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**Fire Protection Flash MCU**

**BA45F0082**

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## Features

### CPU Features

- Operating Voltage
  - ♦  $f_{SYS}=2/4\text{MHz}$ : 2.2V~5.5V
- Up to 1 $\mu\text{s}$  instruction cycle with 4MHz system clock at  $V_{DD}=5\text{V}$
- Power down and wake-up functions to reduce power consumption
- Oscillator types:
  - ♦ Internal High Speed RC – HIRC
  - ♦ Internal Low Speed 32kHz RC – LIRC
- Multi-mode operation: FAST, SLOW, IDLE and SLEEP
- Fully integrated internal oscillators require no external components
- All instructions executed in one or two instruction cycles
- Table read instructions
- 63 powerful instructions
- 6-level subroutine nesting
- Bit manipulation instruction

### Peripheral Features

- Flash Program Memory: 2K $\times$ 15
- RAM Data Memory: 128 $\times$ 8
- True EEPROM Memory: 64 $\times$ 8
- Watchdog Timer function
- 14 bidirectional I/O lines
- Two pin-shared external interrupt
- Multiple Timer Modules for time measurement, input capture, compare match output or PWM output or single pulse output function
- Dual Time-Base functions for generation of fixed time interrupt signals
- Multi-channel 12-bit resolution A/D converter
- Low voltage reset function
- Low voltage detect function
- Package type: 16-pin NSOP

## General Description

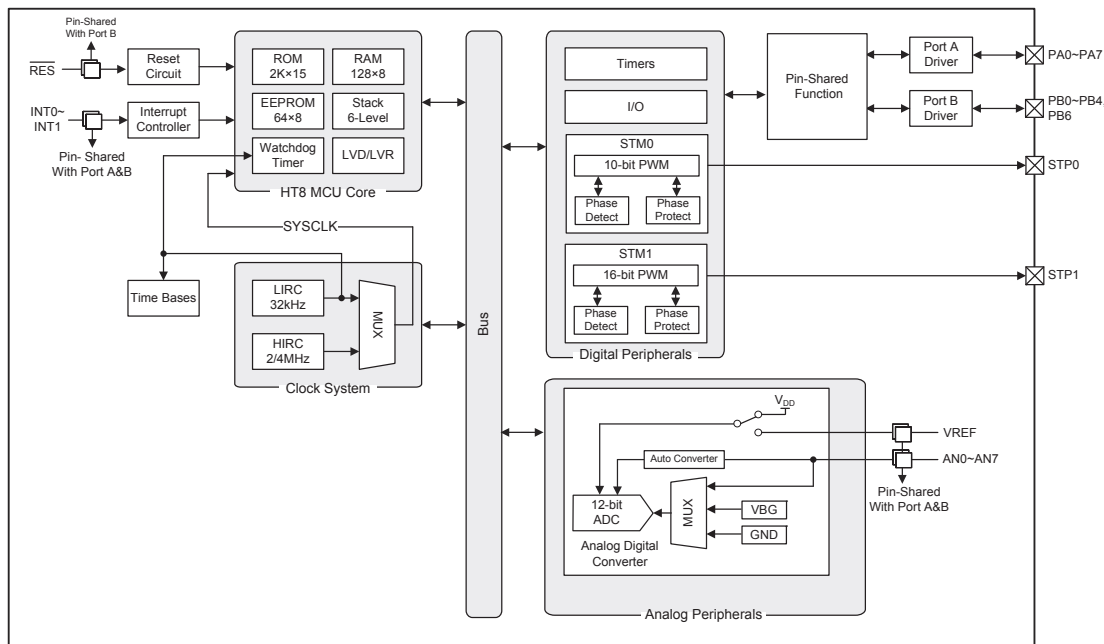
The BA45F0082 is a Flash memory type 8-bit high performance RISC architecture microcontroller, designed especially for networking fire product peripheral applications. Offering users the convenience of Flash memory multi-programming features, the device also includes a wide range of flexible functions and features. Other memory includes an area of RAM Data Memory as well as an area of true EEPROM memory for storage of non-volatile data such as serial numbers, calibration data etc.

Analog features include a multi-channel Analog to Digital converter. Multiple and extremely flexible Timer Modules provide timing, pulse generation, capture input, compare match output, single pulse output and PWM generation functions. Protective features such as an internal Watchdog Timer, Low Voltage Reset and Low Voltage Detector coupled with excellent noise immunity and ESD protection ensure that reliable operation is maintained in hostile electrical environments.

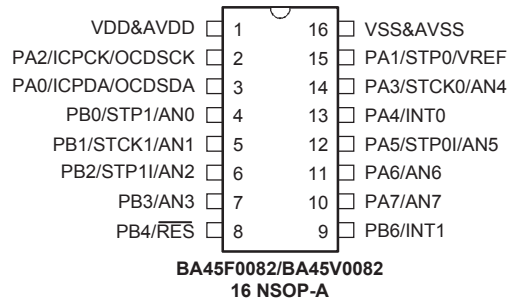
The device also includes fully integrated high and low speed oscillators which can be flexibly used for different applications. The ability to operate and switch dynamically between a range of operating modes using different clock sources gives users the ability to optimise microcontroller operation can minimum power consumption. The usual Holtek MCU features such as power down and wake-up functions, oscillator options, programmable frequency divider, etc. combine to ensure user applications require a minimum of external components.

While the inclusion of flexible I/O programming features, Time-Base functions along with many other features ensure that the device will find excellent use in fire protection peripheral product applications such as temperature alarms, Input/Output modules, sound-light alarms, fire door monitoring in addition to many others.

## Block Diagrams



## Pin Assignment



- Notes:
1. If the pin-shared pin functions have multiple outputs, the desired pin-shared function is determined by the corresponding software control bits.
  2. VDD&AVDD means the VDD and AVDD are the double bonding. VSS&AVSS means the VSS and AVSS are the double bonding.
  3. The OCSDA and OCDSCK pins are used as the OCDS dedicated pins and only available for the BA45V0082 device which is the OCDS EV chip of the BA45F0082.
  4. For less pin-count package types there will be unbonded pins of which status should be properly configured to avoid the current consumption resulting from an input floating condition. Refer to the “Standby Current Considerations” and “Input/Output Ports” sections.

## Pin Description

The function of each pin is listed in the following table, however the details behind how each pin is configured is contained in other sections of the datasheet.

Pin Name	Function	OPT	I/T	O/T	Description
PA0/ICPDA/ OCSDA	PA0	PAWU PAPU	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	ICPDA	—	ST	CMOS	ICP Data Line
	OCSDA	—	ST	CMOS	On Chip Debug System Data Line (OCDS EV only)
PA1/STP0/VREF	PA1	PAWU PAPU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	STP0	PAS0	—	CMOS	STM0 output
	VREF	PAS0	AN	—	A/D Converter reference voltage input
PA2/ICPCK/ OCDSCK	PA2	PAWU PAPU	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	ICPCK	—	ST	—	ICP Clock Line
	OCDSCK	—	ST	—	On Chip Debug System Clock Line (OCDS EV only)
PA3/STCK0/AN4	PA3	PAWU PAPU PAS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	STCK0	PAS0 STM0C0	ST	—	STM0 clock input
	AN4	PAS0	AN	—	A/D Converter input channel 4
PA4/INT0	PA4	PAWU PAPU	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	INT0	INTEG	ST	—	External interrupt input

Pin Name	Function	OPT	I/T	O/T	Description
PA5/STP0I/AN5	PA5	PAWU PAPU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	STP0I	PAS1 STM0C0 STM0C1	ST	—	STM0 capture input pin
	AN5	PAS1	AN	—	A/D Converter input channel 5
PA6/AN6	PA6	PAWU PAPU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	AN6	PAS1	AN	—	A/D Converter input channel 6
PA7/AN7	PA7	PAWU PAPU PAS1	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	AN7	PAS1	AN	—	A/D Converter input channel 7
PB0/STP1/AN0	PB0	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	STP1	PBS0	—	CMOS	STM1 output
	AN0	PBS0	AN	—	A/D Converter input channel 0
PB1/STCK1/AN1	PB1	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	STCK1	PBS0 STM1C0	ST	—	STM1 clock input
	AN1	PBS0	AN	—	A/D Converter input channel 1
PB2/STP1I/AN2	PB2	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	STP1I	PBS0 STM1C0 STM1C1	ST	—	STM1 capture input pin
	AN2	PBS0	AN	—	A/D Converter input channel 2
PB3/AN3	PB3	PBPU PBS0	ST	CMOS	General purpose I/O. Register enabled pull-up and wake-up
	AN3	PBS0	AN	—	A/D Converter input channel 3
PB4/ $\overline{\text{RES}}$	PB4	PBPU	ST	CMOS	General purpose I/O. Register enabled pull-up
	$\overline{\text{RES}}$	RSTC	ST	—	External reset pin
PB6/INT1	PB6	PBPU	ST	CMOS	General purpose I/O. Register enabled pull-up
	INT1	INTEG	ST	—	External interrupt input
VDD&AVDD*	VDD	—	PWR	—	Digital Positive power supply
	AVDD	—	PWR	—	Analog positive power supply
VSS&AVSS**	VSS	—	PWR	—	Digital negative power supply
	AVSS	—	PWR	—	Analog negative power supply

Legend: I/T: Input type; O/T: Output type;  
 OPT: Optional by register option; PWR: Power;  
 ST: Schmitt Trigger input; CMOS: CMOS output;  
 AN: Analog signal;

\*: VDD is the device digital power supply while AVDD is the analog power supply. The AVDD pin is bonded together internally with VDD.

\*\* : VSS is the device digital ground pin while AVSS is the analog ground pin. The AVSS pin is bonded together internally with VSS.

## Absolute Maximum Ratings

Supply Voltage .....	$V_{SS}-0.3V$ to $V_{SS}+6.0V$
Input Voltage .....	$V_{SS}-0.3V$ to $V_{DD}+0.3V$
Storage Temperature.....	$-50^{\circ}C$ to $125^{\circ}C$
Operating Temperature.....	$-40^{\circ}C$ to $85^{\circ}C$
$I_{OL}$ Total .....	80mA
$I_{OH}$ Total .....	-80mA
Total Power Dissipation .....	500mW

Note: These are stress ratings only. Stresses exceeding the range specified under "Absolute Maximum Ratings" may cause substantial damage to the devices. Functional operation of the devices at other conditions beyond those listed in the specification is not implied and prolonged exposure to extreme conditions may affect device reliability.

## D.C. Characteristics

For data in the following tables, note that factors such as oscillator type, operating voltage, operating frequency, pin load conditions, temperature and program instruction type, etc., can all exert an influence on the measured values.

### Operating Voltage Characteristics

$T_a = -40^{\circ}C \sim 85^{\circ}C$

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
$V_{DD}$	Operating Voltage (HIRC)	$f_{SYS} = 2MHz$	2.2	—	5.5	V
		$f_{SYS} = 4MHz$	2.2	—	5.5	
	Operating Voltage (LIRC)	$f_{SYS} = 32kHz$	2.2	—	5.5	V

### Operating Current Characteristics

$T_a = -40^{\circ}C \sim 85^{\circ}C$

Symbol	Normal Operation	Test Conditions		Min.	Typ.	Max.	Unit
		$V_{DD}$	Conditions				
$I_{DD}$	SLOW Mode (LIRC)	2.2V	$f_{SYS} = 32kHz$	—	8	16	$\mu A$
		3V		—	10	20	
		5V		—	30	50	
	FAST Mode (HIRC)	2.2V	$f_{SYS} = 2MHz$	—	0.15	0.2	mA
		3V		—	0.2	0.3	
		5V		—	0.4	0.6	
		2.2V	$f_{SYS} = 4MHz$	—	0.3	0.5	
		3V		—	0.4	0.6	
		5V		—	0.8	1.2	

Note: When using the characteristic table data, the following notes should be taken into consideration:

- Any digital inputs are setup in a non-floating condition.
- All measurements are taken under conditions of no load and with all peripherals in an off state.
- There are no DC current paths.
- All Operating Current values are measured using a continuous NOP instruction program loop.

**Standby Current Characteristics**

Ta= -40°C~85°C

Symbol	Standby Mode	Test Conditions		Min.	Typ.	Max.	Max. 85°C	Unit
		V <sub>DD</sub>	Conditions					
I <sub>STB</sub>	SLEEP Mode	2.2V	WDT off	—	0.2	0.6	0.7	μA
		3V		—	0.2	0.8	1	
		5V		—	0.5	1	1.2	
		2.2V	WDT on	—	1.2	2.4	2.9	μA
		3V		—	1.5	3	3.6	
		5V		—	3	5	6	
	IDLE0 Mode – LIRC	2.2V	f <sub>SUB</sub> on	—	2.4	4	4.8	μA
		3V		—	3	5	6	
		5V		—	5	10	12	
	IDLE1 Mode – HIRC	2.2V	f <sub>SUB</sub> on, f <sub>SYS</sub> = 2MHz	—	60	120	140	μA
		3V		—	70	140	160	
		5V		—	130	260	280	
		2.2V	f <sub>SUB</sub> on, f <sub>SYS</sub> = 4MHz	—	90	200	220	μA
		3V		—	110	220	240	
		5V		—	210	420	460	

Note: When using the characteristic table data, the following notes should be taken into consideration:

- Any digital inputs are setup in a non-floating condition.
- All measurements are taken under conditions of no load and with all peripherals in an off state.
- There are no DC current paths.
- All Standby Current values are taken after a HALT instruction execution thus stopping all instruction execution.

## A.C. Characteristics

For data in the following tables, note that factors such as oscillator type, operating voltage, operating frequency and temperature etc., can all exert an influence on the measured values.

### High Speed Internal Oscillator Frequency Accuracy

During the program writing operation the writer will trim the HIRC oscillator at a user selected HIRC frequency and user selected voltage of either 3V or 5V.

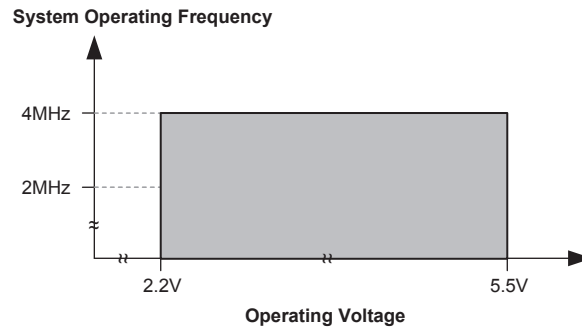
Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Temp.				
f <sub>HIRC</sub>	2MHz Writer Trimmed HIRC Frequency	3V/5V	25°C	-1%	2	+1%	MHz
			-20°C~60°C	-2%	2	+2%	
			-40°C~85°C	-3%	2	+3%	
		2.2V~5.5V	25°C	-9%	2	+9%	
			-40°C~85°C	-10%	2	+10%	
	4MHz Writer Trimmed HIRC Frequency	3V/5V	25°C	-1%	4	+1%	MHz
			-40°C~85°C	-2%	4	+2%	
2.2V~5.5V		25°C	-2.5%	4	+2.5%		
		-40°C~85°C	-3%	4	+3%		

- Notes:
1. The 3V/5V values for V<sub>DD</sub> are provided as these are the two selectable fixed voltages at which the HIRC frequency is trimmed by the writer.
  2. The row below the 3V/5V trim voltage row is provided to show the values for the full V<sub>DD</sub> range operating voltage. It is recommended that the trim voltage is fixed at 3V for application voltage ranges from 2.2V to 3.6V and fixed at 5V for application voltage ranges from 3.3V to 5.5V.
  3. The minimum and maximum tolerance values provided in the table are only for the frequency at which the writer trims the HIRC oscillator. After trimming at this chosen specific frequency any change in HIRC oscillator frequency using the oscillator register control bits by the application program will give a frequency tolerance to within ±20%.

### Low Speed Internal Oscillator Characteristics – LIRC

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Temp.				
f <sub>LIRC</sub>	LIRC Frequency	2.2V~5.5V	25°C	-10%	32	+10%	kHz
			-40°C~85°C	-50%	32	+60%	
t <sub>START</sub>	LIRC Start up Time	—	—	—	—	500	µs

### Operating Frequency Characteristic Curves



### System Start Up Time Characteristics

Ta= -40°C~85°C

Symbol	Parameter	Test Conditions	Min.	Typ.	Max.	Unit
t <sub>SST</sub>	System Start-up Time (Wake-up from condition where f <sub>sys</sub> is off)	f <sub>sys</sub> = f <sub>H</sub> ~ f <sub>H</sub> /64, f <sub>H</sub> = f <sub>HIRC</sub>	—	16	—	t <sub>HIRC</sub>
		f <sub>sys</sub> = f <sub>SUB</sub> = f <sub>LIRC</sub>	—	2	—	t <sub>LIRC</sub>
	System Start-up Time (Wake-up from condition where f <sub>sys</sub> is on)	f <sub>sys</sub> = f <sub>H</sub> ~ f <sub>H</sub> /64, f <sub>H</sub> = f <sub>HIRC</sub>	—	2	—	t <sub>H</sub>
		f <sub>sys</sub> = f <sub>SUB</sub> = f <sub>LIRC</sub>	—	2	—	t <sub>SUB</sub>
	System Speed Switch Time (FAST to SLOW Mode or SLOW to FAST Mode)	f <sub>HIRC</sub> switches from off → on	—	16	—	t <sub>HIRC</sub>
t <sub>RSTD</sub>	System Reset Delay Time (Reset source from Power-on reset or LVR hardware reset)	RR <sub>POR</sub> =5V/ms	42	48	54	ms
	System Reset Delay Time (RSTC/WDT register software reset)	—				
	System Reset Delay Time (WDT overflow reset or Reset pin reset)	—	14	16	18	
t <sub>SRESET</sub>	Minimum Software Reset Width to Reset	—	45	90	120	μs
t <sub>RES</sub>	External Reset Minimum Low Pulse Width	—	10	—	—	μs

Notes: For the System Start-up time values, whether f<sub>sys</sub> is on or off depends upon the mode type and the chosen f<sub>sys</sub> system oscillator. Details are provided in the System Operating Modes section.

- The time units, shown by the symbols t<sub>HIRC</sub> etc. are the inverse of the corresponding frequency values as provided in the frequency tables. For example t<sub>HIRC</sub> = 1/f<sub>HIRC</sub>, t<sub>sys</sub> = 1/f<sub>sys</sub> etc.
- If the LIRC is used as the system clock and if it is off when in the SLEEP Mode, then an additional LIRC start up time, t<sub>START</sub>, as provided in the LIRC frequency table, must be added to the t<sub>SST</sub> time in the table above.
- The System Speed Switch Time is effectively the time taken for the newly activated oscillator to start up.

## Input/Output Characteristics

Ta=25°C, unless otherwise specify

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Conditions				
V <sub>IL</sub>	Input Low Voltage for I/O Ports or Input Pins (except RES pin)	5V	—	0	—	1.5	V
		—	—	0	—	0.2V <sub>DD</sub>	
	—	—	0	—	0.4V <sub>DD</sub>		
V <sub>IH</sub>	Input High Voltage for I/O Ports or Input Pins (except RES pin)	5V	—	3.5	—	5	V
		—	—	0.8V <sub>DD</sub>	—	V <sub>DD</sub>	
	—	—	0.9V <sub>DD</sub>	—	V <sub>DD</sub>		
I <sub>OL</sub>	Sink Current for I/O Ports	3V	V <sub>OL</sub> =0.1V <sub>DD</sub>	15.5	31	—	mA
		5V		31	62	—	
I <sub>OH</sub>	Source Current for I/O Ports	3V	V <sub>OH</sub> = 0.9V <sub>DD</sub>	-3.5	-7.0	—	mA
		5V		-7.2	-14.5	—	
R <sub>PH</sub>	Pull-High Resistance for I/O Ports <small>(Note)</small>	3V	—	20	60	100	kΩ
		5V		10	30	50	
I <sub>LEAK</sub>	Input Leakage Current	5V	V <sub>IN</sub> = V <sub>DD</sub> or V <sub>IN</sub> = V <sub>SS</sub>	—	—	±1	μA
t <sub>TCK</sub>	STMn TCK Input Pin Minimum Pulse Width	—	—	0.3	—	—	μs
t <sub>TPI</sub>	STMn TPI Input Pin Minimum Pulse Width	—	—	0.3	—	—	μs
t <sub>INT</sub>	External Interrupt Minimum Pulse Width	—	—	10	—	—	μs

Note: The R<sub>PH</sub> internal pull high resistance value is calculated by connecting to ground and enabling the input pin with a pull-high resistor and then measuring the input sink current at the specified supply voltage level. Dividing the voltage by this measured current provides the R<sub>PH</sub> value.

## Memory Characteristics

Ta=-40°C~85°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Conditions				
V <sub>RW</sub>	V <sub>DD</sub> for Read/Write	—	—	V <sub>DDmin</sub>	—	V <sub>DDmax</sub>	V
<b>Program Flash/Data EEPROM Memory</b>							
t <sub>DEW</sub>	Erase/Write Cycle Time	—	—	—	2	4	ms
I <sub>DDPGM</sub>	Programming/Erase Current on V <sub>DD</sub>	—	—	—	—	5.0	mA
E <sub>P</sub>	Cell Endurance	—	—	100K	—	—	E/W
t <sub>RETD</sub>	ROM Data Retention Time	—	Ta = 25°C	—	40	—	Year
<b>RAM Data Memory</b>							
V <sub>DR</sub>	RAM Data Retention Voltage	—	Device in SLEEP Mode	1	—	—	V

## A/D Converter Electrical Characteristics

Ta=25°C, unless otherwise specify

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Conditions				
V <sub>DD</sub>	Operating Voltage	—	—	2.2	—	5.5	V
V <sub>ADI</sub>	Input Voltage	—	—	0	—	V <sub>REF</sub>	V
V <sub>REF</sub>	Reference Voltage	—	—	2	—	V <sub>DD</sub>	V
DNL	Differential Non-linearity	3V	V <sub>REF</sub> = V <sub>DD</sub> , t <sub>ADCK</sub> = 0.5μs	—	—	±3	LSB
		5V					
		3V	V <sub>REF</sub> = V <sub>DD</sub> , t <sub>ADCK</sub> = 8μs				
		5V					
INL	Integral Non-linearity	3V	V <sub>REF</sub> = V <sub>DD</sub> , t <sub>ADCK</sub> = 0.5μs	—	—	±4	LSB
		5V					
		3V	V <sub>REF</sub> = V <sub>DD</sub> , t <sub>ADCK</sub> = 8μs				
		5V					
I <sub>ADC</sub>	Additional Current for A/D Converter Enable	3V	No load,	—	1	2	mA
		5V	t <sub>ADCK</sub> = 0.5μs	—	1.5	3	
t <sub>ADCK</sub>	Clock Period	—	—	0.5	—	10	μs
t <sub>ON2ST</sub>	A/D Converter On-to-Start Time	—	—	4	—	—	μs
t <sub>ADS</sub>	Sampling Time	—	—	—	4	—	t <sub>ADCK</sub>
t <sub>ADC</sub>	Conversion Time (Include A/D Conversion Sample and Hold Time)	—	—	—	16	—	t <sub>ADCK</sub>

## Reference Voltage Characteristics

Ta=25°C, unless otherwise specify

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Conditions				
V <sub>BG</sub>	Bandgap Reference Voltage	—	—	-5%	1.04	+5%	V
t <sub>BGS</sub>	V <sub>BG</sub> Turn On Stable Time	—	No load	—	—	150	μs
I <sub>BG</sub>	Additional Current for Bandgap Reference Enable	—	LVR disable, LVD disable	—	—	180	μA

Note: The V<sub>BG</sub> voltage is used as the A/D converter internal signal input.

