulled low. This automatically sets the MODF bit. Master mode fault affects the SPI interface in the following ways:

- The MODF bit is set and an SPI interrupt is generated if the ERRIE bit is set.
- The SPE bit is cleared. This blocks all output from the device and disables the SPI interface.
- The MSTR bit is cleared, thus forcing the device into slave mode.

Use the following software sequence to clear the MODF bit:

1. Make a read or write access to the SPIx_SR register while the MODF bit is set.
2. Then write to the SPIx_CR1 register.

To avoid any multiple slave conflicts in a system comprising several MCUs, the NSS pin must be pulled high during the MODF bit clearing sequence. The SPE and MSTR bits can be restored to their original state after this clearing sequence. As a security, hardware does not allow the SPE and MSTR bits to be set while the MODF bit is set. In a slave device the MODF bit cannot be set except as the result of a previous multimaster conflict.

CRC error (CRCERR)

This flag is used to verify the validity of the value received when the CRCEN bit in the SPIx_CR1 register is set. The CRCERR flag in the SPIx_SR register is set if the value received in the shift register does not match the receiver SPIx_RXCRCR value. The flag is cleared by the software.

TI mode frame format error (FRE)

A TI mode frame format error is detected when an NSS pulse occurs during an ongoing communication when the SPI is operating in slave mode and configured to conform to the TI mode protocol. When this error occurs, the FRE flag is set in the SPIx_SR register. The SPI is not disabled when an error occurs, the NSS pulse is ignored, and the SPI waits for the next NSS pulse before starting a new transfer. The data may be corrupted since the error detection may result in the loss of two data bytes.

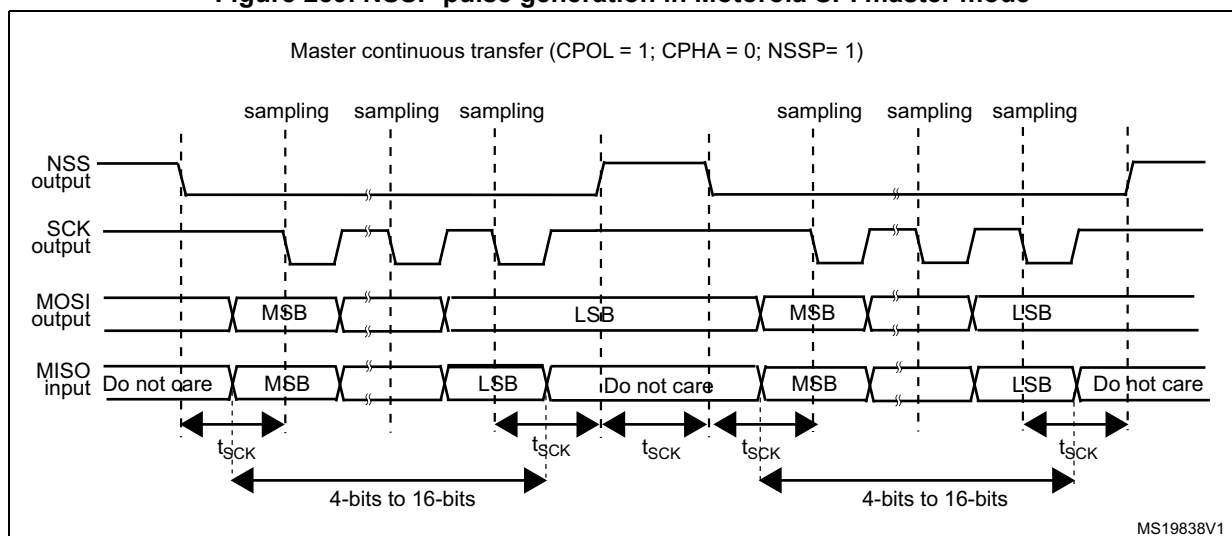
The FRE flag is cleared when SPIx_SR register is read. If the ERRIE bit is set, an interrupt is generated on the NSS error detection. In this case, the SPI should be disabled because data consistency is no longer guaranteed and communications should be reinitiated by the master when the slave SPI is enabled again.

24.4.12 NSS pulse mode

This mode is activated by the NSSP bit in the SPIx_CR2 register and it takes effect only if the SPI interface is configured as Motorola SPI master (FRF=0) with capture on the first edge (SPIx_CR1 CPHA = 0, CPOL setting is ignored). When activated, an NSS pulse is generated between two consecutive data frame transfers when NSS stays at high level for the duration of one clock period at least. This mode allows the slave to latch data. NSSP pulse mode is designed for applications with a single master-slave pair.

[Figure 259](#) illustrates NSS pin management when NSSP pulse mode is enabled.

Figure 259. NSSP pulse generation in Motorola SPI master mode



Note: Similar behavior is encountered when CPOL = 0. In this case the sampling edge is the *rising* edge of SCK, and NSS assertion and deassertion refer to this sampling edge.

24.4.13 TI mode

TI protocol in master mode

The SPI interface is compatible with the TI protocol. The FRF bit of the SPIx_CR2 register can be used to configure the SPI to be compliant with this protocol.

The clock polarity and phase are forced to conform to the TI protocol requirements whatever the values set in the SPIx_CR1 register. NSS management is also specific to the TI protocol which makes the configuration of NSS management through the SPIx_CR1 and SPIx_CR2 registers (SSM, SSI, SSOE) impossible in this case.

In slave mode, the SPI baud rate prescaler is used to control the moment when the MISO pin state changes to HiZ when the current transaction finishes (see [Figure 260](#)). Any baud rate can be used, making it possible to determine this moment with optimal flexibility. However, the baud rate is generally set to the external master clock baud rate. The delay for the MISO signal to become HiZ ($t_{release}$) depends on internal resynchronization and on the

baud rate value set in through the BR[2:0] bits in the SPIx_CR1 register. It is given by the formula:

$$\frac{t_{\text{baud\_rate}}}{2} + 4 \times t_{\text{pclk}} < t_{\text{release}} < \frac{t_{\text{baud\_rate}}}{2} + 6 \times t_{\text{pclk}}$$

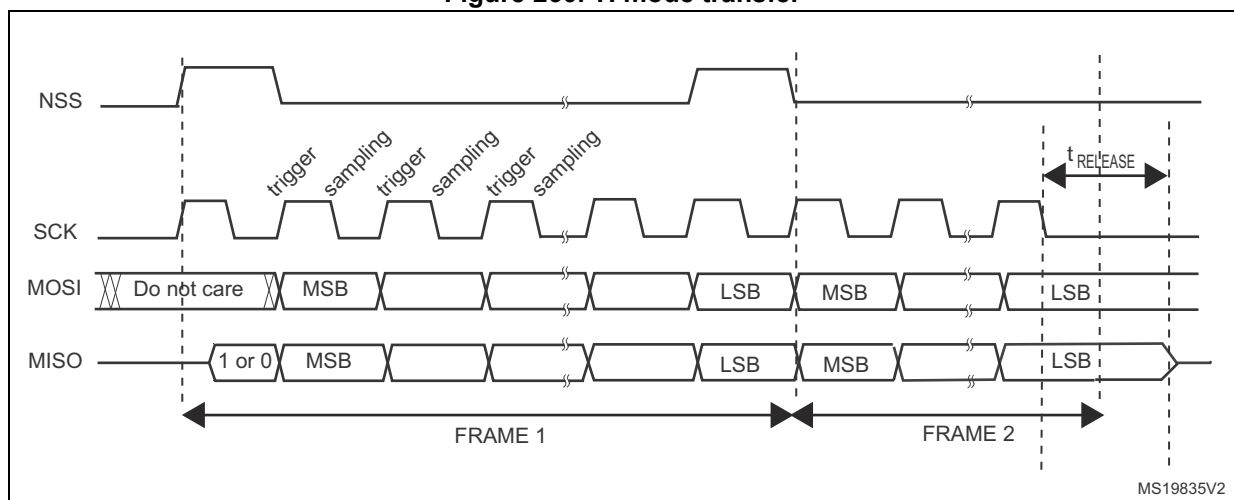
If the slave detects a misplaced NSS pulse during a data frame transaction the TIFRE flag is set.

If the data size is equal to 4-bits or 5-bits, the master in full-duplex mode or transmit-only mode uses a protocol with one more dummy data bit added after LSB. TI NSS pulse is generated above this dummy bit clock cycle instead of the LSB in each period.

This feature is not available for Motorola SPI communications (FRF bit set to 0).

Figure 260: TI mode transfer shows the SPI communication waveforms when TI mode is selected.

Figure 260. TI mode transfer



24.4.14 CRC calculation

Two separate CRC calculators are implemented in order to check the reliability of transmitted and received data. The SPI offers CRC8 or CRC16 calculation independently of the frame data length, which can be fixed to 8-bit or 16-bit. For all the other data frame lengths, no CRC is available.

CRC principle

CRC calculation is enabled by setting the CRCEN bit in the SPIx_CR1 register before the SPI is enabled (SPE = 1). The CRC value is calculated using an odd programmable polynomial on each bit. The calculation is processed on the sampling clock edge defined by the CPHA and CPOL bits in the SPIx_CR1 register. The calculated CRC value is checked automatically at the end of the data block as well as for transfer managed by CPU or by the DMA. When a mismatch is detected between the CRC calculated internally on the received data and the CRC sent by the transmitter, a CRCERR flag is set to indicate a data corruption error. The right procedure for handling the CRC calculation depends on the SPI configuration and the chosen transfer management.

Note: The polynomial value should only be odd. No even values are supported.

CRC transfer managed by CPU

Communication starts and continues normally until the last data frame has to be sent or received in the SPIx_DR register. Then CRCNEXT bit has to be set in the SPIx_CR1 register to indicate that the CRC frame transaction will follow after the transaction of the currently processed data frame. The CRCNEXT bit must be set before the end of the last data frame transaction. CRC calculation is frozen during CRC transaction.

The received CRC is stored in the RXFIFO like a data byte or word. That is why in CRC mode only, the reception buffer has to be considered as a single 16-bit buffer used to receive only one data frame at a time.

A CRC-format transaction usually takes one more data frame to communicate at the end of data sequence. However, when setting an 8-bit data frame checked by 16-bit CRC, two more frames are necessary to send the complete CRC.

When the last CRC data is received, an automatic check is performed comparing the received value and the value in the SPIx_RXCRC register. Software has to check the CRCERR flag in the SPIx_SR register to determine if the data transfers were corrupted or not. Software clears the CRCERR flag by writing '0' to it.

After the CRC reception, the CRC value is stored in the RXFIFO and must be read in the SPIx_DR register in order to clear the RXNE flag.

CRC transfer managed by DMA

When SPI communication is enabled with CRC communication and DMA mode, the transmission and reception of the CRC at the end of communication is automatic (with the exception of reading CRC data in receive only mode). The CRCNEXT bit does not have to be handled by the software. The counter for the SPI transmission DMA channel has to be set to the number of data frames to transmit excluding the CRC frame. On the receiver side, the received CRC value is handled automatically by DMA at the end of the transaction but user must take care to flush out received CRC information from RXFIFO as it is always loaded into it. In full-duplex mode, the counter of the reception DMA channel can be set to the number of data frames to receive including the CRC, which means, for example, in the specific case of an 8-bit data frame checked by 16-bit CRC:

$$\text{DMA\_RX} = \text{Numb\_of\_data} + 2$$

In receive only mode, the DMA reception channel counter should contain only the amount of data transferred, excluding the CRC calculation. Then based on the complete transfer from DMA, all the CRC values must be read back by software from FIFO as it works as a single buffer in this mode.

At the end of the data and CRC transfers, the CRCERR flag in the SPIx_SR register is set if corruption occurred during the transfer.

If packing mode is used, the LDMA_RX bit needs managing if the number of data is odd.

Resetting the SPIx_TXCRC and SPIx_RXCRC values

The SPIx_TXCRC and SPIx_RXCRC values are cleared automatically when new data is sampled after a CRC phase. This allows the use of DMA circular mode (not available in receive-only mode) in order to transfer data without any interruption, (several data blocks covered by intermediate CRC checking phases).

If the SPI is disabled during a communication the following sequence must be followed:

1. Disable the SPI
2. Clear the CRCEN bit
3. Enable the CRCEN bit
4. Enable the SPI

Note:

When the SPI is in slave mode, the CRC calculator is sensitive to the SCK slave input clock as soon as the CRCEN bit is set, and this is the case whatever the value of the SPE bit. In order to avoid any wrong CRC calculation, the software must enable CRC calculation only when the clock is stable (in steady state).

When the SPI interface is configured as a slave, the NSS internal signal needs to be kept low during transaction of the CRC phase once the CRCNEXT signal is released. That is why the CRC calculation can't be used at NSS Pulse mode when NSS hardware mode should be applied at slave normally (see more details at the product errata sheet).

At TI mode, despite the fact that clock phase and clock polarity setting is fixed and independent on SPIx_CR1 register, the corresponding setting CPOL=0 CPHA=1 has to be kept at the SPIx_CR1 register anyway if CRC is applied. In addition, the CRC calculation has to be reset between sessions by SPI disable sequence with re-enable the CRCEN bit described above at both master and slave side, else CRC calculation can be corrupted at this specific mode.

24.5 SPI interrupts

During SPI communication an interrupts can be generated by the following events:

- Transmit TXFIFO ready to be loaded
- Data received in Receive RXFIFO
- Master mode fault
- Overrun error
- TI frame format error
- CRC protocol error

Interrupts can be enabled and disabled separately.

Table 95. SPI interrupt requests

Interrupt event	Event flag	Enable Control bit
Transmit TXFIFO ready to be loaded	TXE	TXEIE
Data received in RXFIFO	RXNE	RXNEIE
Master Mode fault event	MODF	ERRIE
Overrun error	OVR	
TI frame format error	FRE	
CRC protocol error	CRCERR	

For code example refer to the Appendix section [A.14.4: SPI interrupt code example](#).

24.6 SPI registers

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit). SPI_DR in addition by can be accessed by 8-bit access.

24.6.1 SPI control register 1 (SPIx_CR1)

Address offset: 0x00

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BIDI MODE	BIDI OE	CRC EN	CRC NEXT	CRCL	RX ONLY	SSM	SSI	LSB FIRST	SPE	BR [2:0]			MSTR	CPOL	CPHA
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 15 **BIDIMODE**: Bidirectional data mode enable. This bit enables half-duplex communication using common single bidirectional data line. Keep RXONLY bit clear when bidirectional mode is active.

0: 2-line unidirectional data mode selected

1: 1-line bidirectional data mode selected

Bit 14 **BIDIOE**: Output enable in bidirectional mode

This bit combined with the BIDIMODE bit selects the direction of transfer in bidirectional mode

0: Output disabled (receive-only mode)

1: Output enabled (transmit-only mode)

Note: In master mode, the MOSI pin is used and in slave mode, the MISO pin is used.

Bit 13 **CRCE**: Hardware CRC calculation enable

0: CRC calculation disabled

1: CRC calculation Enabled

Note: This bit should be written only when SPI is disabled (SPE = '0') for correct operation.

Bit 12 **CRCNEXT**: Transmit CRC next

0: Next transmit value is from Tx buffer

1: Next transmit value is from Tx CRC register

Note: This bit has to be written as soon as the last data is written in the SPIx_DR register.

Bit 11 **CRCL**: CRC length

This bit is set and cleared by software to select the CRC length.

0: 8-bit CRC length

1: 16-bit CRC length

Note: This bit should be written only when SPI is disabled (SPE = '0') for correct operation.

Bit 10 **RXONLY**: Receive only mode enabled.

This bit enables simplex communication using a single unidirectional line to receive data exclusively. Keep BIDIMODE bit clear when receive only mode is active. This bit is also useful in a multislave system in which this particular slave is not accessed, the output from the accessed slave is not corrupted.

- 0: Full-duplex (Transmit and receive)
- 1: Output disabled (Receive-only mode)

Bit 9 **SSM**: Software slave management

When the SSM bit is set, the NSS pin input is replaced with the value from the SSI bit.

- 0: Software slave management disabled
- 1: Software slave management enabled

Note: This bit is not used in SPI TI mode.

Bit 8 **SSI**: Internal slave select

This bit has an effect only when the SSM bit is set. The value of this bit is forced onto the NSS pin and the I/O value of the NSS pin is ignored.

Note: This bit is not used in SPI TI mode.

Bit 7 **LSBFIRST**: Frame format

- 0: data is transmitted / received with the MSB first
- 1: data is transmitted / received with the LSB first

- Note: 1. This bit should not be changed when communication is ongoing.*
- 2. This bit is not used in SPI TI mode.*

Bit 6 **SPE**: SPI enable

- 0: Peripheral disabled
- 1: Peripheral enabled

Note: When disabling the SPI, follow the procedure described in [Procedure for disabling the SPI on page 653](#).

Bits 5:3 **BR[2:0]**: Baud rate control

- 000: $f_{PCLK}/2$
- 001: $f_{PCLK}/4$
- 010: $f_{PCLK}/8$
- 011: $f_{PCLK}/16$
- 100: $f_{PCLK}/32$
- 101: $f_{PCLK}/64$
- 110: $f_{PCLK}/128$
- 111: $f_{PCLK}/256$

Note: These bits should not be changed when communication is ongoing.

Bit 2 **MSTR**: Master selection

- 0: Slave configuration
- 1: Master configuration

Note: This bit should not be changed when communication is ongoing.

Bit1 **CPOL**: Clock polarity

- 0: CK to 0 when idle
- 1: CK to 1 when idle

Note: This bit should not be changed when communication is ongoing.

This bit is not used in SPI TI mode except the case when CRC is applied at TI mode.

Bit 0 **CPHA**: Clock phase

- 0: The first clock transition is the first data capture edge
- 1: The second clock transition is the first data capture edge

Note: This bit should not be changed when communication is ongoing.

This bit is not used in SPI TI mode except the case when CRC is applied at TI mode.

24.6.2 SPI control register 2 (SPIx_CR2)

Address offset: 0x04

Reset value: 0x0700

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	LDMA_TX	LDMA_RX	FRXTH	DS [3:0]				TXEIE	RXNEIE	ERRIE	FRF	NSSP	SSOE	TXDMAEN	RXDMAEN
	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 15 Reserved, must be kept at reset value.

Bit 14 **LDMA_TX**: Last DMA transfer for transmission

This bit is used in data packing mode, to define if the total number of data to transmit by DMA is odd or even. It has significance only if the TXDMAEN bit in the SPIx_CR2 register is set and if packing mode is used (data length ≤ 8-bit and write access to SPIx_DR is 16-bit wide). It has to be written when the SPI is disabled (SPE = 0 in the SPIx_CR1 register).

- 0: Number of data to transfer is even
- 1: Number of data to transfer is odd

Note: Refer to [Procedure for disabling the SPI on page 653](#) if the CRCEN bit is set.

Bit 13 **LDMA_RX**: Last DMA transfer for reception

This bit is used in data packing mode, to define if the total number of data to receive by DMA is odd or even. It has significance only if the RXDMAEN bit in the SPIx_CR2 register is set and if packing mode is used (data length ≤ 8-bit and write access to SPIx_DR is 16-bit wide). It has to be written when the SPI is disabled (SPE = 0 in the SPIx_CR1 register).

- 0: Number of data to transfer is even
- 1: Number of data to transfer is odd

Note: Refer to [Procedure for disabling the SPI on page 653](#) if the CRCEN bit is set.

Bit 12 **FRXTH**: FIFO reception threshold

This bit is used to set the threshold of the RXFIFO that triggers an RXNE event

- 0: RXNE event is generated if the FIFO level is greater than or equal to 1/2 (16-bit)
- 1: RXNE event is generated if the FIFO level is greater than or equal to 1/4 (8-bit)

Bits 11:8 **DS [3:0]**: Data size

These bits configure the data length for SPI transfers:

0000: Not used
0001: Not used
0010: Not used
0011: 4-bit
0100: 5-bit
0101: 6-bit
0110: 7-bit
0111: 8-bit
1000: 9-bit
1001: 10-bit
1010: 11-bit
1011: 12-bit
1100: 13-bit
1101: 14-bit
1110: 15-bit
1111: 16-bit

If software attempts to write one of the “Not used” values, they are forced to the value “0111”(8-bit).

Bit 7 **TXEIE**: Tx buffer empty interrupt enable

0: TXE interrupt masked
1: TXE interrupt not masked. Used to generate an interrupt request when the TXE flag is set.

Bit 6 **RXNEIE**: RX buffer not empty interrupt enable

0: RXNE interrupt masked
1: RXNE interrupt not masked. Used to generate an interrupt request when the RXNE flag is set.

Bit 5 **ERRIE**: Error interrupt enable

This bit controls the generation of an interrupt when an error condition occurs (CRCERR, OVR, MODF in SPI mode, FRE at TI mode).

0: Error interrupt is masked
1: Error interrupt is enabled

Bit 4 **FRF**: Frame format

0: SPI Motorola mode
1 SPI TI mode

Note: This bit must be written only when the SPI is disabled (SPE=0).

Bit 3 **NSSP**: NSS pulse management

This bit is used in master mode only. it allow the SPI to generate an NSS pulse between two consecutive data when doing continuous transfers. In the case of a single data transfer, it forces the NSS pin high level after the transfer.

It has no meaning if CPHA = '1', or FRF = '1'.

0: No NSS pulse
1: NSS pulse generated

Note: 1. This bit must be written only when the SPI is disabled (SPE=0).

2. This bit is not used in SPI TI mode.

Bit 2 **SSOE**: SS output enable

0: SS output is disabled in master mode and the SPI interface can work in multimaster configuration

1: SS output is enabled in master mode and when the SPI interface is enabled. The SPI interface cannot work in a multimaster environment.

Note: This bit is not used in SPI TI mode.

Bit 1 **TXDMAEN**: Tx buffer DMA enable

When this bit is set, a DMA request is generated whenever the TXE flag is set.

0: Tx buffer DMA disabled

1: Tx buffer DMA enabled

Bit 0 **RXDMAEN**: Rx buffer DMA enable

When this bit is set, a DMA request is generated whenever the RXNE flag is set.

0: Rx buffer DMA disabled

1: Rx buffer DMA enabled

24.6.3 SPI status register (SPIx_SR)

Address offset: 0x08

Reset value: 0x0002

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	FTLVL[1:0]		FRLVL[2:0]		FRE	BSY	OVR	MODF	CRC ERR	Res.	Res.	TXE	RXNE
			r	r	r	r	r	r	r	r	rc_w0			r	r

Bits 15:13 Reserved, must be kept at reset value.

Bits 12:11 **FTLVL[1:0]**: FIFO Transmission Level

These bits are set and cleared by hardware.

00: FIFO empty

01: 1/4 FIFO

10: 1/2 FIFO

11: FIFO full (considered as FULL when the FIFO threshold is greater than 1/2)

Bits 10:9 **FRLVL[1:0]**: FIFO reception level

These bits are set and cleared by hardware.

00: FIFO empty

01: 1/4 FIFO

10: 1/2 FIFO

11: FIFO full

Note: These bits are not used in SPI receive-only mode while CRC calculation is enabled.

Bit 8 **FRE**: Frame format error

This flag is used for SPI in TI slave mode. Refer to [Section 24.4.11: SPI error flags](#).

This flag is set by hardware and reset when SPIx_SR is read by software.

0: No frame format error

1: A frame format error occurred

Bit 7 **BSY**: Busy flag

0: SPI not busy

1: SPI is busy in communication or Tx buffer is not empty

This flag is set and cleared by hardware.

Note: The BSY flag must be used with caution: refer to [Section 24.4.10: SPI status flags and Procedure for disabling the SPI on page 653](#).

Bit 6 **OVR**: Overrun flag

0: No overrun occurred

1: Overrun occurred

This flag is set by hardware and reset by a software sequence.

Bit 5 **MODF**: Mode fault

0: No mode fault occurred

1: Mode fault occurred

This flag is set by hardware and reset by a software sequence. Refer to [Section : Mode fault \(MODF\) on page 663](#) for the software sequence.

Bit 4 **CRCERR**: CRC error flag

0: CRC value received matches the SPIx_RXCR value

1: CRC value received does not match the SPIx_RXCR value

This flag is set by hardware and cleared by software writing 0.

Bits 3:2 Reserved, must be kept at reset value.

Bit 1 **TXE**: Transmit buffer empty

0: Tx buffer not empty
1: Tx buffer empty

Bit 0 **RXNE**: Receive buffer not empty

0: Rx buffer empty
1: Rx buffer not empty

24.6.4 SPI data register (SPIx_DR)

Address offset: 0x0C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DR[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **DR[15:0]**: Data register

Data received or to be transmitted

The data register serves as an interface between the Rx and Tx FIFOs. When the data register is read, RxFIFO is accessed while the write to data register accesses TxFIFO (See [Section 24.4.9: Data transmission and reception procedures](#)).

Note: Data is always right-aligned. Unused bits are ignored when writing to the register, and read as zero when the register is read. The Rx threshold setting must always correspond with the read access currently used.

24.6.5 SPI CRC polynomial register (SPIx_CRCPR)

Address offset: 0x10

Reset value: 0x0007

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CRCPOLY[15:0]															
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:0 **CRCPOLY[15:0]**: CRC polynomial register

This register contains the polynomial for the CRC calculation.

The CRC polynomial (0007h) is the reset value of this register. Another polynomial can be configured as required.

Note: The polynomial value should be odd only. No even value is supported.

24.6.6 SPI Rx CRC register (SPIx_RXCRCR)

Address offset: 0x14

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RxCRC[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 15:0 **RxCRC[15:0]**: Rx CRC register

When CRC calculation is enabled, the RxCRC[15:0] bits contain the computed CRC value of the subsequently received bytes. This register is reset when the CRCEN bit in SPIx_CR1 register is written to 1. The CRC is calculated serially using the polynomial programmed in the SPIx_CRCPR register.

Only the 8 LSB bits are considered when the CRC frame format is set to be 8-bit length (CRCL bit in the SPIx_CR1 is cleared). CRC calculation is done based on any CRC8 standard.

The entire 16-bits of this register are considered when a 16-bit CRC frame format is selected (CRCL bit in the SPIx_CR1 register is set). CRC calculation is done based on any CRC16 standard.

A read to this register when the BSY Flag is set could return an incorrect value.

24.6.7 SPI Tx CRC register (SPIx_TXCRCR)

Address offset: 0x18

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
TxCRC[15:0]															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 15:0 **TxCRC[15:0]**: Tx CRC register

When CRC calculation is enabled, the TxCRC[7:0] bits contain the computed CRC value of the subsequently transmitted bytes. This register is reset when the CRCEN bit of SPIx_CR1 is written to 1. The CRC is calculated serially using the polynomial programmed in the SPIx_CRCPR register.

Only the 8 LSB bits are considered when the CRC frame format is set to be 8-bit length (CRCL bit in the SPIx_CR1 is cleared). CRC calculation is done based on any CRC8 standard.

The entire 16-bits of this register are considered when a 16-bit CRC frame format is selected (CRCL bit in the SPIx_CR1 register is set). CRC calculation is done based on any CRC16 standard.

A read to this register when the BSY flag is set could return an incorrect value.

24.6.8 SPI register map

Table 96 shows the SPI register map and reset values.

Table 96. SPI register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x00	SPIx_CR1	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	BIDIMODE	BIDIOE	CRCEN	CRCNEXT	CRCL	RXONLY	SSM	SSI	LSBFIRST	SPE	BR [2:0]			MSTR	CPOL	CPHA
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
0x04	SPIx_CR2	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	LDMA_TX	LDMA_RX	FRXTH	DS[3:0]			TXEIE	RXNEIE	ERRIE	FRF	NSSP	SSOE	TXDMAEN	RXDMAEN	
	Reset value																		0	0	0	0	1	1	1	0	0	0	0	0	0	0	0
0x08	SPIx_SR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	FTLVL[1:0]	FRLVL[1:0]			FRE	BSY	OVR	MODF	CRCERR	Res	Res	TXE	RXNE	
	Reset value																			0	0	0	0	0	0	0	0	0	0	0	1	0	
0x0C	SPIx_DR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	DR[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x10	SPIx_CRCPR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	CRCPOLY[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1
0x14	SPIx_RXCRCR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	RxCRC[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	
0x18	SPIx_TXCRCR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	TxCRC[15:0]															
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

25 Universal serial bus full-speed device interface (USB)

This section applies to STM32F070x6 and STM32F070xB devices only.

25.1 Introduction

The USB peripheral implements an interface between a full-speed USB 2.0 bus and the APB bus.

USB suspend/resume are supported which allows to stop the device clocks for low-power consumption.

25.2 USB main features

- USB specification version 2.0 full-speed compliant
- Configurable number of endpoints from 1 to 8
- 1024 bytes of dedicated packet buffer memory SRAM
- Cyclic redundancy check (CRC) generation/checking, Non-return-to-zero Inverted (NRZI) encoding/decoding and bit-stuffing
- Isochronous transfers support
- Double-buffered bulk/isochronous endpoint support
- USB Suspend/Resume operations
- Frame locked clock pulse generation
- USB 2.0 Link Power Management support
- Battery Charging Specification Revision 1.2 support
- USB connect / disconnect capability (controllable embedded pull-up resistor on USB_DP line)

25.3 USB implementation

[Table 97](#) describes the USB implementation in the devices.

Table 97. STM32F0x0 USB implementation

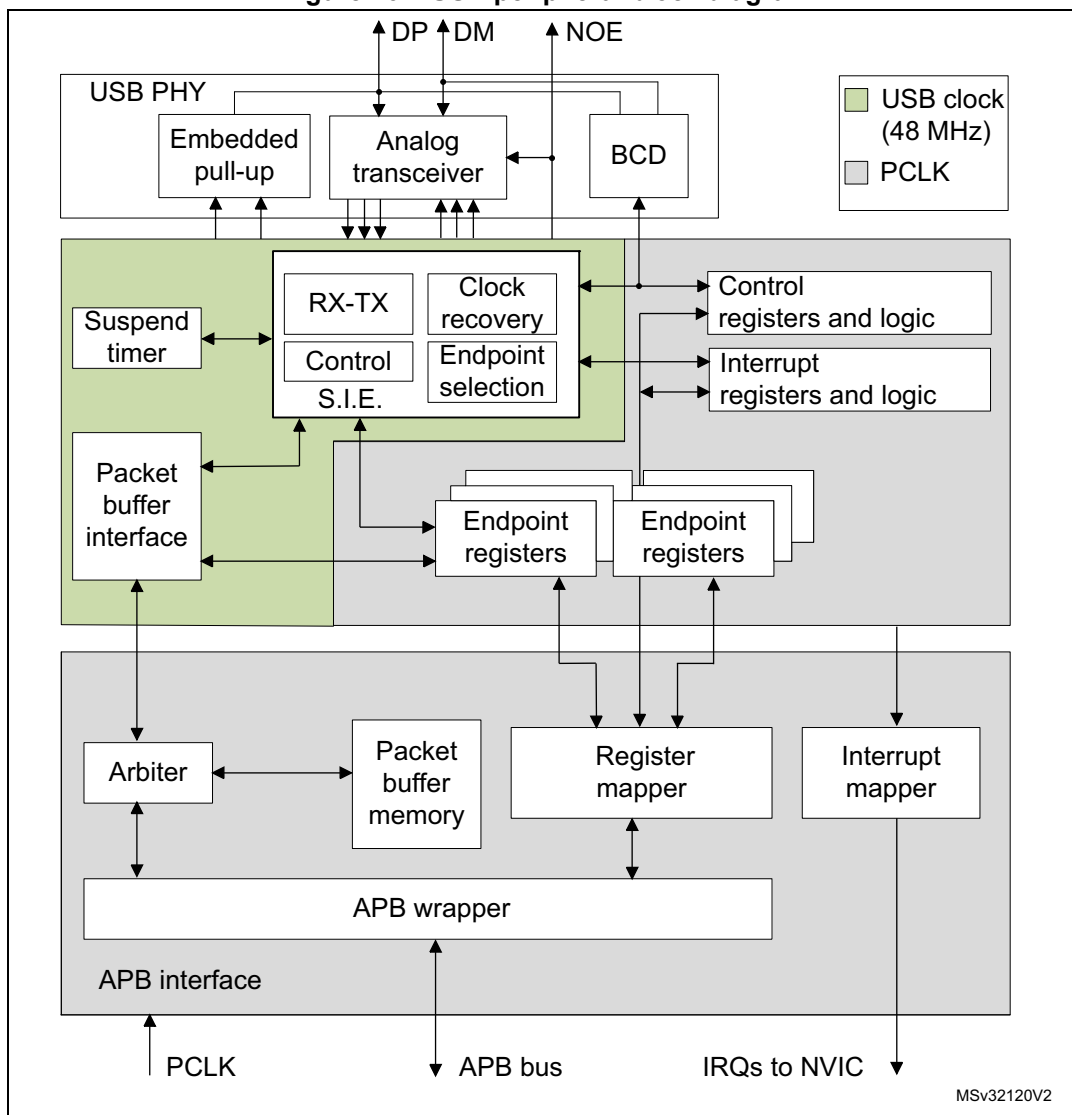
USB features ⁽¹⁾	STM32F070x6, STM32F070xB
	USB
Number of endpoints	8
Size of dedicated packet buffer memory SRAM	1024 bytes
Dedicated packet buffer memory SRAM access scheme	2 x 16 bits / word
USB 2.0 Link Power Management (LPM) support	X
Battery Charging Detection (BCD) support	X
Embedded pull-up resistor on USB_DP line	X

1. $X = \text{supported}$

25.4 USB functional description

Figure 261 shows the block diagram of the USB peripheral.

Figure 261. USB peripheral block diagram



The USB peripheral provides an USB-compliant connection between the host PC and the function implemented by the microcontroller. Data transfer between the host PC and the system memory occurs through a dedicated packet buffer memory accessed directly by the USB peripheral. This dedicated memory size is 1024 bytes, and up to 16 mono-directional or 8 bidirectional endpoints can be used. The USB peripheral interfaces with the USB host, detecting token packets, handling data transmission/reception, and processing handshake packets as required by the USB standard. Transaction formatting is performed by the hardware, including CRC generation and checking.

Each endpoint is associated with a buffer description block indicating where the endpoint-related memory area is located, how large it is or how many bytes must be transmitted. When a token for a valid function/endpoint pair is recognized by the USB peripheral, the related data transfer (if required and if the endpoint is configured) takes place. The data buffered by the USB peripheral is loaded in an internal 16-bit register and memory access to the dedicated buffer is performed. When all the data has been transferred, if needed, the proper handshake packet over the USB is generated or expected according to the direction of the transfer.

At the end of the transaction, an endpoint-specific interrupt is generated, reading status registers and/or using different interrupt response routines. The microcontroller can determine:

- which endpoint has to be served,
- which type of transaction took place, if errors occurred (bit stuffing, format, CRC, protocol, missing ACK, over/underrun, etc.).

Special support is offered to isochronous transfers and high throughput bulk transfers, implementing a double buffer usage, which allows to always have an available buffer for the USB peripheral while the microcontroller uses the other one.

The unit can be placed in low-power mode (SUSPEND mode), by writing in the control register, whenever required. At this time, all static power dissipation is avoided, and the USB clock can be slowed down or stopped. The detection of activity at the USB inputs, while in low-power mode, wakes the device up asynchronously. A special interrupt source can be connected directly to a wakeup line to allow the system to immediately restart the normal clock generation and/or support direct clock start/stop.

25.4.1 Description of USB blocks

The USB peripheral implements all the features related to USB interfacing, which include the following blocks:

- **USB Physical Interface (USB PHY):** This block is maintaining the electrical interface to an external USB host. It contains the differential analog transceiver itself, controllable embedded pull-up resistor (connected to USB_DP line) and support for Battery Charging Detection (BCD), multiplexed on same USB_DP and USB_DM lines. The output enable control signal of the analog transceiver (active low) is provided externally on USB_NOE. It can be used to drive some activity LED or to provide information about the actual communication direction to some other circuitry.
- **Serial Interface Engine (SIE):** The functions of this block include: synchronization pattern recognition, bit-stuffing, CRC generation and checking, PID verification/generation, and handshake evaluation. It must interface with the USB transceivers and uses the virtual buffers provided by the packet buffer interface for local data storage. This unit also generates signals according to USB peripheral events, such as Start of Frame (SOF), USB_Reset, Data errors etc. and to Endpoint related events like end of transmission or correct reception of a packet; these signals are then used to generate interrupts.
- **Timer:** This block generates a start-of-frame locked clock pulse and detects a global suspend (from the host) when no traffic has been received for 3 ms.
- **Packet Buffer Interface:** This block manages the local memory implementing a set of buffers in a flexible way, both for transmission and reception. It can choose the proper buffer according to requests coming from the SIE and locate them in the memory addresses pointed by the Endpoint registers. It increments the address after each

exchanged byte until the end of packet, keeping track of the number of exchanged bytes and preventing the buffer to overrun the maximum capacity.

- **Endpoint-Related Registers:** Each endpoint has an associated register containing the endpoint type and its current status. For mono-directional/single-buffer endpoints, a single register can be used to implement two distinct endpoints. The number of registers is 8, allowing up to 16 mono-directional/single-buffer or up to 7 double-buffer endpoints in any combination. For example the USB peripheral can be programmed to have 4 double buffer endpoints and 8 single-buffer/mono-directional endpoints.
- **Control Registers:** These are the registers containing information about the status of the whole USB peripheral and used to force some USB events, such as resume and power-down.
- **Interrupt Registers:** These contain the Interrupt masks and a record of the events. They can be used to inquire an interrupt reason, the interrupt status or to clear the status of a pending interrupt.

Note: * Endpoint 0 is always used for control transfer in single-buffer mode.

The USB peripheral is connected to the APB bus through an APB interface, containing the following blocks:

- **Packet Memory:** This is the local memory that physically contains the Packet Buffers. It can be used by the Packet Buffer interface, which creates the data structure and can be accessed directly by the application software. The size of the Packet Memory is 1024 bytes, structured as 512 half-words by 16 bits.
- **Arbiter:** This block accepts memory requests coming from the APB bus and from the USB interface. It resolves the conflicts by giving priority to APB accesses, while always reserving half of the memory bandwidth to complete all USB transfers. This time-duplex scheme implements a virtual dual-port SRAM that allows memory access, while an USB transaction is happening. Multiword APB transfers of any length are also allowed by this scheme.
- **Register Mapper:** This block collects the various byte-wide and bit-wide registers of the USB peripheral in a structured 16-bit wide half-word set addressed by the APB.
- **APB Wrapper:** This provides an interface to the APB for the memory and register. It also maps the whole USB peripheral in the APB address space.
- **Interrupt Mapper:** This block is used to select how the possible USB events can generate interrupts and map them to the NVIC.

25.5 Programming considerations

In the following sections, the expected interactions between the USB peripheral and the application program are described, in order to ease application software development.

25.5.1 Generic USB device programming

This part describes the main tasks required of the application software in order to obtain USB compliant behavior. The actions related to the most general USB events are taken into account and paragraphs are dedicated to the special cases of double-buffered endpoints and Isochronous transfers. Apart from system reset, action is always initiated by the USB peripheral, driven by one of the USB events described below.

25.5.2 System and power-on reset

Upon system and power-on reset, the first operation the application software should perform is to provide all required clock signals to the USB peripheral and subsequently de-assert its reset signal so to be able to access its registers. The whole initialization sequence is hereafter described.

As a first step application software needs to activate register macrocell clock and de-assert macrocell specific reset signal using related control bits provided by device clock management logic.

After that, the analog part of the device related to the USB transceiver must be switched on using the PDWN bit in CNTR register, which requires a special handling. This bit is intended to switch on the internal voltage references that supply the port transceiver. This circuit has a defined startup time (t_{STARTUP} specified in the datasheet) during which the behavior of the USB transceiver is not defined. It is thus necessary to wait this time, after setting the PDWN bit in the CNTR register, before removing the reset condition on the USB part (by clearing the FRES bit in the CNTR register). Clearing the ISTR register then removes any spurious pending interrupt before any other macrocell operation is enabled.

At system reset, the microcontroller must initialize all required registers and the packet buffer description table, to make the USB peripheral able to properly generate interrupts and data transfers. All registers not specific to any endpoint must be initialized according to the needs of application software (choice of enabled interrupts, chosen address of packet buffers, etc.). Then the process continues as for the USB reset case (see further paragraph).

USB reset (RESET interrupt)

When this event occurs, the USB peripheral is put in the same conditions it is left by the system reset after the initialization described in the previous paragraph: communication is disabled in all endpoint registers (the USB peripheral will not respond to any packet). As a response to the USB reset event, the USB function must be enabled, having as USB address 0, implementing only the default control endpoint (endpoint address is 0 too). This is accomplished by setting the Enable Function (EF) bit of the USB_DADDR register and initializing the EP0R register and its related packet buffers accordingly. During USB enumeration process, the host assigns a unique address to this device, which must be written in the ADD[6:0] bits of the USB_DADDR register, and configures any other necessary endpoint.

When a RESET interrupt is received, the application software is responsible to enable again the default endpoint of USB function 0 within 10 ms from the end of reset sequence which triggered the interrupt.

Structure and usage of packet buffers

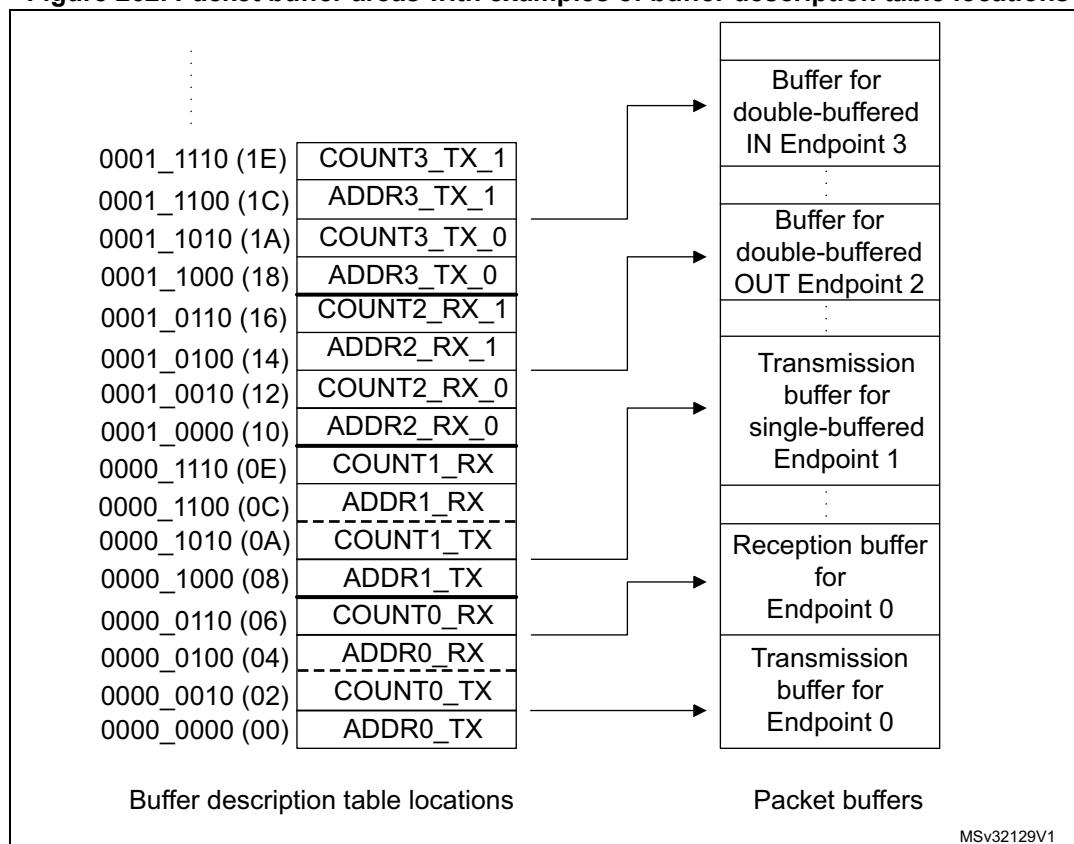
Each bidirectional endpoint may receive or transmit data from/to the host. The received data is stored in a dedicated memory buffer reserved for that endpoint, while another memory buffer contains the data to be transmitted by the endpoint. Access to this memory is performed by the packet buffer interface block, which delivers a memory access request and waits for its acknowledgment. Since the packet buffer memory has to be accessed by the microcontroller also, an arbitration logic takes care of the access conflicts, using half APB cycle for microcontroller access and the remaining half for the USB peripheral access. In this way, both the agents can operate as if the packet memory is a dual-port SRAM, without being aware of any conflict even when the microcontroller is performing back-to-

back accesses. The USB peripheral logic uses a dedicated clock. The frequency of this dedicated clock is fixed by the requirements of the USB standard at 48 MHz, and this can be different from the clock used for the interface to the APB bus. Different clock configurations are possible where the APB clock frequency can be higher or lower than the USB peripheral one.

Note: Due to USB data rate and packet memory interface requirements, the APB clock must have a minimum frequency of 10 MHz to avoid data overrun/underrun problems.

Each endpoint is associated with two packet buffers (usually one for transmission and the other one for reception). Buffers can be placed anywhere inside the packet memory because their location and size is specified in a buffer description table, which is also located in the packet memory at the address indicated by the USB_BTABLER register. Each table entry is associated to an endpoint register and it is composed of four 16-bit half-words so that table start address must always be aligned to an 8-byte boundary (the lowest three bits of USB_BTABLER register are always “000”). Buffer descriptor table entries are described in the [Section 25.6.2: Buffer descriptor table](#). If an endpoint is unidirectional and it is neither an Isochronous nor a double-buffered bulk, only one packet buffer is required (the one related to the supported transfer direction). Other table locations related to unsupported transfer directions or unused endpoints, are available to the user. Isochronous and double-buffered bulk endpoints have special handling of packet buffers (Refer to [Section 25.5.4: Isochronous transfers](#) and [Section 25.5.3: Double-buffered endpoints](#) respectively). The relationship between buffer description table entries and packet buffer areas is depicted in [Figure 262](#).

Figure 262. Packet buffer areas with examples of buffer description table locations



Each packet buffer is used either during reception or transmission starting from the bottom. The USB peripheral will never change the contents of memory locations adjacent to the allocated memory buffers; if a packet bigger than the allocated buffer length is received (buffer overrun condition) the data will be copied to the memory only up to the last available location.

Endpoint initialization

The first step to initialize an endpoint is to write appropriate values to the ADDRn_TX/ADDRn_RX registers so that the USB peripheral finds the data to be transmitted already available and the data to be received can be buffered. The EP_TYPE bits in the USB_EPnR register must be set according to the endpoint type, eventually using the EP_KIND bit to enable any special required feature. On the transmit side, the endpoint must be enabled using the STAT_TX bits in the USB_EPnR register and COUNTn_TX must be initialized. For reception, STAT_RX bits must be set to enable reception and COUNTn_RX must be written with the allocated buffer size using the BL_SIZE and NUM_BLOCK fields. Unidirectional endpoints, except Isochronous and double-buffered bulk endpoints, need to initialize only bits and registers related to the supported direction. Once the transmission and/or reception are enabled, register USB_EPnR and locations ADDRn_TX/ADDRn_RX, COUNTn_TX/COUNTn_RX (respectively), should not be modified by the application software, as the hardware can change their value on the fly. When the data transfer operation is completed, notified by a CTR interrupt event, they can be accessed again to re-enable a new operation.

IN packets (data transmission)

When receiving an IN token packet, if the received address matches a configured and valid endpoint, the USB peripheral accesses the contents of ADDRn_TX and COUNTn_TX locations inside the buffer descriptor table entry related to the addressed endpoint. The content of these locations is stored in its internal 16 bit registers ADDR and COUNT (not accessible by software). The packet memory is accessed again to read the first byte to be transmitted (Refer to [Structure and usage of packet buffers on page 681](#)) and starts sending a DATA0 or DATA1 PID according to USB_EPnR bit DTOG_TX. When the PID is completed, the first byte, read from buffer memory, is loaded into the output shift register to be transmitted on the USB bus. After the last data byte is transmitted, the computed CRC is sent. If the addressed endpoint is not valid, a NAK or STALL handshake packet is sent instead of the data packet, according to STAT_TX bits in the USB_EPnR register.

The ADDR internal register is used as a pointer to the current buffer memory location while COUNT is used to count the number of remaining bytes to be transmitted. Each half-word read from the packet buffer memory is transmitted over the USB bus starting from the least significant byte. Transmission buffer memory is read starting from the address pointed by ADDRn_TX for COUNTn_TX/2 half-words. If a transmitted packet is composed of an odd number of bytes, only the lower half of the last half-word accessed will be used.

On receiving the ACK receipt by the host, the USB_EPnR register is updated in the following way: DTOG_TX bit is toggled, the endpoint is made invalid by setting STAT_TX=10 (NAK) and bit CTR_TX is set. The application software must first identify the endpoint, which is requesting microcontroller attention by examining the EP_ID and DIR bits in the USB_ISTR register. Servicing of the CTR_TX event starts clearing the interrupt bit; the application software then prepares another buffer full of data to be sent, updates the COUNTn_TX table location with the number of byte to be transmitted during the next transfer, and finally sets STAT_TX to '11 (VALID) to re-enable transmissions. While the STAT_TX bits are equal to '10 (NAK), any IN request addressed to that endpoint is NAKed,

indicating a flow control condition: the USB host will retry the transaction until it succeeds. It is mandatory to execute the sequence of operations in the above mentioned order to avoid losing the notification of a second IN transaction addressed to the same endpoint immediately following the one which triggered the CTR interrupt.

OUT and SETUP packets (data reception)

These two tokens are handled by the USB peripheral more or less in the same way; the differences in the handling of SETUP packets are detailed in the following paragraph about control transfers. When receiving an OUT/SETUP PID, if the address matches a valid endpoint, the USB peripheral accesses the contents of the ADDRn_RX and COUNTn_RX locations inside the buffer descriptor table entry related to the addressed endpoint. The content of the ADDRn_RX is stored directly in its internal register ADDR. While COUNT is now reset and the values of BL_SIZE and NUM_BLOCK bit fields, which are read within COUNTn_RX content are used to initialize BUF_COUNT, an internal 16 bit counter, which is used to check the buffer overrun condition (all these internal registers are not accessible by software). Data bytes subsequently received by the USB peripheral are packed in half-words (the first byte received is stored as least significant byte) and then transferred to the packet buffer starting from the address contained in the internal ADDR register while BUF_COUNT is decremented and COUNT is incremented at each byte transfer. When the end of DATA packet is detected, the correctness of the received CRC is tested and only if no errors occurred during the reception, an ACK handshake packet is sent back to the transmitting host.

In case of wrong CRC or other kinds of errors (bit-stuff violations, frame errors, etc.), data bytes are still copied in the packet memory buffer, at least until the error detection point, but ACK packet is not sent and the ERR bit in USB_ISTR register is set. However, there is usually no software action required in this case: the USB peripheral recovers from reception errors and remains ready for the next transaction to come. If the addressed endpoint is not valid, a NAK or STALL handshake packet is sent instead of the ACK, according to bits STAT_RX in the USB_EPnR register and no data is written in the reception memory buffers.

Reception memory buffer locations are written starting from the address contained in the ADDRn_RX for a number of bytes corresponding to the received data packet length, CRC included (i.e. data payload length + 2), or up to the last allocated memory location, as defined by BL_SIZE and NUM_BLOCK, whichever comes first. In this way, the USB peripheral never writes beyond the end of the allocated reception memory buffer area. If the length of the data packet payload (actual number of bytes used by the application) is greater than the allocated buffer, the USB peripheral detects a buffer overrun condition. In this case, a STALL handshake is sent instead of the usual ACK to notify the problem to the host, no interrupt is generated and the transaction is considered failed.

When the transaction is completed correctly, by sending the ACK handshake packet, the internal COUNT register is copied back in the COUNTn_RX location inside the buffer description table entry, leaving unaffected BL_SIZE and NUM_BLOCK fields, which normally do not require to be re-written, and the USB_EPnR register is updated in the following way: DTOG_RX bit is toggled, the endpoint is made invalid by setting STAT_RX = '10 (NAK) and bit CTR_RX is set. If the transaction has failed due to errors or buffer overrun condition, none of the previously listed actions take place. The application software must first identify the endpoint, which is requesting microcontroller attention by examining the EP_ID and DIR bits in the USB_ISTR register. The CTR_RX event is serviced by first determining the transaction type (SETUP bit in the USB_EPnR register); the application software must clear the interrupt flag bit and get the number of received bytes reading the COUNTn_RX location inside the buffer description table entry related to the endpoint being

processed. After the received data is processed, the application software should set the STAT_RX bits to '11 (Valid) in the USB_EPnR, enabling further transactions. While the STAT_RX bits are equal to '10 (NAK), any OUT request addressed to that endpoint is NAKed, indicating a flow control condition: the USB host will retry the transaction until it succeeds. It is mandatory to execute the sequence of operations in the above mentioned order to avoid losing the notification of a second OUT transaction addressed to the same endpoint following immediately the one which triggered the CTR interrupt.

Control transfers

Control transfers are made of a SETUP transaction, followed by zero or more data stages, all of the same direction, followed by a status stage (a zero-byte transfer in the opposite direction). SETUP transactions are handled by control endpoints only and are very similar to OUT ones (data reception) except that the values of DTOG_TX and DTOG_RX bits of the addressed endpoint registers are set to 1 and 0 respectively, to initialize the control transfer, and both STAT_TX and STAT_RX are set to '10 (NAK) to let software decide if subsequent transactions must be IN or OUT depending on the SETUP contents. A control endpoint must check SETUP bit in the USB_EPnR register at each CTR_RX event to distinguish normal OUT transactions from SETUP ones. A USB device can determine the number and direction of data stages by interpreting the data transferred in the SETUP stage, and is required to STALL the transaction in the case of errors. To do so, at all data stages before the last, the unused direction should be set to STALL, so that, if the host reverses the transfer direction too soon, it gets a STALL as a status stage.

While enabling the last data stage, the opposite direction should be set to NAK, so that, if the host reverses the transfer direction (to perform the status stage) immediately, it is kept waiting for the completion of the control operation. If the control operation completes successfully, the software will change NAK to VALID, otherwise to STALL. At the same time, if the status stage will be an OUT, the STATUS_OUT (EP_KIND in the USB_EPnR register) bit should be set, so that an error is generated if a status transaction is performed with not-zero data. When the status transaction is serviced, the application clears the STATUS_OUT bit and sets STAT_RX to VALID (to accept a new command) and STAT_TX to NAK (to delay a possible status stage immediately following the next setup).

Since the USB specification states that a SETUP packet cannot be answered with a handshake different from ACK, eventually aborting a previously issued command to start the new one, the USB logic doesn't allow a control endpoint to answer with a NAK or STALL packet to a SETUP token received from the host.

When the STAT_RX bits are set to '01 (STALL) or '10 (NAK) and a SETUP token is received, the USB accepts the data, performing the required data transfers and sends back an ACK handshake. If that endpoint has a previously issued CTR_RX request not yet acknowledged by the application (i.e. CTR_RX bit is still set from a previously completed reception), the USB discards the SETUP transaction and does not answer with any handshake packet regardless of its state, simulating a reception error and forcing the host to send the SETUP token again. This is done to avoid losing the notification of a SETUP transaction addressed to the same endpoint immediately following the transaction, which triggered the CTR_RX interrupt.

25.5.3 Double-buffered endpoints

All different endpoint types defined by the USB standard represent different traffic models, and describe the typical requirements of different kind of data transfer operations. When large portions of data are to be transferred between the host PC and the USB function, the bulk endpoint type is the most suited model. This is because the host schedules bulk transactions so as to fill all the available bandwidth in the frame, maximizing the actual transfer rate as long as the USB function is ready to handle a bulk transaction addressed to it. If the USB function is still busy with the previous transaction when the next one arrives, it will answer with a NAK handshake and the host PC will issue the same transaction again until the USB function is ready to handle it, reducing the actual transfer rate due to the bandwidth occupied by re-transmissions. For this reason, a dedicated feature called 'double-buffering' can be used with bulk endpoints.

When 'double-buffering' is activated, data toggle sequencing is used to select, which buffer is to be used by the USB peripheral to perform the required data transfers, using both 'transmission' and 'reception' packet memory areas to manage buffer swapping on each successful transaction in order to always have a complete buffer to be used by the application, while the USB peripheral fills the other one. For example, during an OUT transaction directed to a 'reception' double-buffered bulk endpoint, while one buffer is being filled with new data coming from the USB host, the other one is available for the microcontroller software usage (the same would happen with a 'transmission' double-buffered bulk endpoint and an IN transaction).

Since the swapped buffer management requires the usage of all 4 buffer description table locations hosting the address pointer and the length of the allocated memory buffers, the USB_EPnR registers used to implement double-buffered bulk endpoints are forced to be used as unidirectional ones. Therefore, only one STAT bit pair must be set at a value different from '00 (Disabled): STAT_RX if the double-buffered bulk endpoint is enabled for reception, STAT_TX if the double-buffered bulk endpoint is enabled for transmission. In case it is required to have double-buffered bulk endpoints enabled both for reception and transmission, two USB_EPnR registers must be used.

To exploit the double-buffering feature and reach the highest possible transfer rate, the endpoint flow control structure, described in previous chapters, has to be modified, in order to switch the endpoint status to NAK only when a buffer conflict occurs between the USB peripheral and application software, instead of doing it at the end of each successful transaction. The memory buffer which is currently being used by the USB peripheral is defined by the DTOG bit related to the endpoint direction: DTOG_RX (bit 14 of USB_EPnR register) for 'reception' double-buffered bulk endpoints or DTOG_TX (bit 6 of USB_EPnR register) for 'transmission' double-buffered bulk endpoints. To implement the new flow control scheme, the USB peripheral should know which packet buffer is currently in use by the application software, so to be aware of any conflict. Since in the USB_EPnR register, there are two DTOG bits but only one is used by USB peripheral for data and buffer sequencing (due to the unidirectional constraint required by double-buffering feature) the other one can be used by the application software to show which buffer it is currently using. This new buffer flag is called SW_BUF. In the following table the correspondence between USB_EPnR register bits and DTOG/SW_BUF definition is explained, for the cases of 'transmission' and 'reception' double-buffered bulk endpoints.

Table 98. Double-buffering buffer flag definition

Buffer flag	'Transmission' endpoint	'Reception' endpoint
DTOG	DTOG_TX (USB_EPnR bit 6)	DTOG_RX (USB_EPnR bit 14)
SW_BUF	USB_EPnR bit 14	USB_EPnR bit 6

The memory buffer which is currently being used by the USB peripheral is defined by DTOG buffer flag, while the buffer currently in use by application software is identified by SW_BUF buffer flag. The relationship between the buffer flag value and the used packet buffer is the same in both cases, and it is listed in the following table.

Table 99. Bulk double-buffering memory buffers usage

Endpoint Type	DTOG	SW_BUF	Packet buffer used by USB Peripheral	Packet buffer used by Application Software
IN	0	1	ADDRn_TX_0 / COUNTn_TX_0 Buffer description table locations.	ADDRn_TX_1 / COUNTn_TX_1 Buffer description table locations.
	1	0	ADDRn_TX_1 / COUNTn_TX_1 Buffer description table locations.	ADDRn_TX_0 / COUNTn_TX_0 Buffer description table locations.
	0	0	None ⁽¹⁾	ADDRn_TX_0 / COUNTn_TX_0 Buffer description table locations.
	1	1	None ⁽¹⁾	ADDRn_TX_0 / COUNTn_TX_0 Buffer description table locations.
OUT	0	1	ADDRn_RX_0 / COUNTn_RX_0 Buffer description table locations.	ADDRn_RX_1 / COUNTn_RX_1 Buffer description table locations.
	1	0	ADDRn_RX_1 / COUNTn_RX_1 Buffer description table locations.	ADDRn_RX_0 / COUNTn_RX_0 Buffer description table locations.
	0	0	None ⁽¹⁾	ADDRn_RX_0 / COUNTn_RX_0 Buffer description table locations.
	1	1	None ⁽¹⁾	ADDRn_RX_1 / COUNTn_RX_1 Buffer description table locations.