## LVD/LVR Electrical Characteristics

Ta=25°C

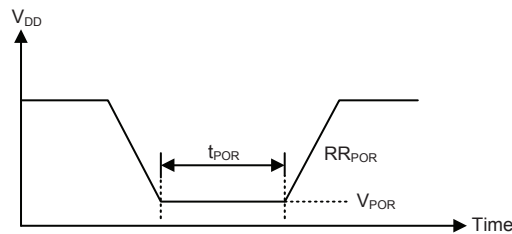
Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Conditions				
V <sub>DD</sub>	Operating Voltage	—	—	1.9	—	5.5	V
V <sub>LVR</sub>	Low Voltage Reset Voltage	—	LVR Enable, 2.1V option	-5%	2.1	+5%	V
V <sub>LVD</sub>	Low Voltage Detector Voltage	—	LVD enable, voltage select 2.0V	-5%	2.0	+5%	V
			LVD enable, voltage select 2.2V		2.2		
			LVD enable, voltage select 2.4V		2.4		
			LVD enable, voltage select 2.7V		2.7		
			LVD enable, voltage select 3.0V		3.0		
			LVD enable, voltage select 3.3V		3.3		
			LVD enable, voltage select 3.6V		3.6		
			LVD enable, voltage select 4.0V		4.0		

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Conditions				
I <sub>LVRLVDBG</sub>	Operating Current	3V	LVD enable, LVR enable, VBGEN = 0	—	—	18	μA
		5V	VBGEN = 0	—	20	25	
		3V	LVD enable, LVR enable, VBGEN = 1	—	—	150	μA
		5V	VBGEN = 1	—	180	200	
t <sub>LVDS</sub>	LVDO Stable Time	—	For LVR enable, VBGEN = 0, LVD off → on	—	—	15	μs
		—	For LVR disable, VBGEN = 0, LVD off → on	—	—	150	
t <sub>LVR</sub>	Minimum Low Voltage Width to Reset	—	—	120	240	480	μs
t <sub>LVD</sub>	Minimum Low Voltage Width to Interrupt	—	—	60	120	240	μs
I <sub>LVR</sub>	Additional Current for LVR Enable	—	LVD disable, VBGEN = 0	—	—	24	μA
I <sub>LVD</sub>	Additional Current for LVD Enable	—	LVR disable, VBGEN = 0	—	—	24	μA

### Power-on Reset Characteristics

T<sub>a</sub>=25°C

Symbol	Parameter	Test Conditions		Min.	Typ.	Max.	Unit
		V <sub>DD</sub>	Conditions				
V <sub>POR</sub>	V <sub>DD</sub> Start Voltage to Ensure Power-on Reset	—	—	—	—	100	mV
RR <sub>POR</sub>	V <sub>DD</sub> Rising Rate to Ensure Power-on Reset	—	—	0.035	—	—	V/ms
t <sub>POR</sub>	Minimum Time for V <sub>DD</sub> Stays at V <sub>POR</sub> to Ensure Power-on Reset	—	—	1	—	—	ms

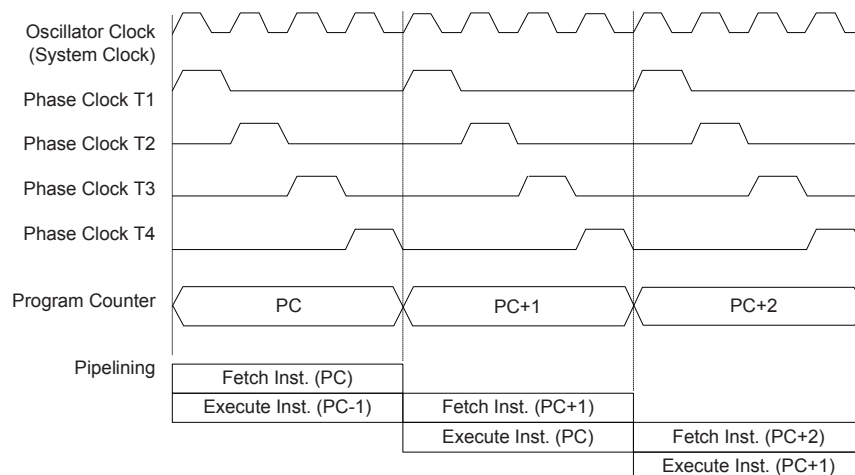


## System Architecture

A key factor in the high-performance features of the Holtek range of microcontrollers is attributed to their internal system architecture. The device takes advantage of the usual features found within RISC microcontrollers providing increased speed of operation and Periodic performance. The pipelining scheme is implemented in such a way that instruction fetching and instruction execution are overlapped, hence instructions are effectively executed in one cycle, with the exception of branch or call instructions. An 8-bit wide ALU is used in practically all instruction set operations, which carries out arithmetic operations, logic operations, rotation, increment, decrement, branch decisions, etc. The internal data path is simplified by moving data through the Accumulator and the ALU. Certain internal registers are implemented in the Data Memory and can be directly or indirectly addressed. The simple addressing methods of these registers along with additional architectural features ensure that a minimum of external components is required to provide a functional I/O and A/D control system with maximum reliability and flexibility. This makes the device suitable for low-cost, high-volume production for controller applications

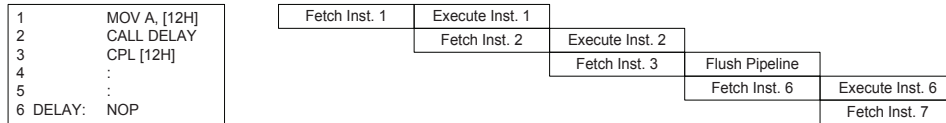
### Clocking and Pipelining

The main system clock, derived from either a HIRC or LIRC oscillator is subdivided into four internally generated non-overlapping clocks, T1~T4. The Program Counter is incremented at the beginning of the T1 clock during which time a new instruction is fetched. The remaining T2~T4 clocks carry out the decoding and execution functions. In this way, one T1~T4 clock cycle forms one instruction cycle. Although the fetching and execution of instructions takes place in consecutive instruction cycles, the pipelining structure of the microcontroller ensures that instructions are effectively executed in one instruction cycle. The exception to this are instructions where the contents of the Program Counter are changed, such as subroutine calls or jumps, in which case the instruction will take one more instruction cycle to execute.



**System Clock and Pipelining**

For instructions involving branches, such as jump or call instructions, two machine cycles are required to complete instruction execution. An extra cycle is required as the program takes one cycle to first obtain the actual jump or call address and then another cycle to actually execute the branch. The requirement for this extra cycle should be taken into account by programmers in timing sensitive applications.



**Instruction Fetching**

### Program Counter

During program execution, the Program Counter is used to keep track of the address of the next instruction to be executed. It is automatically incremented by one each time an instruction is executed except for instructions, such as "JMP" or "CALL" that demand a jump to a non-consecutive Program Memory address. Only the lower 8 bits, known as the Program Counter Low Register, are directly addressable by the application program.

When executing instructions requiring jumps to non-consecutive addresses such as a jump instruction, a subroutine call, interrupt or reset, etc., the microcontroller manages program control by loading the required address into the Program Counter. For conditional skip instructions, once the condition has been met, the next instruction, which has already been fetched during the present instruction execution, is discarded and a dummy cycle takes its place while the correct instruction is obtained.

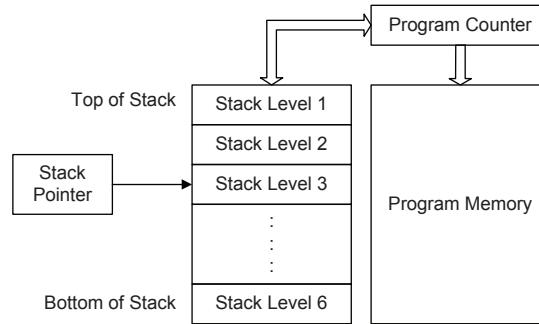
Program Counter	
Program Counter High byte	PCL Register
PC10~PC8	PCL7~PCL0

The lower byte of the Program Counter, known as the Program Counter Low register or PCL, is available for program control and is a readable and writeable register. By transferring data directly into this register, a short program jump can be executed directly, however, as only this low byte is available for manipulation, the jumps are limited to the present page of memory, that is 256 locations. When such program jumps are executed it should also be noted that a dummy cycle will be inserted. Manipulating the PCL register may cause program branching, so an extra cycle is needed to pre-fetch.

### Stack

This is a special part of the memory which is used to save the contents of the Program Counter only. The stack is neither part of the data nor part of the program space, and is neither readable nor writeable. The activated level is indexed by the Stack Pointer, and is neither readable nor writeable. At a subroutine call or interrupt acknowledge signal, the contents of the Program Counter are pushed onto the stack. At the end of a subroutine or an interrupt routine, signaled by a return instruction, RET or RETI, the Program Counter is restored to its previous value from the stack. After a device reset, the Stack Pointer will point to the top of the stack.

If the stack is full and an enabled interrupt takes place, the interrupt request flag will be recorded but the acknowledge signal will be inhibited. When the Stack Pointer is decremented, by RET or RETI, the interrupt will be serviced. This feature prevents stack overflow allowing the programmer to use the structure more easily. However, when the stack is full, a CALL subroutine instruction can still be executed which will result in a stack overflow. Precautions should be taken to avoid such cases which might cause unpredictable program branching. If the stack is overflow, the first Program Counter save in the stack will be lost.



### Arithmetic and Logic Unit – ALU

The arithmetic-logic unit or ALU is a critical area of the microcontroller that carries out arithmetic and logic operations of the instruction set. Connected to the main microcontroller data bus, the ALU receives related instruction codes and performs the required arithmetic or logical operations after which the result will be placed in the specified register. As these ALU calculation or operations may result in carry, borrow or other status changes, the status register will be correspondingly updated to reflect these changes. The ALU supports the following functions:

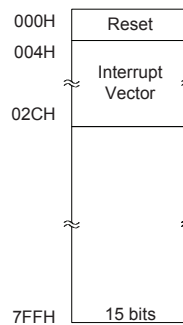
- Arithmetic operations: ADD, ADDM, ADC, ADCM, SUB, SUBM, SBC, SBCM, DAA
- Logic operations: AND, OR, XOR, ANDM, ORM, XORM, CPL, CPLA
- Rotation: RRA, RR, RRCA, RRC, RLA, RL, RLCA, RLC
- Increment and Decrement: INCA, INC, DECA, DEC
- Branch decision: JMP, SZ, SZA, SNZ, SIZ, SDZ, SIZA, SDZA, CALL, RET, RETI

### Flash Program Memory

The Program Memory is the location where the user code or program is stored. For the device the Program Memory is Flash type, which means it can be programmed and re-programmed a large number of times, allowing the user the convenience of code modification on the same device. By using the appropriate programming tools, the Flash device offers users the flexibility to conveniently debug and develop their applications while also offering a means of field programming and updating.

#### Structure

The Program Memory has a capacity of 2K×15 bits. The Program Memory is addressed by the Program Counter and also contains data, table information and interrupt entries. Table data, which can be setup in any location within the Program Memory, is addressed by a separate table pointer register.



**Program Memory Structure**

**Special Vectors**

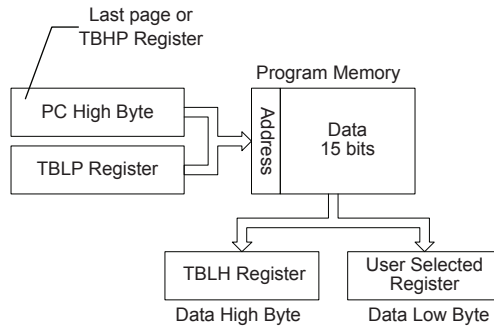
Within the Program Memory, certain locations are reserved for the reset and interrupts. The location 000H is reserved for use by the devices reset for program initialisation. After a device reset is initiated, the program will jump to this location and begin execution.

**Look-up Table**

Any location within the Program Memory can be defined as a look-up table where programmers can store fixed data. To use the look-up table, the table pointer must first be setup by placing the address of the look up data to be retrieved in the table pointer registers, TBLP and TBHP. These registers define the total address of the look-up table.

After setting up the table pointer, the table data can be retrieved from the Program Memory using the "TABRD[m]" or "TABRDL[m]" instructions, respectively. When the instruction is executed, the lower order table byte from the Program Memory will be transferred to the user defined Data Memory register [m] as specified in the instruction. The higher order table data byte from the Program Memory will be transferred to the TBLH special register. Any unused bits in this transferred higher order byte will be read as "0".

The accompanying diagram illustrates the addressing data flow of the look-up table.



**Table Program Example**

The following example shows how the table pointer and table data is defined and retrieved from the microcontroller. This example uses raw table data located in the Program Memory which is stored there using the ORG statement. The value at this ORG statement is "700H" which refers to the start address of the last page within the 2K words Program Memory of the device. The table pointer is setup here to have an initial value of "06H". This will ensure that the first data read from the data table will be at the Program Memory address "706H" or 6 locations after the start of the last page. Note that the value for the table pointer is referenced to the address specified by TBLP and TBHP if the "TABRD [m]" instruction is being used. The high byte of the table data which in this case is equal to zero will be transferred to the TBLH register automatically when the "TABRDL [m]" instruction is executed.

Because the TBLH register is a read-only register and cannot be restored, care should be taken to ensure its protection if both the main routine and Interrupt Service Routine use table read instructions. If using the table read instructions, the Interrupt Service Routines may change the value of the TBLH and subsequently cause errors if used again by the main routine. As a rule it is recommended that simultaneous use of the table read instructions should be avoided. However, in situations where simultaneous use cannot be avoided, the interrupts should be disabled prior to the execution of any main routine table-read instructions. Note that all table related instructions require two instruction cycles to complete their operation.

**Table Read Program Example**

```

tempreg1 db ?      ; temporary register #1
tempreg2 db ?      ; temporary register #2
:
:
mov a,06h          ; initialise low table pointer - note that this address is referenced
mov tblp,a        ; to the last page or the page that tblp pointed
:
:
tabrdl tempreg1   ; transfers value in table referenced by table pointer data at program
                  ; memory address "706H" transferred to tempreg1 and TBLH
dec tblp          ; reduce value of table pointer by one
tabrdl tempreg2   ; transfers value in table referenced by table pointer data at program
                  ; memory address "705H" transferred to tempreg2 and TBLH in this
                  ; example the data "1AH" is transferred to tempreg1 and data "0FH" to
                  ; register tempreg2
:
:
org 700h          ; sets initial address of program memory
dc 00Ah, 00Bh, 00Ch, 00Dh, 00Eh, 00Fh, 01Ah, 01Bh
:
:

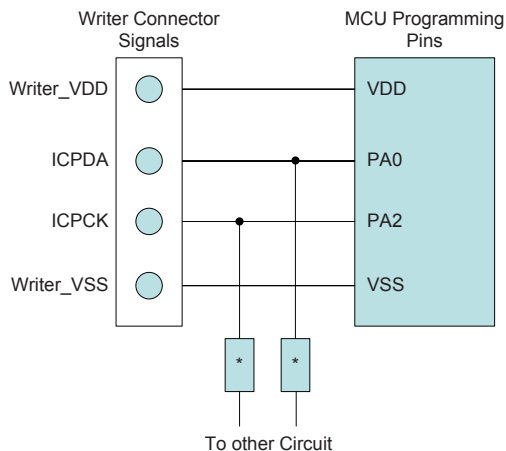
```

**In Circuit Programming**

The provision of Flash type Program Memory provides the user with a means of convenient and easy upgrades and modifications to their programs on the same device. As an additional convenience, Holtek has provided a means of programming the microcontroller in-circuit using a 4-pin interface. This provides manufacturers with the possibility of manufacturing their circuit boards complete with a programmed or un-programmed microcontroller, and then programming or upgrading the program at a later stage. This enables product manufacturers to easily keep their manufactured products supplied with the latest program releases without removal and re-insertion of the device.

Holtek Write Pins	MCU Programming Pins	Function
ICPDA	PA0	Programming Serial Data
ICPCK	PA2	Programming Serial Clock
VDD	VDD	Power Supply
VSS	VSS	Ground

The Program Memory and EEPROM data memory can both be programmed serially in-circuit using this 4-wire interface. Data is downloaded and uploaded serially on a single pin with an additional line for the clock. Two additional lines are required for the power supply and ground. The technical details regarding the in-circuit programming of the device are beyond the scope of this document and will be supplied in supplementary literature.



Note: \* may be resistor or capacitor. The resistance of \* must be greater than 1kΩ or the capacitance of \* must be less than 1nF.

### On-Chip Debug Support – OCDS

There is an EV chip which is used to emulate the real device. This EV chip device also provides an "On-Chip Debug" function to debug the device during the development process. The EV chip and the actual MCU device are almost functionally compatible except for the "On-Chip Debug" function. Users can use the EV chip device to emulate the real chip device behavior by connecting the OCDSDA and OCDSCK pins to the Holtek HT-IDE development tools. The OCDSDA pin is the OCDS Data/Address input/output pin while the OCDSCK pin is the OCDS clock input pin. When users use the EV chip for debugging, other functions which are shared with the OCDSDA and OCDSCK pins in the device will have no effect in the EV chip. However, the two OCDS pins which are pin-shared with the ICP programming pins are still used as the Flash Memory programming pins for ICP. For more detailed OCDS information, refer to the corresponding document named "Holtek e-Link for 8-bit MCU OCDS User's Guide".

Holtek e-Link Pins	EV Chip Pins	Pin Description
OCDSDA	OCDSDA	On-chip Debug Support Data/Address input/output
OCDSCK	OCDSCK	On-chip Debug Support Clock input
VDD	VDD	Power Supply
GND	VSS	Ground

## Data Memory

The Data Memory is a volatile area of 8-bit wide RAM internal memory and is the location where temporary information is stored.

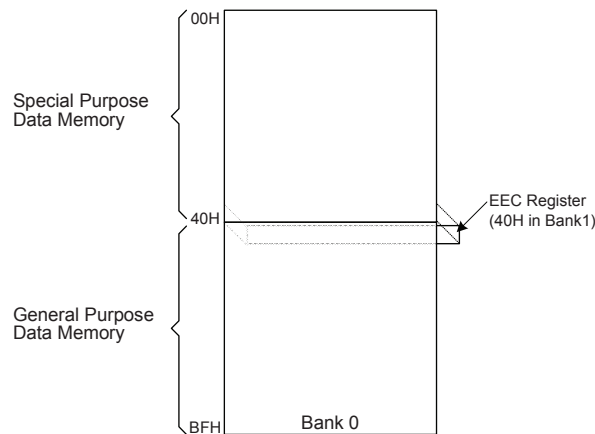
### Structure

Divided into two sections, the first of these is an area of RAM, known as the Special Function Data Memory. Here are located registers which are necessary for correct operation of the device. Many of these registers can be read from and written to directly under program control, however, some remain protected from user manipulation. The second area of Data Memory is known as the General Purpose Data Memory, which is reserved for general purpose use. All locations within this area are read and write accessible under program control.

The overall Data Memory is subdivided into two banks. The Special Purpose Data Memory registers are almost located in Bank 0, while the EEC register is at address 40H in Bank 1. Switching between the different Data Memory banks is achieved by setting the Bank Pointer to the correct value. The start address of the Data Memory is the address 00H.

MCU Special Purpose Data Memory	MCU General Purpose Data Memory	
Located Banks	Capacity	Address
0, 1	128×8	Bank 0: 40H~BFH

**Data Memory Summary**



**Data Memory Structure**

### General Purpose Data Memory

There is a 128 byte general purpose data memory which is arranged in Bank 0. All microcontroller programs require an area of read/write memory where temporary data can be stored and retrieved for use later. It is this area of RAM memory that is known as General Purpose Data Memory. This area of Data Memory is fully accessible by the user programming for both reading and writing operations. By using the bit operation instructions individual bits can be set or reset under program control giving the user a large range of flexibility for bit manipulation in the Data Memory.

### Special Purpose Data Memory

This area of Data Memory is where registers, necessary for the correct operation of the microcontroller, are stored. Most of the registers are both readable and writeable but some are protected and are readable only, the details of which are located under the relevant Special Function Register section. Note that for locations that are unused, any read instruction to these addresses will return the value "00H".

Bank 0		Bank 1	Bank 0		Bank 1
00H	IAR0		20H	SADOL	
01H	MP0		21H	SADOH	
02H	IAR1		22H	SADC0	
03H	MP1		23H	SADC1	
04H	BP		24H	LVDC	
05H	ACC		25H	RSTC	
06H	PCL		26H		
07H	TBLP		27H		
08H	TBLH		28H	STM0C0	
09H	TBHP		29H	STM0C1	
0AH	STATUS		2AH	STM0DL	
0BH			2BH	STM0DH	
0CH			2CH	STM0AL	
0DH			2DH	STM0AH	
0EH			2EH	PB	
0FH	RSTFC		2FH	PBC	
10H	INTEG		30H	PBPU	
11H	INTC0		31H	STM1C0	
12H	INTC1		32H	STM1C1	
13H	INTC2	33H	STM1DL		
14H	PA	34H	STM1DH		
15H	PAC	35H	STM1AL		
16H	PAPU	36H	STM1AH		
17H	PAWU	37H	STM1RP		
18H	SCC	38H	PAS0		
19H	HIRCC	39H	PAS1		
1AH	WDTC	3AH	PBS0		
1BH	TB0C	3BH			
1CH	TB1C	3CH			
1DH	PSCR	3DH			
1EH	EEA	3EH			
1FH	EED	3FH			
		40H		EEC	

□ : Unused, read as "00"

**Special Purpose Data Memory Structure**

## Special Function Register Description

Most of the Special Function Register details will be described in their relevant functional section, however several registers require a separate description in this section.

### Indirect Addressing Registers – IAR0, IAR1

The Indirect Addressing Registers, IAR0 and IAR1, although having their locations in normal Data Memory register space, do not actually physically exist as normal registers. The method of indirect addressing for RAM data manipulation uses these Indirect Addressing Registers and Memory Pointers, in contrast to direct memory addressing, where the actual memory address is specified. Actions on the IAR0 and IAR1 registers will result in no actual read or write operation to these registers but rather to the memory location specified by their corresponding Memory Pointers, MP0 or MP1. Acting as a pair, IAR0 and MP0 can together access data from Bank 0 while the IAR1 and MP1 register pair can access data from any bank. As the Indirect Addressing Registers are not physically implemented, reading the Indirect Addressing Registers indirectly will return a result of "00H" and writing to the registers indirectly will result in no operation.

### Memory Pointers – MP0, MP1

Two Memory Pointers, known as MP0 and MP1 are provided. These Memory Pointers are physically implemented in the Data Memory and can be manipulated in the same way as normal registers providing a convenient way with which to address and track data. When any operation to the relevant Indirect Addressing Registers is carried out, the actual address that the microcontroller is directed to is the address specified by the related Memory Pointer. MP0, together with Indirect Addressing Register, IAR0, are used to access data from Bank 0, while MP1 and IAR1 are used to access data from all banks according to BP register. Direct Addressing can only be used with Bank 0, all other Banks must be addressed indirectly using MP1 and IAR1.

The following example shows how to clear a section of four Data Memory locations already defined as locations `adres1` to `adres4`.

### Indirect Addressing Program Example

```
data .section 'data'
adres1 db ?
adres2 db ?
adres3 db ?
adres4 db ?
block db ?
code .section at 0 'code'
org 00h
start:
    mov a, 04h          ; setup size of block
    mov block, a
    mov a, offset adres1 ; Accumulator loaded with first RAM address
    mov mp0, a         ; setup memory pointer with first RAM address
loop:
    clr IAR0           ; clear the data at address defined by mp0
    inc mp0            ; increment memory pointer
    sdz block          ; check if last memory location has been cleared
    jmp loop
continue:
```

The important point to note here is that in the example shown above, no reference is made to specific Data Memory addresses.

### Bank Pointer – BP

For this device, the Data Memory is divided into two banks, Bank0 and Bank1. Selecting the required Data Memory area is achieved using the Bank Pointer. Bit 0 of the Bank Pointer is used to select Data Memory Banks 0~1.

The Data Memory is initialised to Bank 0 after a reset, except for a WDT time-out reset in the IDLE or SLEEP Mode, in which case, the Data Memory bank remains unaffected. It should be noted that the Special Function Data Memory is not affected by the bank selection, which means that the Special Function Registers can be accessed from within any bank. Directly addressing the Data Memory will always result in Bank 0 being accessed irrespective of the value of the Bank Pointer. Accessing data from Bank1 must be implemented using Indirect Addressing.

### BP Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	—	DMBP0
R/W	—	—	—	—	—	—	—	R/W
POR	—	—	—	—	—	—	—	0

Bit 7 ~ 1      Unimplemented, read as "0"

Bit 0          **DMBP0**: Select Data Memory Bank  
                  0: Bank 0  
                  1: Bank 1

### Accumulator – ACC

The Accumulator is central to the operation of any microcontroller and is closely related with operations carried out by the ALU. The Accumulator is the place where all intermediate results from the ALU are stored. Without the Accumulator it would be necessary to write the result of each calculation or logical operation such as addition, subtraction, shift, etc., to the Data Memory resulting in higher programming and timing overheads. Data transfer operations usually involve the temporary storage function of the Accumulator; for example, when transferring data between one user-defined register and another, it is necessary to do this by passing the data through the Accumulator as no direct transfer between two registers is permitted.

### Program Counter Low Register – PCL

To provide additional program control functions, the low byte of the Program Counter is made accessible to programmers by locating it within the Special Purpose area of the Data Memory. By manipulating this register, direct jumps to other program locations are easily implemented. Loading a value directly into this PCL register will cause a jump to the specified Program Memory location, however, as the register is only 8-bit wide, only jumps within the current Program Memory page are permitted. When such operations are used, note that a dummy cycle will be inserted.

### Look-up Table Registers – TBLP, TBHP, TBLH

These three special function registers are used to control operation of the look-up table which is stored in the Program Memory. TBLP and TBHP are the table pointers and indicate the location where the table data is located. Their value must be setup before any table read commands are executed. Their value can be changed, for example using the "INC" or "DEC" instructions, allowing for easy table data pointing and reading. TBLH is the location where the high order byte of the table data is stored after a table read data instruction has been executed. Note that the lower order table data byte is transferred to a user defined location.

## **Status Register – STATUS**

This 8-bit register contains the zero flag (Z), carry flag (C), auxiliary carry flag (AC), overflow flag (OV), power down flag (PDF), and watchdog time-out flag (TO). These arithmetic/logical operation and system management flags are used to record the status and operation of the microcontroller.

With the exception of the TO and PDF flags, bits in the status register can be altered by instructions like most other registers. Any data written into the status register will not change the TO or PDF flag. In addition, operations related to the status register may give different results due to the different instruction operations. The TO flag can be affected only by a system power-up, a WDT time-out or by executing the "CLR WDT" or "HALT" instruction. The PDF flag is affected only by executing the "HALT" or "CLR WDT" instruction or during a system power-up.

The Z, OV, AC and C flags generally reflect the status of the latest operations.