1. Endpoint in NAK Status.

Double-buffering feature for a bulk endpoint is activated by:

- Writing EP_TYPE bit field at '00 in its USB_EPnR register, to define the endpoint as a bulk, and
- Setting EP_KIND bit at '1 (DBL_BUF), in the same register.

The application software is responsible for DTOG and SW_BUF bits initialization according to the first buffer to be used; this has to be done considering the special toggle-only property that these two bits have. The end of the first transaction occurring after having set DBL_BUF, triggers the special flow control of double-buffered bulk endpoints, which is used for all other transactions addressed to this endpoint until DBL_BUF remain set. At the end of each transaction the CTR_RX or CTR_TX bit of the addressed endpoint USB_EPnR register is set, depending on the enabled direction. At the same time, the affected DTOG bit in the USB_EPnR register is hardware toggled making the USB peripheral buffer swapping completely software independent. Unlike common transactions, and the first one after

DBL_BUF setting, STAT bit pair is not affected by the transaction termination and its value remains '11 (Valid). However, as the token packet of a new transaction is received, the actual endpoint status will be masked as '10 (NAK) when a buffer conflict between the USB peripheral and the application software is detected (this condition is identified by DTOG and SW_BUF having the same value, see [Table 99 on page 687](#)). The application software responds to the CTR event notification by clearing the interrupt flag and starting any required handling of the completed transaction. When the application packet buffer usage is over, the software toggles the SW_BUF bit, writing '1 to it, to notify the USB peripheral about the availability of that buffer. In this way, the number of NAKed transactions is limited only by the application elaboration time of a transaction data: if the elaboration time is shorter than the time required to complete a transaction on the USB bus, no re-transmissions due to flow control will take place and the actual transfer rate will be limited only by the host PC.

The application software can always override the special flow control implemented for double-buffered bulk endpoints, writing an explicit status different from '11 (Valid) into the STAT bit pair of the related USB_EPnR register. In this case, the USB peripheral will always use the programmed endpoint status, regardless of the buffer usage condition.

25.5.4 Isochronous transfers

The USB standard supports full speed peripherals requiring a fixed and accurate data production/consume frequency, defining this kind of traffic as 'Isochronous'. Typical examples of this data are: audio samples, compressed video streams, and in general any sort of sampled data having strict requirements for the accuracy of delivered frequency. When an endpoint is defined to be 'isochronous' during the enumeration phase, the host allocates in the frame the required bandwidth and delivers exactly one IN or OUT packet each frame, depending on endpoint direction. To limit the bandwidth requirements, no re-transmission of failed transactions is possible for Isochronous traffic; this leads to the fact that an isochronous transaction does not have a handshake phase and no ACK packet is expected or sent after the data packet. For the same reason, Isochronous transfers do not support data toggle sequencing and always use DATA0 PID to start any data packet.

The Isochronous behavior for an endpoint is selected by setting the EP_TYPE bits at '10 in its USB_EPnR register; since there is no handshake phase the only legal values for the STAT_RX/STAT_TX bit pairs are '00 (Disabled) and '11 (Valid), any other value will produce results not compliant to USB standard. Isochronous endpoints implement double-buffering to ease application software development, using both 'transmission' and 'reception' packet memory areas to manage buffer swapping on each successful transaction in order to have always a complete buffer to be used by the application, while the USB peripheral fills the other.

The memory buffer which is currently used by the USB peripheral is defined by the DTOG bit related to the endpoint direction (DTOG_RX for 'reception' isochronous endpoints, DTOG_TX for 'transmission' isochronous endpoints, both in the related USB_EPnR register) according to [Table 100](#).

Table 100. Isochronous memory buffers usage

Endpoint Type	DTOG bit value	Packet buffer used by the USB peripheral	Packet buffer used by the application software
IN	0	ADDRn_TX_0 / COUNTn_TX_0 buffer description table locations.	ADDRn_TX_1 / COUNTn_TX_1 buffer description table locations.
	1	ADDRn_TX_1 / COUNTn_TX_1 buffer description table locations.	ADDRn_TX_0 / COUNTn_TX_0 buffer description table locations.
OUT	0	ADDRn_RX_0 / COUNTn_RX_0 buffer description table locations.	ADDRn_RX_1 / COUNTn_RX_1 buffer description table locations.
	1	ADDRn_RX_1 / COUNTn_RX_1 buffer description table locations.	ADDRn_RX_0 / COUNTn_RX_0 buffer description table locations.

As it happens with double-buffered bulk endpoints, the USB_EPnR registers used to implement Isochronous endpoints are forced to be used as unidirectional ones. In case it is required to have Isochronous endpoints enabled both for reception and transmission, two USB_EPnR registers must be used.

The application software is responsible for the DTOG bit initialization according to the first buffer to be used; this has to be done considering the special toggle-only property that these two bits have. At the end of each transaction, the CTR_RX or CTR_TX bit of the addressed endpoint USB_EPnR register is set, depending on the enabled direction. At the same time, the affected DTOG bit in the USB_EPnR register is hardware toggled making buffer swapping completely software independent. STAT bit pair is not affected by transaction completion; since no flow control is possible for Isochronous transfers due to the lack of handshake phase, the endpoint remains always '11 (Valid). CRC errors or buffer-overflow conditions occurring during Isochronous OUT transfers are anyway considered as correct transactions and they always trigger an CTR_RX event. However, CRC errors will anyway set the ERR bit in the USB_ISTR register to notify the software of the possible data corruption.

25.5.5 Suspend/Resume events

The USB standard defines a special peripheral state, called SUSPEND, in which the average current drawn from the USB bus must not be greater than 2.5 mA. This requirement is of fundamental importance for bus-powered devices, while self-powered devices are not required to comply to this strict power consumption constraint. In suspend mode, the host PC sends the notification by not sending any traffic on the USB bus for more than 3 ms: since a SOF packet must be sent every 1 ms during normal operations, the USB peripheral detects the lack of 3 consecutive SOF packets as a suspend request from the host PC and set the SUSP bit to '1 in USB_ISTR register, causing an interrupt if enabled. Once the device is suspended, its normal operation can be restored by a so called RESUME sequence, which can be started from the host PC or directly from the peripheral itself, but it is always terminated by the host PC. The suspended USB peripheral must be anyway able to detect a RESET sequence, reacting to this event as a normal USB reset event.

The actual procedure used to suspend the USB peripheral is device dependent since according to the device composition, different actions may be required to reduce the total consumption.

A brief description of a typical suspend procedure is provided below, focused on the USB-related aspects of the application software routine responding to the SUSP notification of the USB peripheral:

1. Set the FSUSP bit in the USB_CNTR register to 1. This action activates the suspend mode within the USB peripheral. As soon as the suspend mode is activated, the check on SOF reception is disabled to avoid any further SUSP interrupts being issued while the USB is suspended.
2. Remove or reduce any static power consumption in blocks different from the USB peripheral.
3. Set LP_MODE bit in USB_CNTR register to 1 to remove static power consumption in the analog USB transceivers but keeping them able to detect resume activity.
4. Optionally turn off external oscillator and device PLL to stop any activity inside the device.

When an USB event occurs while the device is in SUSPEND mode, the RESUME procedure must be invoked to restore nominal clocks and regain normal USB behavior. Particular care must be taken to insure that this process does not take more than 10 ms when the wakening event is an USB reset sequence (See “Universal Serial Bus Specification” for more details). The start of a resume or reset sequence, while the USB peripheral is suspended, clears the LP_MODE bit in USB_CNTR register asynchronously. Even if this event can trigger an WKUP interrupt if enabled, the use of an interrupt response routine must be carefully evaluated because of the long latency due to system clock restart; to have the shorter latency before re-activating the nominal clock it is suggested to put the resume procedure just after the end of the suspend one, so its code is immediately executed as soon as the system clock restarts. To prevent ESD discharges or any other kind of noise from waking-up the system (the exit from suspend mode is an asynchronous event), a suitable analog filter on data line status is activated during suspend; the filter width is about 70 ns.

The following is a list of actions a resume procedure should address:

1. Optionally turn on external oscillator and/or device PLL.
2. Clear FSUSP bit of USB_CNTR register.
3. If the resume triggering event has to be identified, bits RXDP and RXDM in the USB_FNR register can be used according to [Table 101](#), which also lists the intended software action in all the cases. If required, the end of resume or reset sequence can be detected monitoring the status of the above mentioned bits by checking when they reach the “10” configuration, which represent the Idle bus state; moreover at the end of a reset sequence the RESET bit in USB_ISTR register is set to 1, issuing an interrupt if enabled, which should be handled as usual.

Table 101. Resume event detection

[RXDP,RXDM] status	Wakeup event	Required resume software action
“00”	Root reset	None
“10”	None (noise on bus)	Go back in Suspend mode
“01”	Root resume	None
“11”	Not allowed (noise on bus)	Go back in Suspend mode

A device may require to exit from suspend mode as an answer to particular events not directly related to the USB protocol (e.g. a mouse movement wakes up the whole system). In this case, the resume sequence can be started by setting the RESUME bit in the USB_CNTR register to ‘1 and resetting it to 0 after an interval between 1 ms and 15 ms (this interval can be timed using ESOE interrupts, occurring with a 1 ms period when the system clock is running at nominal frequency). Once the RESUME bit is clear, the resume sequence will be completed by the host PC and its end can be monitored again using the RXDP and RXDM bits in the USB_FNR register.

Note: The RESUME bit must be anyway used only after the USB peripheral has been put in suspend mode, setting the FSUSP bit in USB_CNTR register to 1.

25.6 USB registers

The USB peripheral registers can be divided into the following groups:

- Common Registers: Interrupt and Control registers
- Endpoint Registers: Endpoint configuration and status
- Buffer Descriptor Table: Location of packet memory used to locate data buffers

All register addresses are expressed as offsets with respect to the USB peripheral registers base address 0x4000 5C00, except the buffer descriptor table locations, which starts at the address specified by the USB_BTABLE register.

Refer to [Section 1.1 on page 33](#) for a list of abbreviations used in register descriptions.

The peripheral registers can be accessed by half-words (16-bit) or words (32-bit).

25.6.1 Common registers

These registers affect the general behavior of the USB peripheral defining operating mode, interrupt handling, device address and giving access to the current frame number updated by the host PC.

USB control register (USB_CNTR)

Address offset: 0x40

Reset value: 0x0003

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CTRM	PMAOVRM	ERRM	WKUPM	SUSPM	RESETM	SOFM	ESOFM	L1REQM	RESUME	L1RESUME	RESUME	FUSP	LP_MODE	PDWN	FRES
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw

Bit 15 **CTRM**: Correct transfer interrupt mask

0: Correct Transfer (CTR) Interrupt disabled.

1: CTR Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.

Bit 14 **PMAOVRM**: Packet memory area over / underrun interrupt mask

0: PMAOVR Interrupt disabled.

1: PMAOVR Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.

Bit 13 **ERRM**: Error interrupt mask

0: ERR Interrupt disabled.

1: ERR Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.

Bit 12 **WKUPM**: Wakeup interrupt mask

0: WKUP Interrupt disabled.

1: WKUP Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.

Bit 11 **SUSPM**: Suspend mode interrupt mask

0: Suspend Mode Request (SUSP) Interrupt disabled.

1: SUSP Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.

- Bit 10 **RESETM**: USB reset interrupt mask
0: RESET Interrupt disabled.
1: RESET Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.
- Bit 9 **SOFM**: Start of frame interrupt mask
0: SOF Interrupt disabled.
1: SOF Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.
- Bit 8 **ESOFM**: Expected start of frame interrupt mask
0: Expected Start of Frame (ESOF) Interrupt disabled.
1: ESOF Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.
- Bit 7 **L1REQM**: LPM L1 state request interrupt mask
0: LPM L1 state request (L1REQ) Interrupt disabled.
1: L1REQ Interrupt enabled, an interrupt request is generated when the corresponding bit in the USB_ISTR register is set.
- Bit 6 Reserved.
- Bit 5 **L1RESUME**: LPM L1 Resume request
The microcontroller can set this bit to send a LPM L1 Resume signal to the host. After the signaling ends, this bit is cleared by hardware.
- Bit 4 **RESUME**: Resume request
The microcontroller can set this bit to send a Resume signal to the host. It must be activated, according to USB specifications, for no less than 1 ms and no more than 15 ms after which the Host PC is ready to drive the resume sequence up to its end.
- Bit 3 **FSUSP**: Force suspend
Software must set this bit when the SUSP interrupt is received, which is issued when no traffic is received by the USB peripheral for 3 ms.
0: No effect.
1: Enter suspend mode. Clocks and static power dissipation in the analog transceiver are left unaffected. If suspend power consumption is a requirement (bus-powered device), the application software should set the LP_MODE bit after FSUSP as explained below.

Bit 2 LP_MODE: Low-power mode

This mode is used when the suspend-mode power constraints require that all static power dissipation is avoided, except the one required to supply the external pull-up resistor. This condition should be entered when the application is ready to stop all system clocks, or reduce their frequency in order to meet the power consumption requirements of the USB suspend condition. The USB activity during the suspend mode (WKUP event) asynchronously resets this bit (it can also be reset by software).

0: No Low-power mode.

1: Enter Low-power mode.

Bit 1 PDWN: Power down

This bit is used to completely switch off all USB-related analog parts if it is required to completely disable the USB peripheral for any reason. When this bit is set, the USB peripheral is disconnected from the transceivers and it cannot be used.

0: Exit Power Down.

1: Enter Power down mode.

Bit 0 FRES: Force USB Reset

0: Clear USB reset.

1: Force a reset of the USB peripheral, exactly like a RESET signaling on the USB. The USB peripheral is held in RESET state until software clears this bit. A “USB-RESET” interrupt is generated, if enabled.

USB interrupt status register (USB_ISTR)

Address offset: 0x44

Reset value: 0x0000 0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CTR	PMA OVR	ERR	WKUP	SUSP	RESET	SOF	ESOF	L1REQ	Res.	Res.	DIR	EP_ID[3:0]			
r	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0	rc_w0			r	r	r	r	r

This register contains the status of all the interrupt sources allowing application software to determine, which events caused an interrupt request.

The upper part of this register contains single bits, each of them representing a specific event. These bits are set by the hardware when the related event occurs; if the corresponding bit in the USB_CNTR register is set, a generic interrupt request is generated. The interrupt routine, examining each bit, will perform all necessary actions, and finally it will clear the serviced bits. If any of them is not cleared, the interrupt is considered to be still pending, and the interrupt line will be kept high again. If several bits are set simultaneously, only a single interrupt will be generated.

Endpoint transaction completion can be handled in a different way to reduce interrupt response latency. The CTR bit is set by the hardware as soon as an endpoint successfully completes a transaction, generating a generic interrupt request if the corresponding bit in USB_CNTR is set. An endpoint dedicated interrupt condition is activated independently from the CTRM bit in the USB_CNTR register. Both interrupt conditions remain active until software clears the pending bit in the corresponding USB_EPnR register (the CTR bit is actually a read only bit). For endpoint-related interrupts, the software can use the Direction of Transaction (DIR) and EP_ID read-only bits to identify, which endpoint made the last interrupt request and called the corresponding interrupt service routine.

The user can choose the relative priority of simultaneously pending USB_ISTR events by specifying the order in which software checks USB_ISTR bits in an interrupt service routine. Only the bits related to events, which are serviced, are cleared. At the end of the service routine, another interrupt will be requested, to service the remaining conditions.

To avoid spurious clearing of some bits, it is recommended to clear them with a load instruction where all bits which must not be altered are written with 1, and all bits to be cleared are written with '0 (these bits can only be cleared by software). Read-modify-write cycles should be avoided because between the read and the write operations another bit could be set by the hardware and the next write will clear it before the microprocessor has the time to serve the event.

The following describes each bit in detail:

Bit 15 **CTR**: Correct transfer

This bit is set by the hardware to indicate that an endpoint has successfully completed a transaction; using DIR and EP_ID bits software can determine which endpoint requested the interrupt. This bit is read-only.

Bit 14 **PMAOVR**: Packet memory area over / underrun

This bit is set if the microcontroller has not been able to respond in time to an USB memory request. The USB peripheral handles this event in the following way: During reception an ACK handshake packet is not sent, during transmission a bit-stuff error is forced on the transmitted stream; in both cases the host will retry the transaction. The PMAOVR interrupt should never occur during normal operations. Since the failed transaction is retried by the host, the application software has the chance to speed-up device operations during this interrupt handling, to be ready for the next transaction retry; however this does not happen during Isochronous transfers (no isochronous transaction is anyway retried) leading to a loss of data in this case. This bit is read/write but only '0 can be written and writing '1 has no effect.

Bit 13 **ERR**: Error

This flag is set whenever one of the errors listed below has occurred:

NANS: No ANSwer. The timeout for a host response has expired.

CRC: Cyclic Redundancy Check error. One of the received CRCs, either in the token or in the data, was wrong.

BST: Bit Stuffing error. A bit stuffing error was detected anywhere in the PID, data, and/or CRC.

FVIO: Framing format Violation. A non-standard frame was received (EOP not in the right place, wrong token sequence, etc.).

The USB software can usually ignore errors, since the USB peripheral and the PC host manage retransmission in case of errors in a fully transparent way. This interrupt can be useful during the software development phase, or to monitor the quality of transmission over the USB bus, to flag possible problems to the user (e.g. loose connector, too noisy environment, broken conductor in the USB cable and so on). This bit is read/write but only '0 can be written and writing '1 has no effect.

Bit 12 **WKUP**: Wakeup

This bit is set to 1 by the hardware when, during suspend mode, activity is detected that wakes up the USB peripheral. This event asynchronously clears the LP_MODE bit in the CTLR register and activates the USB_WAKEUP line, which can be used to notify the rest of the device (e.g. wakeup unit) about the start of the resume process. This bit is read/write but only '0 can be written and writing '1 has no effect.

Bit 11 SUSP: Suspend mode request

This bit is set by the hardware when no traffic has been received for 3 ms, indicating a suspend mode request from the USB bus. The suspend condition check is enabled immediately after any USB reset and it is disabled by the hardware when the suspend mode is active (FSUSP=1) until the end of resume sequence. This bit is read/write but only '0 can be written and writing '1 has no effect.

Bit 10 RESET: USB reset request

Set when the USB peripheral detects an active USB RESET signal at its inputs. The USB peripheral, in response to a RESET, just resets its internal protocol state machine, generating an interrupt if RESETM enable bit in the USB_CNTR register is set. Reception and transmission are disabled until the RESET bit is cleared. All configuration registers do not reset: the microcontroller must explicitly clear these registers (this is to ensure that the RESET interrupt can be safely delivered, and any transaction immediately followed by a RESET can be completed). The function address and endpoint registers are reset by an USB reset event.

This bit is read/write but only '0 can be written and writing '1 has no effect.

Bit 9 SOF: Start of frame

This bit signals the beginning of a new USB frame and it is set when a SOF packet arrives through the USB bus. The interrupt service routine may monitor the SOF events to have a 1 ms synchronization event to the USB host and to safely read the USB_FNR register which is updated at the SOF packet reception (this could be useful for isochronous applications).

This bit is read/write but only '0 can be written and writing '1 has no effect.

Bit 8 ESOF: Expected start of frame

This bit is set by the hardware when an SOF packet is expected but not received. The host sends an SOF packet each 1 ms, but if the hub does not receive it properly, the Suspend Timer issues this interrupt. If three consecutive ESOF interrupts are generated (i.e. three SOF packets are lost) without any traffic occurring in between, a SUSP interrupt is generated. This bit is set even when the missing SOF packets occur while the Suspend Timer is not yet locked. This bit is read/write but only '0 can be written and writing '1 has no effect.

Bit 7 L1REQ: LPM L1 state request

This bit is set by the hardware when LPM command to enter the L1 state is successfully received and acknowledged. This bit is read/write but only '0 can be written and writing '1 has no effect.

Bits 6:5 Reserved.

Bit 4 **DIR**: Direction of transaction

This bit is written by the hardware according to the direction of the successful transaction, which generated the interrupt request.

If DIR bit=0, CTR_TX bit is set in the USB_EPnR register related to the interrupting endpoint. The interrupting transaction is of IN type (data transmitted by the USB peripheral to the host PC).

If DIR bit=1, CTR_RX bit or both CTR_TX/CTR_RX are set in the USB_EPnR register related to the interrupting endpoint. The interrupting transaction is of OUT type (data received by the USB peripheral from the host PC) or two pending transactions are waiting to be processed.

This information can be used by the application software to access the USB_EPnR bits related to the triggering transaction since it represents the direction having the interrupt pending. This bit is read-only.

Bits 3:0 **EP_ID[3:0]**: Endpoint Identifier

These bits are written by the hardware according to the endpoint number, which generated the interrupt request. If several endpoint transactions are pending, the hardware writes the endpoint identifier related to the endpoint having the highest priority defined in the following way: Two endpoint sets are defined, in order of priority: Isochronous and double-buffered bulk endpoints are considered first and then the other endpoints are examined. If more than one endpoint from the same set is requesting an interrupt, the EP_ID bits in USB_ISTR register are assigned according to the lowest requesting endpoint register, EP0R having the highest priority followed by EP1R and so on. The application software can assign a register to each endpoint according to this priority scheme, so as to order the concurring endpoint requests in a suitable way. These bits are read only.

USB frame number register (USB_FNR)

Address offset: 0x48

Reset value: 0x0XXX where X is undefined

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
RXDP	RXDM	LCK	LSOF[1:0]		FN[10:0]										
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bit 15 **RXDP**: Receive data + line status

This bit can be used to observe the status of received data plus upstream port data line. It can be used during end-of-suspend routines to help determining the wakeup event.

Bit 14 **RXDM**: Receive data - line status

This bit can be used to observe the status of received data minus upstream port data line. It can be used during end-of-suspend routines to help determining the wakeup event.

Bit 13 **LCK**: Locked

This bit is set by the hardware when at least two consecutive SOF packets have been received after the end of an USB reset condition or after the end of an USB resume sequence. Once locked, the frame timer remains in this state until an USB reset or USB suspend event occurs.

Bits 12:11 **LSOF[1:0]**: Lost SOF

These bits are written by the hardware when an ESOF interrupt is generated, counting the number of consecutive SOF packets lost. At the reception of an SOF packet, these bits are cleared.

Bits 10:0 **FN[10:0]**: Frame number

This bit field contains the 11-bits frame number contained in the last received SOF packet. The frame number is incremented for every frame sent by the host and it is useful for Isochronous transfers. This bit field is updated on the generation of an SOF interrupt.

USB device address (USB_DADDR)

Address offset: 0x4C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EF	ADD6	ADD5	ADD4	ADD3	ADD2	ADD1	ADD0
								rw	rw	rw	rw	rw	rw	rw	rw

Bits 15:8 Reserved

Bit 7 **EF**: Enable function

This bit is set by the software to enable the USB device. The address of this device is contained in the following ADD[6:0] bits. If this bit is at '0 no transactions are handled, irrespective of the settings of USB_EPnR registers.

Bits 6:0 **ADD[6:0]**: Device address

These bits contain the USB function address assigned by the host PC during the enumeration process. Both this field and the Endpoint Address (EA) field in the associated USB_EPnR register must match with the information contained in a USB token in order to handle a transaction to the required endpoint.

Buffer table address (USB_BTABLE)

Address offset: 0x50

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BTABLE[15:3]													Res.	Res.	Res.
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw			

Bits 15:3 **BTABLE[15:3]**: Buffer table

These bits contain the start address of the buffer allocation table inside the dedicated packet memory. This table describes each endpoint buffer location and size and it must be aligned to an 8 byte boundary (the 3 least significant bits are always '0'). At the beginning of every transaction addressed to this device, the USB peripheral reads the element of this table related to the addressed endpoint, to get its buffer start location and the buffer size (Refer to [Structure and usage of packet buffers on page 681](#)).

Bits 2:0 Reserved, forced by hardware to 0.

LPM control and status register (USB_LPMCSR)

Address offset: 0x54

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	BESL[3:0]				REM WAKE	Res.	LPM ACK	LPM EN
								r				r		rw	rw

Bits 15:8 Reserved.

Bits 7:4 **BESL[3:0]**: BESL value

These bits contain the BESL value received with last ACKed LPM Token

Bit 3 **REM WAKE**: bRemoteWake value

This bit contains the bRemoteWake value received with last ACKed LPM Token

Bit 2 Reserved

Bit 1 **LPMACK**: LPM Token acknowledge enable

0: the valid LPM Token will be NYET.

1: the valid LPM Token will be ACK.

The NYET/ACK will be returned only on a successful LPM transaction:

No errors in both the EXT token and the LPM token (else ERROR)

A valid bLinkState = 0001B (L1) is received (else STALL)

Bit 0 **LPMEN**: LPM support enable

This bit is set by the software to enable the LPM support within the USB device. If this bit is at '0' no LPM transactions are handled.

Battery charging detector (USB_BCDR)

Address offset: 0x58

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
DPPU	Res.	Res.	Res.	Res.	Res.	Res.	Res.	PS2 DET	SDET	PDET	DC DET	SDEN	PDEN	DCD EN	BCD EN
rw								r	r	r	r	rw	rw	rw	rw

Bit 15 **DPPU**: DP pull-up control

This bit is set by software to enable the embedded pull-up on the DP line. Clearing it to '0' can be used to signalize disconnect to the host when needed by the user software.

Bits 14:8 Reserved.

Bit 7 **PS2DET**: DM pull-up detection status

This bit is active only during PD and gives the result of comparison between DM voltage level and V_{LGC} threshold. In normal situation, the DM level should be below this threshold. If it is above, it means that the DM is externally pulled high. This can be caused by connection to a PS2 port (which pulls-up both DP and DM lines) or to some proprietary charger not following the BCD specification.

0: Normal port detected (connected to SDP, ACA, CDP or DCP).
1: PS2 port or proprietary charger detected.

Bit 6 **SDET**: Secondary detection (SD) status

This bit gives the result of SD.

0: CDP detected.
1: DCP detected.

Bit 5 **PDET**: Primary detection (PD) status

This bit gives the result of PD.

0: no BCD support detected (connected to SDP or proprietary device).
1: BCD support detected (connected to ACA, CDP or DCP).

Bit 4 **DCDET**: Data contact detection (DCD) status

This bit gives the result of DCD.

0: data lines contact not detected.
1: data lines contact detected.

Bit 3 **SDEN**: Secondary detection (SD) mode enable

This bit is set by the software to put the BCD into SD mode. Only one detection mode (DCD, PD, SD or OFF) should be selected to work correctly.

Bit 2 **PDEN**: Primary detection (PD) mode enable

This bit is set by the software to put the BCD into PD mode. Only one detection mode (DCD, PD, SD or OFF) should be selected to work correctly.

Bit 1 **DCDEN**: Data contact detection (DCD) mode enable

This bit is set by the software to put the BCD into DCD mode. Only one detection mode (DCD, PD, SD or OFF) should be selected to work correctly.

Bit 0 **BCDEN**: Battery charging detector (BCD) enable

This bit is set by the software to enable the BCD support within the USB device. When enabled, the USB PHY is fully controlled by BCD and cannot be used for normal communication. Once the BCD discovery is finished, the BCD should be placed in OFF mode by clearing this bit to '0' in order to allow the normal USB operation.

Endpoint-specific registers

The number of these registers varies according to the number of endpoints that the USB peripheral is designed to handle. The USB peripheral supports up to 8 bidirectional endpoints. Each USB device must support a control endpoint whose address (EA bits) must be set to 0. The USB peripheral behaves in an undefined way if multiple endpoints are enabled having the same endpoint number value. For each endpoint, an USB_EPnR register is available to store the endpoint specific information.

USB endpoint n register (USB_EPnR), n=[0..7]

Address offset: 0x00 to 0x1C

Reset value: 0x0000

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
CTR_RX	DTOG_RX	STAT_RX[1:0]		SETUP	EP_TYPE[1:0]		EP_KIND	CTR_TX	DTOG_TX	STAT_TX[1:0]		EA[3:0]			
rc_w0	t	t	t	r	rw	rw	rw	rc_w0	t	t	t	rw	rw	rw	rw

They are also reset when an USB reset is received from the USB bus or forced through bit FRES in the CTLR register, except the CTR_RX and CTR_TX bits, which are kept unchanged to avoid missing a correct packet notification immediately followed by an USB reset event. Each endpoint has its USB_EPnR register where *n* is the endpoint identifier.

Read-modify-write cycles on these registers should be avoided because between the read and the write operations some bits could be set by the hardware and the next write would modify them before the CPU has the time to detect the change. For this purpose, all bits affected by this problem have an 'invariant' value that must be used whenever their modification is not required. It is recommended to modify these registers with a load instruction where all the bits, which can be modified only by the hardware, are written with their 'invariant' value.

Bit 15 CTR_RX: Correct Transfer for reception

This bit is set by the hardware when an OUT/SETUP transaction is successfully completed on this endpoint; the software can only clear this bit. If the CTRM bit in USB_CNTR register is set accordingly, a generic interrupt condition is generated together with the endpoint related interrupt condition, which is always activated. The type of occurred transaction, OUT or SETUP, can be determined from the SETUP bit described below.

A transaction ended with a NAK or STALL handshake does not set this bit, since no data is actually transferred, as in the case of protocol errors or data toggle mismatches.

This bit is read/write but only '0' can be written, writing 1 has no effect.

Bit 14 DTOG_RX: Data Toggle, for reception transfers

If the endpoint is not Isochronous, this bit contains the expected value of the data toggle bit (0=DATA0, 1=DATA1) for the next data packet to be received. Hardware toggles this bit, when the ACK handshake is sent to the USB host, following a data packet reception having a matching data PID value; if the endpoint is defined as a control one, hardware clears this bit at the reception of a SETUP PID addressed to this endpoint.

If the endpoint is using the double-buffering feature this bit is used to support packet buffer swapping too (Refer to [Section 25.5.3: Double-buffered endpoints](#)).

If the endpoint is Isochronous, this bit is used only to support packet buffer swapping since no data toggling is used for this sort of endpoints and only DATA0 packet are transmitted (Refer to [Section 25.5.4: Isochronous transfers](#)). Hardware toggles this bit just after the end of data packet reception, since no handshake is used for isochronous transfers.