- C is set if an operation results in a carry during an addition operation or if a borrow does not take place during a subtraction operation; otherwise C is cleared. C is also affected by a rotate through carry instruction.
- AC is set if an operation results in a carry out of the low nibbles in addition, or no borrow from the high nibble into the low nibble in subtraction; otherwise AC is cleared.
- Z is set if the result of an arithmetic or logical operation is zero; otherwise Z is cleared.
- OV is set if an operation results in a carry into the highest-order bit but not a carry out of the highest-order bit, or vice versa; otherwise OV is cleared.
- PDF is cleared by a system power-up or executing the "CLR WDT" instruction. PDF is set by executing the "HALT" instruction.
- TO is cleared by a system power-up or executing the "CLR WDT" or "HALT" instruction. TO is set by a WDT time-out.

In addition, on entering an interrupt sequence or executing a subroutine call, the status register will not be pushed onto the stack automatically. If the contents of the status registers are important and if the subroutine can corrupt the status register, precautions must be taken to correctly save it.

**STATUS Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	TO	PDF	OV	Z	AC	C
R/W	—	—	R	R	R/W	R/W	R/W	R/W
POR	—	—	0	0	x	x	x	x

"x" unknown

- Bit 7~6      Unimplemented, read as "0"
- Bit 5        **TO**: Watchdog Time-out flag  
               0: After power up or executing the "CLR WDT" or "HALT" instruction  
               1: A watchdog time-out occurred.
- Bit 4        **PDF**: Power down flag  
               0: After power up or executing the "CLR WDT" instruction  
               1: By executing the "HALT" instruction
- Bit 3        **OV**: Overflow flag  
               0: No overflow  
               1: An operation results in a carry into the highest-order bit but not a carry out of the highest-order bit or vice versa.
- Bit 2        **Z**: Zero flag  
               0: The result of an arithmetic or logical operation is not zero  
               1: The result of an arithmetic or logical operation is zero
- Bit 1        **AC**: Auxiliary flag  
               0: No auxiliary carry  
               1: An operation results in a carry out of the low nibbles in addition, or no borrow from the high nibble into the low nibble in subtraction
- Bit 0        **C**: Carry flag  
               0: No carry-out  
               1: An operation results in a carry during an addition operation or if a borrow does not take place during a subtraction operation  
               The "C" flag is also affected by a rotate through carry instruction.

## EEPROM Data Memory

This device contains an area of internal EEPROM Data Memory. EEPROM, which stands for Electrically Erasable Programmable Read Only Memory, is by its nature a non-volatile form of re-programmable memory, with data retention even when its power supply is removed. By incorporating this kind of data memory, a whole new host of application possibilities are made available to the designer. The availability of EEPROM storage allows information such as product identification numbers, calibration values, specific user data, system setup data or other product information to be stored directly within the product microcontroller. The process of reading and writing data to the EEPROM memory has been reduced to a very trivial affair.

### EEPROM Data Memory Structure

The EEPROM Data Memory capacity is 64×8 bits for the device. Unlike the Program Memory and RAM Data Memory, the EEPROM Data Memory is not directly mapped into memory space and is therefore not directly addressable in the same way as the other types of memory. Read and Write operations to the EEPROM are carried out in single byte operations using an address and a data register in Bank 0 and a single control register in Bank 1.

### EEPROM Registers

Three registers control the overall operation of the internal EEPROM Data Memory. These are the address registers, EEA, the data register, EED and a single control register, EEC. As both the EEA and EED registers are located in Bank 0, they can be directly accessed in the same way as any other Special Function Register. The EEC register however, being located in Bank1, cannot be directly addressed and can only be read from or written to indirectly using the MP1 Memory Pointer and Indirect Addressing Register, IAR1. Because the EEC control register is located at address 40H in Bank 1, the MP1 Memory Pointer must first be set to the value 40H and the Bank Pointer register, BP, set to the value, 01H, before any operations on the EEC register are executed.

Register Name	Bit							
	7	6	5	4	3	2	1	0
EEA	—	—	EEA5	EEA4	EEA3	EEA2	EEA1	EEA0
EED	D7	D6	D5	D4	D3	D2	D1	D0
EEC	—	—	—	—	WREN	WR	RDEN	RD

EEPROM Register List

#### EEA Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	EEA5	EEA4	EEA3	EEA2	EEA1	EEA0
R/W	—	—	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5~0 **EEA5~EEA0**: Data EEPROM address bit 5 ~ bit 0

#### EED Register

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: Data EEPROM data bit 7 ~ bit 0

### EEC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	WREN	WR	RDEN	RD
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

Bit 7~4 Unimplemented, read as "0"

Bit 3 **WREN**: Data EEPROM Write Enable

0: Disable

1: Enable

This is the Data EEPROM Write Enable Bit which must be set high before Data EEPROM write operations are carried out. Clearing this bit to zero will inhibit Data EEPROM write operations.

Bit 2 **WR**: EEPROM Write Control

0: Write cycle has finished

1: Activate a write cycle

This is the Data EEPROM Write Control Bit and when set high by the application program will activate a write cycle. This bit will be automatically reset to zero by the hardware after the write cycle has finished. Setting this bit high will have no effect if the WREN has not first been set high.

Bit 1 **RDEN**: Data EEPROM Read Enable

0: Disable

1: Enable

This is the Data EEPROM Read Enable Bit which must be set high before Data EEPROM read operations are carried out. Clearing this bit to zero will inhibit Data EEPROM read operations.

Bit 0 **RD**: EEPROM Read Control

0: Read cycle has finished

1: Activate a read cycle

This is the Data EEPROM Read Control Bit and when set high by the application program will activate a read cycle. This bit will be automatically reset to zero by the hardware after the read cycle has finished. Setting this bit high will have no effect if the RDEN has not first been set high.

Note: The WREN, WR, RDEN and RD cannot be set high at the same time in one instruction. The WR and RD cannot be set high at the same time.

### Reading Data from the EEPROM

To read data from the EEPROM, the read enable bit, RDEN, in the EEC register must first be set high to enable the read function. The EEPROM address of the data to be read must then be placed in the EEA register. If the RD bit in the EEC register is now set high, a read cycle will be initiated. Setting the RD bit high will not initiate a read operation if the RDEN bit has not been set. When the read cycle terminates, the RD bit will be automatically cleared to zero, after which the data can be read from the EED register. The data will remain in the EED register until another read or write operation is executed. The application program can poll the RD bit to determine when the data is valid for reading.

## **Writing Data to the EEPROM**

The EEPROM address of the data to be written must first be placed in the EEA register and the data placed in the EED register. To write data to the EEPROM, the write enable bit, WREN, in the EEC register must first be set high to enable the write function. After this, the WR bit in the EEC register must be immediately set high to initiate a write cycle. These two instructions must be executed consecutively. The global interrupt bit EMI should also first be cleared before implementing any write operations, and then set again after the write cycle has started. Note that setting the WR bit high will not initiate a write cycle if the WREN bit has not been set. As the EEPROM write cycle is controlled using an internal timer whose operation is asynchronous to microcontroller system clock, a certain time will elapse before the data will have been written into the EEPROM. Detecting when the write cycle has finished can be implemented either by polling the WR bit in the EEC register or by using the EEPROM interrupt. When the write cycle terminates, the WR bit will be automatically cleared to zero by the microcontroller, informing the user that the data has been written to the EEPROM. The application program can therefore poll the WR bit to determine when the write cycle has ended.

## **Write Protection**

Protection against inadvertent write operation is provided in several ways. After the device is powered-on the Write Enable bit in the control register will be cleared preventing any write operations. Also at power-on the Bank Pointer, BP, will be reset to zero, which means that Data Memory Bank 0 will be selected. As the EEPROM control register is located in Bank 1, this adds a further measure of protection against spurious write operations. During normal program operation, ensuring that the Write Enable bit in the control register is cleared will safeguard against incorrect write operations.

## **EEPROM Interrupt**

The EEPROM write interrupt is generated when an EEPROM write cycle has ended. The EEPROM interrupt must first be enabled by setting the DEE bit in the relevant interrupt register. When an EEPROM write cycle ends, the DEF request flag will be set. If the global and EEPROM interrupt are enabled and the stack is not full, a jump to the EEPROM Interrupt vector will take place. When the EEPROM interrupt is serviced, the EEPROM interrupt flag will be automatically reset. More details can be obtained in the Interrupt section.

## Programming Considerations

Care must be taken that data is not inadvertently written to the EEPROM. Protection can be enhanced by ensuring that the Write Enable bit is normally cleared to zero when not writing. Also the Bank Pointer could be normally cleared to zero as this would inhibit access to Bank 1 where the EEPROM control register exists. Although certainly not necessary, consideration might be given in the application program to the checking of the validity of new write data by a simple read back process.

When writing data the WR bit must be set high immediately after the WREN bit has been set high, to ensure the write cycle executes correctly. The global interrupt bit EMI should also be cleared before a write cycle is executed and then re-enabled after the write cycle starts. Note that the device should not enter the IDLE or SLEEP mode until the EEPROM read or write operation is totally complete. Otherwise, the EEPROM read or write operation will fail.

## Programming Examples

### • Reading data from the EEPROM – polling method

```
MOV A, EEPROM_ADRES      ; user defined address
MOV EEA, A
MOV A, 040H              ; setup memory pointer MP1
MOV MP1, A               ; MP1 points to EEC register
MOV A, 01H               ; setup Bank Pointer
MOV BP, A
SET IAR1.1               ; set RDEN bit, enable read operations
SET IAR1.0               ; start Read Cycle - set RD bit
BACK:
SZ IAR1.0                ; check for read cycle end
JMP BACK
CLR IAR1                  ; disable EEPROM write
CLR BP
MOV A, EED                ; move read data to register
MOV READ_DATA, A
```

### • Writing Data to the EEPROM – polling method

```
MOV A, EEPROM_ADRES      ; user defined address
MOV EEA, A
MOV A, EEPROM_DATA       ; user defined data
MOV EED, A
MOV A, 040H              ; setup memory pointer MP1
MOV MP1, A               ; MP1 points to EEC register
MOV A, 01H               ; setup Bank Pointer
MOV BP, A
CLR EMI
SET IAR1.3               ; set WREN bit, enable write operations
SET IAR1.2               ; start Write Cycle - set WR bit- executed immediately
                        ; after set WREN bit

SET EMI
BACK:
SZ IAR1.2                ; check for write cycle end
JMP BACK
CLR IAR1                  ; disable EEPROM write
CLR BP
```

## Oscillators

Various oscillator options offer the user a wide range of functions according to their various application requirements. The flexible features of the oscillator functions ensure that the best optimisation can be achieved in terms of speed and power saving. Oscillator selections and operation are selected through the application program by using some control registers.

### Oscillator Overview

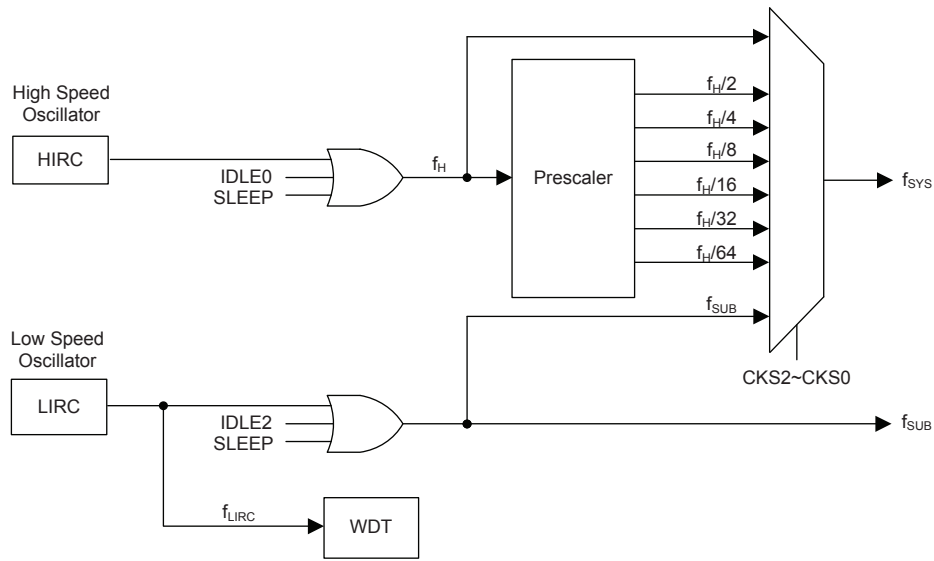
In addition to being the source of the main system clock the oscillators also provide clock sources for the Watchdog Timer and Time Base Interrupts. External oscillators requiring some external components as well as fully integrated internal oscillators, requiring no external components, are provided to form a wide range of both fast and slow system oscillators. All oscillator options all can be selected through register programming. The higher frequency oscillators provide higher performance but carry with it the disadvantage of higher power requirements, while the opposite is of course true for the lower frequency oscillators. With the capability of dynamically switching between fast and slow system clock, the device have the flexibility to optimize the performance/power ratio, a feature especially important in power sensitive portable applications.

Type	Name	Frequency
Internal High Speed RC	HIRC	2/4MHz
Internal Low Speed RC	LIRC	32kHz

Oscillator Types

### System Clock Configurations

There are two methods of generating the system clock, a high speed oscillator and a low speed oscillator. The high speed clocks is sourced from the internal 2/4MHz RC oscillator, HIRC. The low speed oscillator is the internal 32kHz RC oscillator, LIRC. Selecting whether the low or high speed oscillator is used as the system oscillator is implemented using the CKS2~CKS0 bits in the SCC register and as the system clock can be dynamically selected.



System Clock Configurations

### **Internal High Speed RC Oscillator – HIRC**

The internal RC oscillator is a fully integrated system oscillator requiring no external components. The internal RC oscillator has three selectable frequencies of 2MHz and 4MHz. Device trimming during the manufacturing process and the inclusion of internal frequency compensation circuits are used to ensure that the influence of the power supply voltage, temperature and process variations on the oscillation frequency are minimised.

### **Internal 32kHz Oscillator – LIRC**

The Internal 32kHz System Oscillator is also a fully integrated RC oscillator with a typical frequency of 32kHz at 5V, requiring no external components for its implementation. Device trimming during the manufacturing process and the inclusion of internal frequency compensation circuits are used to ensure that the influence of the power supply voltage, temperature and process variations on the oscillation frequency are minimised.

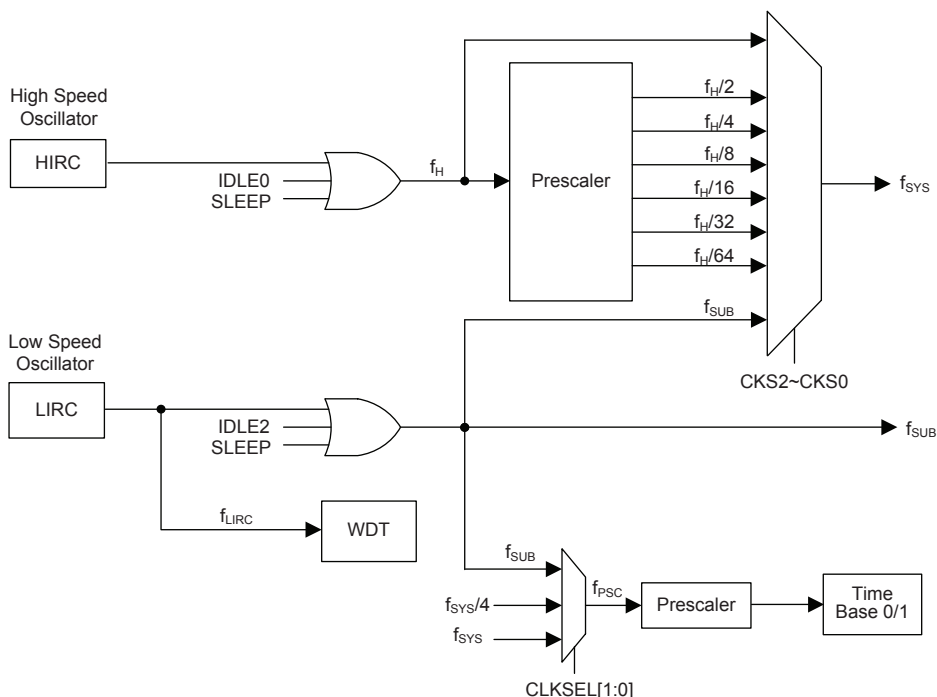
## **Operating Modes and System Clocks**

Present day applications require that their microcontrollers have high performance but often still demand that they consume as little power as possible, conflicting requirements that are especially true in battery powered portable applications. The fast clocks required for high performance will by their nature increase current consumption and of course vice versa, lower speed clocks reduce current consumption. As Holtek has provided the device with both high and low speed clock sources and the means to switch between them dynamically, the user can optimise the operation of their microcontroller to achieve the best performance/power ratio.

### **System Clocks**

The device has many different clock sources for both the CPU and peripheral function operation. By providing the user with a wide range of clock options using register programming, a clock system can be configured to obtain maximum application performance.

The main system clock, can come from a high frequency,  $f_H$ , or low frequency,  $f_{SUB}$ , source, and is selected using the CKS2~CKS0 bits in the SCC register. The high speed system clock is sourced from the HIRC oscillator, while the low speed system clock source is sourced from the internal clock  $f_{SUB}$  which is sourced by the LIRC oscillator. The other choice, which is a divided version of the high speed system oscillator has a range of  $f_H/2 \sim f_H/64$ .



**Device Clock Configurations**

Note: When the system clock source  $f_{SYS}$  is switched to  $f_{SUB}$  from  $f_H$ , the high speed oscillator can stop to conserve the power by clearing the corresponding high speed oscillator enable control bit. Thus there is no  $f_H \sim f_H/64$  for peripheral circuit to use.

### System Operation Modes

There are six different modes of operation for the microcontroller, each one with its own special characteristics and which can be chosen according to the specific performance and power requirements of the application. There are two modes allowing normal operation of the microcontroller, the FAST Mode and SLOW Mode. The remaining four modes, the SLEEP, IDLE0, IDLE1 and IDLE2 Mode are used when the microcontroller CPU is switched off to conserve power.

Operation Mode	CPU	Related Register Value			$f_{SYS}$	$f_H$	$f_{SUB}$	$f_{LIRC}$
		FHIDEN	FSIDEN	CKS2~CKS0				
FAST	On	x	x	000~110	$f_H \sim f_H/64$	On	On	On
SLOW	On	x	x	111	$f_{SUB}$	On/Off <sup>(1)</sup>	On	On
IDLE0	Off	0	1	000~110	Off	Off	On	On
				111	On			
IDLE1	Off	1	1	xxx	On	On	On	On
IDLE2	Off	1	0	000~110	On	On	Off	On
				111	Off			
SLEEP	Off	0	0	xxx	Off	Off	Off	On <sup>(2)</sup>

"x": Don't care

Note: 1. The  $f_H$  clock will be switched on or off by configuring the corresponding oscillator enable bit in the SLOW mode.

2. The  $f_{LIRC}$  clock will be switched on since the WDT function is always enabled even in the SLEEP mode.

**FAST Mode**

This is one of the main operating modes where the microcontroller has all of its functions operational and where the system clock is provided the high speed oscillator. This mode operates allowing the microcontroller to operate normally with a clock source from the HIRC high speed oscillator. The high speed oscillator will however first be divided by a ratio ranging from 1 to 64, the actual ratio being selected by the CKS2~CKS0 bits in the SCC register. Although a high speed oscillator is used, running the microcontroller at a divided clock ratio reduces the operating current.

**SLOW Mode**

This is also a mode where the microcontroller operates normally although now with a slower speed clock source. The clock source used will be from  $f_{SUB}$ . The  $f_{SUB}$  clock is derived from the LIRC oscillator.

**SLEEP Mode**

The SLEEP Mode is entered when an HALT instruction is executed and when the FHIDEN and FSIDEN bit both are low. In the SLEEP mode the CPU will be stopped. The  $f_{SUB}$  clock provided to the peripheral function will also be stopped. However the  $f_{LIRC}$  clock still continues to operate since the WDT function is enabled.

**IDLE0 Mode**

The IDLE0 Mode is entered when an HALT instruction is executed and when the FHIDEN bit in the SCC register is low and the FSIDEN bit in the SCC register is high. In the IDLE0 Mode the CPU will be switched off but the low speed oscillator will be turned on to drive some peripheral functions.

**IDLE1 Mode**

The IDLE1 Mode is entered when an HALT instruction is executed and when the FHIDEN bit in the SCC register is high and the FSIDEN bit in the SCC register is high. In the IDLE1 Mode the system oscillator will be inhibited from driving the CPU but may continue to provide a clock to keep some peripheral functions operational. In the IDLE1 Mode, the system oscillator will continue to run, and this system oscillator may be the high or low speed oscillator.

**IDLE2 Mode**

The IDLE2 Mode is entered when an HALT instruction is executed and when the FHIDEN bit in the SCC register is high and the FSIDEN bit in the SCC register is low. In the IDLE2 Mode the CPU will be switched off but the high speed oscillator will be turned on to provide a clock source to keep some peripheral functions operational.

**Control Registers**

The registers, SCC and HIRCC, are used to control the system clock and the HIRC oscillator configurations.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SCC	CKS2	CKS1	CKS0	—	—	—	FHIDEN	FSIDEN
HIRCC	—	—	—	—	HIRC1	HIRC0	HIRCF	HIRCEN

**System Operating Mode Control Register List**

**SCC Register**

Bit	7	6	5	4	3	2	1	0
Name	CKS2	CKS1	CKS0	—	—	—	FHIDEN	FSIDEN
R/W	R/W	R/W	R/W	—	—	—	R/W	R/W
POR	0	0	0	—	—	—	0	0

Bit 7~5 **CKS2~CKS0**: System clock selection

- 000:  $f_H$
- 001:  $f_H/2$
- 010:  $f_H/4$
- 011:  $f_H/8$
- 100:  $f_H/16$
- 101:  $f_H/32$
- 110:  $f_H/64$
- 111:  $f_{SUB}$

These three bits are used to select which clock is used as the system clock source. In addition to the system clock source directly derived from  $f_H$  or  $f_{SUB}$ , a divided version of the high speed system oscillator can also be chosen as the system clock source.

Bit 4~2 Unimplemented, read as 0.

Bit 1 **FHIDEN**: High Frequency oscillator control when CPU is switched off

- 0: Disable
- 1: Enable

This bit is used to control whether the high speed oscillator is activated or stopped when the CPU is switched off by executing a "HALT" instruction.

Bit 0 **FSIDEN**: Low Frequency oscillator control when CPU is switched off

- 0: Disable
- 1: Enable

This bit is used to control whether the low speed oscillator is activated or stopped when the CPU is switched off by executing a "HALT" instruction. The LIRC oscillator is controlled by this bit together with the WDT function enable control. If this bit is cleared to 0 but the WDT function is enabled, the LIRC will also be enabled.

**HIRCC Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	HIRC1	HIRC0	HIRCF	HIRCEN
R/W	—	—	—	—	R/W	R/W	R	R/W
POR	—	—	—	—	0	0	0	1

Bit 7~4 Unimplemented, read as 0.

Bit 3~2 **HIRC1~HIRC0**: HIRC frequency selection

- 00: 2MHz
- 01: 4MHz
- 11: 2MHz

When the HIRC oscillator is enabled, the HIRC frequency is changed by changing these two bits, the clock frequency will automatically be changed after the HIRCF flag is set to 1.

Bit 1 **HIRCF**: HIRC oscillator stable flag

- 0: HIRC unstable
- 1: HIRC stable

This bit is used to indicate whether the HIRC oscillator is stable or not. When the HIRCEN bit is set to 1 to enable the HIRC oscillator or the HIRC frequency selection is changed by application program, the HIRCF bit will first be cleared to 0 and then set to 1 after the HIRC oscillator is stable.

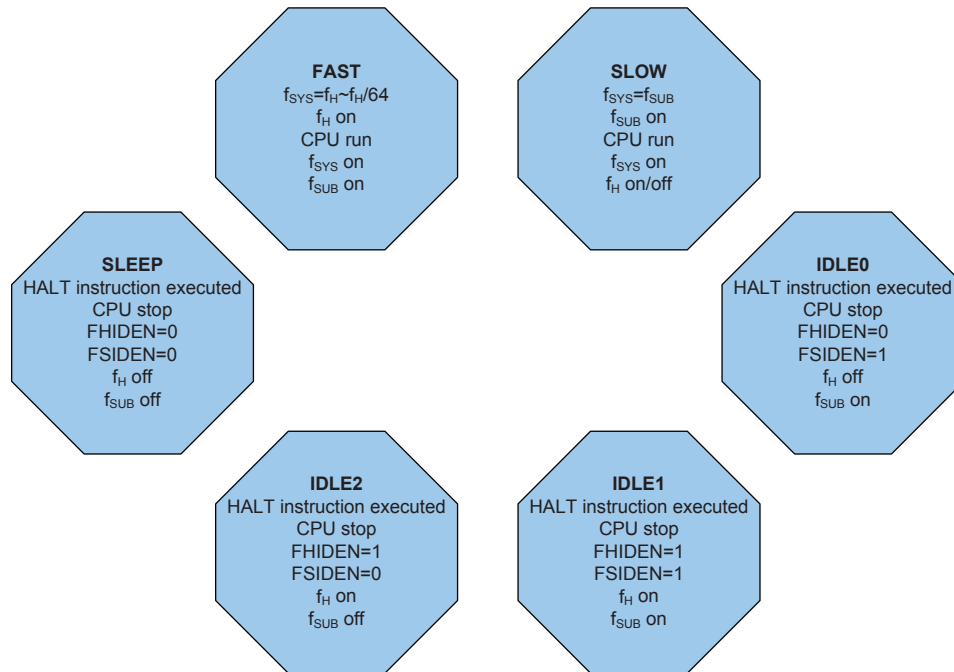
Bit 0 **HIRCEN**: HIRC oscillator enable control

- 0: Disable
- 1: Enable

### Operating Mode Switching

The device can switch between operating modes dynamically allowing the user to select the best performance/power ratio for the present task in hand. In this way microcontroller operations that do not require high performance can be executed using slower clocks thus requiring less operating current and prolonging battery life in portable applications.