This bit can also be toggled by the software to initialize its value (mandatory when the endpoint is not a control one) or to force specific data toggle/packet buffer usage. When the application software writes '0, the value of DTOG_RX remains unchanged, while writing '1 makes the bit value toggle. This bit is read/write but it can be only toggled by writing 1.

Bits 13:12 **STAT_RX [1:0]**: Status bits, for reception transfers

These bits contain information about the endpoint status, which are listed in [Table 102: Reception status encoding on page 703](#). These bits can be toggled by software to initialize their value. When the application software writes '0', the value remains unchanged, while writing '1' makes the bit value toggle. Hardware sets the STAT_RX bits to NAK when a correct transfer has occurred (CTR_RX=1) corresponding to a OUT or SETUP (control only) transaction addressed to this endpoint, so the software has the time to elaborate the received data before it acknowledge a new transaction

Double-buffered bulk endpoints implement a special transaction flow control, which control the status based upon buffer availability condition (Refer to [Section 25.5.3: Double-buffered endpoints](#)).

If the endpoint is defined as Isochronous, its status can be only "VALID" or "DISABLED", so that the hardware cannot change the status of the endpoint after a successful transaction. If the software sets the STAT_RX bits to 'STALL' or 'NAK' for an Isochronous endpoint, the USB peripheral behavior is not defined. These bits are read/write but they can be only toggled by writing '1'.

Bit 11 **SETUP**: Setup transaction completed

This bit is read-only and it is set by the hardware when the last completed transaction is a SETUP. This bit changes its value only for control endpoints. It must be examined, in the case of a successful receive transaction (CTR_RX event), to determine the type of transaction occurred. To protect the interrupt service routine from the changes in SETUP bits due to next incoming tokens, this bit is kept frozen while CTR_RX bit is at 1; its state changes when CTR_RX is at 0. This bit is read-only.

Bits 10:9 **EP_TYPE[1:0]**: Endpoint type

These bits configure the behavior of this endpoint as described in [Table 103: Endpoint type encoding on page 704](#). Endpoint 0 must always be a control endpoint and each USB function must have at least one control endpoint which has address 0, but there may be other control endpoints if required. Only control endpoints handle SETUP transactions, which are ignored by endpoints of other kinds. SETUP transactions cannot be answered with NAK or STALL. If a control endpoint is defined as NAK, the USB peripheral will not answer, simulating a receive error, in the receive direction when a SETUP transaction is received. If the control endpoint is defined as STALL in the receive direction, then the SETUP packet will be accepted anyway, transferring data and issuing the CTR interrupt. The reception of OUT transactions is handled in the normal way, even if the endpoint is a control one.

Bulk and interrupt endpoints have very similar behavior and they differ only in the special feature available using the EP_KIND configuration bit.

The usage of Isochronous endpoints is explained in [Section 25.5.4: Isochronous transfers](#)

Bit 8 **EP_KIND**: Endpoint kind

The meaning of this bit depends on the endpoint type configured by the EP_TYPE bits. [Table 104](#) summarizes the different meanings.

DBL_BUF: This bit is set by the software to enable the double-buffering feature for this bulk endpoint. The usage of double-buffered bulk endpoints is explained in [Section 25.5.3: Double-buffered endpoints](#).

STATUS_OUT: This bit is set by the software to indicate that a status out transaction is expected: in this case all OUT transactions containing more than zero data bytes are answered 'STALL' instead of 'ACK'. This bit may be used to improve the robustness of the application to protocol errors during control transfers and its usage is intended for control endpoints only. When STATUS_OUT is reset, OUT transactions can have any number of bytes, as required.

Bit 7 CTR_TX: Correct Transfer for transmission

This bit is set by the hardware when an IN transaction is successfully completed on this endpoint; the software can only clear this bit. If the CTRM bit in the USB_CNTR register is set accordingly, a generic interrupt condition is generated together with the endpoint related interrupt condition, which is always activated.

A transaction ended with a NAK or STALL handshake does not set this bit, since no data is actually transferred, as in the case of protocol errors or data toggle mismatches.

This bit is read/write but only '0' can be written.

Bit 6 DTOG_TX: Data Toggle, for transmission transfers

If the endpoint is non-isochronous, this bit contains the required value of the data toggle bit (0=DATA0, 1=DATA1) for the next data packet to be transmitted. Hardware toggles this bit when the ACK handshake is received from the USB host, following a data packet transmission. If the endpoint is defined as a control one, hardware sets this bit to 1 at the reception of a SETUP PID addressed to this endpoint.

If the endpoint is using the double buffer feature, this bit is used to support packet buffer swapping too (Refer to [Section 25.5.3: Double-buffered endpoints](#))

If the endpoint is Isochronous, this bit is used to support packet buffer swapping since no data toggling is used for this sort of endpoints and only DATA0 packet are transmitted (Refer to [Section 25.5.4: Isochronous transfers](#)). Hardware toggles this bit just after the end of data packet transmission, since no handshake is used for Isochronous transfers.

This bit can also be toggled by the software to initialize its value (mandatory when the endpoint is not a control one) or to force a specific data toggle/packet buffer usage. When the application software writes '0', the value of DTOG_TX remains unchanged, while writing '1' makes the bit value toggle. This bit is read/write but it can only be toggled by writing 1.

Bits 5:4 STAT_TX [1:0]: Status bits, for transmission transfers

These bits contain the information about the endpoint status, listed in [Table 105](#). These bits can be toggled by the software to initialize their value. When the application software writes '0', the value remains unchanged, while writing '1' makes the bit value toggle. Hardware sets the STAT_TX bits to NAK, when a correct transfer has occurred (CTR_TX=1) corresponding to a IN or SETUP (control only) transaction addressed to this endpoint. It then waits for the software to prepare the next set of data to be transmitted.

Double-buffered bulk endpoints implement a special transaction flow control, which controls the status based on buffer availability condition (Refer to [Section 25.5.3: Double-buffered endpoints](#)).

If the endpoint is defined as Isochronous, its status can only be "VALID" or "DISABLED".

Therefore, the hardware cannot change the status of the endpoint after a successful transaction. If the software sets the STAT_TX bits to 'STALL' or 'NAK' for an Isochronous endpoint, the USB peripheral behavior is not defined. These bits are read/write but they can be only toggled by writing '1'.

Bits 3:0 EA[3:0]: Endpoint address

Software must write in this field the 4-bit address used to identify the transactions directed to this endpoint. A value must be written before enabling the corresponding endpoint.

Table 102. Reception status encoding

STAT_RX[1:0]	Meaning
00	DISABLED: all reception requests addressed to this endpoint are ignored.
01	STALL: the endpoint is stalled and all reception requests result in a STALL handshake.
10	NAK: the endpoint is naked and all reception requests result in a NAK handshake.
11	VALID: this endpoint is enabled for reception.

Table 103. Endpoint type encoding

EP_TYPE[1:0]	Meaning
00	BULK
01	CONTROL
10	ISO
11	INTERRUPT

Table 104. Endpoint kind meaning

EP_TYPE[1:0]		EP_KIND meaning
00	BULK	DBL_BUF
01	CONTROL	STATUS_OUT
10	ISO	Not used
11	INTERRUPT	Not used

Table 105. Transmission status encoding

STAT_TX[1:0]	Meaning
00	DISABLED : all transmission requests addressed to this endpoint are ignored.
01	STALL : the endpoint is stalled and all transmission requests result in a STALL handshake.
10	NAK : the endpoint is naked and all transmission requests result in a NAK handshake.
11	VALID : this endpoint is enabled for transmission.

25.6.2 Buffer descriptor table

Although the buffer descriptor table is located inside the packet buffer memory, its entries can be considered as additional registers used to configure the location and size of the packet buffers used to exchange data between the USB macro cell and the device.

The first packet memory location is located at 0x4000 6000. The buffer descriptor table entry associated with the USB_EPnR registers is described below. The packet memory should be accessed only by byte (8-bit) or half-word (16-bit) accesses. Word (32-bit) accesses are not allowed.

A thorough explanation of packet buffers and the buffer descriptor table usage can be found in [Structure and usage of packet buffers on page 681](#).

Transmission buffer address n (USB_ADDRn_TX)

Address offset: [USB_BTABLE] + n*8

Note: *In case of double-buffered or isochronous endpoints in the IN direction, this address location is referred to as USB_ADDRn_TX_0.*

In case of double-buffered or isochronous endpoints in the OUT direction, this address location is used for USB_ADDRn_RX_0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ADDRn_TX[15:1]															-
rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	rW	-

Bits 15:1 **ADDRn_TX[15:1]**: Transmission buffer address

These bits point to the starting address of the packet buffer containing data to be transmitted by the endpoint associated with the USB_EPnR register at the next IN token addressed to it.

Bit 0 Must always be written as '0 since packet memory is half-word wide and all packet buffers must be half-word aligned.

Transmission byte count n (USB_COUNTn_TX)

Address offset: [USB_BTABLE] + n*8 + 2

Note: *In case of double-buffered or isochronous endpoints in the IN direction, this address location is referred to as USB_COUNTn_TX_0.*

In case of double-buffered or isochronous endpoints in the OUT direction, this address location is used for USB_COUNTn_RX_0.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	COUNTn_TX[9:0]									
						rW	rW	rW	rW	rW	rW	rW	rW	rW	rW

Bits 15:10 These bits are not used since packet size is limited by USB specifications to 1023 bytes. Their value is not considered by the USB peripheral.

Bits 9:0 **COUNTn_TX[9:0]**: Transmission byte count

These bits contain the number of bytes to be transmitted by the endpoint associated with the USB_EPnR register at the next IN token addressed to it.

Reception buffer address n (USB_ADDRn_RX)

Address offset: [USB_BTABLE] + n*8 + 4

Note: In case of double-buffered or isochronous endpoints in the OUT direction, this address location is referred to as USB_ADDRn_RX_1.

In case of double-buffered or isochronous endpoints in the IN direction, this address location is used for USB_ADDRn_TX_1.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
ADDRn_RX[15:1]															-
rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	rw	-

Bits 15:1 **ADDRn_RX[15:1]**: Reception buffer address

These bits point to the starting address of the packet buffer, which will contain the data received by the endpoint associated with the USB_EPnR register at the next OUT/SETUP token addressed to it.

Bit 0 This bit must always be written as '0 since packet memory is half-word wide and all packet buffers must be half-word aligned.

Reception byte count n (USB_COUNTn_RX)

Address offset: [USB_BTABLE] + n*8 + 6

Note: In case of double-buffered or isochronous endpoints in the OUT direction, this address location is referred to as USB_COUNTn_RX_1.

In case of double-buffered or isochronous endpoints in the IN direction, this address location is used for USB_COUNTn_TX_1.

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
BLSIZE	NUM_BLOCK[4:0]					COUNTn_RX[9:0]									
rw	rw	rw	rw	rw	rw	r	r	r	r	r	r	r	r	r	r

This table location is used to store two different values, both required during packet reception. The most significant bits contains the definition of allocated buffer size, to allow buffer overflow detection, while the least significant part of this location is written back by the USB peripheral at the end of reception to give the actual number of received bytes. Due to the restrictions on the number of available bits, buffer size is represented using the number of allocated memory blocks, where block size can be selected to choose the trade-off between fine-granularity/small-buffer and coarse-granularity/large-buffer. The size of allocated buffer is a part of the endpoint descriptor and it is normally defined during the

enumeration process according to its maxPacketSize parameter value (See “Universal Serial Bus Specification”).

Bit 15 **BL_SIZE**: Block size

This bit selects the size of memory block used to define the allocated buffer area.

- If BL_SIZE=0, the memory block is 2-byte large, which is the minimum block allowed in a half-word wide memory. With this block size the allocated buffer size ranges from 2 to 62 bytes.
- If BL_SIZE=1, the memory block is 32-byte large, which allows to reach the maximum packet length defined by USB specifications. With this block size the allocated buffer size theoretically ranges from 32 to 1024 bytes, which is the longest packet size allowed by USB standard specifications. However, the applicable size is limited by the available buffer memory.

Bits 14:10 **NUM_BLOCK[4:0]**: Number of blocks

These bits define the number of memory blocks allocated to this packet buffer. The actual amount of allocated memory depends on the BL_SIZE value as illustrated in [Table 106](#).

Bits 9:0 **COUNTn_RX[9:0]**: Reception byte count

These bits contain the number of bytes received by the endpoint associated with the USB_EPnR register during the last OUT/SETUP transaction addressed to it.

Table 106. Definition of allocated buffer memory

Value of NUM_BLOCK[4:0]	Memory allocated when BL_SIZE=0	Memory allocated when BL_SIZE=1
0 ('00000)	Not allowed	32 bytes
1 ('00001)	2 bytes	64 bytes
2 ('00010)	4 bytes	96 bytes
3 ('00011)	6 bytes	128 bytes
...	...	...
14 ('01110)	28 bytes	480 bytes
15 ('01111)	30 bytes	512 bytes
16 ('10000)	32 bytes	544 bytes
...	...	...
29 ('11101)	58 bytes	960 bytes
30 ('11110)	60 bytes	992 bytes
31 ('11111)	62 bytes	N/A

25.6.3 USB register map

The table below provides the USB register map and reset values.

Table 107. USB register map and reset values

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0								
0x00	USB_EP0R	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR_RX	0	0	0	0	SETUP	EP_TYPE [1:0]	EP_KIND	CTR_TX	0	0	0	0	0	0	0	0	EA[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
0x04	USB_EP1R	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR_RX	0	0	0	0	SETUP	EP_TYPE [1:0]	EP_KIND	CTR_TX	0	0	0	0	0	0	0	0	EA[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
0x08	USB_EP2R	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR_RX	0	0	0	0	SETUP	EP_TYPE [1:0]	EP_KIND	CTR_TX	0	0	0	0	0	0	0	0	EA[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
0x0C	USB_EP3R	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR_RX	0	0	0	0	SETUP	EP_TYPE [1:0]	EP_KIND	CTR_TX	0	0	0	0	0	0	0	0	EA[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
0x10	USB_EP4R	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR_RX	0	0	0	0	SETUP	EP_TYPE [1:0]	EP_KIND	CTR_TX	0	0	0	0	0	0	0	0	EA[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
0x14	USB_EP5R	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR_RX	0	0	0	0	SETUP	EP_TYPE [1:0]	EP_KIND	CTR_TX	0	0	0	0	0	0	0	0	EA[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
0x18	USB_EP6R	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR_RX	0	0	0	0	SETUP	EP_TYPE [1:0]	EP_KIND	CTR_TX	0	0	0	0	0	0	0	0	EA[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
0x1C	USB_EP7R	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR_RX	0	0	0	0	SETUP	EP_TYPE [1:0]	EP_KIND	CTR_TX	0	0	0	0	0	0	0	0	EA[3:0]						
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0							
0x20-0x3F	Reserved																																								
0x40	USB_CNTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTRM	0	0	0	0	PMAOVRM	ERRM	WKUPM	SUSPM	RESETM	SOFM	ESOFM	L1REQM	Res.	L1RESUME	RESUME	FSUSP	LPMODE	PDWN	FRES				
	Reset value																	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	1	1					
0x44	USB_ISTR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	CTR	0	0	0	0	PMAOVR	ERR	WKUP	SUSP	RESET	SOF	ESOF	L1REQ	Res.	Res.	DIR	EP_ID[3:0]							
	Reset value																	0	0	0	0	0	0	0	0	0	0	0			0	0	0	0	0	0					
0x48	USB_FNR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	RXDP	0	0	0	0	LSOF [1:0]	FN[10:0]																	
	Reset value																	0	0	0	0	0		x	x	x	x	x	x	x	x	x	x	x	x	x					
0x4C	USB_DADDR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	EF	ADD[6:0]															
	Reset value																								0	0	0	0	0	0	0	0	0	0	0	0	0				

Table 107. USB register map and reset values (continued)

Offset	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
0x50	USB_BTABLE	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	BTABLE[15:3]												Res	Res	Res	
	Reset value																	0	0	0	0	0	0	0	0	0	0	0	0				
0x54	USB_LPMCSR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	BESL[3:0]				REMWAKE	Res	Res	Res
	Reset value																												0	0	0	0	
0x58	USB_BCDR	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	Res	PS2DET	SDET	PDET	DCDET	SDEN	PDEN	DCDEN	BCDEN
	Reset value																	0								0	0	0	0	0	0	0	0

Refer to [Section 2.2.2 on page 37](#) for the register boundary addresses.

26 Debug support (DBG)

26.1 Overview

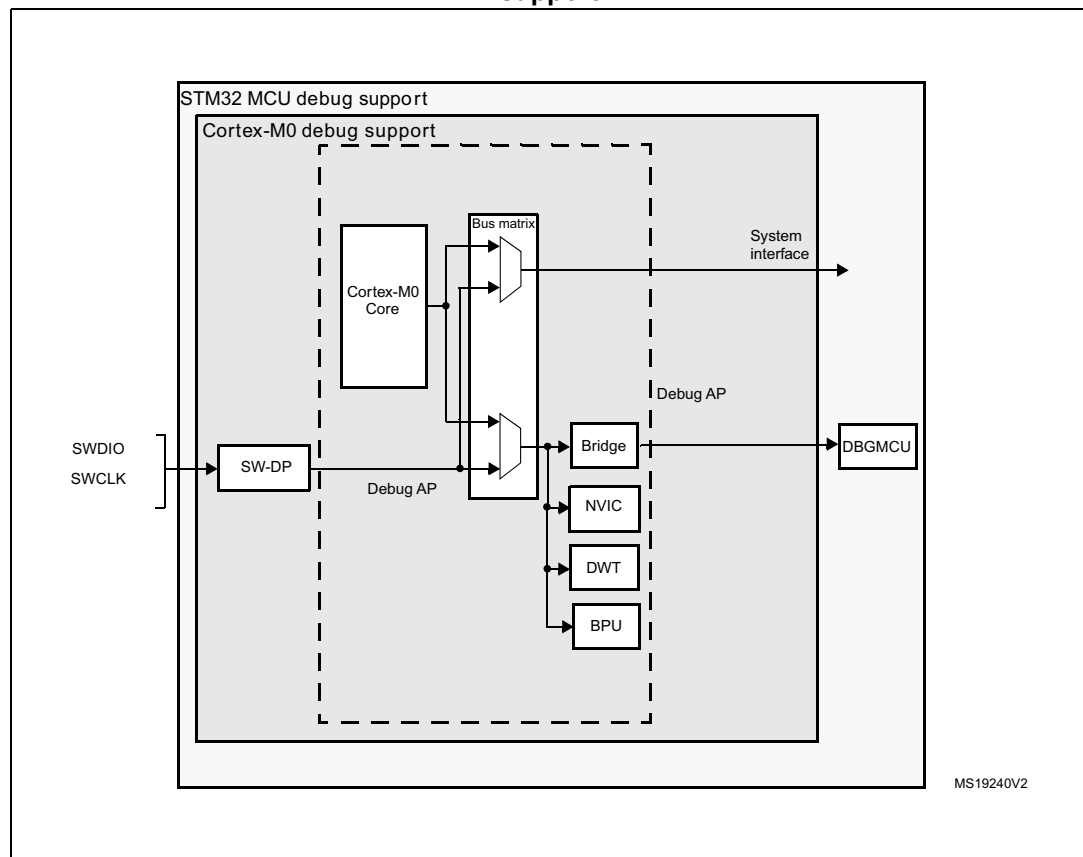
The STM32F0x0 devices are built around a ARM® Cortex®-M0 core which contains hardware extensions for advanced debugging features. The debug extensions allow the core to be stopped either on a given instruction fetch (breakpoint) or data access (watchpoint). When stopped, the core's internal state and the system's external state may be examined. Once examination is complete, the core and the system may be restored and program execution resumed.

The debug features are used by the debugger host when connecting to and debugging the STM32F0x0 MCUs.

One interface for debug is available:

- Serial wire

Figure 263. Block diagram of STM32F0x0 MCU and ARM® Cortex®-M0-level debug support



1. The debug features embedded in the ARM® Cortex®-M0 core are a subset of the ARM CoreSight Design Kit.

The ARM ARM[®] Cortex[®]-M0 core provides integrated on-chip debug support. It is comprised of:

- SW-DP: Serial wire
- BPU: Break point unit
- DWT: Data watchpoint trigger

It also includes debug features dedicated to the STM32F0x0:

- Flexible debug pinout assignment
- MCU debug box (support for low-power modes, control over peripheral clocks, etc.)

Note: For further information on debug functionality supported by the ARM ARM[®] Cortex[®]-M0 core, refer to the ARM[®] Cortex[®]-M0 Technical Reference Manual (see [Section 26.2: Reference ARM documentation](#)).

26.2 Reference ARM documentation

- ARM[®] Cortex[®]-M0 Technical Reference Manual (TRM)
It is available from:
<http://infocenter.arm.com>
- ARM Debug Interface V5
- ARM CoreSight Design Kit revision r1p1 Technical Reference Manual

26.3 Pinout and debug port pins

The STM32F0x0 MCUs are available in various packages with different numbers of available pins.

26.3.1 SWD port pins

Two pins are used as outputs for the SW-DP as alternate functions of general purpose I/Os. These pins are available on all packages.

Table 108. SW debug port pins

SW-DP pin name	SW debug port		Pin assignment
	Type	Debug assignment	
SWDIO	IO	Serial Wire Data Input/Output	PA13
SWCLK	I	Serial Wire Clock	PA14

26.3.2 SW-DP pin assignment

After reset (SYSRESETn or PORESETn), the pins used for the SW-DP are assigned as dedicated pins which are immediately usable by the debugger host.

However, the MCU offers the possibility to disable the SWD port and can then release the associated pins for general-purpose I/O (GPIO) usage. For more details on how to disable SW-DP port pins, please refer to [Section 8.3.2: I/O pin alternate function multiplexer and mapping on page 129](#).

26.3.3 Internal pull-up & pull-down on SWD pins

Once the SW I/O is released by the user software, the GPIO controller takes control of these pins. The reset states of the GPIO control registers put the I/Os in the equivalent states:

- SWDIO: input pull-up
- SWCLK: input pull-down

Having embedded pull-up and pull-down resistors removes the need to add external resistors.

26.4 ID codes and locking mechanism

There are several ID codes inside the MCU. ST strongly recommends the tool manufacturers (for example Keil, IAR, Raisonance) to lock their debugger using the MCU device ID located at address 0x40015800.

Only the DEV_ID[15:0] should be used for identification by the debugger/programmer tools (the revision ID must not be taken into account).

26.4.1 MCU device ID code

The STM32F0xx products integrate an MCU ID code. This ID identifies the ST MCU part number and the die revision.

This code is accessible by the software debug port (two pins) or by the user software.

For code example refer to the Appendix section [A.10.1: DBG read device ID code example](#).

DBGMCU_IDCODE

Address: 0x40015800

Only 32-bit access supported. Read-only

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
REV_ID															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	DEV_ID											
				r	r	r	r	r	r	r	r	r	r	r	r

Bits 31:16 **REV_ID[15:0]** Revision identifier

This field indicates the revision of the device. Refer to [Table 114](#).

Bits 15:12 Reserved: read 0b0110.

Bits 11:0 **DEV_ID[11:0]**: Device identifier

This field indicates the device ID. Refer to [Table 114](#).

Table 109. DEV_ID and REV_ID field values

Device	DEV_ID	Revision code	Revision number	REV_ID
STM32F030x4 STM32F030x6	0x444	A or 1	1.0	0x1000
STM32F070x6	0x445	A	1.0	0x1000
STM32F030x8	0x440	B or 1	1.1	0x1001
STM32F070xB	0x448	Y or 1	2.1	0x2001
STM32F030xC	0x442	A	1.0	0x1000

26.5 SWD port

26.5.1 SWD protocol introduction

This synchronous serial protocol uses two pins:

- SWCLK: clock from host to target
- SWDIO: bidirectional

The protocol allows two banks of registers (DPACC registers and APACC registers) to be read and written to.

Bits are transferred LSB-first on the wire.

For SWDIO bidirectional management, the line must be pulled-up on the board (100 kΩ recommended by ARM).

Each time the direction of SWDIO changes in the protocol, a turnaround time is inserted where the line is not driven by the host nor the target. By default, this turnaround time is one bit time, however this can be adjusted by configuring the SWCLK frequency.

26.5.2 SWD protocol sequence

Each sequence consist of three phases:

1. Packet request (8 bits) transmitted by the host
2. Acknowledge response (3 bits) transmitted by the target
3. Data transfer phase (33 bits) transmitted by the host or the target

Table 110. Packet request (8-bits)

Bit	Name	Description
0	Start	Must be “1”
1	APnDP	0: DP Access 1: AP Access
2	RnW	0: Write Request 1: Read Request
4:3	A[3:2]	Address field of the DP or AP registers (refer to Table 114 on page 718)
5	Parity	Single bit parity of preceding bits
6	Stop	0
7	Park	Not driven by the host. Must be read as “1” by the target because of the pull-up

Refer to the ARM® Cortex®-M0 *TRM* for a detailed description of DPACC and APACC registers.

The packet request is always followed by the turnaround time (default 1 bit) where neither the host nor target drive the line.

Table 111. ACK response (3 bits)

Bit	Name	Description
0..2	ACK	001: FAULT 010: WAIT 100: OK

The ACK Response must be followed by a turnaround time only if it is a READ transaction or if a WAIT or FAULT acknowledge has been received.

Table 112. DATA transfer (33 bits)

Bit	Name	Description
0..31	WDATA or RDATA	Write or Read data
32	Parity	Single parity of the 32 data bits

The DATA transfer must be followed by a turnaround time only if it is a READ transaction.

26.5.3 SW-DP state machine (reset, idle states, ID code)

The State Machine of the SW-DP has an internal ID code which identifies the SW-DP. It follows the JEP-106 standard. This ID code is the default ARM one and is set to **0x0BB11477** (corresponding to ARM® Cortex®-M0).

Note: Note that the SW-DP state machine is inactive until the target reads this ID code.

- The SW-DP state machine is in RESET STATE either after power-on reset, or after the line is high for more than 50 cycles
- The SW-DP state machine is in IDLE STATE if the line is low for at least two cycles after RESET state.
- After RESET state, it is **mandatory** to first enter into an IDLE state AND to perform a READ access of the DP-SW ID CODE register. Otherwise, the target will issue a FAULT acknowledge response on another transactions.

Further details of the SW-DP state machine can be found in the ARM® Cortex®-M0 TRM and the CoreSight Design Kit r1p0 TRM.

26.5.4 DP and AP read/write accesses

- Read accesses to the DP are not posted: the target response can be immediate (if ACK=OK) or can be delayed (if ACK=WAIT).
- Read accesses to the AP are posted. This means that the result of the access is returned on the next transfer. If the next access to be done is NOT an AP access, then the DP-RDBUFF register must be read to obtain the result.
The READOK flag of the DP-CTRL/STAT register is updated on every AP read access or RDBUFF read request to know if the AP read access was successful.
- The SW-DP implements a write buffer (for both DP or AP writes), that enables it to accept a write operation even when other transactions are still outstanding. If the write buffer is full, the target acknowledge response is "WAIT". With the exception of

IDCODE read or CTRL/STAT read or ABORT write which are accepted even if the write buffer is full.

- Because of the asynchronous clock domains SWCLK and HCLK, two extra SWCLK cycles are needed after a write transaction (after the parity bit) to make the write effective internally. These cycles should be applied while driving the line low (IDLE state)

This is particularly important when writing the CTRL/STAT for a power-up request. If the next transaction (requiring a power-up) occurs immediately, it will fail.

26.5.5 SW-DP registers

Access to these registers are initiated when APnDP=0

Table 113. SW-DP registers

A[3:2]	R/W	CTRLSEL bit of SELECT register	Register	Notes
00	Read		IDCODE	The manufacturer code is set to the default ARM code for Cortex-M0: 0x0BB11477 (identifies the SW-DP)
00	Write		ABORT	
01	Read/Write	0	DP-CTRL/STAT	Purpose is to: – request a system or debug power-up – configure the transfer operation for AP accesses – control the pushed compare and pushed verify operations. – read some status flags (overrun, power-up acknowledges)
01	Read/Write	1	WIRE CONTROL	Purpose is to configure the physical serial port protocol (like the duration of the turnaround time)
10	Read		READ RESEND	Enables recovery of the read data from a corrupted debugger transfer, without repeating the original AP transfer.
10	Write		SELECT	The purpose is to select the current access port and the active 4-words register window
11	Read/Write		READ BUFFER	This read buffer is useful because AP accesses are posted (the result of a read AP request is available on the next AP transaction). This read buffer captures data from the AP, presented as the result of a previous read, without initiating a new transaction

26.5.6 SW-AP registers

Access to these registers are initiated when APnDP=1

There are many AP Registers addressed as the combination of:

- The shifted value A[3:2]
- The current value of the DP SELECT register.

Table 114. 32-bit debug port registers addressed through the shifted value A[3:2]

Address	A[3:2] value	Description
0x0	00	Reserved, must be kept at reset value.
0x4	01	DP CTRL/STAT register. Used to: – Request a system or debug power-up – Configure the transfer operation for AP accesses – Control the pushed compare and pushed verify operations. – Read some status flags (overrun, power-up acknowledges)
0x8	10	DP SELECT register: Used to select the current access port and the active 4-words register window. – Bits 31:24: APSEL: select the current AP – Bits 23:8: reserved – Bits 7:4: APBANKSEL: select the active 4-words register window on the current AP – Bits 3:0: reserved
0xC	11	DP RDBUFF register: Used to allow the debugger to get the final result after a sequence of operations (without requesting new JTAG-DP operation)

26.6 Core debug

Core debug is accessed through the core debug registers. Debug access to these registers is by means of the debug access port. It consists of four registers:

Table 115. Core debug registers

Register	Description
DHCSR	<i>The 32-bit Debug Halting Control and Status Register</i> This provides status information about the state of the processor enable core debug halt and step the processor
DCRSR	<i>The 17-bit Debug Core Register Selector Register:</i> This selects the processor register to transfer data to or from.
DCRDR	<i>The 32-bit Debug Core Register Data Register:</i> This holds data for reading and writing registers to and from the processor selected by the DCRSR (Selector) register.
DEMCR	<i>The 32-bit Debug Exception and Monitor Control Register:</i> This provides Vector Catching and Debug Monitor Control.

These registers are not reset by a system reset. They are only reset by a power-on reset. Refer to the ARM® Cortex®-M0 TRM for further details.

To Halt on reset, it is necessary to:

- enable the bit0 (VC_CORRESET) of the Debug and Exception Monitor Control Register
- enable the bit0 (C_DEBUGEN) of the Debug Halting Control and Status Register

26.7 BPU (Break Point Unit)

The Cortex-M0 BPU implementation provides four breakpoint registers. The BPU is a subset of the Flash Patch and Breakpoint (FPB) block available in ARMv7-M (Cortex-M3 & Cortex-M4).

26.7.1 BPU functionality

The processor breakpoints implement PC based breakpoint functionality.

Refer the ARMv6-M ARM and the ARM CoreSight Components Technical Reference Manual for more information about the BPU CoreSight identification registers, and their addresses and access types.

26.8 DWT (Data Watchpoint)

The Cortex-M0 DWT implementation provides two watchpoint register sets.

26.8.1 DWT functionality

The processor watchpoints implement both data address and PC based watchpoint functionality, a PC sampling register, and support comparator address masking, as described in the *ARMv6-M ARM*.

26.8.2 DWT Program Counter Sample Register

A processor that implements the data watchpoint unit also implements the ARMv6-M optional *DWT Program Counter Sample Register* (DWT_PCSR). This register permits a debugger to periodically sample the PC without halting the processor. This provides coarse grained profiling. See the *ARMv6-M ARM* for more information.

The Cortex-M0 DWT_PCSR records both instructions that pass their condition codes and those that fail.

26.9 MCU debug component (DBGMCU)

The MCU debug component helps the debugger provide support for:

- Low-power modes
- Clock control for timers, watchdog and I2C during a breakpoint

26.9.1 Debug support for low-power modes

To enter low-power mode, the instruction WFI or WFE must be executed.

The MCU implements several low-power modes which can either deactivate the CPU clock or reduce the power of the CPU.

The core does not allow FCLK or HCLK to be turned off during a debug session. As these are required for the debugger connection, during a debug, they must remain active. The MCU integrates special means to allow the user to debug software in low-power modes.

For this, the debugger host must first set some debug configuration registers to change the low-power mode behavior:

- In Sleep mode: FCLK and HCLK are still active. Consequently, this mode does not impose any restrictions on the standard debug features.
- In Stop/Standby mode, the DBG_STOP bit must be previously set by the debugger.

This enables the internal RC oscillator clock to feed FCLK and HCLK in Stop mode.

For code example refer to the Appendix section [A.10.2: DBG debug in Low-power mode code example](#).

26.9.2 Debug support for timers, watchdog and I²C

During a breakpoint, it is necessary to choose how the counter of timers and watchdog should behave:

- They can continue to count inside a breakpoint. This is usually required when a PWM is controlling a motor, for example.
- They can stop to count inside a breakpoint. This is required for watchdog purposes.

For the I²C, the user can choose to block the SMBUS timeout during a breakpoint.

26.9.3 Debug MCU configuration register (DBGMCU_CR)

This register allows the configuration of the MCU under DEBUG. This concerns:

- Low-power mode support

This DBGMCU_CR is mapped at address 0x4001 5804.

It is asynchronously reset by the PORESET (and not the system reset). It can be written by the debugger under system reset.

If the debugger host does not support these features, it is still possible for the user software to write to these registers.

Address: 0x40015804

Only 32-bit access supported

POR Reset: 0x0000 0000 (not reset by system reset)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG_STANDBY	DBG_STOP	Res.
													rw	rw	

Bits 31:3 Reserved, must be kept at reset value.

Bit 2 **DBG_STANDBY**: Debug Standby mode

0: (FCLK=Off, HCLK=Off) The whole digital part is unpowered.

From software point of view, exiting from Standby is identical than fetching reset vector (except a few status bit indicated that the MCU is resuming from Standby)

1: (FCLK=On, HCLK=On) In this case, the digital part is not unpowered and FCLK and HCLK are provided by the internal RC oscillator which remains active. In addition, the MCU generate a system reset during Standby mode so that exiting from Standby is identical than fetching from reset

Bit 1 **DBG_STOP**: Debug Stop mode

0: (FCLK=Off, HCLK=Off) In STOP mode, the clock controller disables all clocks (including HCLK and FCLK). When exiting from STOP mode, the clock configuration is identical to the one after RESET (CPU clocked by the 8 MHz internal RC oscillator (HSI)). Consequently, the software must reprogram the clock controller to enable the PLL, the Xtal, etc.

1: (FCLK=On, HCLK=On) In this case, when entering STOP mode, FCLK and HCLK are provided by the internal RC oscillator which remains active in STOP mode. When exiting STOP mode, the software must reprogram the clock controller to enable the PLL, the Xtal, etc. (in the same way it would do in case of DBG_STOP=0)

26.9.4 Debug MCU APB1 freeze register (DBGMCU_APB1_FZ)

The DBGMCU_APB1_FZ register is used to configure the MCU under DEBUG. It concerns some APB peripherals:

- Timer clock counter freeze
- I2C SMBUS timeout freeze
- System window watchdog and independent watchdog counter freeze support

This DBGMCU_APB1_FZ is mapped at address 0x4001 5808.

The register is asynchronously reset by the POR (and not the system reset). It can be written by the debugger under system reset.

Address offset: 0x08

Only 32-bit access are supported.

Power on reset (POR): 0x0000 0000 (not reset by system reset)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG_I2C1_SMBUS_TIMEOUT	Res.	Res.	Res.	Res.	Res.
										rw					
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	DBG_IWDG_STOP	DBG_WWDG_STOP	DBG_RTC_STOP	Res.	DBG_TIM14_STOP	Res.	Res.	DBG_TIM7_STOP	DBG_TIM6_STOP	Res.	Res.	DBG_TIM3_STOP	Res.
			rw	rw	rw		rw			rw	rw			rw	

Bits 31:22 Reserved, must be kept at reset value.

- Bit 21 **DBG_I2C1_SMBUS_TIMEOUT**: SMBUS timeout mode stopped when core is halted
- 0: Same behavior as in normal mode
 - 1: The SMBUS timeout is frozen

Bits 20:13 Reserved, must be kept at reset value.

- Bit 12 **DBG_IWDG_STOP**: Debug independent watchdog stopped when core is halted
- 0: The independent watchdog counter clock continues even if the core is halted
 - 1: The independent watchdog counter clock is stopped when the core is halted

- Bit 11 **DBG_WWDG_STOP**: Debug window watchdog stopped when core is halted
- 0: The window watchdog counter clock continues even if the core is halted
 - 1: The window watchdog counter clock is stopped when the core is halted

- Bit 10 **DBG_RTC_STOP**: Debug RTC stopped when core is halted
0: The clock of the RTC counter is fed even if the core is halted
1: The clock of the RTC counter is stopped when the core is halted
- Bit 9 Reserved, must be kept at reset value.
- Bit 8 **DBG_TIM14_STOP**: TIM14 counter stopped when core is halted
0: The counter clock of TIM14 is fed even if the core is halted
1: The counter clock of TIM14 is stopped when the core is halted
- Bits 7:6 Reserved, must be kept at reset value.
- Bit 5 **DBG_TIM7_STOP**: TIM7 counter stopped when core is halted.
0: The counter clock of TIM7 is fed even if the core is halted
1: The counter clock of TIM7 is stopped when the core is halted
- Bit 4 **DBG_TIM6_STOP**: TIM6 counter stopped when core is halted
0: The counter clock of TIM6 is fed even if the core is halted
1: The counter clock of TIM6 is stopped when the core is halted
- Bits 3:2 Reserved, must be kept at reset value.
- Bit 1 **DBG_TIM3_STOP**: TIM3 counter stopped when core is halted
0: The counter clock of TIM3 is fed even if the core is halted
1: The counter clock of TIM3 is stopped when the core is halted
- Bit 0 Reserved, must be kept at reset value.

26.9.5 Debug MCU APB2 freeze register (DBGMCU_APB2_FZ)

The DBGMCU_APB2_FZ register is used to configure the MCU under DEBUG. It concerns some APB peripherals:

- Timer clock counter freeze

This register is mapped at address 0x4001580C.

It is asynchronously reset by the POR (and not the system reset). It can be written by the debugger under system reset.

Address offset: 0x0C

Only 32-bit access is supported.

POR: 0x0000 0000 (not reset by system reset)

31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16
Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG_TIM17_STOP	DBG_TIM16_STOP	DBG_TIM15_STOP
													rw	rw	rw
15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
Res.	Res.	Res.	Res.	DBG_TIM1_STOP	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.
				rw											

Bits 31:19 Reserved, must be kept at reset value.

Bit 18 **DBG_TIM17_STOP**: TIM17 counter stopped when core is halted

0: The counter clock of TIM17 is fed even if the core is halted

1: The counter clock of TIM17 is stopped when the core is halted

Bit 17 **DBG_TIM16_STOP**: TIM16 counter stopped when core is halted

0: The counter clock of TIM16 is fed even if the core is halted

1: The counter clock of TIM16 is stopped when the core is halted

Bit 16 **DBG_TIM15_STOP**: TIM15 counter stopped when core is halted

0: The counter clock of TIM15 is fed even if the core is halted

1: The counter clock of TIM15 is stopped when the core is halted

Bits 15:12 Reserved, must be kept at reset value.

Bit 11 **DBG_TIM1_STOP**: TIM1 counter stopped when core is halted

0: The counter clock of TIM 1 is fed even if the core is halted

1: The counter clock of TIM 1 is stopped when the core is halted

Bits 0:10 Reserved, must be kept at reset value.

26.9.6 DBG register map

The following table summarizes the Debug registers.

Table 116. DBG register map and reset values

Addr.	Register	31	30	29	28	27	26	25	24	23	22	21	20	19	18	17	16	15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0	
0x40015800	DBGMCU_IDCODE	REV_ID																Res.	Res.	Res.	Res.	DEV_ID												
	Reset value ⁽¹⁾	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X					X	X	X	X	X	X	X	X	X	X	X	X	
0x40015804	DBGMCU_CR	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG_STANDBY	DBG_STOP	Res.
	Reset value																														0	0		
0x40015808	DBGMCU_APB1_FZ	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG_IWDG_STOP	DBG_WWDG_STOP	DBG_RTC_STOP	Res.	DBG_TIM14_STOP	Res.	Res.	DBG_TIM7_STOP	DBG_TIM6_STOP	Res.	Res.	DBG_TIM3_STOP	Res.	
	Reset value											0									0	0	0		0				0	0		0	0	
0x4001580C	DBGMCU_APB2_FZ	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	DBG_TIM1_STOP	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	Res.	
	Reset value																					0										0	0	

1. The reset value is product dependent. For more information, refer to [Section 26.4.1: MCU device ID code](#).

27 Device electronic signature

The device electronic signature is stored in the System memory area of the Flash memory module, and can be read using the debug interface or by the CPU. It contains factory-programmed identification and calibration data that allow the user firmware or other external devices to automatically match to the characteristics of the STM32F0x0 microcontroller.

27.1 Memory size data register

27.1.1 Flash size data register

Base address: 0x1FFF F7CC
Address offset: 0x00
Read only = 0xXXXX where X is factory-programmed

15	14	13	12	11	10	9	8	7	6	5	4	3	2	1	0
FLASH_SIZE															
r	r	r	r	r	r	r	r	r	r	r	r	r	r	r	r

Bits 15:0 **FLASH_SIZE[15:0]**: Flash memory size
This bitfield indicates the size of the device Flash memory expressed in Kbytes.
As an example, 0x040 corresponds to 64 Kbytes.



Appendix A Code examples

A.1 Introduction

This appendix shows the code examples of the sequence described in this Reference Manual.

These code examples are extracted from the STM32F0xx Snippet firmware package **STM32SnippetsF0** available on www.st.com.

These code examples used the peripheral bit and register description from the CMSIS header file (stm32f0xx.h).

Code lines starting with // should be uncommented if the given register has been modified before.

A.2 Flash operation code example

A.2.1 Flash memory unlocking sequence code

```
/* (1) Wait till no operation is on going */
/* (2) Check that the Flash is unlocked */
/* (3) Perform unlock sequence */
while ((FLASH->SR & FLASH_SR_BSY) != 0) /* (1) */
{
    /* For robust implementation, add here time-out management */
}
if ((FLASH->CR & FLASH_CR_LOCK) != 0) /* (2) */
{
    FLASH->KEYR = FLASH_FKEY1; /* (3) */
    FLASH->KEYR = FLASH_FKEY2;
}
}
```

A.2.2 Main Flash programming sequence code example

```
/* (1) Set the PG bit in the FLASH_CR register to enable programming */
/* (2) Perform the data write (half-word) at the desired address */
/* (3) Wait until the BSY bit is reset in the FLASH_SR register */
/* (4) Check the EOP flag in the FLASH_SR register */
/* (5) clear it by software by writing it at 1 */
/* (6) Reset the PG Bit to disable programming */
FLASH->CR |= FLASH_CR_PG; /* (1) */
*(__IO uint16_t*)(flash_addr) = data; /* (2) */
while ((FLASH->SR & FLASH_SR_BSY) != 0) /* (3) */
{
    /* For robust implementation, add here time-out management */
}
}
```

```
if ((FLASH->SR & FLASH_SR_EOP) != 0) /* (4) */
{
    FLASH->SR = FLASH_SR_EOP; /* (5) */
}
else
{
    /* Manage the error cases */
}
FLASH->CR &= ~FLASH_CR_PG; /* (6) */
```

A.2.3 Page erase sequence code example

```
/* (1) Set the PER bit in the FLASH_CR register to enable page erasing */
/* (2) Program the FLASH_AR register to select a page to erase */
/* (3) Set the STRT bit in the FLASH_CR register to start the erasing */
/* (4) Wait until the BSY bit is reset in the FLASH_SR register */
/* (5) Check the EOP flag in the FLASH_SR register */
/* (6) Clear EOP flag by software by writing EOP at 1 */
/* (7) Reset the PER Bit to disable the page erase */
FLASH->CR |= FLASH_CR_PER; /* (1) */
FLASH->AR = page_addr; /* (2) */
FLASH->CR |= FLASH_CR_STRT; /* (3) */
while ((FLASH->SR & FLASH_SR_BSY) != 0) /* (4) */
{
    /* For robust implementation, add here time-out management */
}
if ((FLASH->SR & FLASH_SR_EOP) != 0) /* (5) */
{
    FLASH->SR = FLASH_SR_EOP; /* (6) */
}
else
{
    /* Manage the error cases */
}
FLASH->CR &= ~FLASH_CR_PER; /* (7) */
```

A.2.4 Mass erase sequence code example

```

/* (1) Set the MER bit in the FLASH_CR register to enable mass erasing */
/* (2) Set the STRT bit in the FLASH_CR register to start the erasing */
/* (3) Wait until the BSY bit is reset in the FLASH_SR register */
/* (4) Check the EOP flag in the FLASH_SR register */
/* (5) Clear EOP flag by software by writing EOP at 1 */
/* (6) Reset the PER Bit to disable the mass erase */
FLASH->CR |= FLASH_CR_MER; /* (1) */
FLASH->CR |= FLASH_CR_STRT; /* (2) */
while ((FLASH->SR & FLASH_SR_BSY) != 0) /* (3) */
{
    /* For robust implementation, add here time-out management */
}

if ((FLASH->SR & FLASH_SR_EOP) != 0) /* (4) */
{
    FLASH->SR = FLASH_SR_EOP; /* (5) */
}
else
{
    /* Manage the error cases */
}
FLASH->CR &= ~FLASH_CR_MER; /* (6) */

```

A.2.5 Option byte unlocking sequence code example

```

/* (1) Wait till no operation is on going */
/* (2) Check that the Flash is unlocked */
/* (3) Perform unlock sequence for Flash */
/* (4) Check that the Option Bytes are unlocked */
/* (5) Perform unlock sequence for Option Bytes */
while ((FLASH->SR & FLASH_SR_BSY) != 0) /* (1) */
{
    /* For robust implementation, add here time-out management */
}
if ((FLASH->CR & FLASH_CR_LOCK) != 0) /* (2) */
{
    FLASH->KEYR = FLASH_FKEY1; /* (3) */
    FLASH->KEYR = FLASH_FKEY2;
}
if ((FLASH->CR & FLASH_CR_OPTWRE) == 0) /* (4) */
{
    FLASH->OPTKEYR = FLASH_OPTKEY1; /* (5) */
    FLASH->OPTKEYR = FLASH_OPTKEY2;
}

```

A.2.6 Option byte programming sequence code example

```
/* (1) Set the PG bit in the FLASH_CR register to enable programming */
/* (2) Perform the data write */
/* (3) Wait until the BSY bit is reset in the FLASH_SR register */
/* (4) Check the EOP flag in the FLASH_SR register */
/* (5) Clear the EOP flag by software by writing it at 1 */
/* (6) Reset the PG Bit to disable programming */
FLASH->CR |= FLASH_CR_OPTPG; /* (1) */
*opt_addr = data; /* (2) */
while ((FLASH->SR & FLASH_SR_BSY) != 0) /* (3) */
{
    /* For robust implementation, add here time-out management */
}
if ((FLASH->SR & FLASH_SR_EOP) != 0) /* (4) */
{
    FLASH->SR = FLASH_SR_EOP; /* (5) */
}
else
{
    /* Manage the error cases */
}
FLASH->CR &= ~FLASH_CR_OPTPG; /* (6) */
```

A.2.7 Option byte erasing sequence code example

```
/* (1) Set the OPTER bit in the FLASH_CR register to enable option byte
    erasing */
/* (2) Set the STRT bit in the FLASH_CR register to start the erasing */
/* (3) Wait until the BSY bit is reset in the FLASH_SR register */
/* (4) Check the EOP flag in the FLASH_SR register */
/* (5) Clear EOP flag by software by writing EOP at 1 */
/* (6) Reset the PER Bit to disable the page erase */
FLASH->CR |= FLASH_CR_OPTER; /* (1) */
FLASH->CR |= FLASH_CR_STRT; /* (2) */
while ((FLASH->SR & FLASH_SR_BSY) != 0) /* (3) */
{
    /* For robust implementation, add here time-out management */
}
if ((FLASH->SR & FLASH_SR_EOP) != 0) /* (4) */
{
    FLASH->SR = FLASH_SR_EOP; /* (5) */
}
else
{
    /* Manage the error cases */
}
FLASH->CR &= ~FLASH_CR_OPTER; /* (6) */
```

A.3 Clock controller

A.3.1 HSE start sequence code example

```

/**
 * Description: This function enables the interrupt on HSE ready,
 *              and start the HSE as external clock.
 */
__INLINE void StartHSE(void)
{
    /* Configure NVIC for RCC */
    /* (1) Enable Interrupt on RCC */
    /* (2) Set priority for RCC */
    NVIC_EnableIRQ(RCC_CRG_IRQn); /* (1) */
    NVIC_SetPriority(RCC_CRG_IRQn, 0); /* (2) */

    /* (1) Enable interrupt on HSE ready */
    /* (2) Enable the CSS
       Enable the HSE and set HSEBYP to use the external clock
       instead of an oscillator
       Enable HSE */
    /* Note : the clock is switched to HSE in the RCC_CRG_IRQHandler ISR */
    RCC->CR |= RCC_CR_HSERDYIE; /* (1) */
    RCC->CR |= RCC_CR_CSSON | RCC_CR_HSEBYP | RCC_CR_HSEON; /* (2) */
}

/**
 * Description: This function handles RCC interrupt request
 *              and switch the system clock to HSE.
 */
void RCC_CRG_IRQHandler(void)
{
    /* (1) Check the flag HSE ready */
    /* (2) Clear the flag HSE ready */
    /* (3) Switch the system clock to HSE */

    if ((RCC->CR & RCC_CR_HSERDYF) != 0) /* (1) */
    {
        RCC->CR |= RCC_CR_HSERDYC; /* (2) */
        RCC->CFGR = ((RCC->CFGR & (~RCC_CFGR_SW)) | RCC_CFGR_SW_0); /* (3) */
    }
    else
    {
        /* Report an error */
    }
}

```

A.3.2 PLL configuration modification code example

```

/* (1) Test if PLL is used as System clock */
/* (2) Select HSI as system clock */
/* (3) Wait for HSI switched */
/* (4) Disable the PLL */
/* (5) Wait until PLLRDY is cleared */
/* (6) Set the PLL multiplier to 6 */
/* (7) Enable the PLL */
/* (8) Wait until PLLRDY is set */
/* (9) Select PLL as system clock */
/* (10) Wait until the PLL is switched on */
if ((RCC->CFGR & RCC_CFGR_SWS) == RCC_CFGR_SWS_PLL) /* (1) */
{
    RCC->CFGR &= (uint32_t) (~RCC_CFGR_SW); /* (2) */
    while ((RCC->CFGR & RCC_CFGR_SWS) != RCC_CFGR_SWS_HSI) /* (3) */
    {
        /* For robust implementation, add here time-out management */
    }
}
RCC->CR &= (uint32_t) (~RCC_CR_PLLON); /* (4) */
while((RCC->CR & RCC_CR_PLLRDY) != 0) /* (5) */
{
    /* For robust implementation, add here time-out management */
}
RCC->CFGR = RCC->CFGR & (~RCC_CFGR_PLLMUL) | (RCC_CFGR_PLLMUL6); /* (6) */
RCC->CR |= RCC_CR_PLLON; /* (7) */
while((RCC->CR & RCC_CR_PLLRDY) == 0) /* (8) */
{
    /* For robust implementation, add here time-out management */
}
RCC->CFGR |= (uint32_t) (RCC_CFGR_SW_PLL); /* (9) */
while ((RCC->CFGR & RCC_CFGR_SWS) != RCC_CFGR_SWS_PLL) /* (10) */
{
    /* For robust implementation, add here time-out management */
}
}

```

A.3.3 MCO selection code example

```

/* Select system clock to be output on the MCO without prescaler */
RCC->CFGR |= RCC_CFGR_MCO_SYSCLK;

```


A.3.4 Clock measurement configuration with TIM14 code example

```

/**
 * Description: This function configures the TIM14 as input capture
 *             and enables the interrupt on TIM14
 */
__INLINE void ConfigureTIM14asInputCapture(void)
{
    /* (1) Enable the peripheral clock of Timer 14 */
    /* (2) Select the active input TI1, Program the input filter, and prescaler
        */
    /* (3) Enable interrupt on Capture/Compare */
    RCC->APB1ENR |= RCC_APB1ENR_TIM14EN; /* (1) */
    TIM14->CCMR1 |= TIM_CCMR1_IC1F_0 | TIM_CCMR1_IC1F_1 \
        | TIM_CCMR1_CC1S_0 | TIM_CCMR1_IC1PSC_1; /* (2) */
    TIM14->DIER |= TIM_DIER_CC1IE; /* (3) */

    /* Configure NVIC for TIM14 */
    /* (4) Enable Interrupt on TIM14 */
    /* (5) Set priority for TIM14 */
    NVIC_EnableIRQ(TIM14_IRQn); /* (4) */
    NVIC_SetPriority(TIM14_IRQn, 0); /* (5) */

    /* (6) Select HSE/32 as input on TI1 */
    /* (7) Enable counter */
    /* (8) Enable capture */
    TIM14->OR |= TIM14_OR_TI1_RMP_1; /* (6) */
    TIM14->CR1 |= TIM_CR1_CEN; /* (7) */
    TIM14->CCER |= TIM_CCER_CC1E; /* (8) */
}

```

Note: The measurement is done in the TIM14 interrupt subroutine.

A.4 GPIO

A.4.1 Lock sequence code example

```
/**
 * Description: This function locks the targeted pins of Port A
 *              configuration
 *              This function can be easily modified to lock Port B
 * Parameter: lock contains the port pin mask to be locked
 */
void LockGPIOA(uint16_t lock)
{
    /* (1) Write LCKK bit to 1 and set the pin bits to lock */
    /* (2) Write LCKK bit to 0 and set the pin bits to lock */
    /* (3) Write LCKK bit to 1 and set the pin bits to lock */
    /* (4) Read the Lock register */
    /* (5) Check the Lock register (optional) */
    GPIOA->LCKR = GPIO_LCKR_LCKK + lock; /* (1) */
    GPIOA->LCKR = lock; /* (2) */
    GPIOA->LCKR = GPIO_LCKR_LCKK + lock; /* (3) */
    GPIOA->LCKR; /* (4) */
    if ((GPIOA->LCKR & GPIO_LCKR_LCKK) == 0) /* (5) */
    {
        /* Manage an error */
    }
}
```

A.4.2 Alternate function selection sequence code example

```
/* This sequence select AF2 for GPIOA4, 8 and 9. This can be easily adapted
   with another port by changing all GPIOA references by another GPIO port,
   and the alternate function number can be changed by replacing 0x04 or
   0x02 for
   each pin by the targeted alternate function in the 2 last code lines. */
/* (1) Enable the peripheral clock of GPIOA */
/* (2) Select alternate function mode on GPIOA pin 4, 8 and 9 */
/* (3) Select AF4 on PA4 in AFRL for TIM14_CH1 */
/* (4) Select AF2 on PA8 and PA9 in AFRH for TIM1_CH1 and TIM1_CH2 */
RCC->AHBENR |= RCC_AHBENR_GPIOAEN; /* (1) */
GPIOA->MODER = (GPIOA->MODER & ~(GPIO_MODER_MODER4 | GPIO_MODER_MODER8
| GPIO_MODER_MODER9)) | GPIO_MODER_MODER4_1
| GPIO_MODER_MODER8_1 | GPIO_MODER_MODER9_1; /* (2) */
GPIOA->AFR[0] |= 0x04 << GPIO_AFRL_AFRL4_Pos; /* (3) */
GPIOA->AFR[1] |= (0x02 << GPIO_AFRH_AFRH8_Pos) | (0x02 <<
GPIO_AFRH_AFRH9_Pos); /* (4) */
```

A.4.3 Analog GPIO configuration code example

```

/* (1) Enable the peripheral clock of GPIOA, GPIOB and GPIOC */
/* (2) Select analog mode for PA1 */
/* (3) Select analog mode for PB1 */
/* (4) Select analog mode for PC0 */
RCC->AHBENR |= RCC_AHBENR_GPIOAEN | RCC_AHBENR_GPIOBEN
              | RCC_AHBENR_GPIOCEN; /* (1) */
GPIOA->MODER |= GPIO_MODER_MODER1; /* (2) */
GPIOB->MODER |= GPIO_MODER_MODER1; /* (3) */
GPIOC->MODER |= GPIO_MODER_MODER0; /* (4) */

```

A.5 DMA

A.5.1 DMA Channel Configuration sequence code example

```

/* The following example is given for the ADC. It can be easily ported on
   any peripheral supporting DMA transfer taking of the associated channel
   to the peripheral, this must check in the datasheet. */
/* (1) Enable the peripheral clock on DMA */
/* (2) Enable DMA transfer on ADC */
/* (3) Configure the peripheral data register address */
/* (4) Configure the memory address */
/* (5) Configure the number of DMA transfer to be performs on channel 1 */
/* (6) Configure increment, size and interrupts */
/* (7) Enable DMA Channel 1 */
RCC->AHBENR |= RCC_AHBENR_DMA1EN; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_DMAEN; /* (2) */
DMA1_Channel1->CPAR = (uint32_t) (&(ADC1->DR)); /* (3) */
DMA1_Channel1->CMAR = (uint32_t)(ADC_array); /* (4) */
DMA1_Channel1->CNDTR = 3; /* (5) */
DMA1_Channel1->CCR |= DMA_CCR_MINC | DMA_CCR_MSIZE_0 | DMA_CCR_PSIZE_0
                    | DMA_CCR_TEIE | DMA_CCR_TCIE ; /* (6) */
DMA1_Channel1->CCR |= DMA_CCR_EN; /* (7) */
/* Configure NVIC for DMA */
/* (1) Enable Interrupt on DMA Channel 1 */
/* (2) Set priority for DMA Channel 1 */
NVIC_EnableIRQ(DMA1_Channel1_IRQn); /* (1) */
NVIC_SetPriority(DMA1_Channel1_IRQn, 0); /* (2) */

```

A.6 Interrupts and event

A.6.1 NVIC initialization example

```
/* (1) Enable Interrupt on ADC */
/* (2) Set priority for ADC to 2*/
NVIC_EnableIRQ(ADC1_COMP_IRQn); /* (1) */
NVIC_SetPriority(ADC1_COMP_IRQn,2); /* (2) */
```

A.6.2 External interrupt selection code example

```
/* (1) Enable the peripheral clock of GPIOA */
/* (2) Select Port A for pin 0 external interrupt by writing 0000 in
EXTI0 (reset value)*/
/* (3) Configure the corresponding mask bit in the EXTI_IMR register */
/* (4) Configure the Trigger Selection bits of the Interrupt line on
rising edge*/
/* (5) Configure the Trigger Selection bits of the Interrupt line on
falling edge*/
RCC->AHBENR |= RCC_AHBENR_GPIOAEN; /* (1) */
//SYSCFG->EXTICR[1] &= (uint16_t)~SYSCFG_EXTICR1_EXTI0_PA; /* (2) */
EXTI->IMR = 0x0001; /* (3) */
EXTI->RTSR = 0x0001; /* (4) */
EXTI->FTSR = 0x0001; /* (5) */
/* Configure NVIC for External Interrupt */
/* (1) Enable Interrupt on EXTI0_1 */
/* (2) Set priority for EXTI0_1 */
NVIC_EnableIRQ(EXTI0_1_IRQn); /* (1) */
NVIC_SetPriority(EXTI0_1_IRQn,0); /* (2) */
```

A.7 ADC

A.7.1 ADC Calibration code example

```
/* (1) Ensure that ADEN = 0 */
/* (2) Clear ADEN by setting ADDIS*/
/* (3) Clear DMAEN */
/* (4) Launch the calibration by setting ADCAL */
/* (5) Wait until ADCAL=0 */
if ((ADC1->CR & ADC_CR_ADEN) != 0) /* (1) */
{
    ADC1->CR |= ADC_CR_ADDIS; /* (2) */
}
while ((ADC1->CR & ADC_CR_ADEN) != 0)
{
    /* For robust implementation, add here time-out management */
}
ADC1->CFGR1 &= ~ADC_CFGR1_DMAEN; /* (3) */
ADC1->CR |= ADC_CR_ADCAL; /* (4) */
while ((ADC1->CR & ADC_CR_ADCAL) != 0) /* (5) */
{
    /* For robust implementation, add here time-out management */
}
```