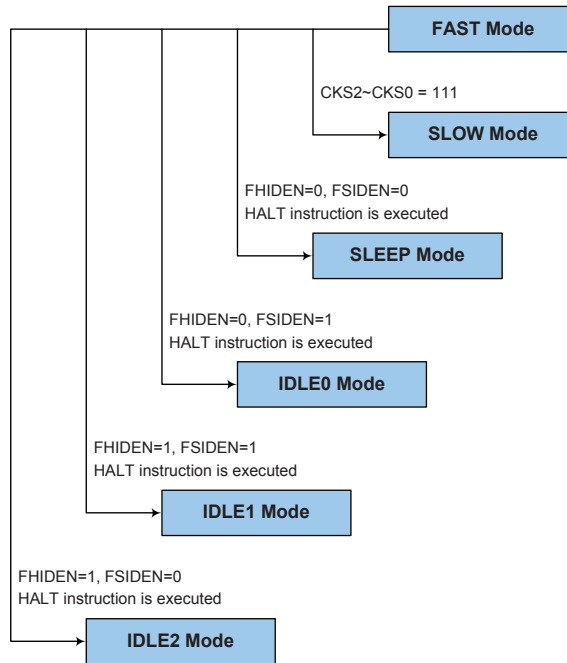
In simple terms, Mode Switching between the FAST Mode and SLOW Mode is executed using the CKS2~CKS0 bits in the SCC register while Mode Switching from the FAST / SLOW Modes to the SLEEP/IDLE Modes is executed via the HALT instruction. When an HALT instruction is executed, whether the device enter the IDLE Mode or the SLEEP Mode is determined by the condition of the FHIDEN and FSIDEN bits in the SCC register.



### FAST Mode to SLOW Mode Switching

When running in the FAST Mode, which uses the high speed system oscillator, and therefore consumes more power, the system clock can switch to run in the SLOW Mode by set the CKS2~CKS0 bits to "111" in the SCC register. This will then use the low speed system oscillator which will consume less power. Users may decide to do this for certain operations which do not require high performance and can subsequently reduce power consumption.

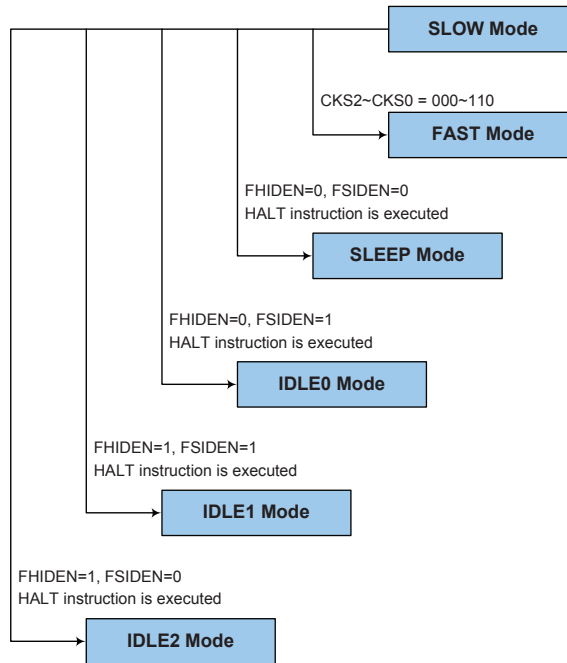
The SLOW Mode is sourced from the LIRC oscillator and therefore requires this oscillator to be stable before full mode switching occurs.



**SLOW Mode to FAST Mode Switching**

In SLOW mode the system clock is derived from  $f_{SUB}$ . When system clock is switched back to the FAST mode from  $f_{SUB}$ , the CKS2~CKS0 bits should be set to "000"~"110" and then the system clock will respectively be switched to  $f_H \sim f_H/64$ .

However, if  $f_H$  is not used in SLOW mode and thus switched off, it will take some time to re-oscillate and stabilise when switching to the FAST mode from the SLOW Mode. This is monitored using the HIRCF bit in the HIRCC register. The time duration required for the high speed system oscillator stabilization is specified in the System Start Up Time Characteristics.



**Entering the SLEEP Mode**

There is only one way for the device to enter the SLEEP Mode and that is to execute the "HALT" instruction in the application program with both the FHIDEN and FSIDEN bits in the SCC register equal to "0". In this mode all the clocks and functions will be switched off except the WDT function. When this instruction is executed under the conditions described above, the following will occur:

- The system clock will be stopped and the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag, PDF, will be set and the Watchdog time-out flag, TO, will be cleared.
- The WDT will be cleared and resume counting as the WDT function is always enabled.

### **Entering the IDLE0 Mode**

There is only one way for the device to enter the IDLE0 Mode and that is to execute the "HALT" instruction in the application program with the FHIDEN bit in the SCC register equal to "0" and the FSIDEN bit in the SCC register equal to "1". When this instruction is executed under the conditions described above, the following will occur:

- The  $f_H$  clock will be stopped and the application program will stop at the "HALT" instruction, but the  $f_{SUB}$  clock will be on.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag, PDF, will be set and the Watchdog time-out flag, TO, will be cleared.
- The WDT will be cleared and resume counting as the WDT function is always enabled.

### **Entering the IDLE1 Mode**

There is only one way for the device to enter the IDLE1 Mode and that is to execute the "HALT" instruction in the application program with both the FHIDEN and FSIDEN bits in the SCC register equal to "1". When this instruction is executed under the conditions described above, the following will occur:

- The  $f_H$  and  $f_{SUB}$  clocks will be on but the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag, PDF, will be set and the Watchdog time-out flag, TO, will be cleared.
- The WDT will be cleared and resume counting as the WDT function is always enabled.

### **Entering the IDLE2 Mode**

There is only one way for the device to enter the IDLE2 Mode and that is to execute the "HALT" instruction in the application program with the FHIDEN bit in the SCC register equal to "1" and the FSIDEN bit in the SCC register equal to "0". When this instruction is executed under the conditions described above, the following will occur:

- The  $f_H$  clock will be on but the  $f_{SUB}$  clock will be off and the application program will stop at the "HALT" instruction.
- The Data Memory contents and registers will maintain their present condition.
- The I/O ports will maintain their present conditions.
- In the status register, the Power Down flag, PDF, will be set and the Watchdog time-out flag, TO, will be cleared.
- The WDT will be cleared and resume counting as the WDT function is always enabled.

## Standby Current Considerations

As the main reason for entering the SLEEP or IDLE Mode is to keep the current consumption of the device to as low a value as possible, perhaps only in the order of several micro-amps in the IDLE0 and SLEEP Mode, there are other considerations which must also be taken into account by the circuit designer if the power consumption is to be minimised. Special attention must be made to the I/O pins on the device. All high-impedance input pins must be connected to either a fixed high or low level as any floating input pins could create internal oscillations and result in increased current consumption. This also applies to the device which has different package types, as there may be unbonded pins. These must either be setup as outputs or if setup as inputs must have pull-high resistors connected.

Care must also be taken with the loads, which are connected to I/O pins, which are setup as outputs. These should be placed in a condition in which minimum current is drawn or connected only to external circuits that do not draw current, such as other CMOS inputs.

In the IDLE1 and IDLE2 Mode the high speed oscillator is on, if the peripheral function clock source is derived from the high speed oscillator, the additional standby current will also be perhaps in the order of several hundred micro-amps.

## Wake-up

To minimise power consumption the device can enter the SLEEP or any IDLE Mode, where the system clock source to the CPU will be stopped. However, when the device is woken up again, it will take a considerable time for the original system oscillator to restart, stabilise and allow normal operation to resume.

After the system enters the SLEEP or IDLE Mode, it can be woken up from one of various sources listed as follows:

- An external pin reset
- An external falling edge on Port A
- A system interrupt
- A WDT overflow

When the device executes the "HALT" instruction, it will enter the Power down mode and the PDF flag will be set high. The PDF flag is cleared to 0 if the device experiences a system power-up or executes the clear Watchdog Timer instruction.

If the system is woken up by an external pin reset, the device will experience a full system reset, however, if the device is woken up by a WDT overflow, a Watchdog Timer Time-out reset will be initiated and the TO flag will be set to 1. The TO flag is set high if a WDT time-out occurs, and causes a wake-up that only resets the Program Counter and Stack Pointer, the other flags remain in their original status.

Each pin on Port A can be setup using the PAWU register to permit a negative transition on the pin to wake-up the system. When a pin wake-up occurs, the program will resume execution at the instruction following the "HALT" instruction.

If the system is woken up by an interrupt, then two possible situations may occur. The first is where the related interrupt is disabled or the interrupt is enabled but the stack is full, in which case the program will resume execution at the instruction following the "HALT" instruction. In this situation, the interrupt which woke-up the device will not be immediately serviced, but will rather be serviced later when the related interrupt is finally enabled or when a stack level becomes free. The other situation is where the related interrupt is enabled and the stack is not full, in which case the regular interrupt response takes place. If an interrupt request flag is set high before entering the SLEEP or IDLE Mode, the wake-up function of the related interrupt will be disabled.

## Watchdog Timer

The Watchdog Timer is provided to prevent program malfunctions or sequences from jumping to unknown locations, due to certain uncontrollable external events such as electrical noise.

### Watchdog Timer Clock Source

The Watchdog Timer clock source is provided by the internal clock,  $f_{LIRC}$  which is sourced from the LIRC oscillator. The LIRC internal oscillator has an approximate frequency of 32kHz and this specified internal clock period can vary with  $V_{DD}$ , temperature and process variations. The Watchdog Timer source clock is then subdivided by a ratio of  $2^8$  to  $2^{18}$  to give longer timeouts, the actual value being chosen using the WS2~WS0 bits in the WDTC register.

### Watchdog Timer Control Register

A single register, WDTC, controls the required timeout period as well as the enable and reset MCU operation.

#### WDTC Register

Bit	7	6	5	4	3	2	1	0
Name	WE4	WE3	WE2	WE1	WE0	WS2	WS1	WS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	0	1	1

Bit 7~3 **WE4~WE0**: WDT function software control

01010/10101: Enable

Others: Reset MCU

When these bits are changed by the environmental noise or software setting to reset the microcontroller, the reset operation will be activated after a delay time,  $t_{SRESET}$  and the WRF bit in the RSTFC register will be set high.

Bit 2~0 **WS2~WS0**: WDT time-out period selection

000:  $2^8/f_{LIRC}$

001:  $2^{10}/f_{LIRC}$

010:  $2^{12}/f_{LIRC}$

011:  $2^{14}/f_{LIRC}$

100:  $2^{15}/f_{LIRC}$

101:  $2^{16}/f_{LIRC}$

110:  $2^{17}/f_{LIRC}$

111:  $2^{18}/f_{LIRC}$

These three bits determine the division ratio of the watchdog timer source clock, which in turn determines the time-out period.

#### RSTFC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	RSTF	LVRF	—	WRF
R/W	—	—	—	—	R/W	R/W	—	R/W
POR	—	—	—	—	0	x	—	0

"x"unknown

Bit 7~4 Unimplemented, read as "0"

Bit 3 **RSTF**: RSTC register software reset flag

Described elsewhere

Bit 2 **LVRF**: LVR function reset flag

Described elsewhere

Bit 1 Unimplemented, read as "0"

Bit 0 **WRF**: WDTC register software reset flag  
 0: Not occurred  
 1: Occurred  
 This bit is set to 1 by the WDTC register software reset and cleared by the application program. Note that this bit can be cleared to 0 only by the application program.

**Watchdog Timer Operation**

The Watchdog Timer operates by providing a device reset when its timer overflows. This means that in the application program and during normal operation the user has to strategically clear the Watchdog Timer before it overflows to prevent the Watchdog Timer from executing a reset. This is done using the clear watchdog instruction. If the program malfunctions for whatever reason, jumps to an unknown location, or enters an endless loop, the clear instruction will not be executed in the correct manner, in which case the Watchdog Timer will overflow and reset the device. There are five bits, WE4~WE0, in the WDTC register to offer the enable control and reset control of the Watchdog Timer. The WDT function will be enabled if the WE4~WE0 bits are equal to 01010B or 10101B. If the WE4~WE0 bits are set to any other values, other than 01010B and 10101B, it will reset the device after a delay time,  $t_{SRESET}$ . After power on these bits will have a value of 01010B.

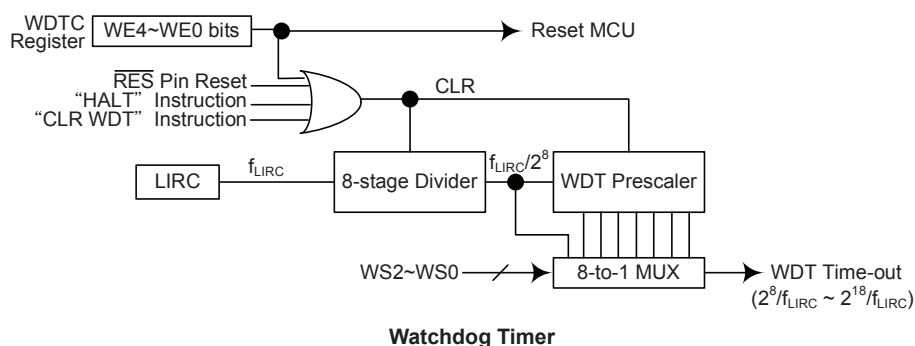
WE4~WE0 Bits	WDT Function
01010B or 10101B	Enable
Any other values	Reset MCU

**Watchdog Timer Enable/Reset Control**

Under normal program operation, a Watchdog Timer time-out will initialise a device reset and set the status bit TO high. However, if the system is in the SLEEP or IDLE Mode, when a Watchdog Timer time-out occurs, the TO bit in the status register will be set high and only the Program Counter and Stack Pointer will be reset. Four methods can be adopted to clear the contents of the Watchdog Timer. The first is a WDT reset, which means a certain value except 01010B and 10101B written into the WE4~WE0 bits, the second is an external hardware reset, which means a low level on the external reset pin, the third is using the Watchdog Timer software clear instruction and the fourth is via a HALT instruction.

There is only one method of using software instruction to clear the Watchdog Timer. That is to use the single "CLR WDT" instruction to clear the WDT.

The maximum time out period is when the  $2^{18}$  division ratio is selected. As an example, with a 32kHz LIRC oscillator as its source clock, this will give a maximum watchdog period of around 8 seconds for the  $2^{18}$  division ratio, and a minimum timeout of 8ms for the  $2^8$  division ratio.



## Reset and Initialisation

A reset function is a fundamental part of any microcontroller ensuring that the device can be set to some predetermined condition irrespective of outside parameters. The most important reset condition is after power is first applied to the microcontroller. In this case, internal circuitry will ensure that the microcontroller, after a short delay, will be in a well defined state and ready to execute the first program instruction. After this power-on reset, certain important internal registers will be set to defined states before the program commences. One of these registers is the Program Counter, which will be reset to zero forcing the microcontroller to begin program execution from the lowest Program Memory address.

In addition to the power-on reset, situations may arise where it is necessary to forcefully apply a reset condition when the microcontroller is running. One example of this is where after power has been applied and the microcontroller is already running, the  $\overline{\text{RES}}$  line is forcefully pulled low. In such a case, known as a normal operation reset, some of the microcontroller registers remain unchanged allowing the microcontroller to proceed with normal operation after the reset line is allowed to return high.

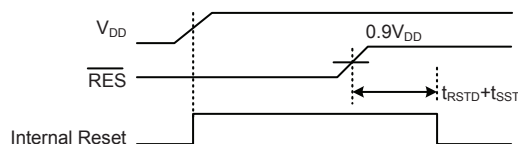
Another type of reset is when the Watchdog Timer overflows and resets the microcontroller. All types of reset operations result in different register conditions being setup. Another reset exists in the form of a Low Voltage Reset, LVR, where a full reset is implemented in situations where the power supply voltage falls below a certain threshold.

### Reset Functions

There are several ways in which a microcontroller reset can occur, through events occurring both internally and externally:

#### Power-on Reset

The most fundamental and unavoidable reset is the one that occurs after power is first applied to the microcontroller. As well as ensuring that the Program Memory begins execution from the first memory address, a power-on reset also ensures that certain other registers are preset to known conditions. All the I/O port and port control registers will power up in a high condition ensuring that all pins will be first set to inputs.



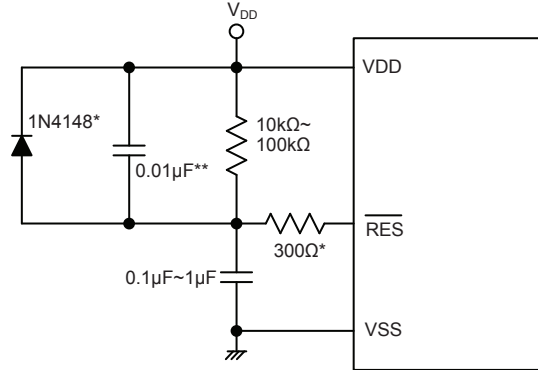
Note:  $t_{\text{RSTD}}$  is power-on delay, typical time=48ms

**Power-On Reset Timing Chart**

#### $\overline{\text{RES}}$ Pin Reset

Although the microcontroller has an internal RC reset function, if the  $V_{DD}$  power supply rise time is not fast enough or does not stabilise quickly at power-on, the internal reset function may be incapable of providing proper reset operation. For this reason it is recommended that an external RC network is connected to the  $\overline{\text{RES}}$  pin, whose additional time delay will ensure that the  $\overline{\text{RES}}$  pin remains low for an extended period to allow the power supply to stabilise. During this time delay, normal operation of the microcontroller will be inhibited. After the  $\overline{\text{RES}}$  line reaches a certain voltage value, the reset delay time  $t_{\text{RSTD}}$  is invoked to provide an extra delay time after which the microcontroller will begin normal operation. The abbreviation SST in the figures stands for System Start-up Timer.

For most applications a resistor connected between  $V_{DD}$  and the  $\overline{RES}$  pin and a capacitor connected between  $VSS$  and the  $\overline{RES}$  pin will provide a suitable external reset circuit. Any wiring connected to the  $\overline{RES}$  pin should be kept as short as possible to minimize any stray noise interference. For applications that operate within an environment where more noise is present the Enhanced Reset Circuit shown is recommended.

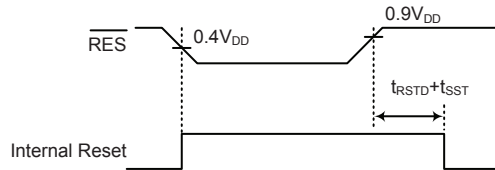


Note: "\*" It is recommended that this component is added for added ESD protection

"\*\*" It is recommended that this component is added in environments where power line noise is significant

**External  $\overline{RES}$  Circuit**

Pulling the  $\overline{RES}$  Pin low using external hardware will also execute a device reset. In this case, as in the case of other resets, the Program Counter will reset to zero and program execution initiated from this point.



Note:  $t_{RSTD}$  is power-on delay, typical time=16ms

**$\overline{RES}$  Reset Timing Chart**

• **RSTC External Reset Register**

Bit	7	6	5	4	3	2	1	0
Name	RSTC7	RSTC6	RSTC5	RSTC4	RSTC3	RSTC2	RSTC1	RSTC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	1	0	1	0	1	0	1

Bit 7 ~ 0 **RSTC7 ~ RSTC0:** PB4/ $\overline{RES}$  selection

01010101: Configured as input/output PB4 pin function

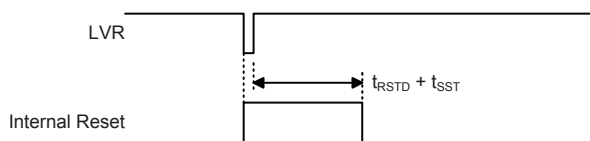
10101010: Configured as external reset  $\overline{RES}$  pin

Other Values: MCU reset (reset will be active after  $t_{SRESET}$  time for debounce time)

All reset will reset this register as POR value except WDT time out Hardware warm reset.

### Low Voltage Reset – LVR

The microcontroller contains a low voltage reset circuit in order to monitor the supply voltage of the device and provide an MCU reset should the value fall below a certain predefined level. The LVR function is always enabled during the FAST and SLOW modes with a specific LVR voltage  $V_{LVR}$ . If the supply voltage of the device drops to within a range of  $0.9V \sim V_{LVR}$  such as might occur when changing the battery, the LVR will automatically reset the device internally and the LVRF bit in the SMOD1 register will also be set to 1. For a valid LVR signal, a low voltage, i.e., a voltage in the range between  $0.9V \sim V_{LVR}$  must exist for greater than the value  $t_{LVR}$  specified in the LVD/LVR Electrical Characteristics. If the low voltage state does not exceed this value, the LVR will ignore the low supply voltage and will not perform a reset function. The actual  $V_{LVR}$  is 2.1V, the LVR will reset the device after a delay time,  $t_{SRESET}$ . Note that the LVR function will be automatically disabled when the device enters the SLEEP/IDLE mode.



Note:  $t_{RSTD}$  is power-on delay, typical time = 48ms

**Low Voltage Reset Timing Chart**

#### • RSTFC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	RSTF	LVRF	—	WRF
R/W	—	—	—	—	R/W	R/W	—	R/W
POR	—	—	—	—	0	x	—	0

"x" unknown

Bit 7~4 Unimplemented, read as "0"

Bit 3 **RSTF**: RSTC register software reset flag  
 0: Not active  
 1: Active

This bit is set to 1 by the RSTC register setting and cleared to 0 by the application program. Note that this bit can only be cleared to 0 by the application program or POR reset.

Bit 2 **LVRF**: LVR function reset flag  
 0: Not active  
 1: Active

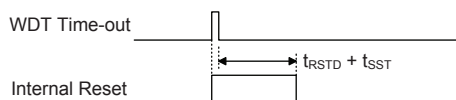
This bit can be cleared to "0", but can not be set to "1"

Bit 1 Unimplemented, read as "0"

Bit 0 **WRF**: WDTC register software reset flag  
 Described elsewhere

### Watchdog Time-out Reset during Normal Operation

The Watchdog time-out flag TO will be set to "1" when Watchdog time-out Reset during normal operations.

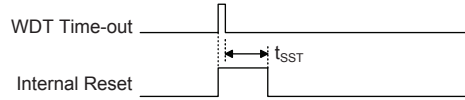


Note:  $t_{RSTD}$  is power-on delay, typical time=16ms

**WDT Time-out Reset during Normal Operation Timing Chart**

**Watchdog Time-out Reset during SLEEP or IDLE Mode**

The Watchdog time-out Reset during SLEEP or IDLE Mode is a little different from other kinds of reset. Most of the conditions remain unchanged except that the Program Counter and the Stack Pointer will be cleared to "0" and the TO flag will be set to "1". Refer to the A.C. Characteristics for  $t_{SST}$  details.



**WDT Time-out Reset during SLEEP or IDLE Timing Chart**

**Reset Initial Conditions**

The different types of reset described affect the reset flags in different ways. These flags, known as PDF and TO are located in the status register and are controlled by various microcontroller operations, such as the SLEEP or IDLE Mode function or Watchdog Timer. The reset flags are shown in the table:

TO	PDF	RESET Conditions
0	0	Power-on reset
u	u	LVR reset
1	u	WDT time-out reset during FAST or SLOW Mode
1	1	WDT time-out reset during IDLE or SLEEP Mode

Note: "u" stands for unchanged

The following table indicates the way in which the various components of the microcontroller are affected after a power-on reset occurs.

Item	Condition After RESET
Program Counter	Reset to zero
Interrupts	All interrupts will be disabled
WDT	Clear after reset, WDT begins counting
Timer Modules	Timer Modules will be turned off
Input/Output Ports	I/O ports will be setup as inputs
Stack Pointer	Stack Pointer will point to the top of the stack

The different kinds of resets all affect the internal registers of the microcontroller in different ways. To ensure reliable continuation of normal program execution after a reset occurs, it is important to know what condition the microcontroller is in after a particular reset occurs. The following table describes how each type of reset affects each of the microcontroller internal registers. Note that where more than one package type exists the table will reflect the situation for the larger package type.