A.7.2 ADC enable sequence code example

```
/* (1) Ensure that ADRDY = 0 */
/* (2) Clear ADRDY */
/* (3) Enable the ADC */
/* (4) Wait until ADC ready */
if ((ADC1->ISR & ADC_ISR_ADRDY) != 0) /* (1) */
{
    ADC1->ISR |= ADC_CR_ADRDY; /* (2) */
}
ADC1->CR |= ADC_CR_ADEN; /* (3) */
while ((ADC1->ISR & ADC_ISR_ADRDY) == 0) /* (4) */
{
    /* For robust implementation, add here time-out management */
}
```

A.7.3 ADC disable sequence code example

```
/* (1) Stop any ongoing conversion */
/* (2) Wait until ADSTP is reset by hardware i.e. conversion is stopped */
/* (3) Disable the ADC */
/* (4) Wait until the ADC is fully disabled */
ADC1->CR |= ADC_CR_ADSTP; /* (1) */
while ((ADC1->CR & ADC_CR_ADSTP) != 0) /* (2) */
{
    /* For robust implementation, add here time-out management */
}
ADC1->CR |= ADC_CR_ADDIS; /* (3) */
while ((ADC1->CR & ADC_CR_ADEN) != 0) /* (4) */
{
    /* For robust implementation, add here time-out management */
}
```

A.7.4 ADC Clock selection code example

```
/* This code selects the HSI14 as clock source. */
/* (1) Enable the peripheral clock of the ADC */
/* (2) Start HSI14 RC oscillator */
/* (3) Wait HSI14 is ready */
/* (4) Select HSI14 by writing 00 in CKMODE (reset value) */
RCC->APB2ENR |= RCC_APB2ENR_ADC1EN; /* (1) */
RCC->CR2 |= RCC_CR2_HSI14ON; /* (2) */
while ((RCC->CR2 & RCC_CR2_HSI14RDY) == 0) /* (3) */
{
    /* For robust implementation, add here time-out management */
}
//ADC1->CFGR2 &= (~ADC_CFGR2_CKMODE); /* (4) */
```

A.7.5 Single conversion sequence code example - Software trigger

```

/* (1) Select HSI14 by writing 00 in CKMODE (reset value) */
/* (2) Select CHSEL0, CHSEL9, CHSEL10 and CHSEL17 for VRefInt */
/* (3) Select a sampling mode of 111 i.e. 239.5 ADC clk to be greater
    than 17.1us */
/* (4) Wake-up the VREFINT (only for VBAT, Temp sensor and VRefInt) */
//ADC1->CFGR2 &= ~ADC_CFGR2_CKMODE; /* (1) */
ADC1->CHSELR = ADC_CHSELR_CHSEL0 | ADC_CHSELR_CHSEL9
               | ADC_CHSELR_CHSEL10 | ADC_CHSELR_CHSEL17; /* (2) */
ADC1->SMPR |= ADC_SMPR_SMP_0 | ADC_SMPR_SMP_1 | ADC_SMPR_SMP_2; /* (3) */
ADC->CCR |= ADC_CCR_VREFEN; /* (4) */
while (1)
{
    /* Performs the AD conversion */
    ADC1->CR |= ADC_CR_ADSTART; /* Start the ADC conversion */
    for (i=0; i < 4; i++)
    {
        while ((ADC1->ISR & ADC_ISR_EOC) == 0) /* Wait end of conversion */
        {
            /* For robust implementation, add here time-out management */
        }
        ADC_Result[i] = ADC1->DR; /* Store the ADC conversion result */
    }
    ADC1->CFGR1 ^= ADC_CFGR1_SCANDIR; /* Toggle the scan direction */
}

```

A.7.6 Continuous conversion sequence code example - Software trigger

```

/* This code example configures the AD conversion in continuous mode and in
    backward scan. It also enable the interrupts. */
/* (1) Select HSI14 by writing 00 in CKMODE (reset value) */
/* (2) Select the continuous mode and scanning direction */
/* (3) Select CHSEL1, CHSEL9, CHSEL10 and CHSEL17 */
/* (4) Select a sampling mode of 111 i.e. 239.5 ADC clk to be greater than
    17.1us */
/* (5) Enable interrupts on EOC, EOSEQ and overrun */
/* (6) Wake-up the VREFINT (only for VBAT, Temp sensor and VRefInt) */
//ADC1->CFGR2 &= ~ADC_CFGR2_CKMODE; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_CONT | ADC_CFGR1_SCANDIR; /* (2) */
ADC1->CHSELR = ADC_CHSELR_CHSEL1 | ADC_CHSELR_CHSEL9
               | ADC_CHSELR_CHSEL10 | ADC_CHSELR_CHSEL17; /* (3) */
ADC1->SMPR |= ADC_SMPR_SMP_0 | ADC_SMPR_SMP_1 | ADC_SMPR_SMP_2; /* (4) */
ADC1->IER = ADC_IER_EOCIE | ADC_IER_EOSEQIE | ADC_IER_OVRIE; /* (5) */
ADC->CCR |= ADC_CCR_VREFEN; /* (6) */

/* Configure NVIC for ADC */
/* (7) Enable Interrupt on ADC */
/* (8) Set priority for ADC */
NVIC_EnableIRQ(ADC1_COMP_IRQn); /* (7) */
NVIC_SetPriority(ADC1_COMP_IRQn, 0); /* (8) */

```

A.7.7 Single conversion sequence code example - Hardware trigger

```

/* Configure the ADC, the ADC and its clock having previously been
   enabled. */
/* (1) Select HSI14 by writing 00 in CKMODE (reset value) */
/* (2) Select the external trigger on falling edge and external trigger on
   TIM15_TRG0 */
/* (3) Select CHSEL0, 1, 2 and 3 */
//ADC1->CFGR2 &= ~ADC_CFGR2_CKMODE; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_EXTEN_0 | ADC_CFGR1_EXTSEL_2; /* (2) */
ADC1->CHSELR = ADC_CHSELR_CHSEL0 | ADC_CHSELR_CHSEL1
              | ADC_CHSELR_CHSEL2 | ADC_CHSELR_CHSEL3; /* (3) */

```

A.7.8 Continuous conversion sequence code example - Hardware trigger

```

/* (1) Select HSI14 by writing 00 in CKMODE (reset value) */
/* (2) Select the external trigger on TIM15_TRG0 (EXTSEL = 100), falling
   edge (EXTEN = 10), the continuous mode (CONT = 1) */
/* (3) Select CHSEL0/1/2/3 */
/* (4) Enable interrupts on EOC, EOSEQ and overrun */
//ADC1->CFGR2 &= ~ADC_CFGR2_CKMODE; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_EXTEN_1 | ADC_CFGR1_EXTSEL_2
              | ADC_CFGR1_CONT; /* (2) */
ADC1->CHSELR = ADC_CHSELR_CHSEL0 | ADC_CHSELR_CHSEL1
              | ADC_CHSELR_CHSEL2 | ADC_CHSELR_CHSEL3; /* (3) */
ADC1->IER = ADC_IER_EOCIE | ADC_IER_EOSEQIE | ADC_IER_OVRIE; /* (4) */

/* Configure NVIC for ADC */
/* (1) Enable Interrupt on ADC */
/* (2) Set priority for ADC */
NVIC_EnableIRQ(ADC1_COMP_IRQn); /* (1) */
NVIC_SetPriority(ADC1_COMP_IRQn, 0); /* (2) */

```


A.7.9 DMA one shot mode sequence code example

```

/* (1) Enable the peripheral clock on DMA */
/* (2) Enable DMA transfer on ADC - DMACFG is kept at 0
    for one shot mode */
/* (3) Configure the peripheral data register address */
/* (4) Configure the memory address */
/* (5) Configure the number of DMA transfer to be performs
    on DMA channel 1 */
/* (6) Configure increment, size and interrupts */
/* (7) Enable DMA Channel 1 */
RCC->AHBENR |= RCC_AHBENR_DMA1EN; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_DMAEN; /* (2) */
DMA1_Channel1->CPAR = (uint32_t) (&(ADC1->DR)); /* (3) */
DMA1_Channel1->CMAR = (uint32_t)(ADC_array); /* (4) */
DMA1_Channel1->CNDTR = NUMBER_OF_ADC_CHANNEL; /* (5) */
DMA1_Channel1->CCR |= DMA_CCR_MINC | DMA_CCR_MSIZE_0 | DMA_CCR_PSIZE_0
                    | DMA_CCR_TEIE | DMA_CCR_TCIE ; /* (6) */
DMA1_Channel1->CCR |= DMA_CCR_EN; /* (7) */

```

A.7.10 DMA circular mode sequence code example

```

/* (1) Enable the peripheral clock on DMA */
/* (2) Enable DMA transfer on ADC and circular mode */
/* (3) Configure the peripheral data register address */
/* (4) Configure the memory address */
/* (5) Configure the number of DMA transfer to be performs
    on DMA channel 1 */
/* (6) Configure increment, size, interrupts and circular mode */
/* (7) Enable DMA Channel 1 */
RCC->AHBENR |= RCC_AHBENR_DMA1EN; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_DMAEN | ADC_CFGR1_DMCFG; /* (2) */
DMA1_Channel1->CPAR = (uint32_t) (&(ADC1->DR)); /* (3) */
DMA1_Channel1->CMAR = (uint32_t)(ADC_array); /* (4) */
DMA1_Channel1->CNDTR = NUMBER_OF_ADC_CHANNEL; /* (5) */
DMA1_Channel1->CCR |= DMA_CCR_MINC | DMA_CCR_MSIZE_0 | DMA_CCR_PSIZE_0
                    | DMA_CCR_TEIE | DMA_CCR_CIRC; /* (6) */
DMA1_Channel1->CCR |= DMA_CCR_EN; /* (7) */

```

A.7.11 Wait mode sequence code example

```

/* (1) Select HSI14 by writing 00 in CKMODE (reset value) */
/* (2) Select the continuous mode and the wait mode */
/* (3) Select CHSEL1/2/3 */
ADC1->CFGR2 &= ~ADC_CFGR2_CKMODE; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_CONT | ADC_CFGR1_WAIT; /* (2) */
ADC1->CHSELR = ADC_CHSELR_CHSEL1 | ADC_CHSELR_CHSEL2
              | ADC_CHSELR_CHSEL3; /* (3) */
ADC1->CR |= ADC_CR_ADSTART; /* start the ADC conversions */

```

A.7.12 Auto Off and no wait mode sequence code example

```

/* (1) Select HSI14 by writing 00 in CKMODE (reset value) */
/* (2) Select the external trigger on TIM15_TRG0 and rising edge
    and auto off */
/* (3) Select CHSEL1/2/3/4 */
/* (4) Enable interrupts on EOC, EOSEQ and overrun */
ADC1->CFGR2 &= ~ADC_CFGR2_CKMODE; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_EXTEN_1 | ADC_CFGR1_EXTSEL_2
             | ADC_CFGR1_AUTOFF; /* (2) */
ADC1->CHSELR = ADC_CHSELR_CHSEL1 | ADC_CHSELR_CHSEL2
              | ADC_CHSELR_CHSEL3 | ADC_CHSELR_CHSEL4; /* (3) */
ADC1->IER = ADC_IER_EOCIE | ADC_IER_EOSEQIE | ADC_IER_OVRIE; /* (4) */

```

A.7.13 Auto Off and wait mode sequence code example

```

/* (1) Select HSI14 by writing 00 in CKMODE (reset value) */
/* (2) Select the external trigger on TIM15_TRG0 and falling edge,
    the continuous mode, scanning direction and auto off */
/* (3) Select CHSEL1, CHSEL9, CHSEL10 and CHSEL17 */
/* (4) Enable interrupts on EOC, EOSEQ and overrun */
ADC1->CFGR2 &= ~ADC_CFGR2_CKMODE; /* (1) */
ADC1->CFGR1 |= ADC_CFGR1_EXTEN_0 | ADC_CFGR1_EXTSEL_2
             | ADC_CFGR1_SCANDIR | ADC_CFGR1_AUTOFF; /* (2) */
ADC1->CHSELR = ADC_CHSELR_CHSEL1 | ADC_CHSELR_CHSEL2
              | ADC_CHSELR_CHSEL3 | ADC_CHSELR_CHSEL4; /* (3) */
ADC1->IER = ADC_IER_EOCIE | ADC_IER_EOSEQIE | ADC_IER_OVRIE; /* (4) */

```

A.7.14 Analog watchdog code example

```

/* (1) Select the continuous mode
    and configure the Analog watchdog to monitor only CH17 */
/* (2) Define analog watchdog range : 16b-MSW is the high limit
    and 16b-LSW is the low limit */
/* (3) Enable interrupt on Analog Watchdog */
ADC1->CFGR1 |= ADC_CFGR1_CONT
             | (17 << 26) | ADC_CFGR1_AWDEN | ADC_CFGR1_AWDSGL; /* (1) */
ADC1->TR = (vrefint_high << 16) + vrefint_low; /* (2) */
ADC1->IER = ADC_IER_AWDIE; /* (3) */

```

A.7.15 Temperature configuration code example

```
/* (1) Select CHSEL16 for temperature sensor */
/* (2) Select a sampling mode of 111 i.e. 239.5 ADC clk to be greater than
    17.1us */
/* (3) Wake-up the Temperature sensor (only for VBAT, Temp sensor and
    VRefInt) */
ADC1->CHSELR = ADC_CHSELR_CHSEL16; /* (1) */
ADC1->SMPR |= ADC_SMPR_SMP_0 | ADC_SMPR_SMP_1 | ADC_SMPR_SMP_2; /* (2) */
ADC->CCR |= ADC_CCR_TSEN; /* (3) */
```

A.7.16 Temperature computation code example

```
/* Temperature sensor calibration value address */
#define TEMP30_CAL_ADDR ((uint16_t*) ((uint32_t) 0x1FFFF7B8))
#define VDD_CALIB ((uint32_t) (3300))
#define VDD_APPLI ((uint32_t) (3000))
#define AVG_SLOPE ((uint32_t) (5336)) //AVG_SLOPE in ADC conversion step
(@3.3V)/°C multiplied by 1000 for precision on the division
int32_t temperature; /* will contain the temperature in degrees Celsius */
temperature = ((uint32_t) *TEMP30_CAL_ADDR
    - ((uint32_t) ADC1->DR * VDD_APPLI / VDD_CALIB)) * 1000;
temperature = (temperature / AVG_SLOPE) + 30;
```

A.8 Timers

A.8.1 Upcounter on TI2 rising edge code example

```

/* (1) Enable the peripheral clock of Timer 1 */
/* (2) Enable the peripheral clock of GPIOA */
/* (3) Select Alternate function mode (10) on GPIOA pin 9 */
/* (4) Select TIM1_CH2 on PA9 by enabling AF2 for pin 9 in GPIOA AFRH
    register */
RCC->APB2ENR |= RCC_APB2ENR_TIM1EN; /* (1) */
RCC->AHBENR |= RCC_AHBENR_GPIOAEN; /* (2) */
GPIOA->MODER = (GPIOA->MODER & ~(GPIO_MODER_MODER9))
               | (GPIO_MODER_MODER9_1); /* (3) */
GPIOA->AFR[1] |= 0x2 << ((9-8)*4); /* (4) */
/* (1) Configure channel 2 to detect rising edges on the TI2 input by
    writing CC2S = '01', and configure the input filter duration by
    writing the IC2F[3:0] bits in the TIMx_CCMR1 register (if no filter
    is needed, keep IC2F=0000).*/
/* (2) Select rising edge polarity by writing CC2P=0 in the TIMx_CCER
    register (reset value). */
/* (3) Configure the timer in external clock mode 1 by writing SMS=111
    Select TI2 as the trigger input source by writing TS=110
    in the TIMx_SMCR register.*/
/* (4) Enable the counter by writing CEN=1 in the TIMx_CR1 register. */
TIMx->CCMR1 |= TIM_CCMR1_IC2F_0 | TIM_CCMR1_IC2F_1
              | TIM_CCMR1_CC2S_0; /* (1) */
TIMx->CCER &= (uint16_t)(~TIM_CCER_CC2P); /* (2) */
TIMx->SMCR |= TIM_SMCR_SMS | TIM_SMCR_TS_2 | TIM_SMCR_TS_1; /* (3) */
TIMx->CR1 |= TIM_CR1_CEN; /* (4) */

```

A.8.2 Up counter on each 2 ETR rising edges code example

```

/* (1) Enable the peripheral clock of Timer 1 */
/* (2) Enable the peripheral clock of GPIOA */
/* (3) Select Alternate function mode (10) on GPIOA pin 12 */
/* (4) Select TIM1_ETR on PA12 by enabling AF2 for pin 12 in GPIOA AFRH
    register */
RCC->APB2ENR |= RCC_APB2ENR_TIM1EN; /* (1) */
RCC->AHBENR |= RCC_AHBENR_GPIOAEN; /* (2) */
GPIOA->MODER = (GPIOA->MODER & ~(GPIO_MODER_MODER12))
               | (GPIO_MODER_MODER12_1); /* (3) */
GPIOA->AFR[1] |= 0x2 << ((12-8)*4); /* (4) */
/* (1) As no filter is needed in this example, write ETF[3:0]=0000
    in the TIMx_SMCR register. Keep the reset value.
    Set the prescaler by writing ETPS[1:0]=01 in the TIMx_SMCR
    register.
    Select rising edge detection on the ETR pin by writing ETP=0
    in the TIMx_SMCR register. Keep the reset value.
    Enable external clock mode 2 by writing ECE=1 in the TIMx_SMCR
    register. */
/* (2) Enable the counter by writing CEN=1 in the TIMx_CR1 register. */
TIMX->SMCR |= TIM_SMCR_ETPS_0 | TIM_SMCR_ECE; /* (1) */
TIMX->CR1 |= TIM_CR1_CEN; /* (2) */

```

A.8.3 Input capture configuration code example

```

/* (1) Select the active input TI1 (CC1S = 01),
    program the input filter for 8 clock cycles (IC1F = 0011),
    select the rising edge on CC1 (CC1P = 0, reset value)
    and prescaler at each valid transition (IC1PS = 00, reset value) */
/* (2) Enable capture by setting CC1E */
/* (3) Enable interrupt on Capture/Compare */
/* (4) Enable counter */
TIMX->CCMR1 |= TIM_CCMR1_CC1S_0
               | TIM_CCMR1_IC1F_0 | TIM_CCMR1_IC1F_1; /* (1) */
TIMX->CCER |= TIM_CCER_CC1E; /* (2) */
TIMX->DIER |= TIM_DIER_CC1IE; /* (3) */
TIMX->CR1 |= TIM_CR1_CEN; /* (4) */

```

A.8.4 Input capture data management code example

This code must be inserted in the Timer interrupt subroutine.

```
if ((TIMx->SR & TIM_SR_CC1IF) != 0)
{
    if ((TIMx->SR & TIM_SR_CC1OF) != 0) /* Check the overflow */
    {
        /* Overflow error management */
        gap = 0; /* Reinitialize the laps computing */
        TIMx->SR &= ~(TIM_SR_CC1OF | TIM_SR_CC1IF); /* Clear the flags */
        return;
    }
    if (gap == 0) /* Test if it is the first rising edge */
    {
        counter0 = TIMx->CCR1; /* Read the capture counter which clears the
                                CC1ICF */
        gap = 1; /* Indicate that the first rising edge has yet been detected */
    }
    else
    {
        counter1 = TIMx->CCR1; /* Read the capture counter which clears the
                                CC1ICF */
        if (counter1 > counter0) /* Check capture counter overflow */
        {
            Counter = counter1 - counter0;
        }
        else
        {
            Counter = counter1 + 0xFFFF - counter0 + 1;
        }
        counter0 = counter1;
    }
}
else
{
    /* Unexpected Interrupt */
    /* Manage an error for robust application */
}
```

Note: This code manages only a single counter overflow. To manage many counter overflows the update interrupt must be enabled (**UIE = 1**) and properly managed.

A.8.5 PWM input configuration code example

```

/* (1) Select the active input TI1 for TIMx_CCR1 (CC1S = 01),
   select the active input TI1 for TIMx_CCR2 (CC2S = 10) */
/* (2) Select TI1FP1 as valid trigger input (TS = 101)
   configure the slave mode in reset mode (SMS = 100) */
/* (3) Enable capture by setting CC1E and CC2E
   select the rising edge on CC1 and CC1N (CC1P = 0 and CC1NP = 0, reset
   value),
   select the falling edge on CC2 (CC2P = 1). */
/* (4) Enable interrupt on Capture/Compare 1 */
/* (5) Enable counter */
TIMx->CCMR1 |= TIM_CCMR1_CC1S_0 | TIM_CCMR1_CC2S_1; /* (1) */
TIMx->SMCR |= TIM_SMCR_TS_2 | TIM_SMCR_TS_0
             | TIM_SMCR_SMS_2; /* (2) */
TIMx->CCER |= TIM_CCER_CC1E | TIM_CCER_CC2E | TIM_CCER_CC2P; /* (3) */
TIMx->DIER |= TIM_DIER_CC1IE; /* (4) */
TIMx->CR1 |= TIM_CR1_CEN; /* (5) */

```

A.8.6 PWM input with DMA configuration code example

```

/* (1) Enable the peripheral clock on DMA */
/* (2) Configure the peripheral data register address for DMA channel x */
/* (3) Configure the memory address for DMA channel x */
/* (4) Configure the number of DMA tranfers to be performed
   on DMA channel x */
/* (5) Configure no increment (reset value), size (16-bits), interrupts,
   transfer from peripheral to memory and circular mode
   for DMA channel x */
/* (6) Enable DMA Channel x */
RCC->AHBENR |= RCC_AHBENR_DMA1EN; /* (1) */
DMA1_Channel2->CPAR = (uint32_t) (&(TIM1->CCR1)); /* (2) */
DMA1_Channel2->CMAR = (uint32_t) (&Period); /* (3) */
DMA1_Channel2->CNDTR = 1; /* (4) */
DMA1_Channel2->CCR |= DMA_CCR_MSIZ_0 | DMA_CCR_PSIZE_0
                    | DMA_CCR_TEIE | DMA_CCR_CIRC; /* (5) */
DMA1_Channel2->CCR |= DMA_CCR_EN; /* (6) */
/* repeat (2) to (6) for channel 3 */
DMA1_Channel3->CPAR = (uint32_t) (&(TIM1->CCR2)); /* (2) */
DMA1_Channel3->CMAR = (uint32_t) (&DutyCycle); /* (3) */
DMA1_Channel3->CNDTR = 1; /* (4) */
DMA1_Channel3->CCR |= DMA_CCR_MSIZ_0 | DMA_CCR_PSIZE_0
                    | DMA_CCR_TEIE | DMA_CCR_CIRC; /* (5) */
DMA1_Channel3->CCR |= DMA_CCR_EN; /* (6) */

/* Configure NVIC for DMA */
/* (7) Enable Interrupt on DMA Channels x */
/* (8) Set priority for DMA Channels x */
NVIC_EnableIRQ(DMA1_Channel2_3_IRQn); /* (7) */
NVIC_SetPriority(DMA1_Channel2_3_IRQn, 3); /* (8) */

```

A.8.7 Output compare configuration code example

```

/* (1) Set prescaler to 3, so APBCLK/4 i.e 12MHz */
/* (2) Set ARR = 12000 -1 */
/* (3) Set CCRx = ARR, as timer clock is 12MHz, an event occurs each 1 ms */
/* (4) Select toggle mode on OC1 (OC1M = 011),
    disable preload register on OC1 (OC1PE = 0, reset value) */
/* (5) Select active high polarity on OC1 (CC1P = 0, reset value),
    enable the output on OC1 (CC1E = 1)*/
/* (6) Enable output (MOE = 1)*/
/* (7) Enable counter */
TIMX->PSC |= 3; /* (1) */
TIMX->ARR = 12000 - 1; /* (2) */
TIMX->CCR1 = 12000 - 1; /* (3) */
TIMX->CCMR1 |= TIM_CCMR1_OC1M_0 | TIM_CCMR1_OC1M_1; /* (4) */
TIMX->CCER |= TIM_CCER_CC1E; /* (5)*/
TIMX->BDTR |= TIM_BDTR_MOE; /* (6) */
TIMX->CR1 |= TIM_CR1_CEN; /* (7) */

```

A.8.8 Edge-aligned PWM configuration example

```

/* (1) Set prescaler to 47, so APBCLK/48 i.e 1MHz */
/* (2) Set ARR = 8, as timer clock is 1MHz the period is 9 us */
/* (3) Set CCRx = 4, , the signal will be high during 4 us */
/* (4) Select PWM mode 1 on OC1 (OC1M = 110),
    enable preload register on OC1 (OC1PE = 1) */
/* (5) Select active high polarity on OC1 (CC1P = 0, reset value),
    enable the output on OC1 (CC1E = 1)*/
/* (6) Enable output (MOE = 1)*/
/* (7) Enable counter (CEN = 1)
    select edge aligned mode (CMS = 00, reset value)
    select direction as upcounter (DIR = 0, reset value) */
/* (8) Force update generation (UG = 1) */
TIMX->PSC = 47; /* (1) */
TIMX->ARR = 8; /* (2) */
TIMX->CCR1 = 4; /* (3) */
TIMX->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1
              | TIM_CCMR1_OC1PE; /* (4) */
TIMX->CCER |= TIM_CCER_CC1E; /* (5) */
TIMX->BDTR |= TIM_BDTR_MOE; /* (6) */
TIMX->CR1 |= TIM_CR1_CEN; /* (7) */
TIMX->EGR |= TIM_EGR_UG; /* (8) */

```


A.8.9 Center-aligned PWM configuration example

```
/* (1) Set prescaler to 47, so APBCLK/48 i.e 1MHz */
/* (2) Set ARR = 8, as timer clock is 1MHz and center-aligned counting,
    the period is 16 us */
/* (3) Set CCRx = 7, the signal will be high during 14 us */
/* (4) Select PWM mode 1 on OC1 (OC1M = 110),
    enable preload register on OC1 (OC1PE = 1, reset value) */
/* (5) Select active high polarity on OC1 (CC1P = 0, reset value),
    enable the output on OC1 (CC1E = 1)*/
/* (6) Enable output (MOE = 1)*/
/* (7) Enable counter (CEN = 1)
    select center-aligned mode 1 (CMS = 01) */
/* (8) Force update generation (UG = 1) */
TIMX->PSC = 47; /* (1) */
TIMX->ARR = 8; /* (2) */
TIMX->CCR1 = 7; /* (3) */
TIMX->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1
              | TIM_CCMR1_OC1PE; /* (4) */
TIMX->CCER |= TIM_CCER_CC1E; /* (5) */
TIMX->BDTR |= TIM_BDTR_MOE; /* (6) */
TIMX->CR1 |= TIM_CR1_CMS_0 | TIM_CR1_CEN; /* (7) */
TIMX->EGR |= TIM_EGR_UG; /* (8) */
```

A.8.10 ETR configuration to clear OCxREF code example

```

/* This code is similar to the edge-aligned PWM configuration but it enables
   the clearing on OC1 for ETRclearing (OC1CE = 1) in CCMR1 (5) and ETR is
   configured in SMCR (7).*/
/* (1) Set prescaler to 47, so APBCLK/48 i.e 1MHz */
/* (2) Set ARR = 8, as timer clock is 1MHz the period is 9 us */
/* (3) Set CCRx = 4, , the signal will be high during 4 us */
/* (4) Select PWM mode 1 on OC1 (OC1M = 110),
   enable preload register on OC1 (OC1PE = 1),
   enable clearing on OC1 for ETR clearing (OC1CE = 1) */
/* (5) Select active high polarity on OC1 (CC1P = 0, reset value),
   enable the output on OC1 (CC1E = 1) */
/* (6) Enable output (MOE = 1) */
/* (7) Select ETR as OCREF clear source (OCCS = 1),
   select External Trigger Prescaler off (ETPS = 00, reset value),
   disable external clock mode 2 (ECE = 0, reset value),
   select active at high level (ETP = 0, reset value) */
/* (8) Enable counter (CEN = 1),
   select edge aligned mode (CMS = 00, reset value),
   select direction as upcounter (DIR = 0, reset value) */
/* (9) Force update generation (UG = 1) */
TIMx->PSC = 47; /* (1) */
TIMx->ARR = 8; /* (2) */
TIMx->CCR1 = 4; /* (3) */
TIMx->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1 | TIM_CCMR1_OC1PE
              | TIM_CCMR1_OC1CE; /* (4) */
TIMx->CCER |= TIM_CCER_CC1E; /* (5) */
TIMx->BDTR |= TIM_BDTR_MOE; /* (6) */
TIMx->SMCR |= TIM_SMCR_OCCS; /* (7) */
TIMx->CR1 |= TIM_CR1_CEN; /* (8) */
TIMx->EGR |= TIM_EGR_UG; /* (9) */

```

A.8.11 Encoder interface code example

```

/* (1) Configure TI1FP1 on TI1 (CC1S = 01),
   configure TI1FP2 on TI2 (CC2S = 01) */
/* (2) Configure TI1FP1 and TI1FP2 non inverted (CC1P = CC2P = 0, reset
   value) */
/* (3) Configure both inputs are active on both rising and falling edges
   (SMS = 011) */
/* (4) Enable the counter by writing CEN=1 in the TIMx_CR1 register. */
TIMx->CCMR1 |= TIM_CCMR1_CC1S_0 | TIM_CCMR1_CC2S_0; /* (1) */
TIMx->CCER &= (uint16_t)(~(TIM_CCER_CC21 | TIM_CCER_CC2P)); /* (2) */
TIMx->SMCR |= TIM_SMCR_SMS_0 | TIM_SMCR_SMS_1; /* (3) */
TIMx->CR1 |= TIM_CR1_CEN; /* (4) */