Register	Reset (Power On)	RES Reset	LVR Reset	WDT Time-out (Normal Operation)	WDT Time-out (SLEEP/IDLE)*
IAR0	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
MP0	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
IAR1	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
MP1	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
BP	---- --- 0	---- --- 0	---- --- 0	---- --- 0	---- --- u
ACC	xxxx xxxx	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
PCL	0000 0000	0000 0000	0000 0000	0000 0000	0000 0000
TBLP	xxxx xxxx	xxxx xxxx	uuuu uuuu	uuuu uuuu	uuuu uuuu
TBLH	-xxx xxxx	-xxx xxxx	-uuu uuuu	-uuu uuuu	-uuu uuuu
TBHP	---- -xxx	---- -xxx	---- -uuu	---- -uuu	---- -uuu
STATUS	--00 xxxx	--uu uuuu	--uu uuuu	--1u uuuu	--11 uuuu
RSTFC	---- 0x-0	---- uu-u	---- u1-u	---- uu-u	---- uu-u
INTEG	---- 0000	---- 0000	---- 0000	---- 0000	---- uuuu
INTC0	-000 0000	-000 0000	-000 0000	-000 0000	-uuu uuuu
INTC1	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
INTC2	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PA	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PAC	1111 1111	1111 1111	1111 1111	1111 1111	uuuu uuuu
PAPU	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PAWU	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SCC	000- --00	000- --00	000- --00	000- --00	uuu- --uu
HIRCC	---- 0001	---- 0001	---- 0001	---- 0001	---- uuuu
WDTC	0101 0011	0101 0011	0101 0011	0101 0011	uuuu uuuu
TB0C	0--- -000	0--- -000	0--- -000	0--- -000	u--- -uuu
TB1C	0--- -000	0--- -000	0--- -000	0--- -000	u--- -uuu
PSCR	---- --00	---- --00	---- --00	---- --00	---- --uu
EEA	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
EED	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SADOL (ADRF5=0)	xxxx ----	xxxx ----	xxxx ----	xxxx ----	uuuu ----
SADOL (ADRF5=1)	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
SAD0H (ADRF5=0)	xxxx xxxx	xxxx xxxx	xxxx xxxx	xxxx xxxx	uuuu uuuu
SAD0H (ADRF5=1)	---- xxxx	---- xxxx	---- xxxx	---- xxxx	---- uuuu
SADC0	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
SADC1	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
LVDC	--00 0000	--00 0000	--00 0000	--00 0000	--uu uuuu
RSTC	0101 0101	0101 0101	0101 0101	0101 0101	uuuu uuuu
STM0C0	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STM0C1	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STM0DL	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STM0DH	---- --00	---- --00	---- --00	---- --00	---- --uu
STM0AL	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STM0AH	---- --00	---- --00	---- --00	---- --00	---- --uu
PB	-111 1111	-111 1111	-111 1111	-111 1111	-uuu uuuu
PBC	-111 1111	-111 1111	-111 1111	-111 1111	-uuu uuuu
PBPU	-000 0000	-000 0000	-000 0000	-000 0000	-uuu uuuu
STM1C0	0000 0---	0000 0---	0000 0---	0000 0---	uuuu u---
STM1C1	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu

Register	Reset (Power On)	RES Reset	LVR Reset	WDT Time-out (Normal Operation)	WDT Time-out (SLEEP/IDLE)*
STM1DL	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STM1DH	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STM1AL	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STM1AH	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
STM1RP	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
PAS0	00-- 00--	00-- 00--	00-- 00--	00-- 00--	uu-- uu--
PAS1	0000 00--	0000 00--	0000 00--	0000 00--	uuuu uu--
PBS0	0000 0000	0000 0000	0000 0000	0000 0000	uuuu uuuu
EEC	---- 0000	---- 0000	---- 0000	---- 0000	---- uuuu

Note: "\*" stands for warm reset  
 "-" stands for "unimplemented"  
 "u" stands for "unchanged"  
 "x" stands for "unknown"

## Input/Output Ports

Holtek microcontrollers offer considerable flexibility on their I/O ports. With the input or output designation of every pin fully under user program control, pull-high selections for all ports and wake-up selections on certain pins, the user is provided with an I/O structure to meet the needs of a wide range of application possibilities.

The device provide bidirectional input/output lines labeled with port names PA~PB. These I/O ports are mapped to the RAM Data Memory with specific addresses as shown in the Special Purpose Data Memory table. All of these I/O ports can be used for input and output operations. For input operation, these ports are non-latching, which means the inputs must be ready at the T2 rising edge of instruction "MOV A, [m]", where m denotes the port address. For output operation, all the data is latched and remains unchanged until the output latch is rewritten.

Register Name	Bit							
	7	6	5	4	3	2	1	0
PA	PA7	PA6	PA5	PA4	PA3	PA2	PA1	PA0
PAC	PAC7	PAC6	PAC5	PAC4	PAC3	PAC2	PAC1	PAC0
PAPU	PAPU7	PAPU6	PAPU5	PAPU4	PAPU3	PAPU2	PAPU1	PAPU0
PAWU	PAWU7	PAWU6	PAWU5	PAWU4	PAWU3	PAWU2	PAWU1	PAWU0
PB	—	PB6	—	PB4	PB3	PB2	PB1	PB0
PBC	—	PBC6	PBC5	PBC4	PBC3	PBC2	PBC1	PBC0
PBPU	—	PBPU6	PBPU5	PBPU4	PBPU3	PBPU2	PBPU1	PBPU0

I/O Logic Function Register List

### Pull-high Resistors

Many product applications require pull-high resistors for their switch inputs usually requiring the use of an external resistor. To eliminate the need for these external resistors, all I/O pins, when configured as an input have the capability of being connected to an internal pull-high resistor. These pull-high resistors are selected using registers PAPU~PBPU, and are implemented using weak PMOS transistors.

Note that the pull-high resistor can be controlled by the relevant pull-high control register only when the pin-shared functional pin is selected as a logic input or NMOS output. Otherwise, the pull-high resistors cannot be enabled.

### PxPU Register

Bit	7	6	5	4	3	2	1	0
Name	PxPU7	PxPU6	PxPU5	PxPU4	PxPU3	PxPU2	PxPU1	PxPU0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

**PxPUn:** I/O Port x Pin pull-high function control

0: Disable

1: Enable

The PxPUn bit is used to control the pin pull-high function. Here the "x" can be A or B. However, the actual available bits for each I/O Port may be different.

### Port A Wake-up

The HALT instruction forces the microcontroller into the SLEEP or IDLE Mode which preserves power, a feature that is important for battery and other low-power applications. Various methods exist to wake-up the microcontroller, one of which is to change the logic condition on one of the Port A pins from high to low. This function is especially suitable for applications that can be woken up via external switches. Each pin on Port A can be selected individually to have this wake-up feature using the PAWU register.

Note that the wake-up function can be controlled by the wake-up control registers only when the pin-shared functional pin is selected as general purpose input/output and the MCU enters the IDLE or SLEEP mode.

### PAWU Register

Bit	7	6	5	4	3	2	1	0
Name	PAWU7	PAWU6	PAWU5	PAWU4	PAWU3	PAWU2	PAWU1	PAWU0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **PAWU7~PAWU0**: PA7~PA0 wake-up function control  
 0: Disable  
 1: Enable

### I/O Port Control Registers

Each I/O port has its own control register known as PAC~PBC, to control the input/output configuration. With this control register, each CMOS output or input can be reconfigured dynamically under software control. Each pin of the I/O ports is directly mapped to a bit in its associated port control register. For the I/O pin to function as an input, the corresponding bit of the control register must be written as a "1". This will then allow the logic state of the input pin to be directly read by instructions. When the corresponding bit of the control register is written as a "0", the I/O pin will be setup as a CMOS output. If the pin is currently setup as an output, instructions can still be used to read the output register. However, it should be noted that the program will in fact only read the status of the output data latch and not the actual logic status of the output pin.

### PxC Register

Bit	7	6	5	4	3	2	1	0
Name	PxC7	PxC6	PxC5	PxC4	PxC3	PxC2	PxC1	PxC0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	1	1	1	1	1	1	1	1

**PxCn**: I/O Port x Pin type selection  
 0: Output  
 1: Input

The PxCn bit is used to control the pin type selection. Here the "x" can be A or B. However, the actual available bits for each I/O Port may be different.

## Pin-shared Functions

The flexibility of the microcontroller range is greatly enhanced by the use of pins that have more than one function. Limited numbers of pins can force serious design constraints on designers but by supplying pins with multi-functions, many of these difficulties can be overcome. For these pins, the desired function of the multi-function I/O pins is selected by a series of registers via the application program control.

### Pin-shared Function Selection Registers

The limited number of supplied pins in a package can impose restrictions on the amount of functions a certain device can contain. However by allowing the same pins to share several different functions and providing a means of function selection, a wide range of different functions can be incorporated into even relatively small package sizes. The device includes Port "x" pin shared function selection register, labeled as PxSn, which can select the desired functions of the multi-function pin-shared pins.

When the pin-shared function is selected to be used, the corresponding input and output functions selection should be properly managed. For example, if the STM0 function STP0 pin is used, the corresponding pin-shared function should be configured as the STP0 function by configuring the PxSn register. If the external interrupt function is selected to be used, the relevant pin-shared function should be selected as an I/O function with the pin in input type and the interrupt input signal active edge should be selected.

The most important point to note is to make sure that the desired pin-shared function is properly selected and also deselected. For most pin-shared functions, to select the desired pin-shared function, the pin-shared function should first be correctly selected using the corresponding pin-shared control register. After that the corresponding peripheral functional setting should be configured and then the peripheral function can be enabled. However, a special point must be noted for some digital input pins, such as INTn, STCKn, STPnI, etc, which share the same pin-shared control configuration with their corresponding general purpose I/O functions when setting the relevant pin-shared control bit fields. To select these pin functions, in addition to the necessary pin-shared control and peripheral functional setup aforementioned, they must also be setup as an input by setting the corresponding bit in the I/O port control register. To correctly deselect the pin-shared function, the peripheral function should first be disabled and then the corresponding pin-shared function control register can be modified to select other pin-shared functions.

Register Name	Bit							
	7	6	5	4	3	2	1	0
PAS0	PAS07	PAS06	—	—	PAS03	PAS02	—	—
PAS1	PAS17	PAS16	PAS15	PAS14	PAS13	PAS12	—	—
PBS0	PBS07	PBS06	PBS05	PBS04	PBS03	PBS02	PBS01	PBS00

**Pin-shared Function Selection Register List**

#### • PAS0 Register

Bit	7	6	5	4	3	2	1	0
Name	PAS07	PAS06	—	—	PAS03	PAS02	—	—
R/W	R/W	R/W	—	—	R/W	R/W	—	—
POR	0	0	—	—	0	0	—	—

Bit 7~6 **PAS07~PAS06**: PA3 pin function selection bits  
 00: PA3/STCK0  
 01: AN4  
 10: PA3/STCK0  
 11: PA3/STCK0

- Bit 5~4 Unimplemented, read as "0"
- Bit 3~2 **PAS03~PAS02**: PA1 pin function selection bits  
 00: PA1  
 01: STP0  
 10: VREF  
 11: PA1
- Bit 1~0 Unimplemented, read as "0"

• **PAS1 Register**

Bit	7	6	5	4	3	2	1	0
Name	PAS17	PAS16	PAS15	PAS14	PAS13	PAS12	—	—
R/W	R/W	R/W	R/W	R/W	R/W	R/W	—	—
POR	0	0	0	0	0	0	—	—

- Bit 7~6 **PAS17~PAS16**: PA7 pin function selection bits  
 00: PA7  
 01: AN7  
 10: PA7  
 11: PA7
- Bit 5~4 **PAS15~PAS14**: PA6 pin function selection bits  
 00: PA6  
 01: AN6  
 10: PA6  
 11: PA6
- Bit 3~2 **PAS13~PAS12**: PA5 pin function selection bits  
 00: PA5/STP0I  
 01: AN5  
 10: PA5/STP0I  
 11: PA5/STP0I
- Bit 1~0 Unimplemented, read as "0"

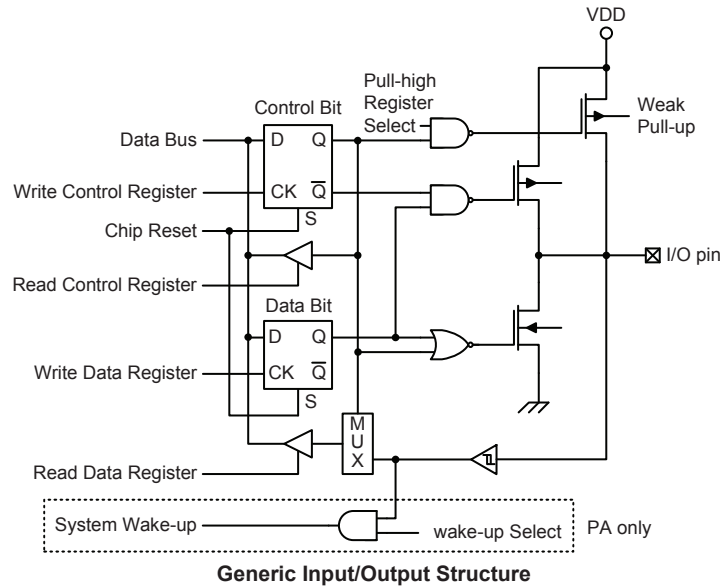
• **PBS0 Register**

Bit	7	6	5	4	3	2	1	0
Name	PBS07	PBS06	PBS05	PBS04	PBS03	PBS02	PBS01	PBS00
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

- Bit 7~6 **PBS07~PBS06**: PB3 pin function selection bits  
 00: PB3  
 01: AN3  
 10: PB3  
 11: PB3
- Bit 5~4 **PBS05~PBS04**: PB2 pin function selection bits  
 00: PB2/STP1I  
 01: AN2  
 10: PB2/STP1I  
 11: PB2/STP1I
- Bit 3~2 **PBS03~PBS02**: PB1 pin function selection bits  
 00: PB1/STCK1  
 01: AN1  
 10: PB1/STCK1  
 11: PB1/STCK1
- Bit 1~0 **PBS01~PBS00**: PB0 pin function selection bits  
 00: PB0  
 01: STP1  
 10: AN0  
 11: PB0

## I/O Pin Structures

The accompanying diagrams illustrate the internal structures of some generic I/O pin types. As the exact logical construction of the I/O pin will differ from these drawings, they are supplied as a guide only to assist with the functional understanding of the I/O pins. The wide range of pin-shared structures does not permit all types to be shown.



## Programming Considerations

Within the user program, one of the first things to consider is port initialisation. After a reset, all of the I/O data and port control registers will be set high. This means that all I/O pins will default to an input state, the level of which depends on the other connected circuitry and whether pull-high selections have been chosen. If the port control registers are then programmed to setup some pins as outputs, these output pins will have an initial high output value unless the associated port data registers are first programmed. Selecting which pins are inputs and which are outputs can be achieved byte-wide by loading the correct values into the appropriate port control register or by programming individual bits in the port control register using the "SET [m].i" and "CLR [m].i" instructions. Note that when using these bit control instructions, a read-modify-write operation takes place. The microcontroller must first read in the data on the entire port, modify it to the required new bit values and then rewrite this data back to the output ports.

Port A has the additional capability of providing wake-up functions. When the device is in the SLEEP or IDLE Mode, various methods are available to wake the device up. One of these is a high to low transition of any of the Port A pins. Single or multiple pins on Port A can be setup to have this function.

## Timer Modules – TM

One of the most fundamental functions in any microcontroller device is the ability to control and measure time. To implement time related functions the device includes several Timer Modules, abbreviated to the name TM. The TMs are multi-purpose timing units and serve to provide operations such as Timer/Counter, Input Capture, Compare Match Output and Single Pulse Output as well as being the functional unit for the generation of PWM signals. Each of the TMs has two individual interrupts. The addition of input and output pins for each TM ensures that users are provided with timing units with a wide and flexible range of features.

The general features of the standard type TM are described here with more detailed information provided in the Standard Type TM section.

### Introduction

The device contains two Standard Type TMs, one of which is 10-bit and the other is 16-bit wide, with each TM having a reference name of STM0 and STM1. The common features to the Standard TMs will be described in this section and the detailed operation will be described in corresponding section. The main features of the STM are summarised in the accompanying table.

Function	STM
Timer/Counter	√
Input Capture	√
Compare Match Output	√
PWM Channels	1
Single Pulse Output	1
PWM Alignment	Edge
PWM Adjustment Period & Duty	Duty or Period

**TM Function Summary**

### TM Operation

The Standard type TMs offer a diverse range of functions, from simple timing operations to PWM signal generation. The key to understanding how the TM operates is to see it in terms of a free running counter whose value is then compared with the value of pre-programmed internal comparators. When the free running counter has the same value as the pre-programmed comparator, known as a compare match situation, a TM interrupt signal will be generated which can clear the counter and perhaps also change the condition of the TM output pin. The internal TM counter is driven by a user selectable clock source, which can be an internal clock or an external pin.

### TM Clock Sources

The clock source which drives the main counter in each TM can originate from various sources. The selection of the required clock source is implemented using the STnCK2~STnCK0 bits in the STMnC0 control registers. The clock source can be a ratio of either the system clock  $f_{SYS}$  or the internal high clock  $f_H$ , the  $f_{SUB}$  clock source or the external STCKn pin. The STCKn pin clock source is used to allow an external signal to drive the TM as an external clock source or for event counting.

### TM Interrupts

The Standard type TMs each has two internal interrupts, the internal comparator A or comparator P, which generate a TM interrupt when a compare match condition occurs. When a TM interrupt is generated, it can be used to clear the counter and also to change the state of the TM output pin.

### TM External Pins

Each of the STMs has two TM input pins, with the label STCKn and STPnI. The STMn input pin STCKn, is essentially a clock source for the STMn and is selected using the STnCK2~STnCK0 bits in the STMnC0 register. This external STMn input pin allows an external clock source to drive the internal TM. The STCKn input pin can be chosen to have either a rising or falling active edge.

The other STMn input pin, STPnI, is the capture input whose active edge can be a rising edge, a falling edge or both rising and falling edges and the active edge transition type is selected using the STnIO1 and STnIO0 bits in the STMnC1 register.

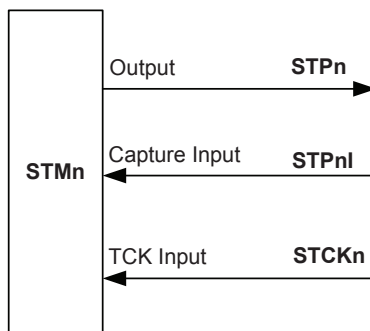
The TMs each has one output pin with the label STPn. When the TM is in the Compare Match Output Mode, the pin can be controlled by the TM to switch to a high or low level or to toggle when a compare match situation occurs. The external STPn output pin is also the pin where the TM generates the PWM output waveform. As the TM output pins are pin-shared with other function, the TM output function must first be setup using registers. A single bit in one of the registers determines if its associated pin is to be used as an external TM output pin or if it is to have another function. The number of output pins for each TM type is different, the details are provided in the accompanying table.

10-bit STM0		16-bit STM1	
Input	Output	Input	Output
STCK0, STP0I	STP0	STCK1, STP1I	STP1

TM External Pins

### TM Input/Output Pin Control

Selecting to have a TM input/output or whether to retain its other shared function is implemented using the relevant pin-shared function selection registers, with the corresponding selection bits in each pin-shared function register corresponding to a TM input/output pin. Configuring the selection bits correctly will setup the corresponding pin as a TM input/output. The details of the pin-shared function selection are described in the pin-shared function section.

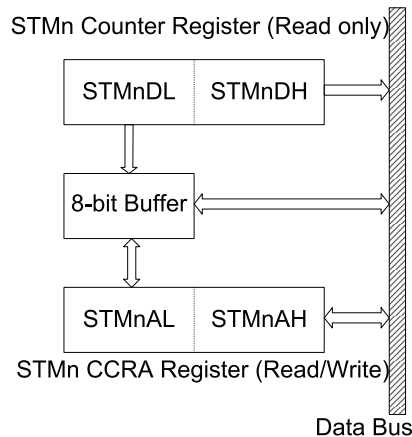


STMn Function Pin Control Block Diagram – n=0~1

### Programming Considerations

The TM Counter Registers and the Capture/Compare CCRA registers, all have a low and high byte structure. The high bytes can be directly accessed, but as the low bytes can only be accessed via an internal 8-bit buffer, reading or writing to these register pairs must be carried out in a specific way. The important point to note is that data transfer to and from the 8-bit buffer and its related low byte only takes place when a write or read operation to its corresponding high byte is executed.

As the CCRA registers are implemented in the way shown in the following diagram and accessing the register is carried out in a specific way described above, it is recommended to use the "MOV" instruction to access the CCRA low byte register, named STMnAL, using the following access procedures. Accessing the CCRA low byte register without following these access procedures will result in unpredictable values.



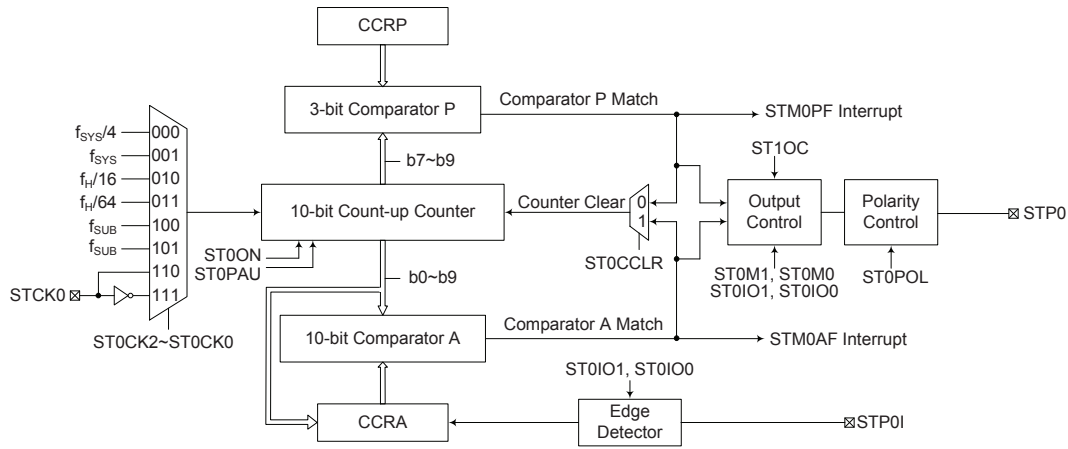
The following steps show the read and write procedures:

- Writing Data to CCRA
  - ♦ Step 1. Write data to Low Byte STMnAL
    - note that here data is only written to the 8-bit buffer.
  - ♦ Step 2. Write data to High Byte STMnAH
    - here data is written directly to the high byte registers and simultaneously data is latched from the 8-bit buffer to the Low Byte registers.
- Reading Data from the Counter Registers and CCRA
  - ♦ Step 1. Read data from the High Byte STMnDH or STMnAH
    - here data is read directly from the High Byte registers and simultaneously data is latched from the Low Byte register into the 8-bit buffer.
  - ♦ Step 2. Read data from the Low Byte STMnDL or STMnAL
    - this step reads data from the 8-bit buffer.

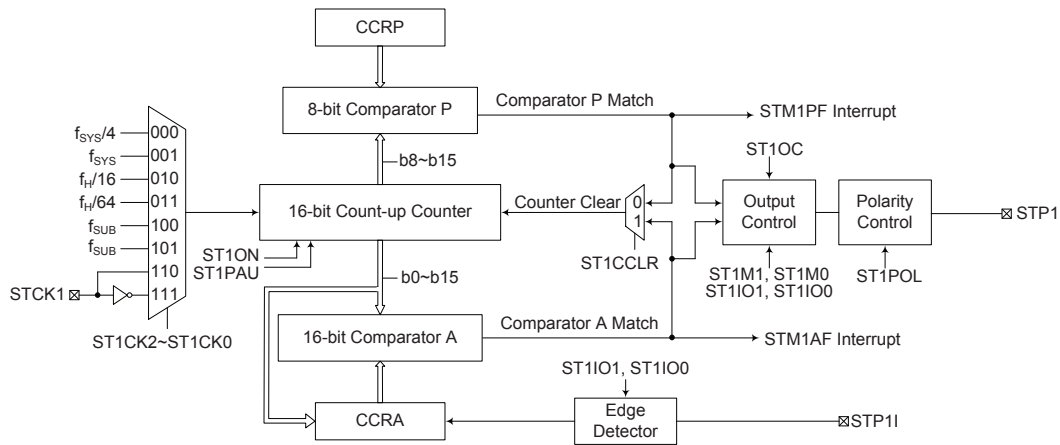
## Standard Type TM – STM

The Standard Type TM contains five operating modes, which are Compare Match Output, Timer/Event Counter, Capture Input, Single Pulse Output and PWM Output modes. The Standard TM can be controlled with two external input pins and can drive one external output pins.

TM Type	TM Name	TM Input Pin	TM Output Pin
10-bit STM	STM0	STCK0, STP0I	STP0
16-bit STM	STM1	STCK1, STP1I	STP1



**10-bit Standard Type TM Block Diagram**



**16-bit Standard Type TM Block Diagram**

Note: The STMn external pins are pin-shared with I/O or other functions, so before using the STMn functions, the pin-shared function registers must be set properly to enable the STMn pin function.

### Standard TM Operation

There are two sizes of Standard TMs, one is 10-bit wide and the other is 16-bit wide. Its core is a 10-bit or 16-bit count-up counter which is driven by a user selectable internal clock source. There are also two internal comparators with the names, Comparator A and Comparator P. These comparators will compare the value in the counter with CCRP and CCRA registers. The CCRP is 3-bit or 8-bit wide whose value is compared with the highest 3 bits or 8 bits in the counter while the CCRA is the 10 bits or 16 bits and therefore compares with all counter bits.

The only way of changing the value of the 10-bit or 16-bit counter using the application program, is to clear the counter by changing the STnON bit from low to high. The counter will also be cleared automatically by a counter overflow or a compare match with one of its associated comparators. When these conditions occur, a TM interrupt signal will also usually be generated. The Standard Type TM can operate in a number of different operational modes, can be driven by different clock sources and can also control an output pin. All operating setup conditions are selected using relevant internal registers.

### Standard Type TM Register Description

Overall operation of the Standard TM is controlled using a series of registers. A read only register pair exists to store the internal counter 10-bit or 16-bit value, while a read/write register pair exists to store the internal 10-bit or 16-bit CCRA value. The remaining two registers are control registers which setup the different operating and control modes. For 16-bit STM, there is another read/write register exists to store the internal 8-bit CCRP value while for 10-bit STM, the 3-bit CCRP value are stored in the STMnC0 register.

Register Name	Bit							
	7	6	5	4	3	2	1	0
STM0C0	ST0PAU	ST0CK2	ST0CK1	ST0CK0	ST0ON	ST0RP2	ST0RP1	ST0RP0
STM0C1	ST0M1	ST0M0	ST0IO1	ST0IO0	ST0OC	ST0POL	ST0DPX	ST0CCLR
STM0DL	D7	D6	D5	D4	D3	D2	D1	D0
STM0DH	—	—	—	—	—	—	D9	D8
STM0AL	D7	D6	D5	D4	D3	D2	D1	D0
STM0AH	—	—	—	—	—	—	D9	D8

**10-bit Standard TM0 Register List**

Register Name	Bit							
	7	6	5	4	3	2	1	0
STM1C0	ST1PAU	ST1CK2	ST1CK1	ST1CK0	ST1ON	—	—	—
STM1C1	ST1M1	ST1M0	ST1IO1	ST1IO0	ST1OC	ST1POL	ST1DPX	ST1CCLR
STM1DL	D7	D6	D5	D4	D3	D2	D1	D0
STM1DH	D15	D14	D13	D12	D11	D10	D9	D8
STM1AL	D7	D6	D5	D4	D3	D2	D1	D0
STM1AH	D15	D14	D13	D12	D11	D10	D9	D8
STM1RP	D7	D6	D5	D4	D3	D2	D1	D0

**16-bit Standard TM1 Register List**

**STMnC0 Register – n=0**

Bit	7	6	5	4	3	2	1	0
Name	STnPAU	STnCK2	STnCK1	STnCK0	STnON	STnRP2	STnRP1	STnRP0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

**Bit 7**      **STnPAU**: STM Counter Pause Control  
 0: Run  
 1: Pause  
 The counter can be paused by setting this bit high. Clearing the bit to zero restores normal counter operation. When in a Pause condition the STM will remain powered up and continue to consume power. The counter will retain its residual value when this bit changes from low to high and resume counting from this value when the bit changes to a low value again.

**Bit 6~4**    **STnCK2~STnCK0**: Select STMn Counter clock  
 000:  $f_{SYS}/4$   
 001:  $f_{SYS}$   
 010:  $f_H/16$   
 011:  $f_H/64$   
 100:  $f_{SUB}$   
 101:  $f_{SUB}$   
 110: STCKn rising edge clock  
 111: STCKn falling edge clock

These three bits are used to select the clock source for the STM. The external pin clock source can be chosen to be active on the rising or falling edge. The clock source  $f_{SYS}$  is the system clock, while  $f_H$  and  $f_{SUB}$  are other internal clocks, the details of which can be found in the oscillator section.

**Bit 3**      **STnON**: STM Counter On/Off Control  
 0: Off  
 1: On  
 This bit controls the overall on/off function of the STM. Setting the bit high enables the counter to run, clearing the bit disables the STM. Clearing this bit to zero will stop the counter from counting and turn off the STM which will reduce its power consumption. When the bit changes state from low to high the internal counter value will be reset to zero, however when the bit changes from high to low, the internal counter will retain its residual value until the bit returns high again. If the STM is in the Compare Match Output Mode or the PWM output Mode or Single Pulse Output Mode then the STM output pin will be reset to its initial condition, as specified by the STnOC bit, when the STnON bit changes from low to high.

**Bit 2~0**    **STnRP2~STnRP0**: STMn CCRP 3-bit register, compared with the STMn Counter bit 9~bit 7 Comparator P Match Period  
 000: 1024 STMn clocks  
 001: 128 STMn clocks  
 010: 256 STMn clocks  
 011: 384 STMn clocks  
 100: 512 STMn clocks  
 101: 640 STMn clocks  
 110: 768 STMn clocks  
 111: 896 STMn clocks

These three bits are used to setup the value on the internal CCRP 3-bit register, which are then compared with the internal counter's highest three bits. The result of this comparison can be selected to clear the internal counter if the STnCCLR bit is set to zero. Setting the STnCCLR bit to zero ensures that a compare match with the CCRP values will reset the internal counter. As the CCRP bits are only compared with the highest three counter bits, the compare values exist in 128 clock cycle multiples. Clearing all three bits to zero is in effect allowing the counter to overflow at its maximum value.

**STMnC0 Register – n=1**

Bit	7	6	5	4	3	2	1	0
Name	STnPAU	STnCK2	STnCK1	STnCK0	STnON	—	—	—
R/W	R/W	R/W	R/W	R/W	R/W	—	—	—
POR	0	0	0	0	0	—	—	—

- Bit 7**     **STnPAU**: STM Counter Pause Control  
0: Run  
1: Pause  
The counter can be paused by setting this bit high. Clearing the bit to zero restores normal counter operation. When in a Pause condition the STM will remain powered up and continue to consume power. The counter will retain its residual value when this bit changes from low to high and resume counting from this value when the bit changes to a low value again.
- Bit 6~4**   **STnCK2~STnCK0**: Select STMn Counter clock  
000:  $f_{SYS}/4$   
001:  $f_{SYS}$   
010:  $f_H/16$   
011:  $f_H/64$   
100:  $f_{SUB}$   
101:  $f_{SUB}$   
110: STCKn rising edge clock  
111: STCKn falling edge clock  
These three bits are used to select the clock source for the STM. The external pin clock source can be chosen to be active on the rising or falling edge. The clock source  $f_{SYS}$  is the system clock, while  $f_H$  and  $f_{SUB}$  are other internal clocks, the details of which can be found in the oscillator section.
- Bit 3**     **STnON**: STM Counter On/Off Control  
0: Off  
1: On  
This bit controls the overall on/off function of the STM. Setting the bit high enables the counter to run, clearing the bit disables the STM. Clearing this bit to zero will stop the counter from counting and turn off the STM which will reduce its power consumption. When the bit changes state from low to high the internal counter value will be reset to zero, however when the bit changes from high to low, the internal counter will retain its residual value until the bit returns high again. If the STM is in the Compare Match Output Mode or the PWM output Mode or Single Pulse Output Mode then the STM output pin will be reset to its initial condition, as specified by the STnOC bit, when the STnON bit changes from low to high.
- Bit 2~0**   Unimplemented, read as "0"

**STMnC1 Register – n=0~1**

Bit	7	6	5	4	3	2	1	0
Name	STnM1	STnM0	STnIO1	STnIO0	STnOC	STnPOL	STnDPX	STnCCLR
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

- Bit 7~6**   **STnM1~STnM0**: Select STMn Operating Mode  
00: Compare Match Output Mode  
01: Capture Input Mode  
10: PWM output Mode or Single Pulse Output Mode  
11: Timer/Counter Mode  
These bits setup the required operating mode for the STM. To ensure reliable operation the STM should be switched off before any changes are made to the STnM1 and STnM0 bits. In the Timer/Counter Mode, the STM output pin state is undefined.

- Bit 5~4     **STnIO1~STnIO0**: Select STMn function
- Compare Match Output Mode
    - 00: No change
    - 01: Output low
    - 10: Output high
    - 11: Toggle output
  - PWM output Mode/Single Pulse Output Mode
    - 00: PWM Output inactive state
    - 01: PWM Output active state
    - 10: PWM output
    - 11: Single pulse output
  - Capture Input Mode
    - 00: Input capture at rising edge of STPnI
    - 01: Input capture at falling edge of STPnI
    - 10: Input capture at falling/rising edge of STPnI
    - 11: Input capture disabled

Timer/counter Mode:

Unused

These two bits are used to determine how the TM output pin changes state when a certain condition is reached. The function that these bits select depends upon in which mode the TM is running.

In the Compare Match Output Mode, the STnIO1~STnIO0 bits determine how the STMn output pin changes state when a compare match occurs from the Comparator A. The TM output pin can be setup to switch high, switch low or to toggle its present state when a compare match occurs from the Comparator A. When the STnIO1~STnIO0 bits are both zero, then no change will take place on the output. The initial value of the TM output pin should be setup using the STnOC bit. Note that the output level requested by the STnIO1~STnIO0 bits must be different from the initial value setup using the STnOC bit otherwise no change will occur on the TM output pin when a compare match occurs. After the TM output pin changes state, it can be reset to its initial level by changing the level of the STnON bit from low to high.

In the PWM Output Mode, the STnIO1 and STnIO0 bits determine how the TM output pin changes state when a certain compare match condition occurs. The PWM output function is modified by changing these two bits. It is necessary to change the values of the STnIO1 and STnIO0 bits only after the TM has been switched off. Unpredictable PWM outputs will occur if the STnIO1 and STnIO0 bits are changed when the TM is running.

- Bit 3     **STnOC**: STMn Output control bit

Compare Match Output Mode

- 0: Initial low
- 1: Initial high

PWM Output Mode/ Single Pulse Output Mode

- 0: Active low
- 1: Active high

This is the output control bit for the STM output pin. Its operation depends upon whether STM is being used in the Compare Match Output Mode or in the PWM Output Mode/ Single Pulse Output Mode. It has no effect if the STM is in the Timer/Counter Mode. In the Compare Match Output Mode it determines the logic level of the STM output pin before a compare match occurs. In the PWM output Mode it determines if the PWM signal is active high or active low. In the Single Pulse Output Mode it determines the logic level of the STM output pin when the STnON bit changes from low to high.

- Bit 2     **STnPOL**: STMn STPn Output polarity Control  
           0: Non-inverted  
           1: Inverted  
           This bit controls the polarity of the STPn output pin. When the bit is set high the STM output pin will be inverted and not inverted when the bit is zero. It has no effect if the TM is in the Timer/Counter Mode.
- Bit 1     **STnDPX**: STMn PWM period/duty Control  
           0: CCRP – period; CCRA – duty  
           1: CCRP – duty; CCRA – period  
           This bit, determines which of the CCRA and CCRP registers are used for period and duty control of the PWM waveform.
- Bit 0     **STnCCLR**: Select STMn Counter clear condition  
           0: STMn Comparator P match  
           1: STMn Comparator A match  
           This bit is used to select the method which clears the counter. Remember that the Standard TM contains two comparators, Comparator A and Comparator P, either of which can be selected to clear the internal counter. With the STnCCLR bit set high, the counter will be cleared when a compare match occurs from the Comparator A. When the bit is low, the counter will be cleared when a compare match occurs from the Comparator P or with a counter overflow. A counter overflow clearing method can only be implemented if the CCRP bits are all cleared to zero. The STnCCLR bit is not used in the PWM output mode, Single Pulse or Input Capture Mode.

**STMnDL Register – n=0~1**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

- Bit 7~0    **D7~D0**: STMn Counter Low Byte Register bit 7 ~ bit 0  
           STMn10-bit/16-bit Counter bit 7 ~ bit 0

**STMnDH Register – n=0**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	D9	D8
R/W	—	—	—	—	—	—	R	R
POR	—	—	—	—	—	—	0	0

- Bit 7~2    Unimplemented, read as "0"
- Bit 1~0    **D9~D8**: STMn Counter High Byte Register bit 1 ~ bit 0  
           STMn 10-bit Counter bit 9 ~ bit 8

**STMnDH Register – n=1**

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R	R	R	R	R	R	R	R
POR	0	0	0	0	0	0	0	0

- Bit 7~0    **D15~D8**: STMn Counter High Byte Register bit 7 ~ bit 0  
           STMn 16-bit Counter bit 15 ~ bit 8

**STMnAL Register – n=0~1**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: STMn CCRA Low Byte Register bit 7 ~ bit 0  
 STMn 10-bit/16-bit CCRA bit 7 ~ bit 0

**STMnAH Register – n=0**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	D9	D8
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"  
 Bit 1~0 **D9~D8**: STMn CCRA High Byte Register bit 1 ~ bit 0  
 STMn 10-bit CCRA bit 9 ~ bit 8

**STMnAH Register – n=1**

Bit	7	6	5	4	3	2	1	0
Name	D15	D14	D13	D12	D11	D10	D9	D8
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 1~0 **D15~D8**: STMn CCRA High Byte Register bit 7 ~ bit 0  
 STMn 16-bit CCRA bit 15 ~ bit 8

**STMnRP Register – n=1**

Bit	7	6	5	4	3	2	1	0
Name	D7	D6	D5	D4	D3	D2	D1	D0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~0 **D7~D0**: STMn CCRP Register bit 7 ~ bit 0  
 STMn CCRP 8-bit register, compared with the STMn Counter bit 15 ~ bit 8.

Comparator P Match Period:  
 0: 65536 STMn clocks  
 1~255: 256 × (1~255) STMn clocks

These eight bits are used to setup the value on the internal CCRP 8-bit register, which are then compared with the internal counter's highest eight bits. The result of this comparison can be selected to clear the internal counter if the STnCCLR bit is set to zero. Setting the STnCCLR bit to zero ensures that a compare match with the CCRP values will reset the internal counter. As the CCRP bits are only compared with the highest eight counter bits, the compare values exist in 256 clock cycle multiples. Clearing all eight bits to zero is in effect allowing the counter to overflow at its maximum value.

## Standard Type TM Operating Modes

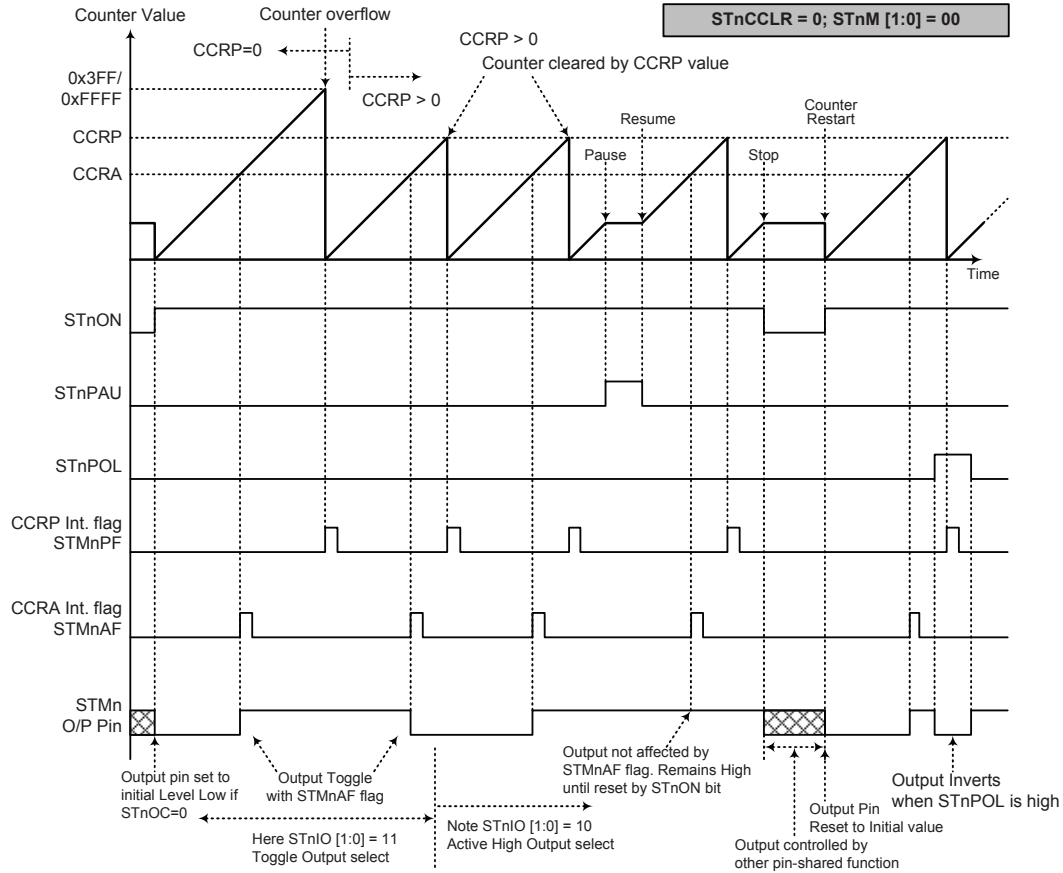
The Standard Type TM can operate in one of five operating modes, Compare Match Output Mode, PWM Output Mode, Single Pulse Output Mode, Capture Input Mode or Timer/Counter Mode. The operating mode is selected using the STnM1 and STnM0 bits in the STMnC1 register.

### Compare Match Output Mode

To select this mode, bits STnM1 and STnM0 in the STMnC1 register, should be set to 00 respectively. In this mode once the counter is enabled and running it can be cleared by three methods. These are a counter overflow, a compare match from Comparator A and a compare match from Comparator P. When the STnCCLR bit is low, there are two ways in which the counter can be cleared. One is when a compare match from Comparator P, the other is when the CCRP bits are all zero which allows the counter to overflow. Here both STMnAF and STMnPF interrupt request flags for Comparator A and Comparator P respectively, will both be generated.

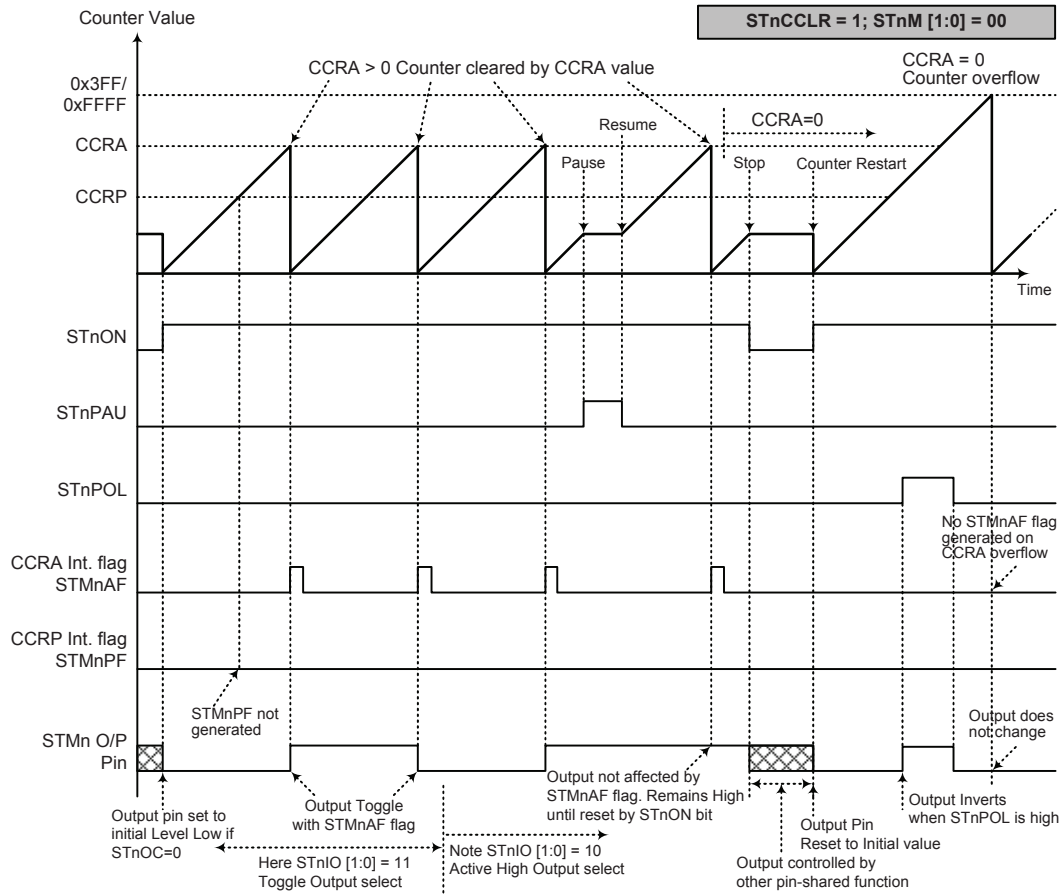
If the STnCCLR bit in the STMnC1 register is high then the counter will be cleared when a compare match occurs from Comparator A. However, here only the STMnAF interrupt request flag will be generated even if the value of the CCRP bits is less than that of the CCRA registers. Therefore when STnCCLR is high no STMnPF interrupt request flag will be generated. In the Compare Match Output Mode, the CCRA can not be set to "0". If the CCRA bits are all zero, the counter will overflow when it reaches its maximum 10-bit, 3FF Hex, value or 16-bit, FFFF Hex, value, however here the STMnAF interrupt request flag will not be generated.

As the name of the mode suggests, after a comparison is made, the STM output pin, will change state. The STM output pin condition however only changes state when an STMnAF interrupt request flag is generated after a compare match occurs from Comparator A. The STMnPF interrupt request flag, generated from a compare match occurs from Comparator P, will have no effect on the STM output pin. The way in which the STM output pin changes state are determined by the condition of the STnIO1 and STnIO0 bits in the STMnC1 register. The STM output pin can be selected using the STnIO1 and STnIO0 bits to go high, to go low or to toggle from its present condition when a compare match occurs from Comparator A. The initial condition of the STM output pin, which is setup after the STnON bit changes from low to high, is setup using the STnOC bit. Note that if the STnIO1 and STnIO0 bits are zero then no pin change will take place.



**Compare Match Output Mode – STnCCLR=0 (n=0~1)**

- Note: 1. With STnCCLR = 0 a Comparator P match will clear the counter  
 2. The TM output pin controlled only by the STMnAF flag  
 3. The output pin reset to initial state by a STnON bit rising edge



**Compare Match Output Mode – STnCCLR=1 (n=0~1)**

- Note: 1. With  $STnCCLR = 1$  a Comparator A match will clear the counter
- 2. The TM output pin controlled only by the STMnAF flag
- 3. The output pin reset to initial state by a STnON rising edge
- 4. The STMnPF flag is not generated when  $STnCCLR = 1$

**Timer/Counter Mode**

To select this mode, bits  $STnM1$  and  $STnM0$  in the  $STMnC1$  register should be set to 11 respectively. The Timer/Counter Mode operates in an identical way to the Compare Match Output Mode generating the same interrupt flags. The exception is that in the Timer/Counter Mode the STM output pin is not used. Therefore the above description and Timing Diagrams for the Compare Match Output Mode can be used to understand its function. As the STM output pin is not used in this mode, the pin can be used as a normal I/O pin or other pin-shared function by setting pin-share function register.

**PWM Output Mode**

To select this mode, bits  $STnM1$  and  $STnM0$  in the  $STMnC1$  register should be set to 10 respectively and also the  $STnIO1$  and  $STnIO0$  bits should be set to 10 respectively. The PWM generation function within the STMn is useful for applications which require functions such as motor control, heating control, illumination control etc. By providing a signal of fixed frequency but of varying duty cycle on the STM output pin, a square wave AC waveform can be generated with varying equivalent DC RMS values.

As both the period and duty cycle of the PWM waveform can be controlled, the choice of generated waveform is extremely flexible. In the PWM output mode, the STnCCLR bit has no effect as the PWM period. Both of the CCRA and CCRP registers are used to generate the PWM waveform, one register is used to clear the internal counter and thus control the PWM waveform frequency, while the other one is used to control the duty cycle. Which register is used to control either frequency or duty cycle is determined using the STnDPX bit in the STMnC1 register. The PWM waveform frequency and duty cycle can therefore be controlled by the values in the CCRA and CCRP registers.

An interrupt flag, one for each of the CCRA and CCRP, will be generated when a compare match occurs from either Comparator A or Comparator P. The STnOC bit in the STMnC1 register is used to select the required polarity of the PWM waveform while the two STnIO1 and STnIO0 bits are used to enable the PWM output or to force the STM output pin to a fixed high or low level. The STnPOL bit is used to reverse the polarity of the PWM output waveform.

• **10-bit STMn, PWM Output Mode, Edge-aligned Mode, STnDPX=0**

CCRP	001b	010b	011b	100b	101b	110b	111b	000b
Period	128	256	384	512	640	768	896	1024
Duty	CCRA							

If  $f_{SYS} = 4\text{MHz}$ , TM clock source is  $f_{SYS}/4$ , CCRP = 100b and CCRA = 128,

The STM PWM output frequency =  $(f_{SYS}/4) / 512 = f_{SYS}/2048 = 2\text{kHz}$ , duty =  $128/512 = 25\%$ .

If the Duty value defined by the CCRA register is equal to or greater than the Period value, then the PWM output duty is 100%.

• **10-bit STMn, PWM Output Mode, Edge-aligned Mode, STnDPX=1**

CCRP	001b	010b	011b	100b	101b	110b	111b	000b
Period	CCRA							
Duty	128	256	384	512	640	768	896	1024

The PWM output period is determined by the CCRA register value together with the STM clock while the PWM duty cycle is defined by the CCRP register value.