```

A.8.12 Reset mode code example

```

/* (1) Configure channel 1 to detect rising edges on the TI1 input
   by writing CC1S = '01',
   and configure the input filter duration by writing the IC1F[3:0]
   bits in the TIMx_CCMR1 register (if no filter is needed, keep
   IC1F=0000). */
/* (2) Select rising edge polarity by writing CC1P=0 in the TIMx_CCER
   register
   Not necessary as it keeps the reset value. */
/* (3) Configure the timer in reset mode by writing SMS=100
   Select TI1 as the trigger input source by writing TS=101
   in the TIMx_SMCR register. */
/* (4) Set prescaler to 48000-1 in order to get an increment each 1ms */
/* (5) Enable the counter by writing CEN=1 in the TIMx_CR1 register. */
TIMx->CCMR1 |= TIM_CCMR1_CC1S_0; /* (1) */
TIMx->CCER &= (uint16_t)(~TIM_CCER_CC1P); /* (2) */
TIMx->SMCR |= TIM_SMCR_SMS_2 | TIM_SMCR_TS_2 | TIM_SMCR_TS_0; /* (3) */
TIM1->PSC = 47999; /* (4) */
TIMx->CR1 |= TIM_CR1_CEN; /* (5) */

```

A.8.13 Gated mode code example

```

/* (1) Configure channel 1 to detect low level on the TI1 input
   by writing CC1S = '01',
   and configure the input filter duration by writing the IC1F[3:0]
   bits in the TIMx_CCMR1 register (if no filter is needed,
   keep IC1F=0000). */
/* (2) Select polarity by writing CC1P=1 in the TIMx_CCER register */
/* (3) Configure the timer in gated mode by writing SMS=101
   Select TI1 as the trigger input source by writing TS=101
   in the TIMx_SMCR register. */
/* (4) Set prescaler to 12000-1 in order to get an increment each 250us */
/* (5) Enable the counter by writing CEN=1 in the TIMx_CR1 register. */
TIMx->CCMR1 |= TIM_CCMR1_CC1S_0; /* (1) */
TIMx->CCER |= TIM_CCER_CC1P; /* (2) */
TIMx->SMCR |= TIM_SMCR_SMS_2 | TIM_SMCR_SMS_0
             | TIM_SMCR_TS_2 | TIM_SMCR_TS_0; /* (3) */
TIMx->PSC = 11999; /* (4) */
TIMx->CR1 |= TIM_CR1_CEN; /* (5) */

```

A.8.14 Trigger mode code example

```

/* (1) Configure channel 2 to detect rising edge on the TI2 input
    by writing CC2S = '01',
    and configure the input filter duration by writing the IC1F[3:0]
    bits in the TIMx_CCMR1 register (if no filter is needed,
    keep IC1F=0000). */
/* (2) Select polarity by writing CC2P=0 (reset value) in the TIMx_CCER
    register */
/* (3) Configure the timer in trigger mode by writing SMS=110
    Select TI2 as the trigger input source by writing TS=110
    in the TIMx_SMCR register. */
/* (4) Set prescaler to 12000-1 in order to get an increment each 250us */
TIMx->CCMR1 |= TIM_CCMR1_CC2S_0; /* (1) */
TIMx->CCER &= ~TIM_CCER_CC2P; /* (2) */
TIMx->SMCR |= TIM_SMCR_SMS_2 | TIM_SMCR_SMS_1
            | TIM_SMCR_TS_2 | TIM_SMCR_TS_1; /* (3) */
TIM1->PSC = 11999; /* (4) */

```

A.8.15 External clock mode 2 + trigger mode code example

```

/* (1) Configure no input filter (ETF=0000, reset value)
    configure prescaler disabled (ETPS = 0, reset value)
    select detection on rising edge on ETR (ETP = 0, reset value)
    enable external clock mode 2 (ECE = 1) */
/* (2) Configure no input filter (IC1F=0000, reset value)
    select input capture source on TI1 (CC1S = 01) */
/* (3) Select polarity by writing CC1P=0 (reset value) in the TIMx_CCER
    register */
/* (4) Configure the timer in trigger mode by writing SMS=110
    Select TI1 as the trigger input source by writing TS=101
    in the TIMx_SMCR register. */
TIMx->SMCR |= TIM_SMCR_ECE; /* (1) */
TIMx->CCMR1 |= TIM_CCMR1_CC1S_0; /* (2) */
TIMx->CCER &= ~TIM_CCER_CC1P; /* (3) */
TIMx->SMCR |= TIM_SMCR_SMS_2 | TIM_SMCR_SMS_1
            | TIM_SMCR_TS_2 | TIM_SMCR_TS_0; /* (4) */
/* Use TI2FP2 as trigger 1 */
/* (1) Map TI2FP2 on TI2 by writing CC2S=01 in the TIMx_CCMR1 register */
/* (2) TI2FP2 must detect a rising edge, write CC2P=0 and CC2NP=0
    in the TIMx_CCER register (keep the reset value) */
/* (3) Configure TI2FP2 as trigger for the slave mode controller (TRGI)
    by writing TS=110 in the TIMx_SMCR register,
    TI2FP2 is used to start the counter by writing SMS to '110'
    in the TIMx_SMCR register (trigger mode) */
TIMx->CCMR1 |= TIM_CCMR1_CC2S_0; /* (1) */
//TIMx->CCER &= ~(TIM_CCER_CC2P | TIM_CCER_CC2NP); /* (2) */
TIMx->SMCR |= TIM_SMCR_TS_2 | TIM_SMCR_TS_1
            | TIM_SMCR_SMS_2 | TIM_SMCR_SMS_1; /* (3) */

```

A.8.16 One-Pulse mode code example

```

/* The OPM waveform is defined by writing the compare registers */
/* (1) Set prescaler to 47, so APBCLK/48 i.e 1MHz */
/* (2) Set ARR = 7, as timer clock is 1MHz the period is 8 us */
/* (3) Set CCRx = 5, the burst will be delayed for 5 us (must be > 0) */
/* (4) Select PWM mode 2 on OC1 (OC1M = 111),
    enable preload register on OC1 (OC1PE = 1, reset value)
    enable fast enable (no delay) if PULSE_WITHOUT_DELAY is set */
/* (5) Select active high polarity on OC1 (CC1P = 0, reset value),
    enable the output on OC1 (CC1E = 1) */
/* (6) Enable output (MOE = 1) */
/* (7) Write '1 in the OPM bit in the TIMx_CR1 register to stop the counter
    at the next update event (OPM = 1),
    enable auto-reload register (ARPE = 1) */
TIMx->PSC = 47; /* (1) */
TIMx->ARR = 7; /* (2) */
TIMx->CCR1 = 5; /* (3) */
TIMx->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1 | TIM_CCMR1_OC1M_0
              | TIM_CCMR1_OC1PE
#ifdef PULSE_WITHOUT_DELAY > 0
              | TIM_CCMR1_OC1FE
#endif
              ; /* (4) */
TIMx->CCER |= TIM_CCER_CC1E; /* (5) */
TIMx->BDTR |= TIM_BDTR_MOE; /* (6) */
TIMx->CR1 |= TIM_CR1_OPM | TIM_CR1_ARPE; /* (7) */

```

A.8.17 Timer prescaling another timer code example

```

/* TIMy is slave of TIMx */
/* (1) Select Update Event as Trigger output (TRG0) by writing MMS = 010
    in TIMx_CR2. */
/* (2) Configure TIMy in slave mode using ITR1 as internal trigger
    by writing TS = 000 in TIMy_SMCR (reset value)
    Configure TIMy in external clock mode 1, by writing SMS=111 in the
    TIMy_SMCR register. */
/* (3) Set TIMx prescaler to 47999 in order to get an increment each 1ms */
/* (4) Set TIMx Autoreload to 999 in order to get an overflow (so an UEV)
    each second */
/* (5) Set TIMx Autoreload to 24*3600-1 in order to get an overflow each 24-
    hour */
/* (6) Enable the counter by writing CEN=1 in the TIMx_CR1 register. */
/* (7) Enable the counter by writing CEN=1 in the TIMy_CR1 register. */
TIMx->CR2 |= TIM_CR2_MMS_1; /* (1) */
TIMy->SMCR |= TIM_SMCR_SMS_2 | TIM_SMCR_SMS_1 | TIM_SMCR_SMS_0; /* (2) */
TIMx->PSC = 47999; /* (3) */
TIMx->ARR = 999; /* (4) */
TIMy->ARR = (24 * 3600) - 1; /* (5) */
TIMx->CR1 |= TIM_CR1_CEN; /* (6) */
TIMy->CR1 |= TIM_CR1_CEN; /* (7) */

```

A.8.18 Timer enabling another timer code example

```

/* TIMy is slave of TIMx */
/* (1) Configure Timer x master mode to send its Output Compare 1 Reference
   (OC1REF) signal as trigger output
   (MMS=100 in the TIM1_CR2 register). */
/* (2) Configure the Timer x OC1REF waveform (TIM1_CCMR1 register)
   Channel 1 is in PWM mode 1 when the counter is less than the
   capture/compare register (write OC1M = 110) */
/* (3) Configure TIMy in slave mode using ITR1 as internal trigger
   by writing TS = 000 in TIMy_SMCR (reset value)
   Configure TIMy in gated mode, by writing SMS=101 in the
   TIMy_SMCR register. */
/* (4) Set TIMx prescaler to 2 */
/* (5) Set TIMy prescaler to 2 */
/* (6) Set TIMx Autoreload to 999 in order to get an overflow (so an UEV)
   each 100ms */
/* (7) Set capture compare register to a value between 0 and 999 */
TIMx->CR2 |= TIM_CR2_MMS_2; /* (1) */
TIMx->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1; /* (2) */
TIMy->SMCR |= TIM_SMCR_SMS_2 | TIM_SMCR_SMS_0; /* (3) */
TIMx->PSC = 2; /* (4) */
TIMy->PSC = 2; /* (5) */
TIMx->ARR = 999; /* (6) */
TIMx->CCR1 = 700; /* (7) */
/* Configure the slave timer to generate toggling on each count */
/* (1) Configure the TIMy in PWM mode 1 (write OC1M = 110) */
/* (2) Set TIMy Autoreload to 1 */
/* (3) Set capture compare register to 1 */
TIMy->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1; /* (1) */
TIMy->ARR = 1; /* (2) */
TIMy->CCR1 = 1; /* (3) */
/* Enable the output of TIMx OC1 */
/* (1) Select active high polarity on OC1 (CC1P = 0, reset value),
   enable the output on OC1 (CC1E = 1) */
/* (2) Enable output (MOE = 1) */
TIMx->CCER |= TIM_CCER_CC1E; /* (1) */
TIMx->BDTR |= TIM_BDTR_MOE; /* (2) */
/* Enable the output of TIMy OC1 */
/* (1) Select active high polarity on OC1 (CC1P = 0, reset value),
   enable the output on OC1 (CC1E = 1) */
/* (2) Enable output (MOE = 1) */
TIMy->CCER |= TIM_CCER_CC1E; /* (1) */
TIMy->BDTR |= TIM_BDTR_MOE; /* (2) */
/* (1) Enable the slave counter first by writing CEN=1
   in the TIMy_CR1 register. */
/* (2) Enable the master counter by writing CEN=1
   in the TIMx_CR1 register. */
TIMy->CR1 |= TIM_CR1_CEN; /* (1) */
TIMx->CR1 |= TIM_CR1_CEN; /* (2) */

```

A.8.19 Master and slave synchronization code example

```

/* (1) Configure Timer x master mode to send its enable signal
   as trigger output (MMS=001 in the TIM1_CR2 register). */
/* (2) Configure the Timer x Channel 1 waveform (TIM1_CCMR1 register)
   is in PWM mode 1 (write OC1M = 110) */
/* (3) Configure TIMy in slave mode using ITR1 as internal trigger
   by writing TS = 000 in TIMy_SMCR (reset value)
   Configure TIMy in gated mode, by writing SMS=101 in the
   TIMy_SMCR register. */
/* (4) Set TIMx prescaler to 2 */
/* (5) Set TIMy prescaler to 2 */
/* (6) Set TIMx Autoreload to 99 in order to get an overflow (so an UEV)
   each 10ms */
/* (7) Set capture compare register to a value between 0 and 99 */
TIMx->CR2 |= TIM_CR2_MMS_0; /* (1) */
TIMx->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1; /* (2) */
TIMy->SMCR |= TIM_SMCR_SMS_2 | TIM_SMCR_SMS_0; /* (3) */
TIMx->PSC = 2; /* (4) */
TIMy->PSC = 2; /* (5) */
TIMx->ARR = 99; /* (6) */
TIMx->CCR1 = 25; /* (7) */
/* Configure the slave timer Channel 1 as PWM as Timer
   to show synchronicity */
/* (1) Configure the TIMy in PWM mode 1 (write OC1M = 110) */
/* (2) Set TIMy Autoreload to 99 */
/* (3) Set capture compare register to 25 */
TIMy->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1; /* (1) */
TIMy->ARR = 99; /* (2) */
TIMy->CCR1 = 25; /* (3) */
/* Enable the output of TIMx OC1 */
/* (1) Select active high polarity on OC1 (CC1P = 0, reset value),
   enable the output on OC1 (CC1E = 1) */
/* (2) Enable output (MOE = 1) */
TIMx->CCER |= TIM_CCER_CC1E; /* (1) */
TIMx->BDTR |= TIM_BDTR_MOE; /* (2) */
/* Enable the output of TIMy OC1 */
/* (1) Select active high polarity on OC1 (CC1P = 0, reset value),
   enable the output on OC1 (CC1E = 1) */
/* (2) Enable output (MOE = 1) */
TIMy->CCER |= TIM_CCER_CC1E; /* (1) */
TIMy->BDTR |= TIM_BDTR_MOE; /* (2) */
/* (1) Reset Timer x by writing '1 in UG bit (TIMx_EGR register) */
/* (2) Reset Timer y by writing '1 in UG bit (TIMy_EGR register) */
TIMx->EGR |= TIM_EGR_UG; /* (1) */
TIMy->EGR |= TIM_EGR_UG; /* (2) */
/* (1) Enable the slave counter first by writing CEN=1 in the TIMy_CR1
   register.
   TIMy will start synchronously with the master timer */
/* (2) Start the master counter by writing CEN=1
   in the TIMx_CR1 register. */
TIMy->CR1 |= TIM_CR1_CEN; /* (1) */
TIMx->CR1 |= TIM_CR1_CEN; /* (2) */

```

A.8.20 Two timers synchronized by an external trigger code example

```

/* (1) Configure TIMx master mode to send its enable signal
   as trigger output (MMS=001 in the TIM1_CR2 register). */
/* (2) Configure TIMx in slave mode to get the input trigger from TI1
   by writing TS = 100 in TIMx_SMCR
   Configure TIMx in trigger mode, by writing SMS=110 in the
   TIMx_SMCR register.
   Configure TIMx in Master/Slave mode by writing MSM = 1
   in TIMx_SMCR */
/* (3) Configure TIMy in slave mode to get the input trigger from Timer1
   by writing TS = 000 in TIMy_SMCR (reset value)
   Configure TIMy in trigger mode, by writing SMS=110 in the
   TIMy_SMCR register. */
/* (4) Reset Timer x counter by writing '1 in UG bit (TIMx_EGR register) */
/* (5) Reset Timer y counter by writing '1 in UG bit (TIMy_EGR register) */
TIMx->CR2 |= TIM_CR2_MMS_0; /* (1) */
TIMx->SMCR |= TIM_SMCR_TS_2 | TIM_SMCR_SMS_2 | TIM_SMCR_SMS_1
            | TIM_SMCR_MSM; /* (2) */
TIMy->SMCR |= TIM_SMCR_SMS_2 | TIM_SMCR_SMS_1; /* (3) */
TIMx->EGR |= TIM_EGR_UG; /* (4) */
TIMy->EGR |= TIM_EGR_UG; /* (5) */
/* Configure the Timer Channel 2 as PWM */
/* (1) Configure the Timer x Channel 2 waveform (TIM1_CCMR1 register)
   is in PWM mode 1 (write OC2M = 110) */
/* (2) Set TIMx prescaler to 2 */
/* (3) Set TIMx Autoreload to 99 in order to get an overflow (so an UEV)
   each 10ms */
/* (4) Set capture compare register to a value between 0 and 99 */
TIMx->CCMR1 |= TIM_CCMR1_OC2M_2 | TIM_CCMR1_OC2M_1; /* (1) */
TIMx->PSC = 2; /* (2) */
TIMx->ARR = 99; /* (3) */
TIMx->CCR2 = 25; /* (4) */
/* Configure the slave timer Channel 1 as PWM as Timer
   to show synchronicity */
/* (1) Configure the TIMy in PWM mode 1 (write OC1M = 110) */
/* (2) Set TIMy prescaler to 2 */
/* (3) Set TIMx Autoreload to 99 */
/* (4) Set capture compare register to 25 */
TIMy->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1; /* (1) */
TIMy->PSC = 2; /* (2) */
TIMy->ARR = 99; /* (3) */
TIMy->CCR1 = 25; /* (4) */
/* Enable the output of TIMx OC1 */
/* (1) Select active high polarity on OC1 (CC1P = 0, reset value),
   enable the output on OC1 (CC1E = 1) */
/* (2) Enable output (MOE = 1) */
TIMx->CCER |= TIM_CCER_CC2E; /* (1) */
TIMx->BDTR |= TIM_BDTR_MOE; /* (2) */
/* Enable the output of TIMy OC1 */
/* (1) Select active high polarity on OC1 (CC1P = 0, reset value),
   enable the output on OC1 (CC1E = 1) */
/* (2) Enable output (MOE = 1) */
TIMy->CCER |= TIM_CCER_CC1E; /* (1) */
TIMy->BDTR |= TIM_BDTR_MOE; /* (2) */

```


A.8.21 DMA burst feature code example

```

/* In this example TIMx has been previously configured
   in PWM center-aligned */
/* Configure DMA Burst Feature */
/* Configure the corresponding DMA channel */
/* (1) Set DMA channel peripheral address is the DMAR register address */
/* (2) Set DMA channel memory address is the address of the buffer
   in the RAM containing the data to be transferred by DMA
   into CCRx registers */
/* (3) Set the number of data transfer to sizeof(Duty_Cycle_Table) */
/* (4) Configure DMA transfer in CCR register,
   enable the circular mode by setting CIRC bit (optional),
   set memory size to 16_bits MSIZE = 01,
   set peripheral size to 32_bits PSIZE = 10,
   enable memory increment mode by setting MINC,
   set data transfer direction read from memory by setting DIR. */
/* (5) Configure TIMx_DCR register with DBL = 3 transfers
   and DBA = (@TIMx->CCR2 - @TIMx->CR1) >> 2 = 0xE */
/* (6) Enable the TIMx update DMA request by setting UDE bit in DIER
   register */
/* (7) Enable TIMx */
/* (8) Enable DMA channel */
DMA1_Channel2->CPAR = (uint32_t)(TIMx->DMAR); /* (1) */
DMA1_Channel2->CMAR = (uint32_t)(Duty_Cycle_Table); /* (2) */
DMA1_Channel2->CNDTR = 10*3; /* (3) */
DMA1_Channel2->CCR |= DMA_CCR_CIRC | DMA_CCR_MSIZE_0 | DMA_CCR_PSIZE_1
                  | DMA_CCR_MINC | DMA_CCR_DIR; /* (4) */
TIMx->DCR = (3 << 8)
          + (((uint32_t)(TIMx->CCR2))
            - ((uint32_t)(TIMx->CR1))) >> 2); /* (5) */
TIMx->DIER |= TIM_DIER_UDE; /* (6) */
TIMx->CR1 |= TIM_CR1_CEN; /* (7) */
DMA1_Channel2->CCR |= DMA_CCR_EN; /* (8) */

```

A.9 IRTIM code example

A.9.1 TIM16 and TIM17 configuration code example

```

/* The following configuration is for RC5 standard */
/* TIM16 is used for the envelope while TIM17 is used for the carrier */
#define TIM_ENV TIM16
#define TIM_CAR TIM17
/* (1) Enable the peripheral clocks of Timer 16 and 17 and SYSCFG */
/* (2) Enable the peripheral clock of GPIOB */
/* (3) Select alternate function mode on GPIOB pin 9 */
/* (4) Select AF0 on PB9 in AFRH for IR_OUT (reset value) */
/* (5) Enable the high sink driver capability by setting I2C_PB9_FM+ bit
    in SYSCFG_CFGR1 */
RCC->APB2ENR |= RCC_APB2ENR_TIM16EN | RCC_APB2ENR_TIM17EN
              | RCC_APB2ENR_SYSCFGEN; /* (1) */
RCC->AHBENR |= RCC_AHBENR_GPIOBEN; /* (2) */
GPIOB->MODER = (GPIOB->MODER & ~GPIO_MODER_MODER9)
              | GPIO_MODER_MODER9_1; /* (3) */
GPIOB->AFR[1] &= ~(0x0F << ((9 - 8) * 4)); /* (4) */
SYSCFG->CFGR1 |= SYSCFG_CFGR1_I2C_FMP_PB9; /* (5) */
/* Configure TIM_CAR as carrier signal */
/* (1) Set prescaler to 1, so APBCLK i.e 48MHz */
/* (2) Set ARR = 1333, as timer clock is 48MHz the frequency is 36kHz */
/* (3) Set CCRx = 1333/4, , the signal will have a 25% duty cycle */
/* (4) Select PWM mode 1 on OC1 (OC1M = 110),
    enable preload register on OC1 (OC1PE = 1) */
/* (5) Select active high polarity on OC1 (CC1P = 0, reset value),
    enable the output on OC1 (CC1E = 1) */
/* (6) Enable output (MOE = 1) */
TIM_CAR->PSC = v; /* (1) */
TIM_CAR->ARR = 1333; /* (2) */
TIM_CAR->CCR1 = (uint16_t)(1333 / 4); /* (3) */
TIM_CAR->CCMR1 |= TIM_CCMR1_OC1M_2 | TIM_CCMR1_OC1M_1
                | TIM_CCMR1_OC1PE; /* (4) */
TIM_CAR->CCER |= TIM_CCER_CC1E; /* (5) */
TIM_CAR->BDTR |= TIM_BDTR_MOE; /* (6) */
/* Configure TIM_ENV is the modulation envelope */
/* (1) Set prescaler to 1, so APBCLK i.e 48MHz */
/* (2) Set ARR = 42627, as timer clock is 48MHz the period is 888 us */
/* (3) Select Forced inactive on OC1 (OC1M = 100) */
/* (4) Select active high polarity on OC1 (CC1P = 0, reset value),
    enable the output on OC1 (CC1E = 1) */
/* (5) Enable output (MOE = 1) */
/* (6) Enable Update interrupt (UIE = 1) */
TIM_ENV->PSC = 0; /* (1) */
TIM_ENV->ARR = 42627; /* (2) */
TIM_ENV->CCMR1 |= TIM_CCMR1_OC1M_2; /* (3) */
TIM_ENV->CCER |= TIM_CCER_CC1E; /* (4) */
TIM_ENV->BDTR |= TIM_BDTR_MOE; /* (5) */
TIM_ENV->DIER |= TIM_DIER_UIE; /* (6) */
/* Enable and reset TIM_CAR only */
/* (1) Enable counter (CEN = 1),
    select edge aligned mode (CMS = 00, reset value),
    select direction as upcounter (DIR = 0, reset value) */

```

```

/* (2) Force update generation (UG = 1) */
TIM_CAR->CR1 |= TIM_CR1_CEN; /* (1) */
TIM_CAR->EGR |= TIM_EGR_UG; /* (2) */
/* Configure TIM_ENV interrupt */
/* (1) Enable Interrupt on TIM_ENV */
/* (2) Set priority for TIM_ENV */
NVIC_EnableIRQ(TIM_ENV_IRQn); /* (1) */
NVIC_SetPriority(TIM_ENV_IRQn, 0); /* (2) */

```

A.9.2 IRQHandler for IRTIM code example

```

/**
 * Description: This function handles TIM_16 interrupt request.
 *             This interrupt subroutine computes the laps between 2
 *             rising edges on T1IC.
 *             This laps is stored in the "Counter" variable.
 */
void TIM16_IRQHandler(void)
{
    uint8_t bit_msg = 0;

    if ((SendOperationReady == 1)
        && (BitsSentCounter < (RC5_GlobalFrameLength * 2)))
    {
        if (BitsSentCounter < 32)
        {
            SendOperationCompleted = 0x00;
            bit_msg = (uint8_t)((ManchesterCodedMsg >> BitsSentCounter)& 1);

            if (bit_msg == 1)
            {
                /* Force active level - OC1REF is forced high */
                TIM_ENV->CCMR1 |= TIM_CCMR1_OC1M_0;
            }
            else
            {
                /* Force inactive level - OC1REF is forced low */
                TIM_ENV->CCMR1 &= (uint16_t)(~TIM_CCMR1_OC1M_0);
            }
        }
        BitsSentCounter++;
    }
    else
    {
        SendOperationCompleted = 0x01;
        SendOperationReady = 0;
        BitsSentCounter = 0;
    }
    /* Clear TIM_ENV update interrupt */
    TIM_ENV->SR &= (uint16_t)(~TIM_SR_UIF);
}

```

A.10 DBG code example

A.10.1 DBG read device ID code example

```
/* Read MCU Id, 32-bit access */  
MCU_Id = DBGMCU->IDCODE;
```

A.10.2 DBG debug in Low-power mode code example

```
/* To be able to debug in stop mode */  
DBGMCU->CR |= DBGMCU_CR_DBG_STOP;
```

A.11 I2C code example

A.11.1 I2C configured in master mode to receive code example

```
/* (1) Timing register value is computed with the AN4235 xls file,  
    fast Mode @400kHz with I2CCLK = 48MHz, rise time = 140ns,  
    fall time = 40ns */  
/* (2) Periph enable, receive interrupt enable */  
/* (3) Slave address = 0x5A, read transfer, 1 byte to receive, autoend */  
I2C2->TIMINGR = (uint32_t)0x00B01A4B; /* (1) */  
I2C2->CR1 = I2C_CR1_PE | I2C_CR1_RXIE; /* (2) */  
I2C2->CR2 = I2C_CR2_AUTOEND | (1<<16) | I2C_CR2_RD_WRN  
    | (I2C1_OWN_ADDRESS << 1); /* (3) */
```

A.11.2 I2C configured in master mode to transmit code example

```
/* (1) Timing register value is computed with the AN4235 xls file,  
    fast Mode @400kHz with I2CCLK = 48MHz, rise time = 140ns,  
    fall time = 40ns */  
/* (2) Periph enable */  
/* (3) Slave address = 0x5A, write transfer, 1 byte to transmit, autoend */  
I2C2->TIMINGR = (uint32_t)0x00B01A4B; /* (1) */  
I2C2->CR1 = I2C_CR1_PE; /* (2) */  
I2C2->CR2 = I2C_CR2_AUTOEND | (1 << 16) | (I2C1_OWN_ADDRESS << 1); /* (3) */
```

A.11.3 I2C configured in slave mode code example

```

/* (1) Timing register value is computed with the AN4235 xls file,
   fast Mode @400kHz with I2CCLK = 48MHz, rise time = 140ns,
   fall time = 40ns */
/* (2) Periph enable, address match interrupt enable */
/* (3) 7-bit address = 0x5A */
/* (4) Enable own address 1 */
I2C1->TIMINGR = (uint32_t)0x00B00000; /* (1) */
I2C1->CR1 = I2C_CR1_PE | I2C_CR1_ADDRIE; /* (2) */
I2C1->OAR1 |= (uint32_t)(I2C1_OWN_ADDRESS << 1); /* (3) */
I2C1->OAR1 |= I2C_OAR1_OA1EN; /* (4) */

```

A.11.4 I2C master transmitter code example

```

/* Check Tx empty */
if ((I2C2->ISR & I2C_ISR_TXE) == I2C_ISR_TXE)
{
    I2C2->TXDR = I2C_BYTE_TO_SEND; /* Byte to send */
    I2C2->CR2 |= I2C_CR2_START; /* Go */
}

```

A.11.5 I2C master receiver code example

```

if ((I2C2->ISR & I2C_ISR_RXNE) == I2C_ISR_RXNE)
{
    /* Read receive register, will clear RXNE flag */
    if (I2C2->RXDR == I2C_BYTE_TO_SEND)
    {
        /* Process */
    }
}

```

A.11.6 I2C slave transmitter code example

```
uint32_t I2C_InterruptStatus = I2C1->ISR; /* Get interrupt status */
/* Check address match */
if ((I2C_InterruptStatus & I2C_ISR_ADDR) == I2C_ISR_ADDR)
{
    I2C1->ICR |= I2C_ICR_ADDRCF; /* Clear address match flag */
    /* Check if transfer direction is read (slave transmitter) */
    if ((I2C1->ISR & I2C_ISR_DIR) == I2C_ISR_DIR)
    {
        I2C1->CR1 |= I2C_CR1_TXIE; /* Set transmit IT */
    }
}
else if ((I2C_InterruptStatus & I2C_ISR_TXIS) == I2C_ISR_TXIS)
{
    I2C1->CR1 &=~ I2C_CR1_TXIE; /* Disable transmit IT */
    I2C1->TXDR = I2C_BYTE_TO_SEND; /* Byte to send */
}
```

A.11.7 I2C slave receiver code example

```
uint32_t I2C_InterruptStatus = I2C1->ISR; /* Get interrupt status */
if ((I2C_InterruptStatus & I2C_ISR_ADDR) == I2C_ISR_ADDR)
{
    I2C1->ICR |= I2C_ICR_ADDRCF; /* Address match event */
}
else if ((I2C_InterruptStatus & I2C_ISR_RXNE) == I2C_ISR_RXNE)
{
    /* Read receive register, will clear RXNE flag */
    if (I2C1->RXDR == I2C_BYTE_TO_SEND)
    {
        /* Process */
    }
}
```