• **16-bit STMn, PWM Output Mode, Edge-aligned Mode, STnDPX=0**

CCRP	1~255	00H
Period	CCRP×256	65536
Duty	CCRA	

If  $f_{SYS} = 4\text{MHz}$ , TM clock source is  $f_{SYS}/4$ , CCRP = 2 and CCRA = 128,

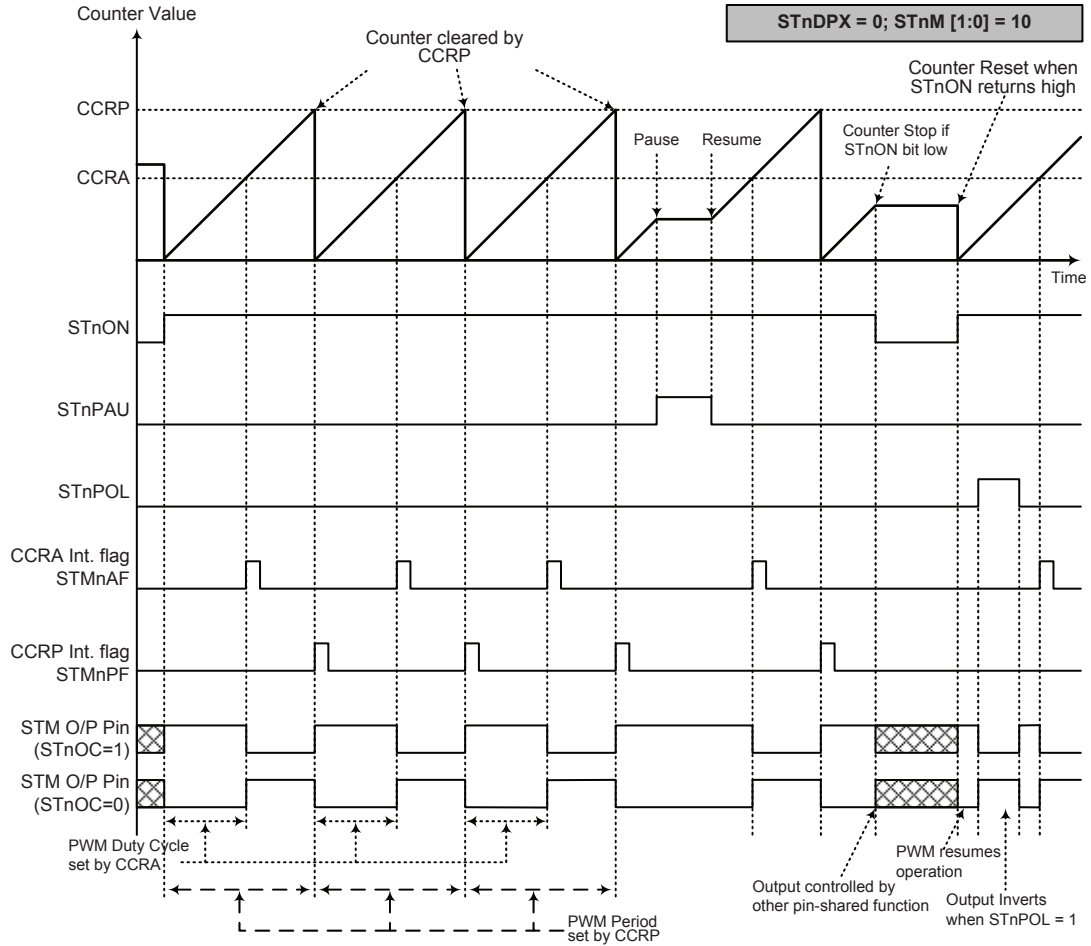
The STM PWM output frequency =  $(f_{SYS}/4) / (2 \times 256) = f_{SYS}/2048 = 2\text{kHz}$ , duty =  $128/512 = 25\%$ .

If the Duty value defined by the CCRA register is equal to or greater than the Period value, then the PWM output duty is 100%.

• **16-bit STMn, PWM Output Mode, Edge-aligned Mode, STnDPX=1**

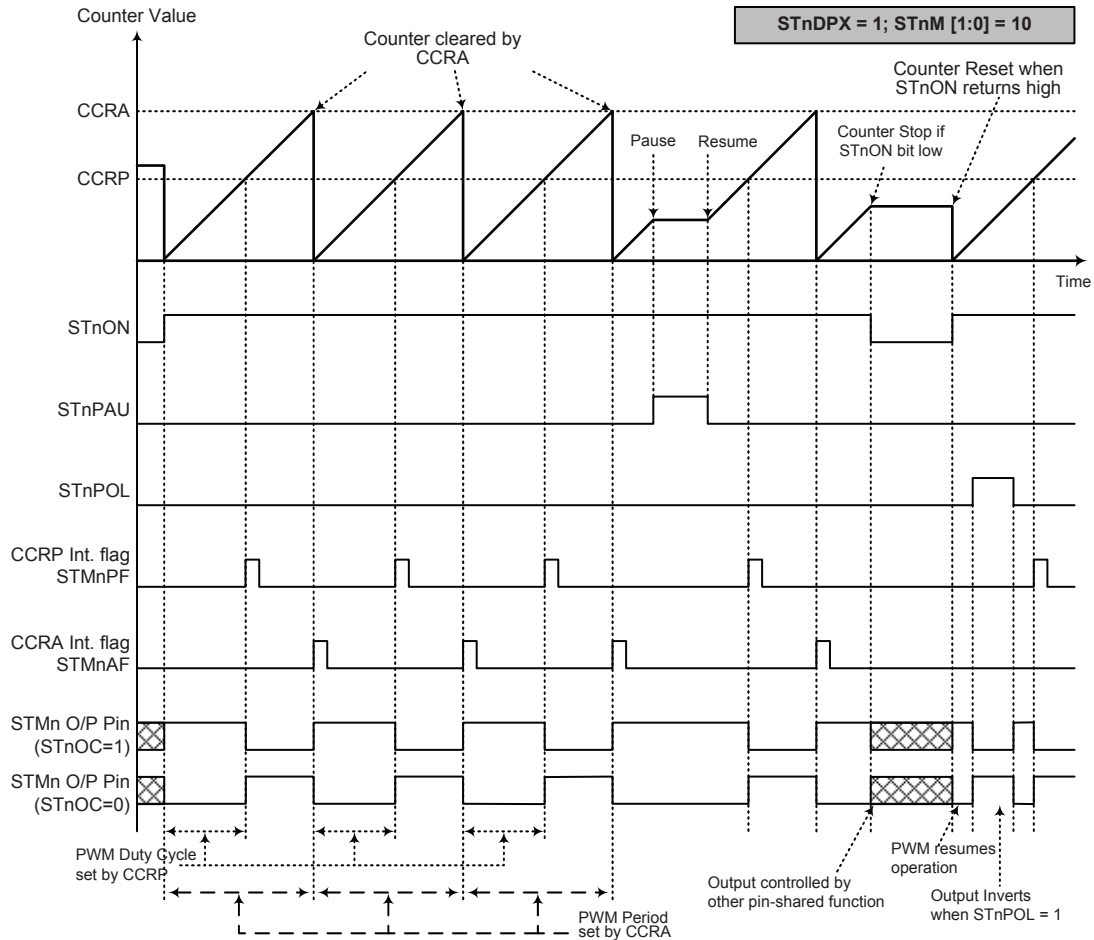
CCRP	1~255	00H
Period	CCRA	
Duty	CCRP×256	65536

The PWM output period is determined by the CCRA register value together with the STM clock while the PWM duty cycle is defined by the CCRP register value.



**PWM Output Mode – STnDPX = 0 (n=0~1)**

- Note: 1. Here STnDPX = 0 – Counter cleared by CCRP  
 2. A counter clear sets PWM Period  
 3. The internal PWM function continues running even when STnIO[1:0] = 00 or 01  
 4. The STnCCLR bit has no influence on PWM operation



**PWM Output Mode – STnDPX = 1**

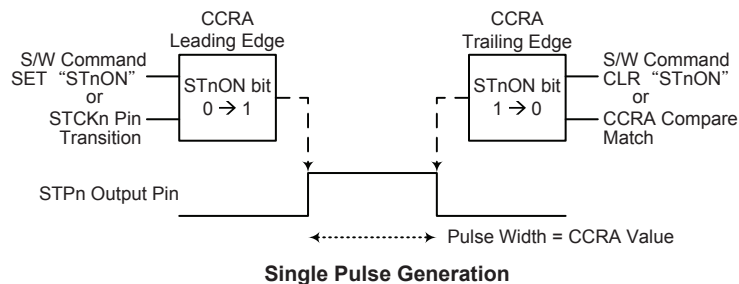
- Note: 1. Here STnDPX = 1 – Counter cleared by CCRA  
 2. A counter clear sets PWM Period  
 3. The internal PWM function continues even when STnIO[1:0] = 00 or 01  
 4. The STnCCLR bit has no influence on PWM operation

**Single Pulse Mode**

To select this mode, bits STnM1 and STnM0 in the STMnC1 register should be set to 10 respectively and also the STnIO1 and STnIO0 bits should be set to 11 respectively. The Single Pulse Output Mode, as the name suggests, will generate a single shot pulse on the STM output pin.

The trigger for the pulse output leading edge is a low to high transition of the STnON bit, which can be implemented using the application program. However in the Single Pulse Mode, the STnON bit can also be made to automatically change from low to high using the external STCKn pin, which will in turn initiate the Single Pulse output. When the STnON bit transitions to a high level, the counter will start running and the pulse leading edge will be generated. The STnON bit should remain high when the pulse is in its active state. The generated pulse trailing edge will be generated when the STnON bit is cleared to zero, which can be implemented using the application program or when a compare match occurs from Comparator A.

However a compare match from Comparator A will also automatically clear the STnON bit and thus generate the Single Pulse output trailing edge. In this way the CCRA value can be used to control the pulse width. A compare match from Comparator A will also generate a STM interrupt. The counter can only be reset back to zero when the STnON bit changes from low to high when the counter restarts. In the Single Pulse Mode CCRP is not used. The STnCCLR and STnDPX bits are not used in this Mode.



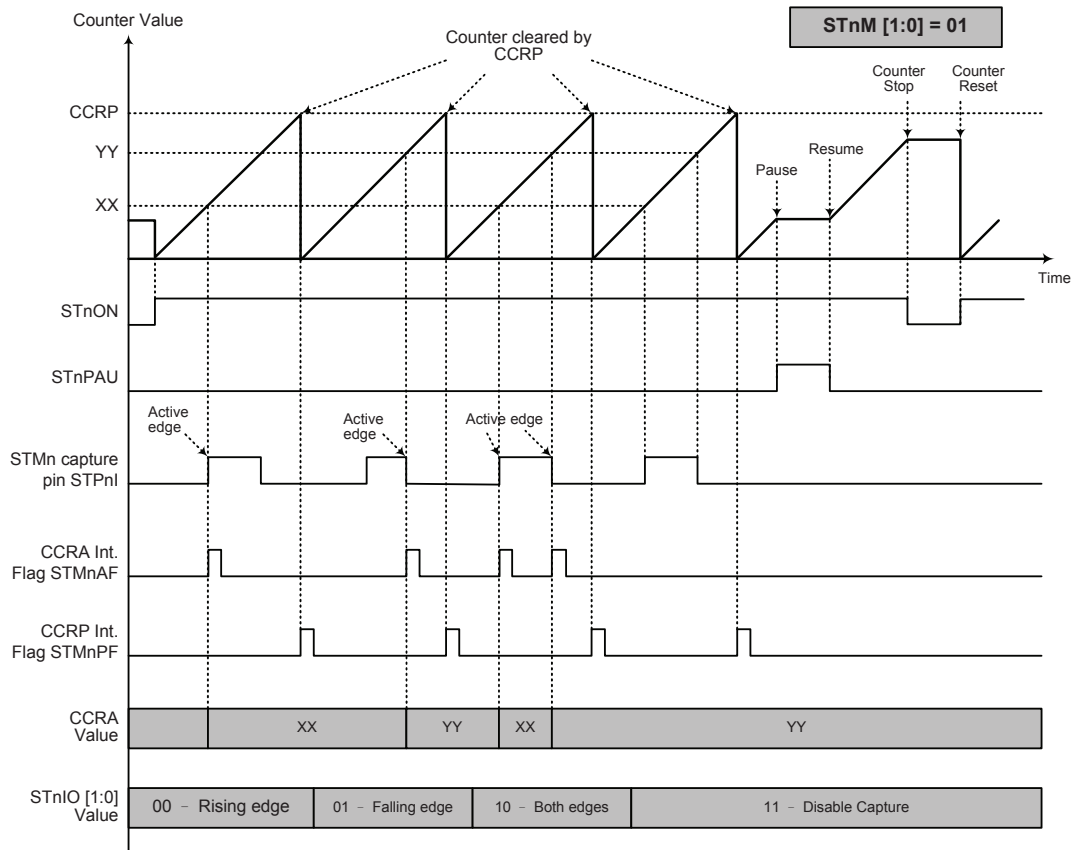


**Capture Input Mode**

To select this mode bits STnM1 and STnM0 in the STMnC1 register should be set to 01 respectively. This mode enables external signals to capture and store the present value of the internal counter and can therefore be used for applications such as pulse width measurements. The external signal is supplied on the STPnI, whose active edge can be either a rising edge, a falling edge or both rising and falling edges; the active edge transition type is selected using the STnIO1 and STnIO0 bits in the STMnC1 register. The counter is started when the STnON bit changes from low to high which is initiated using the application program.

When the required edge transition appears on the STPnI the present value in the counter will be latched into the CCRA registers and a STM interrupt generated. Irrespective of what events occur on the STPnI the counter will continue to free run until the STnON bit changes from high to low. When a CCRP compare match occurs the counter will reset back to zero; in this way the CCRP value can be used to control the maximum counter value. When a CCRP compare match occurs from Comparator P, a STM interrupt will also be generated. Counting the number of overflow interrupt signals from the CCRP can be a useful method in measuring long pulse widths. The STnIO1 and STnIO0 bits can select the active trigger edge on the STPnI to be a rising edge, falling edge or both edge types. If the STnIO1 and STnIO0 bits are both set high, then no capture operation will take place irrespective of what happens on the STPnI, however it must be noted that the counter will continue to run.

The STnCCLR and STnDPX bits are not used in this Mode.



**Capture Input Mode (n=0~1)**

- Note: 1. STnM[1:0] = 01 and active edge set by the STnIO[1:0] bits  
 2. A TM Capture input pin active edge transfers the counter value to CCRA  
 3. The STnCCLR and STnDPX bits are not used  
 4. No output function – STnOC and STnPOL bits are not used  
 5. CCRP determines the counter value and the counter has a maximum count value when CCRP is equal to zero.

## Analog to Digital Converter

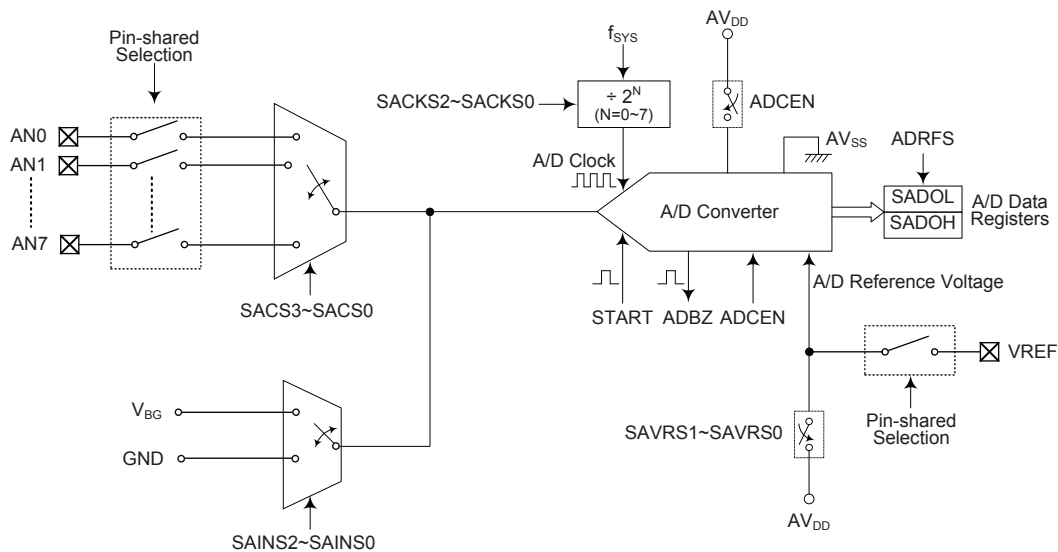
The need to interface to real world analog signals is a common requirement for many electronic systems. However, to properly process these signals by a microcontroller, they must first be converted into digital signals by A/D converters. By integrating the A/D conversion electronic circuitry into the microcontroller, the need for external components is reduced significantly with the corresponding follow-on benefits of lower costs and reduced component space requirements.

### A/D Converter Overview

The device contains a multi-channel analog to digital converter which can directly interface to external analog signals, such as that from sensors or other control signals and convert these signals directly into a 12-bit digital value. It also can convert the internal signal into a 12-bit digital value. The external or internal analog signal to be converted is determined by the SAINS2~SAINS0 bits together with the SACS3~SACS0 bits. More detailed information about the A/D input signal is described in the "A/D Converter Control Registers" and "A/D Converter Input Signals" sections respectively.

External Input Channels	Internal Signals	Channel Select Bits
8: AN0~AN7	V <sub>BG</sub>	SAINS2~SAINS0, SACS3~SACS0

The accompanying block diagram shows the overall internal structure of the A/D converter, together with its associated registers.



**A/D Converter Structure**

### A/D Converter Register Description

Overall operation of the A/D converter is controlled using several registers. A read only register pair exists to store the A/D converter data 12-bit value. The remaining two registers are control registers which setup the operating and control function of the A/D converter.

Register Name	Bit							
	7	6	5	4	3	2	1	0
SADOH (ADRF5=0)	D11	D10	D9	D8	D7	D6	D5	D4
SADOL (ADRF5=0)	D3	D2	D1	D0	—	—	—	—
SADOH (ADRF5=1)	—	—	—	—	D11	D10	D9	D8
SADOL (ADRF5=1)	D7	D6	D5	D4	D3	D2	D1	D0
SADC0	START	ADBZ	ADCEN	ADRF5	SACS3	SACS2	SACS1	SACS0
SADC1	SAINS2	SAINS1	SAINS0	SAVRS1	SAVRS0	SACKS2	SACKS1	SACKS0

**A/D Converter Register List**

### A/D Converter Data Registers – SADOL, SADOH

As the device contains an internal 12-bit A/D converter, it requires two data registers to store the converted value. These are a high byte register, known as SADOH, and a low byte register, known as SADOL. After the conversion process takes place, these registers can be directly read by the microcontroller to obtain the digitised conversion value. As only 12 bits of the 16-bit register space is utilised, the format in which the data is stored is controlled by the ADRFS bit in the SADC0 register as shown in the accompanying table. D0~D11 are the A/D conversion result data bits. Any unused bits will be read as zero. Note that A/D Converter data register contents will be unchanged if the A/D converter is disabled.

ADRF5	SADOH								SADOL							
	7	6	5	4	3	2	1	0	7	6	5	4	3	2	1	0
0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0	0	0	0	0
1	0	0	0	0	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0

**A/D Data Register Pair**

### A/D Converter Control Registers – SADC0, SADC1

To control the function and operation of the A/D converter, two control registers known as SADC0 and SADC1 are provided. These 8-bit registers define functions such as the selection of which analog channel is connected to the internal A/D converter, the digitised data format, the A/D clock source as well as controlling the start function and monitoring the A/D converter busy status. As the device contains only one actual analog to digital converter hardware circuit, each of the external or internal analog signal inputs must be routed to the converter. The SACS3~SACS0 bits in the SADC0 register are used to determine which external channel input is selected to be converted. The SAINS2~SAINS0 bits in the SADC1 register are used to determine that the analog signal to be converted comes from the internal analog signal or external analog channel input.

The relevant pin-shared function selection bits determine which pins on I/O Ports are used as analog inputs for the A/D converter input and which pins are not to be used as the A/D converter input. When the pin is selected to be an A/D input, its original function whether it is an I/O or other pin-shared function will be removed. In addition, any internal pull-high resistor connected to the pin will be automatically removed if the pin is selected to be an A/D converter input.

• **SADC0 Register**

Bit	7	6	5	4	3	2	1	0
Name	START	ADBZ	ADCEN	ADRFS	SACS3	SACS2	SACS1	SACS0
R/W	R/W	R	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

- Bit 7**     **START:** Start the A/D conversion  
0→1→0: Start A/D conversion  
This bit is used to initiate an A/D conversion process. The bit is normally low but if set high and then cleared low again, the A/D converter will initiate a conversion process.
- Bit 6**     **ADBZ:** A/D converter busy flag  
0: No A/D conversion is in progress  
1: A/D conversion is in progress  
This read only flag is used to indicate whether the A/D conversion is in progress or not. When the START bit is set from low to high and then to low again, the ADBZ flag will be set to 1 to indicate that the A/D conversion is initiated. The ADBZ flag will be cleared to 0 after the A/D conversion is complete.
- Bit 5**     **ADCEN:** A/D converter function enable control  
0: Disable  
1: Enable  
This bit controls the A/D internal function. This bit should be set to one to enable the A/D converter. If the bit is set low, then the A/D converter will be switched off reducing the device power consumption. When the A/D converter function is disabled, the contents of the A/D data register pair known as SADOH and SADOL will be unchanged.
- Bit 4**     **ADRFS:** A/D converter data format select  
0: A/D converter data format → SADOH = D[11:4]; SADOL = D[3:0]  
1: A/D converter data format → SADOH = D[11:8]; SADOL = D[7:0]  
This bit controls the format of the 12-bit converted A/D value in the two A/D data registers. Details are provided in the A/D data register section.
- Bit 3~0**   **SACS3~SACS0:** A/D converter external analog channel input select  
0000: AN0  
0001: AN1  
0010: AN2  
0011: AN3  
0100: AN4  
0101: AN5  
0110: AN6  
0111: AN7  
1000~1111: Un-existed channel, the external input is floating

• **SADC1 Register**

Bit	7	6	5	4	3	2	1	0
Name	SAINS2	SAINS1	SAINS0	SAVRS1	SAVRS0	SACKS2	SACKS1	SACKS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

Bit 7~5 **SAINS2~SAINS0**: A/D converter input signal select  
 000: External input – External analog channel input  
 001: Internal input – Internal bandgap reference voltage,  $V_{BG}$   
 010: Internal input – Unused, connected to ground  
 011: Internal input – Unused, connected to ground  
 100: Internal input – Unused, connected to ground  
 101~111: External input – External analog channel input  
 Care must be taken if the SAINS2~SAINS0 bits are set from "001" to "100" to select the internal analog signal to be converted. When the internal analog signal is selected to be converted, the external input pin must never be selected as the A/D input signal by properly setting the SACKS3~SACKS0 bits. Otherwise, the external channel input will be connected together with the internal analog signal. This will result in unpredictable situations such as an irreversible damage.

Bit 4~3 **SAVRS1~SAVRS0**: A/D converter reference voltage select  
 00: From external VREF pin  
 01: Internal A/D converter power,  $AV_{DD}$   
 1x: From external VREF pin  
 These bits are used to select the A/D converter reference voltage. Care must be taken if the SAVRS1~SAVRS0 bits are set to "01" to select the internal A/D converter power as the reference voltage source. When the internal A/D converter power is selected as the reference voltage, the VREF pin cannot be configured as the reference voltage input by properly configuring the corresponding pin-shared function control bits. Otherwise, the external input voltage on VREF pin will be connected to the internal A/D converter power.

Bit 2~0 **SACKS2~SACKS0**: A/D conversion clock source select  
 000:  $f_{SYS}$   
 001:  $f_{SYS}/2$   
 010:  $f_{SYS}/4$   
 011:  $f_{SYS}/8$   
 100:  $f_{SYS}/16$   
 101:  $f_{SYS}/32$   
 110:  $f_{SYS}/64$   
 111:  $f_{SYS}/128$   
 These three bits are used to select the clock source for the A/D converter.

**A/D Converter Operation**

The START bit in the SADC0 register is used to start the AD conversion. When the microcontroller sets this bit from low to high and then low again, an analog to digital conversion cycle will be initiated.

The ADBZ bit in the SADC0 register is used to indicate whether the analog to digital conversion process is in progress or not. This bit will be automatically set to 1 by the microcontroller after an A/D conversion is successfully initiated. When the A/D conversion is complete, the ADBZ will be cleared to 0. In addition, the corresponding A/D interrupt request flag will be set in the interrupt control register, and if the interrupts are enabled, an appropriate internal interrupt signal will be generated. This A/D internal interrupt signal will direct the program flow to the associated A/D internal interrupt address for processing. If the A/D internal interrupt is disabled, the microcontroller can poll the ADBZ bit in the SADC0 register to check whether it has been cleared as an alternative method of detecting the end of an A/D conversion cycle.

The clock source for the A/D converter, which originates from the system clock  $f_{SYS}$ , can be chosen to be either  $f_{SYS}$  or a subdivided version of  $f_{SYS}$ . The division ratio value is determined by the SACKS2~SACKS0 bits in the SADC1 register. Although the A/D clock source is determined by the system clock  $f_{SYS}$  and by bits SACKS2~SACKS0, there are some limitations on the maximum A/D clock source speed that can be selected. As the recommended range of permissible A/D clock period,  $t_{ADCK}$ , is from 0.5 $\mu$ s to 10 $\mu$ s, care must be taken for system clock frequencies. For example, as the system clock operates at a frequency of 4MHz, the SACKS2~SACKS0 bits should not be set to 000, 110 or 111. Doing so will give A/D clock periods that are less than the minimum or larger than the maximum A/D clock period which may result in inaccurate A/D conversion values. Refer to the following table for examples, where values marked with an asterisk \* show where, depending upon the device, special care must be taken, as the values may be less or larger than the specified A/D Clock Period range.