A.11.8 I2C configured in master mode to transmit with DMA code example

```
/* (1) Timing register value is computed with the AN4235 xls file,
    fast Mode @400kHz with I2CCLK = 48MHz, rise time = 140ns,
    fall time = 40ns */
/* (2) Periph enable */
/* (3) Slave address = 0x5A, write transfer, 2 bytes to transmit,
    autoend */
I2C2->TIMINGR = (uint32_t)0x00B01A4B; /* (1) */
I2C2->CR1 = I2C_CR1_PE | I2C_CR1_TXDMAEN; /* (2) */
I2C2->CR2 = I2C_CR2_AUTOEND | (SIZE_OF_DATA << 16)
    | (I2C1_OWN_ADDRESS << 1); /* (3) */
```

A.11.9 I2C configured in slave mode to receive with DMA code example

```

/* (1) Timing register value is computed with the AN4235 xls file,
   fast Mode @400kHz with I2CCLK = 48MHz, rise time = 140ns,
   fall time = 40ns */
/* (2) Periph enable, receive DMA enable */
/* (3) 7-bit address = 0x5A */
/* (4) Enable own address 1 */
I2C1->TIMINGR = (uint32_t)0x00B00000; /* (1) */
I2C1->CR1 = I2C_CR1_PE | I2C_CR1_RXDMAEN | I2C_CR1_ADDRIE; /* (2) */
I2C1->OAR1 |= (uint32_t)(I2C1_OWN_ADDRESS << 1); /* (3) */
I2C1->OAR1 |= I2C_OAR1_OA1EN; /* (4) */

```

A.12 IWDG code example

A.12.1 IWDG configuration code example

```

/* (1) Activate IWDG (not needed if done in option bytes) */
/* (2) Enable write access to IWDG registers */
/* (3) Set prescaler by 8 */
/* (4) Set reload value to have a rollover each 100ms */
/* (5) Check if flags are reset */
/* (6) Refresh counter */
IWDG->KR = IWDG_START; /* (1) */
IWDG->KR = IWDG_WRITE_ACCESS; /* (2) */
IWDG->PR = IWDG_PR_PR_0; /* (3) */
IWDG->RLR = IWDG_RELOAD; /* (4) */
while (IWDG->SR) /* (5) */
{
    /* add time out here for a robust application */
}
IWDG->KR = IWDG_REFRESH; /* (6) */

```

A.12.2 IWDG configuration with window code example

```

/* (1) Activate IWDG (not needed if done in option bytes) */
/* (2) Enable write access to IWDG registers */
/* (3) Set prescaler by 8 */
/* (4) Set reload value to have a rollover each 100ms */
/* (5) Check if flags are reset */
/* (6) Set a 50ms window, this will refresh the IWDG */
IWDG->KR = IWDG_START; /* (1) */
IWDG->KR = IWDG_WRITE_ACCESS; /* (2) */
IWDG->PR = IWDG_PR_PR_0; /* (3) */
IWDG->RLR = IWDG_RELOAD; /* (4) */
while (IWDG->SR) /* (5) */
{
    /* add time out here for a robust application */
}
IWDG->WINR = IWDG_RELOAD >> 1; /* (6) */

```

A.13 RTC code example

A.13.1 RTC calendar configuration code example

```

/* (1) Write access for RTC registers */
/* (2) Enable init phase */
/* (3) Wait until it is allow to modify RTC register values */
/* (4) set prescaler, 40kHz/128 => 312 Hz, 312Hz/312 => 1Hz */
/* (5) New time in TR */
/* (6) Disable init phase */
/* (7) Disable write access for RTC registers */
RTC->WPR = 0xCA; /* (1) */
RTC->WPR = 0x53; /* (1) */
RTC->ISR |= RTC_ISR_INIT; /* (2) */
while ((RTC->ISR & RTC_ISR_INITF) != RTC_ISR_INITF) /* (3) */
{
    /* add time out here for a robust application */
}
RTC->PRER = 0x007F0137; /* (4) */
RTC->TR = RTC_TR_PM | Time; /* (5) */
RTC->ISR &= ~RTC_ISR_INIT; /* (6) */
RTC->WPR = 0xFE; /* (7) */
RTC->WPR = 0x64; /* (7) */

```


A.13.2 RTC alarm configuration code example

```

/* (1) Write access for RTC registers */
/* (2) Disable alarm A to modify it */
/* (3) Wait until it is allow to modify alarm A value */
/* (4) Modify alarm A mask to have an interrupt each 1Hz */
/* (5) Enable alarm A and alarm A interrupt */
/* (6) Disable write access */
RTC->WPR = 0xCA; /* (1) */
RTC->WPR = 0x53; /* (1) */
RTC->CR &= ~RTC_CR_ALRAE; /* (2) */
while ((RTC->ISR & RTC_ISR_ALRAWF) != RTC_ISR_ALRAWF) /* (3) */
{
    /* add time out here for a robust application */
}
RTC->ALRMAR = RTC_ALRMAR_MSK4 | RTC_ALRMAR_MSK3
             | RTC_ALRMAR_MSK2 | RTC_ALRMAR_MSK1; /* (4) */
RTC->CR = RTC_CR_ALRAIE | RTC_CR_ALRAE; /* (5) */
RTC->WPR = 0xFE; /* (6) */
RTC->WPR = 0x64; /* (6) */

```

A.13.3 RTC WUT configuration code example

```

/* (1) Write access for RTC registers */
/* (2) Disable wake up timerto modify it */
/* (3) Wait until it is allow to modify wake up reload value */
/* (4) Modify wake upvalue reload counter to have a wake up each 1Hz */
/* (5) Enable wake up counter and wake up interrupt */
/* (6) Disable write access */
RTC->WPR = 0xCA; /* (1) */
RTC->WPR = 0x53; /* (1) */
RTC->CR &= ~RTC_CR_WUTE; /* (2) */
while ((RTC->ISR & RTC_ISR_WUTWF) != RTC_ISR_WUTWF) /* (3) */
{
    /* add time out here for a robust application */
}
RTC->WUTR = 0x9C0; /* (4) */
RTC->CR = RTC_CR_WUTE | RTC_CR_WUTIE; /* (5) */
RTC->WPR = 0xFE; /* (6) */
RTC->WPR = 0x64; /* (6) */

```

A.13.4 RTC read calendar code example

```

if((RTC->ISR & RTC_ISR_RSF) == RTC_ISR_RSF)
{
    TimeToCompute = RTC->TR; /* get time */
    DateToCompute = RTC->DR; /* need to read date also */
}

```

A.13.5 RTC calibration code example

```

/* (1) Write access for RTC registers */
/* (2) Enable init phase */
/* (3) Wait until it is allow to modify RTC register values */
/* (4) set prescaler, 40kHz/125 => 320 Hz, 320Hz/320 => 1Hz */
/* (5) New time in TR */
/* (6) Disable init phase */
/* (7) Wait until it's allow to modify calibartion register */
/* (8) Set calibration to around +20ppm, which is a standard value @25°C */
/* Note: the calibration is relevant when LSE is selected for RTC clock */
/* (9) Disable write access for RTC registers */
RTC->WPR = 0xCA; /* (1) */
RTC->WPR = 0x53; /* (1) */
RTC->ISR |= RTC_ISR_INIT; /* (2) */
while ((RTC->ISR & RTC_ISR_INITF) != RTC_ISR_INITF) /* (3) */
{
    /* add time out here for a robust application */
}
RTC->PRER = (124<<16) | 319; /* (4) */
RTC->TR = RTC_TR_PM | Time; /* (5) */
RTC->ISR &= ~RTC_ISR_INIT; /* (6) */
while((RTC->ISR & RTC_ISR_RECALPF) == RTC_ISR_RECALPF) /* (7) */
{
    /* add time out here for a robust application */
}
RTC->CALR = RTC_CALR_CALP | 482; /* (8) */
RTC->WPR = 0xFE; /* (9) */
RTC->WPR = 0x64; /* (9) */

```

A.13.6 RTC tamper and time stamp configuration code example

```

/* Tamper configuration:
- Disable precharge (PU)
- RTCCLK/256 tamper sampling frequency
- Activate time stamp on tamper detection
- input rising edge trigger detection on RTC_TAMP2 (PA0)
- Tamper interrupt enable */
RTC->TAFCR = RTC_TAFCR_TAMPPUDIS | RTC_TAFCR_TAMPFREQ | RTC_TAFCR_TAMPTS
            | RTC_TAFCR_TAMP2E | RTC_TAFCR_TAMPIE;

```

A.13.7 RTC tamper and time stamp code example

```

/* Check tamper and timestamp flag */
if (((RTC->ISR & (RTC_ISR_TAMP2F)) == (RTC_ISR_TAMP2F))
    && ((RTC->ISR & (RTC_ISR_TSF)) == (RTC_ISR_TSF)))
{
    RTC->ISR &= ~RTC_ISR_TAMP2F; /* clear tamper flag */
    EXTI->PR = EXTI_PR_PR19; /* clear exti line 19 flag */
    TimeToCompute = RTC->TSTR; /* get tamper time in timestamp register */
    RTC->ISR &= ~RTC_ISR_TSF; /* clear timestamp flag */
}

```

A.13.8 RTC clock output code example

```

/* (1) Write access for RTC registers */
/* (2) Disable alarm A to modify it */
/* (3) Wait until it is allow to modify alarm A value */
/* (4) Modify alarm A mask to have an interrupt each 1Hz */
/* (5) Enable alarm A and alarm A interrupt,
    enable calibration output (1Hz) */
/* (6) Disable write access */
RTC->WPR = 0xCA; /* (1) */
RTC->WPR = 0x53; /* (1) */
RTC->CR &= ~RTC_CR_ALRAE; /* (2) */
while ((RTC->ISR & RTC_ISR_ALRAWF) != RTC_ISR_ALRAWF) /* (3) */
{
    /* add time out here for a robust application */
}
RTC->ALRMAR = RTC_ALRMAR_MSK4 | RTC_ALRMAR_MSK3
             | RTC_ALRMAR_MSK2 | RTC_ALRMAR_MSK1; /* (4) */
RTC->CR = RTC_CR_ALRAIE | RTC_CR_ALRAE | RTC_CR_COE
         | RTC_CR_COSEL; /* (5) */
RTC->WPR = 0xFE; /* (6) */
RTC->WPR = 0x64; /* (6) */

```

A.14 SPI code example

A.14.1 SPI master configuration code example

```

/* (1) Master selection, BR: Fpclk/256 (due to C27 on the board, SPI_CLK is
    set to the minimum) CPOL and CPHA at zero (rising first edge) */
/* (2) Slave select output enabled, RXNE IT, 8-bit Rx fifo */
/* (3) Enable SPI1 */
SPI1->CR1 = SPI_CR1_MSTR | SPI_CR1_BR; /* (1) */
SPI1->CR2 = SPI_CR2_SS0E | SPI_CR2_RXNEIE | SPI_CR2_FRXTH
           | SPI_CR2_DS_2 | SPI_CR2_DS_1 | SPI_CR2_DS_0; /* (2) */
SPI1->CR1 |= SPI_CR1_SPE; /* (3) */

```

A.14.2 SPI slave configuration code example

```
/* nSS hard, slave, CPOL and CPHA at zero (rising first edge) */
/* (1) RXNE IT, 8-bit Rx fifo */
/* (2) Enable SPI2 */
SPI2->CR2 = SPI_CR2_RXNEIE | SPI_CR2_FRXTH
           | SPI_CR2_DS_2 | SPI_CR2_DS_1 | SPI_CR2_DS_0; /* (1) */
SPI2->CR1 |= SPI_CR1_SPE; /* (2) */
```

A.14.3 SPI full duplex communication code example

```
if ((SPI1->SR & SPI_SR_TXE) == SPI_SR_TXE) /* Test Tx empty */
{
    /* Will initiate 8-bit transmission if TXE */
    *(uint8_t *)&(SPI1->DR) = SPI1_DATA;
}
```

A.14.4 SPI interrupt code example

```
if ((SPI1->SR & SPI_SR_RXNE) == SPI_SR_RXNE)
{
    SPI1_Data = (uint8_t)SPI1->DR; /* receive data, clear flag */
    /* Process */
}
```

A.14.5 SPI master configuration with DMA code example

```
/* (1) Master selection, BR: Fpclk/256 (due to C27 on the board, SPI_CLK is
    set to the minimum)
    CPOL and CPHA at zero (rising first edge) */
/* (2) TX and RX with DMA,
    enable slave select output,
    enable RXNE interrupt,
    select 8-bit Rx fifo */
/* (3) Enable SPI1 */
SPI1->CR1 = SPI_CR1_MSTR | SPI_CR1_BR; /* (1) */
SPI1->CR2 = SPI_CR2_TXDMAEN | SPI_CR2_RXDMAEN | SPI_CR2_SS0E
           | SPI_CR2_RXNEIE | SPI_CR2_FRXTH
           | SPI_CR2_DS_2 | SPI_CR2_DS_1 | SPI_CR2_DS_0; /* (2) */
SPI1->CR1 |= SPI_CR1_SPE; /* (3) */
```

A.14.6 SPI slave configuration with DMA code example

```

/* nSS hard, slave, CPOL and CPHA at zero (rising first edge) */
/* (1) Select TX and RX with DMA,
   enable RXNE interrupt,
   select 8-bit Rx fifo */
/* (2) Enable SPI2 */
SPI2->CR2 = SPI_CR2_TXDMAEN | SPI_CR2_RXDMAEN
           | SPI_CR2_RXNEIE | SPI_CR2_FRXTH
           | SPI_CR2_DS_2 | SPI_CR2_DS_1 | SPI_CR2_DS_0; /* (1) */
SPI2->CR1 |= SPI_CR1_SPE; /* (2) */

```

A.15 USART code example

A.15.1 USART transmitter configuration code example

```

/* (1) Oversampling by 16, 9600 baud */
/* (2) 8 data bit, 1 start bit, 1 stop bit, no parity */
USART1->BRR = 480000 / 96; /* (1) */
USART1->CR1 = USART_CR1_TE | USART_CR1_UE; /* (2) */

```

A.15.2 USART transmit byte code example

```

/* Start USART transmission */
USART1->TDR = stringtosend[send++]; /* Will initiate TC if TXE is set */

```

A.15.3 USART transfer complete code example

```

if ((USART1->ISR & USART_ISR_TC) == USART_ISR_TC)
{
    if (send == sizeof(stringtosend))
    {
        send=0;
        USART1->ICR |= USART_ICR_TCCF; /* Clear transfer complete flag */
    }
    else
    {
        /* clear transfer complete flag and fill TDR with a new char */
        USART1->TDR = stringtosend[send++];
    }
}

```

A.15.4 USART receiver configuration code example

```
/* (1) oversampling by 16, 9600 baud */
/* (2) 8 data bit, 1 start bit, 1 stop bit, no parity, reception mode */
USART1->BRR = 480000 / 96; /* (1) */
USART1->CR1 = USART_CR1_RXNEIE | USART_CR1_RE | USART_CR1_UE; /* (2) */
```

A.15.5 USART receive byte code example

```
if ((USART1->ISR & USART_ISR_RXNE) == USART_ISR_RXNE)
{
    chartoreceive = (uint8_t)(USART1->RDR); /* Receive data, clear flag */
}
```

A.15.6 USART synchronous mode code example

```
/* (1) Oversampling by 16, 9600 baud */
/* (2) Synchronous mode
    CPOL and CPHA = 0 => rising first edge
    Last bit clock pulse
    Most significant bit first in transmit/receive */
/* (3) 8 data bit, 1 start bit, 1 stop bit, no parity
    Transmission enabled, reception enabled */
USART1->BRR = 480000 / 96; /* (1) */
USART1->CR2 = USART_CR2_MSBFIRST | USART_CR2_CLKEN
             | USART_CR2_LBCL; /* (2) */
USART1->CR1 = USART_CR1_TE | USART_CR1_RXNEIE
             | USART_CR1_RE | USART_CR1_UE; /* (3) */
/* Polling idle frame Transmission w/o clock */
while ((USART1->ISR & USART_ISR_TC) != USART_ISR_TC)
{
    /* add time out here for a robust application */
}
USART1->ICR |= USART_ICR_TCCF; /* Clear TC flag */
USART1->CR1 |= USART_CR1_TCIE; /* Enable TC interrupt */
```

A.15.7 USART DMA code example

```

/* (1) Oversampling by 16, 9600 baud */
/* (2) Enable DMA in reception and transmission */
/* (3) 8 data bit, 1 start bit, 1 stop bit, no parity, reception and
    transmission enabled */
USART1->BRR = 480000 / 96; /* (1) */
USART1->CR3 = USART_CR3_DMAT | USART_CR3_DMAR; /* (2) */
USART1->CR1 = USART_CR1_TE | USART_CR1_RE | USART_CR1_UE; /* (3) */
/* Polling idle frame Transmission */
while ((USART1->ISR & USART_ISR_TC) != USART_ISR_TC)
{
    /* add time out here for a robust application */
}
USART1->ICR |= USART_ICR_TCCF; /* Clear TC flag */
USART1->CR1 |= USART_CR1_TCIE; /* Enable TC interrupt */

```

A.15.8 USART hardware flow control code example

```

/* (1) oversampling by 16, 9600 baud */
/* (2) RTS and CTS enabled */
/* (3) 8 data bit, 1 start bit, 1 stop bit, no parity, reception and
    transmission enabled */
USART1->BRR = 480000 / 96; /* (1) */
USART1->CR3 = USART_CR3_RTSE | USART_CR3_CTSE; /* (2) */
USART1->CR1 = USART_CR1_TE | USART_CR1_RXNEIE
    | USART_CR1_RE | USART_CR1_UE; /* (3) */
/* Polling idle frame Transmission */
while ((USART1->ISR & USART_ISR_TC) != USART_ISR_TC)
{
    /* add time out here for a robust application */
}
USART1->ICR |= USART_ICR_TCCF; /* Clear TC flag */
USART1->CR1 |= USART_CR1_TCIE; /* Enable TC interrupt */

```

A.16 WWDG code example

A.16.1 WWDG configuration code example

```

/* (1) Set prescaler to have a roll-over each about 5.5ms,
    set window value (about 2.25ms) */
/* (2) Refresh WWDG before activate it */
/* (3) Activate WWDG */
WWDG->CFR = 0x60; /* (1) */
WWDG->CR = WWDG_REFRESH; /* (2) */
WWDG->CR |= WWDG_CR_WDGA; /* (3) */

```

Revision history

Table 117. Document revision history

Date	Revision	Changes
23-Sep-2013	1	Initial release
13-Jan-2015	2	Extended the applicability to STM32F070x6/xB and STM32F030x4/x6/x8/xC. Added <i>Chapter 30: Universal serial bus full-speed device interface (USB)</i> and reviewed the content of most chapters.
19-May-2015	3	Renamed TIM16 and TIM17 in the table <i>TIMx internal trigger connection</i> in the section <i>General purpose timer (TIM15/16/17)</i> . Updated <i>Table 85: STM32F0x0 USART implementation for STM32F070xB</i> . Added <i>Section Appendix A: Code examples</i> . Updated: – Bit 8 (DBP) description of PWR_CR register in <i>Section 6.4.1: Power control register (PWR_CR)</i>, – TIM1_ARR reset value in <i>Section 16.4.12: TIM1 auto-reload register (TIM1_ARR)</i>, – Bit 3 (TE) description of USART_ISR and Bit 21 description of USARTx_ISR in <i>Section 26.8.8: Interrupt and status register (USART_ISR)</i>. – Bit SMS description for encoder mode 1 and encoder mode 2 and added the last note in SMS bit description in <i>Section 16.4.3: TIM1 slave mode control register (TIM1_SMCR)</i>, <i>Section 17.4.3: TIM2 and TIM3 slave mode control register (TIM2_SMCR and TIM3_SMCR)</i> and <i>Section 19.5.3: TIM15 slave mode control register (TIM15_SMCR)</i> – the description of ETF bits in <i>Section 16.4.3: TIM1 slave mode control register (TIM1_SMCR)</i> and <i>Section 17.4.3: TIM2 and TIM3 slave mode control register (TIM2_SMCR and TIM3_SMCR)</i>. – the description of IC1F[3:0] bits in <i>Section 16.4.7: TIM1 capture/compare mode register 1 (TIM1_CCMR1)</i>, <i>Section 17.4.7: TIM2 and TIM3 capture/compare mode register 1 (TIM2_CCMR1 and TIM3_CCMR1)</i> and <i>Section 19.5.7: TIM15 capture/compare mode register 1 (TIM15_CCMR1)</i>.

Table 117. Document revision history

Date	Revision	Changes
24-Apr-2017	4	– Section 4: Option bytes - note and description CRC – Feature list RCC – Section 7.4.9: RTC domain control register (RCC_BDCR) - bit field LSEDRV GPIO – Section 8.4.9: GPIO alternate function low register (GPIOx_AFRL) (x = A..D,) and other AF registers - AFR renamed to AFSEL DMA – Section 10.4.2: DMA interrupt flag clear register (DMA_IFCR) - bit description Interrupt – Section Table 32.: Vector table - removed “(combined with EXTI line 28)” from row position 29 – Section 11.2.5: External and internal interrupt/event line mapping - line 23 reserved – Section 11.3.1: Interrupt mask register (EXTI_IMR) - MRx bits renamed to IMx – Section 11.3.2: Event mask register (EXTI_EMR) - MRx bits renamed to EMx – Section 11.3.3: Rising trigger selection register (EXTI_RTSR) - TRx renamed to RTx and FTx; RT31 added – Section 11.3.5: Software interrupt event register (EXTI_SWIER) - SWIERx renamed to SWIx; SWI31 added – Section 11.3.6: Pending register (EXTI_PR) - PRx renamed to PIFx; PIF31 added ADC – Section 12.4.1: Calibration (ADCAL) - calibration software procedure – Section 12.4.2: ADC on-off control (ADEN, ADDIS, ADRDY) - modified – Section 12.4.9: Starting conversions (ADSTART) and corresponding bit description – Section <i>Reading the temperature</i> - added paragraphs TIM1 – Section 13.3.12: Using the break function TIM3 – removed redundant table before Table 49: TIM3 internal trigger connection – Section 14.4.12: TIM3 auto-reload register (TIM3_ARR) reset value – corrected Table 51: TIM3 register map and reset values TIM6/TIM7 – Section 15.4.7: TIM6/TIM7 auto-reload register (TIMx_ARR) reset value

Table 117. Document revision history

Date	Revision	Changes
24-Apr-2017	4	TIM15/16/17 – Section 17.4.12: Using the break function - break function – corrected Table 17.6.10: TIM16 and TIM17 auto-reload register (TIM16_ARR and TIM17_ARR) IWDG – added Section 19.3.4: Behavior in Stop and Standby modes – Section 19.4.4: Status register (IWDG_SR) RTC – Section 21.4.1: RTC block diagram - figures – Section Programming the wakeup timer – Section 21.4.9: Resetting the RTC – Section 21.4.15: Calibration clock output – Section 21.6: RTC interrupts - EXTI replaced with NVIC – Section 21.7.3: RTC control register (RTC_CR) bits SUB1H and ADD1H; added caution at the end – Section 21.7.4: RTC initialization and status register (RTC_ISR) bit WUTWF I2C – Table 69: STM32F0x0 I2C implementation – Table 70: Comparison of analog vs. digital filters – Figure 201: Slave initialization flowchart – Section I2C timings - multiple additions – Section 22.4.9: I2C master mode - information on STM32CubeMX – Section : Master communication initialization (address phase) - information on 10-bit addressing mode – Section 22.7.2: Control register 2 (I2C_CR2) - bit START - information on 10-bit addressing mode, and bit fields SADD and ADDRCF USART – Table 85: STM32F0x0 USART implementation – Section 23.4: USART functional description - removed 1.5 stop bits – Table 91: Effect of low-power modes on the USART – Table 92: USART interrupt requests – Figure 244: USART interrupt mapping diagram – Section 23.7.1: Control register 1 (USART_CR1) – Section 23.7.2: Control register 2 (USART_CR2) – Section 23.7.3: Control register 3 (USART_CR3) – Section 23.7.7: Interrupt and status register (USART_ISR) – Section “Guard time and prescale register” removed – Table 93: USART register map and reset values – Section “USART smartcard code example” removed

Table 117. Document revision history

Date	Revision	Changes
24-Apr-2017	4	SPI – Table 94: STM32F0x0 SPI implementation – Section 24.4.2: Communications between one master and one slave - NSS pin – Section Half-duplex communication – Section Simplex communications – Section 24.4.4: Multi-master communication – Section 24.4.7: Configuration of SPI - point 1b – Section 24.4.14: CRC calculation – Section 24.6.1: SPI control register 1 (SPIx_CR1) bit MSTR – Section 24.6.6: SPI Rx CRC register (SPIx_RXCR) and Section 24.6.7: SPI Tx CRC register (SPIx_TXCR) - bits 15:0 Debug – Table 109: DEV_ID and REV_ID field values added Appendix – Section A.4.2: Alternate function selection sequence code example – Section A.7.1: ADC Calibration code example – Section A.7.2: ADC enable sequence code example – Section A.7.3: ADC disable sequence code example – Section A.7.14: Analog watchdog code example – Section A.7.16: Temperature computation code example – Section A.8.21: DMA burst feature code example – Sections “USART smartcard mode code example” and “USART IrDA mode code example” removed

Index

A

ADC_CCR	219
ADC_CFGR1	212
ADC_CFGR2	216
ADC_CHSELR	218
ADC_CR	210
ADC_DR	218
ADC_IER	208
ADC_ISR	207
ADC_SMPR	216
ADC_TR	217

C

CRC_CR	73
CRC_DR	72
CRC_IDR	72
CRC_INIT	73

D

DBGMCU_APB1_FZ	722
DBGMCU_APB2_FZ	724
DBGMCU_CR	721
DBGMCU_IDCODE	713
DMA_CCRx	163
DMA_CMARx	166
DMA_CNDTRx	165
DMA_CPARx	165
DMA_CSELR	167
DMA_IFCR	162
DMA_ISR	161

E

EXTI_EMR	176
EXTI_FTSR	177
EXTI_IMR	176
EXTI_PR	178
EXTI_RTSR	176
EXTI_SWIER	178

F

FLASH_ACR	58
FLASH_CR	60
FLASH_KEYR	58
FLASH_OPTKEYR	59
FLASH_SR	60

FMPI2C_ISR	588

G

GPIOx_AFRH	141
GPIOx_AFRL	140
GPIOx_BRR	141
GPIOx_BSRR	138
GPIOx_IDR	138
GPIOx_LCKR	139
GPIOx_MODER	136
GPIOx_ODR	138
GPIOx_OSPEEDR	137
GPIOx_OTYPER	136
GPIOx_PUPDR	137

I

I2C_CR1	578
I2C_CR2	581
I2C_ICR	590
I2C_ISR	588
I2C_OAR1	584
I2C_OAR2	585
I2C_PECR	591
I2C_RXDR	592
I2C_TIMEOUTR	587
I2C_TIMINGR	586
I2C_TXDR	592
I2Cx_CR2	581
IWDG_KR	474
IWDG_PR	475
IWDG_RLR	476
IWDG_SR	477
IWDG_WINR	478

P

PWR_CR	84
PWR_CSR	85

R

RCC_AHBENR	111
RCC_AHBSTR	120
RCC_APB1ENR	114
RCC_APB1RSTR	108
RCC_APB2ENR	112
RCC_APB2RSTR	106

RCC_BDCR	117
RCC_CFGR	101
RCC_CFGR2	122
RCC_CFGR3	123
RCC_CIR	104
RCC_CR	99
RCC_CR2	123
RCC_CSR	119
RTC_ALRMAR	513
RTC_CALR	519
RTC_CR	506
RTC_DR	504
RTC_ISR	509
RTC_PRER	511
RTC_SHIFTR	515
RTC_SSR	514
RTC_TAFCR	520
RTC_TR	503
RTC_TSDR	517
RTC_TSSSR	518
RTC_TSTR	516
RTC_WPR	514
RTC_WUTR	512

S

SPIx_CR1	668
SPIx_CR2	670
SPIx_CRCPR	674
SPIx_DR	674
SPIx_RXCR	675
SPIx_SR	673
SPIx_TXCR	675
SYSCFG_CFGR1	144
SYSCFG_CFGR2	150
SYSCFG_EXTICR1	147
SYSCFG_EXTICR2	147
SYSCFG_EXTICR3	148
SYSCFG_EXTICR4	149

T

TIM15_ARR	443
TIM15_BDTR	445
TIM15_CCER	440
TIM15_CCMR1	437
TIM15_CCR1	444
TIM15_CCR2	445
TIM15_CNT	443
TIM15_CR1	429
TIM15_CR2	430
TIM15_DCR	448
TIM15_DIER	433

TIM15_DMAR	448
TIM15_EGR	436
TIM15_PSC	443
TIM15_RCR	444
TIM15_SMCR	432
TIM15_SR	433
TIM5_OR	394
TIMx_ARR	288, 354, 372, 393, 462
TIMx_BDTR	290, 464
TIMx_CCER	284, 352, 392, 460
TIMx_CCMR1	279, 348, 389, 456
TIMx_CCMR2	282, 351
TIMx_CCR1	288, 354, 394, 463
TIMx_CCR2	289, 355
TIMx_CCR3	289, 355
TIMx_CCR4	290, 356
TIMx_CNT	287, 354, 371, 393, 462
TIMx_CR1	268, 338, 369, 386, 451
TIMx_CR2	269, 340, 452
TIMx_DCR	292, 356, 466
TIMx_DIER	274, 343, 370, 387, 453
TIMx_DMAR	293, 357, 466
TIMx_EGR	277, 347, 371, 388, 455
TIMx_PSC	287, 354, 372, 393, 462
TIMx_RCR	288, 463
TIMx_SMCR	271, 341
TIMx_SR	276, 344, 371, 387, 454

U

USART_BRR	633
USART_CR1	625
USART_CR2	628
USART_CR3	630
USART_ICR	638
USART_ISR	635
USART_RDR	639
USART_RQR	634
USART_RTOR	633
USART_TDR	640
USB_ADDRn_RX	706
USB_ADDRn_TX	705
USB_BCDR	699
USB_BTABLE	698
USB_CNTR	692
USB_COUNTn_RX	706
USB_COUNTn_TX	705
USB_DADDR	698
USB_EPnR	701
USB_FNR	697
USB_ISTR	694
USB_LPMCSR	699

W

WWDG_CFR 484
WWDG_CR 483
WWDG_SR 484



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