$f_{SYS}$	A/D Clock Period ( $t_{ADCK}$ )							
	SACKS [2:0]=000 ( $f_{SYS}$ )	SACKS [2:0]=001 ( $f_{SYS}/2$ )	SACKS [2:0]=010 ( $f_{SYS}/4$ )	SACKS [2:0]=011 ( $f_{SYS}/8$ )	SACKS [2:0]=100 ( $f_{SYS}/16$ )	SACKS [2:0]=101 ( $f_{SYS}/32$ )	SACKS [2:0]=110 ( $f_{SYS}/64$ )	SACKS [2:0]=111 ( $f_{SYS}/128$ )
1MHz	1 $\mu$ s	2 $\mu$ s	4 $\mu$ s	8 $\mu$ s	16 $\mu$ s *	32 $\mu$ s *	64 $\mu$ s *	128 $\mu$ s *
2MHz	500ns	1 $\mu$ s	2 $\mu$ s	4 $\mu$ s	8 $\mu$ s	16 $\mu$ s *	32 $\mu$ s *	64 $\mu$ s *
4MHz	250ns *	500ns	1 $\mu$ s	2 $\mu$ s	4 $\mu$ s	8 $\mu$ s	16 $\mu$ s *	32 $\mu$ s *

**A/D Clock Period Examples**

Controlling the power on/off function of the A/D converter circuitry is implemented using the ADCEN bit in the SADC0 register. This bit must be set high to power on the A/D converter. When the ADCEN bit is set high to power on the A/D converter internal circuitry a certain delay, as indicated in the timing diagram, must be allowed before an A/D conversion is initiated. Even if no pins are selected for use as A/D inputs, if the ADCEN bit is high, then some power will still be consumed. In power conscious applications it is therefore recommended that the ADCEN is set low to reduce power consumption when the A/D converter function is not being used.

### A/D Converter Reference Voltage

The reference voltage supply to the A/D converter can be supplied from the power supply  $AV_{DD}$ , or from an external reference source supplied on pin VREF. The desired selection is made using the SAVRS1 and SAVRS0 bits. When the SAVRS bit field is set to "01", the A/D converter reference voltage will come from the  $AV_{DD}$ . Otherwise, if the SAVRS bit field is set to any other value except "01", the A/D converter reference voltage will come from the VREF pin. As the VREF pin is pin-shared with other functions, when the VREF pin is selected as the reference voltage supply pin, the VREF pin control bit VREFS should first be set high to enable the VREF pin function then the other pin functions will be disabled automatically. However, if the internal A/D converter power  $AV_{DD}$  is selected as the reference voltage, the VREF pin must not be configured as the reference voltage input function to avoid the internal connection between the VREF pin to A/D converter power  $AV_{DD}$ . The analog input values must not be allowed to exceed the value of the selected A/D reference voltage.

### A/D Converter Input Signals

All the external A/D analog channel input pins are pin-shared with the I/O pins as well as other functions. The corresponding control bits for each A/D external input pin in the PxS0 and PxS1 registers determine whether the input pins are setup as A/D converter analog input channel or whether they have other functions. If the pin is setup to be as an A/D analog channel input, the original pin functions will be disabled. In this way, pins can be changed under program control to change their function between A/D inputs and other functions. All pull high resistors, which are setup through register programming, will be automatically disconnected if the pins are setup as A/D inputs. Note that it is not necessary to first setup the A/D pin as an input in the port control register to enable the A/D input as when the pin-shared function control bits enable an A/D input, the status of the port control register will be overridden.

The internal bandgap voltage can be connected to the A/D converter as the analog input signal by configuring the SAINS2~SAINS0 bits. If the external channel input is selected to be converted, the SAINS2~SAINS0 bits should be set to "000" or "101~111" and the SACS3~SACS0 bits can determine which external channel is selected. If the internal analog signal is selected to be converted, the SACS3~SACS0 bits must be configured with an appropriate value to switch off the external analog channel input. Otherwise, the internal analog signal will be connected together with the external channel input. This will result in unpredictable situations.

SAINS[2:0]	SACS[3:0]	Input Signals	Description
000, 101~111	0000~0111	AN0~AN7	External pin analog input
	1000~1111	—	Un-existed channel, input is floating.
001	1000~1111	V <sub>BG</sub>	Internal Bandgap reference voltage
010~100	1000~1111	GND	Unused, connected to ground

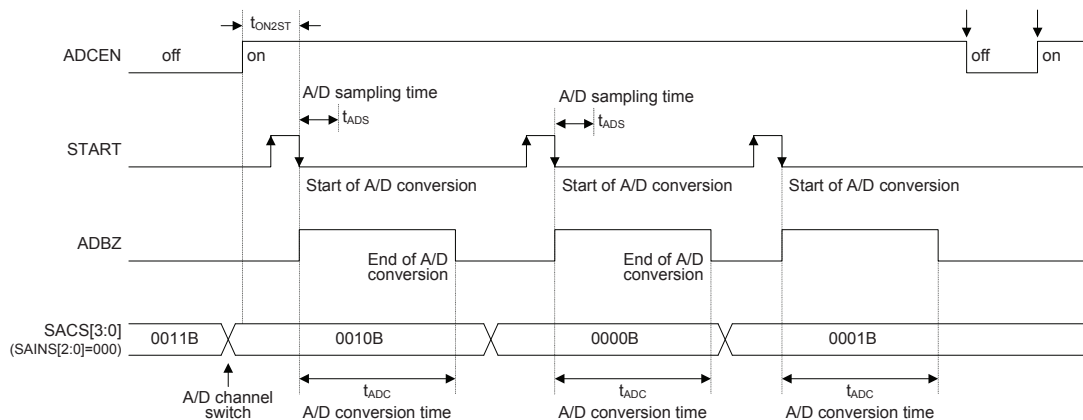
**A/D Converter Input Signal Selection**

### Conversion Rate and Timing Diagram

A complete A/D conversion contains two parts, data sampling and data conversion. The data sampling which is defined as  $t_{ADS}$  takes 4 A/D clock cycles and the data conversion takes 12 A/D clock cycles. Therefore a total of 16 A/D clock cycles for an external input A/D conversion which is defined as  $t_{ADC}$  are necessary.

$$\text{Maximum single A/D conversion rate} = \text{A/D clock period} \times 16$$

The accompanying diagram shows graphically the various stages involved in an analog to digital conversion process and its associated timing. After an A/D conversion process has been initiated by the application program, the microcontroller internal hardware will begin to carry out the conversion, during which time the program can continue with other functions. The time taken for the A/D conversion is 16  $t_{ADCK}$  clock cycles where  $t_{ADCK}$  is equal to the A/D clock period.



**A/D Conversion Timing**

## Summary of A/D Conversion Steps

The following summarises the individual steps that should be executed in order to implement an A/D conversion process.

- Step 1  
Select the required A/D conversion clock by correctly programming bits SACKS2~SACKS0 in the SADC1 register.
- Step 2  
Enable the A/D by setting the ADCEN bit in the SADC0 register to 1.
- Step 3  
Select which signal is to be connected to the internal A/D converter by correctly configuring the SAINS2~SAINS0 bits  
Select the external channel input to be converted, go to Step 4.  
Select the internal analog signal to be converted, go to Step 5.
- Step 4  
If the A/D input signal comes from the external channel input selected by configuring the SAINS bit field, the corresponding pins should be configured as A/D input function by configuring the relevant pin-shared function control bits. The desired analog channel then should be selected by configuring the SACS bit field. After this step, go to Step 6.
- Step 5  
Before the A/D input signal is selected to come from the internal analog signal by configuring the SAINS bit field, the corresponding external input pin must be switched to a non-existent channel input by properly configured the SACS3~SACS0 bits. The desired internal analog signal then can be selected by configuring the SAINS bit field. After this step, go to Step 6.
- Step 6  
Select the reference voltage source by configuring the SAVRS1~SAVRS0 bits in the SADC1 register.
- Step 7  
Select A/D converter output data format by setting the ADRFS bit in the SADC0 register.
- Step 8  
If A/D conversion interrupt is used, the interrupt control registers must be correctly configured to ensure the A/D interrupt function is active. The master interrupt control bit, EMI, and the A/D conversion interrupt control bit, ADE, must both be set high in advance.
- Step 9  
The A/D conversion procedure can now be initialized by setting the START bit from low to high and then low again.
- Step 10  
If A/D conversion is in progress, the ADBZ flag will be set high. After the A/D conversion process is complete, the ADBZ flag will go low and then the output data can be read from SADOH and SADOL registers.

Note: When checking for the end of the conversion process, if the method of polling the ADBZ bit in the SADC0 register is used, the interrupt enable step above can be omitted.

### Programming Considerations

During microcontroller operations where the A/D converter is not being used, the A/D internal circuitry can be switched off to reduce power consumption, by clearing bit ADCEN to 0 in the SADC0 register. When this happens, the internal A/D converter circuits will not consume power irrespective of what analog voltage is applied to their input lines. If the A/D converter input lines are used as normal I/O pins, then care must be taken as if the input voltage is not at a valid logic level, then this may lead to some increase in power consumption.

### A/D Conversion Function

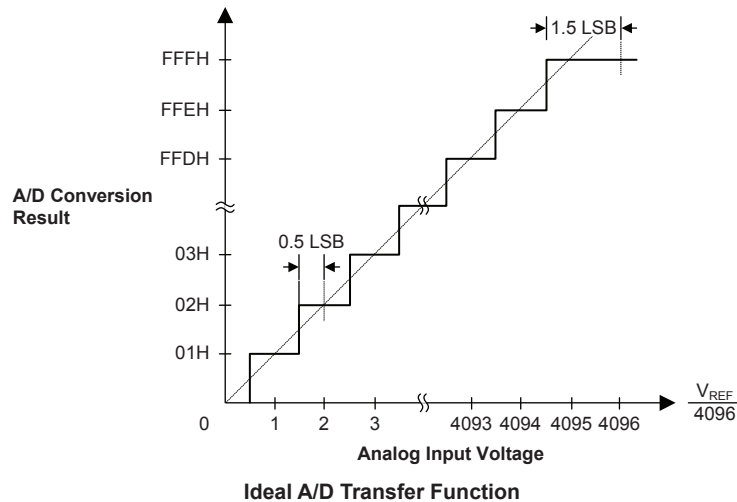
As the device contains a 12-bit A/D converter, its full-scale converted digitised value is equal to FFFH. Since the full-scale analog input value is equal to the actual A/D converter reference voltage,  $V_{REF}$ , this gives a single bit analog input value of  $V_{REF}$  divided by 4096.

$$1 \text{ LSB} = V_{REF} \div 4096$$

The A/D Converter input voltage value can be calculated using the following equation:

$$\text{A/D input voltage} = \text{A/D output digital value} \times (V_{REF} \div 4096)$$

The diagram shows the ideal transfer function between the analog input value and the digitised output value for the A/D converter. Except for the digitised zero value, the subsequent digitised values will change at a point 0.5 LSB below where they would change without the offset, and the last full scale digitised value will change at a point 1.5 LSB below the  $V_{REF}$  level. Note that here the  $V_{REF}$  voltage is the actual A/D converter reference voltage determined by the SAVRS field.



## A/D Conversion Programming Examples

The following two programming examples illustrate how to setup and implement an A/D conversion. In the first example, the method of polling the ADBZ bit in the SADC0 register is used to detect when the conversion cycle is complete, whereas in the second example, the A/D interrupt is used to determine when the conversion is complete.

### Example: using an ADBZ polling method to detect the end of conversion

```
clr ADE                ; disable ADC interrupt
mov a,03H
mov SADC1,a            ; select fsys/8 as A/D clock
set ADCEN
mov a,02h              ; setup PBS0 register to configure pin AN0
mov PBS0,a
mov a,20h
mov SADC0,a           ; enable and connect AN0 channel to A/D converter
:
start_conversion:
clr START              ; high pulse on start bit to initiate conversion
set START              ; reset A/D
clr START              ; start A/D
polling_EOC:
sz ADBZ                ; poll the SADC0 register ADBZ bit to detect end of A/D conversion
jmp polling_EOC        ; continue polling
mov a,SADOL             ; read low byte conversion result value
mov SADOL_buffer,a     ; save result to user defined register
mov a,SADOH             ; read high byte conversion result value
mov SADOH_buffer,a    ; save result to user defined register
:
:
jmp start_conversion   ; start next A/D conversion
```

**Example: using the interrupt method to detect the end of conversion**

```
clr ADE          ; disable ADC interrupt
mov a,03H
mov SADC1,a      ; select fsys/8 as A/D clock
set ADCEN
mov a, 02h       ; setup PBS0 register to configure pin AN0
mov PBS0,a
mov a,20h
mov SADC0,a      ; enable and connect AN0 channel to A/D converter
Start_conversion:
clr START        ; high pulse on START bit to initiate conversion
set START        ; reset A/D
clr START        ; start A/D
clr ADF          ; clear ADC interrupt request flag
set ADE          ; enable ADC interrupt
set EMI          ; enable global interrupt
:
:
; ADC interrupt service routine
ADC_ISR:
mov acc_stack,a  ; save ACC to user defined memory
mov a,STATUS
mov status_stack,a ; save STATUS to user defined memory
:
:
mov a,SADOL      ; read low byte conversion result value
mov SADOL_buffer,a ; save result to user defined register
mov a,SADOH      ; read high byte conversion result value
mov SADOH_buffer,a ; save result to user defined register
:
:
EXIT_INT_ISR:
mov a,status_stack
mov STATUS,a     ; restore STATUS from user defined memory
mov a,acc_stack  ; restore ACC from user defined memory
reti
```

## Interrupts

Interrupts are an important part of any microcontroller system. When an external event or an internal function such as a Timer Module requires microcontroller attention, their corresponding interrupt will enforce a temporary suspension of the main program allowing the microcontroller to direct attention to their respective needs. The device contains several external interrupt and internal interrupt functions. The external interrupt is generated by the action of the external INTn pin, while the internal interrupts are generated by various internal functions such as the TMs, EEPROM write and Time Bases, etc.

### Interrupt Registers

Overall interrupt control, which basically means the setting of request flags when certain microcontroller conditions occur and the setting of interrupt enable bits by the application program, is controlled by a series of registers, located in the Special Purpose Data Memory, as shown in the accompanying table. The number of registers falls into three categories. The first is the INTC0~INTC1 registers which setup the primary interrupts, the second is the MFIO~MFI1 registers which setup the Multi-function interrupts. Finally there is an INTEG register to setup the external interrupt trigger edge type.

Each register contains a number of enable bits to enable or disable individual registers as well as interrupt flags to indicate the presence of an interrupt request. The naming convention of these follows a specific pattern. First is listed an abbreviated interrupt type, then the (optional) number of that interrupt followed by either an "E" for enable/disable bit or "F" for request flag.

Function	Enable Bit	Request Flag	Notes
Global	EMI	—	—
External Interrupt	INTnE	INTnF	n=0 or 1
Time Base	TBnE	TBnF	n=0 or 1
EEPROM	DEE	DEF	—
A/D Converter	ADE	ADF	—
Low Voltage Detector	LVE	LVF	—
STM	STMnPE	STMnPF	n=0 or 1
	STMnAE	STMnAF	

**Interrupt Register Bit Naming Conventions**

Register Name	Bit							
	7	6	5	4	3	2	1	0
INTEG	—	—	—	—	INT1S1	INT1S0	INT0S1	INT0S0
INTC0	—	LVF	INT1F	INT0F	LVE	INT1E	INT0E	EMI
INTC1	STM0AF	STM0PF	DEF	ADF	STM0AE	STM0PE	DEE	ADE
INTC2	STM1AF	STM1PF	TB1F	TB0F	STM1AE	STM1PE	TB1E	TB0E

**Interrupt Register List**

**INTEG Register**

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	INT1S1	INT1S0	INT0S1	INT0S0
R/W	—	—	—	—	R/W	R/W	R/W	R/W
POR	—	—	—	—	0	0	0	0

- Bit 7~4 Unimplemented, read as "0"
- Bit 3~2 **INT1S1~INT1S0**: Defines INT1 pin external interrupt active edge  
 00: Disable INT1 Interrupt  
 01: Rising edge  
 10: Falling edge  
 11: Rising and falling edges
- Bit 1~0 **INT0S1~INT0S0**: Defines INT0 pin external interrupt active edge  
 00: Disable INT0 Interrupt  
 01: Rising edge  
 10: Falling edge  
 11: Rising and falling edges

**INTC0 Register**

Bit	7	6	5	4	3	2	1	0
Name	—	LVF	INT1F	INT0F	LVE	INT1E	INT0E	EMI
R/W	—	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	—	0	0	0	0	0	0	0

- Bit 7 Unimplemented, read as "0"
- Bit 6 **LVF**: LVD interrupt request flag  
 0: No request  
 1: Interrupt request
- Bit 5 **INT1F**: INT1 interrupt request flag  
 0: No request  
 1: Interrupt request
- Bit 4 **INT0F**: INT0 interrupt request flag  
 0: No request  
 1: Interrupt request
- Bit 3 **LVE**: LVD interrupt control  
 0: Disable  
 1: Enable
- Bit 2 **INT1E**: INT1 interrupt control  
 0: Disable  
 1: Enable
- Bit 1 **INT0E**: INT0 interrupt control  
 0: Disable  
 1: Enable
- Bit 0 **EMI**: Global interrupt control  
 0: Disable  
 1: Enable

**INTC1 Register**

Bit	7	6	5	4	3	2	1	0
Name	STM0AF	STM0PF	DEF	ADF	STM0AE	STM0PE	DEE	ADE
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

- Bit 7      **STM0AF**: STM0 Comparator A match interrupt request flag  
0: No request  
1: Interrupt request
- Bit 6      **STM0PF**: STM0 Comparator P match interrupt request flag  
0: No request  
1: Interrupt request
- Bit 5      **DEF**: Data EEPROM interrupt request flag  
0: No request  
1: Interrupt request
- Bit 4      **ADF**: A/D Converter interrupt request flag  
0: No request  
1: Interrupt request
- Bit 3      **STM0AE**: STM0 Comparator A match interrupt control  
0: Disable  
1: Enable
- Bit 2      **STM0PE**: STM0 Comparator P match interrupt control  
0: Disable  
1: Enable
- Bit 1      **DEE**: Data EEPROM interrupt control  
0: Disable  
1: Enable
- Bit 0      **ADE**: A/D Converter interrupt control  
0: Disable  
1: Enable

**INTC2 Register**

Bit	7	6	5	4	3	2	1	0
Name	STM1AF	STM1PF	TB1F	TB0F	STM1AE	STM1PE	TB1E	TB0E
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
POR	0	0	0	0	0	0	0	0

- Bit 7      **STM1AF**: STM1 Comparator A match interrupt request flag  
0: No request  
1: Interrupt request
- Bit 6      **STM1PF**: STM1 Comparator P match interrupt request flag  
0: No request  
1: Interrupt request
- Bit 5      **TB1F**: Time Base 1 interrupt request flag  
0: No request  
1: Interrupt request
- Bit 4      **TB0F**: Time Base 0 interrupt request flag  
0: No request  
1: Interrupt request
- Bit 3      **STM1AE**: STM1 Comparator A match interrupt control  
0: Disable  
1: Enable

Bit 2	<b>STM1PE</b> : STM1 Comparator P match interrupt control 0: Disable 1: Enable
Bit 1	<b>TB1E</b> : Time Base 1 interrupt control 0: Disable 1: Enable
Bit 0	<b>TB0E</b> : Time Base 0 interrupt control 0: Disable 1: Enable

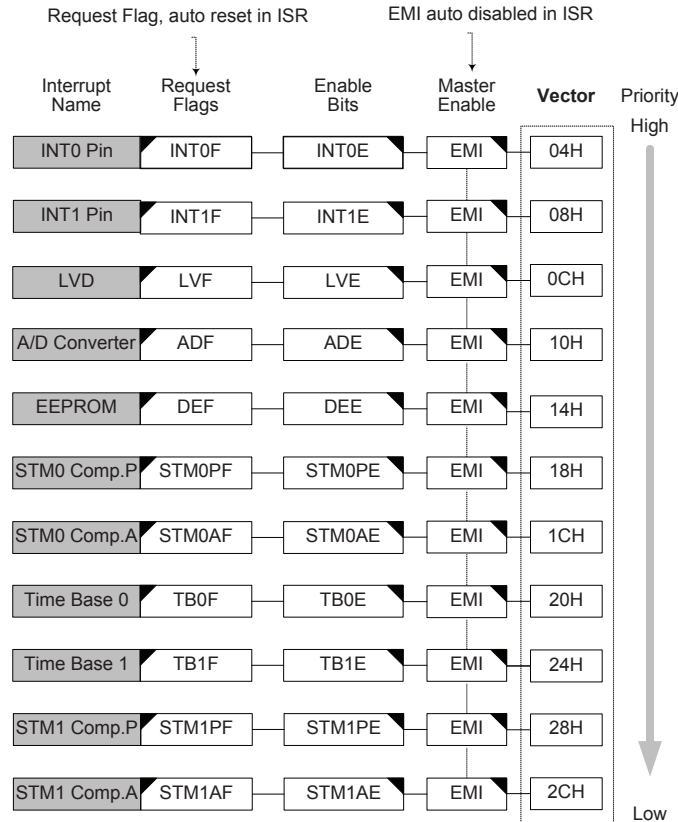
### Interrupt Operation

When the conditions for an interrupt event occur, such as a TM Comparator P or Comparator A match etc., the relevant interrupt request flag will be set. Whether the request flag actually generates a program jump to the relevant interrupt vector is determined by the condition of the interrupt enable bit. If the enable bit is set high then the program will jump to its relevant vector; if the enable bit is zero then although the interrupt request flag is set an actual interrupt will not be generated and the program will not jump to the relevant interrupt vector. The global interrupt enable bit, if cleared to zero, will disable all interrupts.

When an interrupt is generated, the Program Counter, which stores the address of the next instruction to be executed, will be transferred onto the stack. The Program Counter will then be loaded with a new address which will be the value of the corresponding interrupt vector. The microcontroller will then fetch its next instruction from this interrupt vector. The instruction at this vector will usually be a "JMP" which will jump to another section of program which is known as the interrupt service routine. Here is located the code to control the appropriate interrupt. The interrupt service routine must be terminated with a "RETI", which retrieves the original Program Counter address from the stack and allows the microcontroller to continue with normal execution at the point where the interrupt occurred.

The various interrupt enable bits, together with their associated request flags, are shown in the accompanying diagrams with their order of priority. Some interrupt sources have their own individual vector while others share the same multi-function interrupt vector. Once an interrupt subroutine is serviced, all the other interrupts will be blocked, as the global interrupt enable bit, EMI bit will be cleared automatically. This will prevent any further interrupt nesting from occurring. However, if other interrupt requests occur during this interval, although the interrupt will not be immediately serviced, the request flag will still be recorded.

If an interrupt requires immediate servicing while the program is already in another interrupt service routine, the EMI bit should be set after entering the routine, to allow interrupt nesting. If the stack is full, the interrupt request will not be acknowledged, even if the related interrupt is enabled, until the Stack Pointer is decremented. If immediate service is desired, the stack must be prevented from becoming full. In case of simultaneous requests, the accompanying diagram shows the priority that is applied. All of the interrupt request flags when set will wake-up the device if it is in SLEEP or IDLE Mode, however to prevent a wake-up from occurring the corresponding flag should be set before the device is in SLEEP or IDLE Mode.



**Interrupt Structure**

### External Interrupts

The external interrupts are controlled by signal transitions on the pins INT0~INT1. An external interrupt request will take place when the external interrupt request flags, INT0F~INT1F, are set, which will occur when a transition, whose type is chosen by the edge select bits, appears on the external interrupt pins. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and respective external interrupt enable bit, INT0E~INT1E, must first be set. Additionally the correct interrupt edge type must be selected using the INTEG register to enable the external interrupt function and to choose the trigger edge type. As the external interrupt pins are pin-shared with I/O pins, they can only be configured as external interrupt pins if their external interrupt enable bit in the corresponding interrupt register has been set and the external interrupt pin is selected by the corresponding pin-shared function selection bits. The pin must also be setup as an input by setting the corresponding bit in the port control register. When the interrupt is enabled, the stack is not full and the correct transition type appears on the external interrupt pin, a subroutine call to the external interrupt vector, will take place. When the interrupt is serviced, the external interrupt request flags, INT0F~INT1F, will be automatically reset and the EMI bit will be automatically cleared to disable other interrupts. Note that any pull-high resistor selections on the external interrupt pins will remain valid even if the pin is used as an external interrupt input. The INTEG register is used to select the type of active edge that will trigger the external interrupt. A choice of either rising or falling or both edge types can be chosen to trigger an external interrupt. Note that the INTEG register can also be used to disable the external interrupt function.

### LVD Interrupt

An LVD Interrupt request will take place when the LVD Interrupt request flag, LVF, is set, which occurs when the Low Voltage Detector function detects a low power supply voltage. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and Low Voltage Interrupt enable bit, LVE, must first be set. When the interrupt is enabled, the stack is not full and a low voltage condition occurs, a subroutine call to the LVD Interrupt vector, will take place. When the Low Voltage Interrupt is serviced, the LVD Interrupt flag, LVF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts.

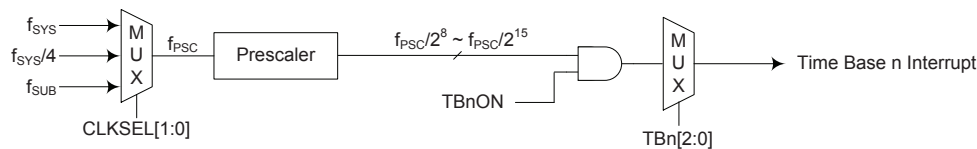
### A/D Converter Interrupt

The A/D Converter Interrupt is controlled by the termination of an A/D conversion process. An A/D Converter Interrupt request will take place when the A/D Converter Interrupt request flag, ADF, is set, which occurs when the A/D conversion process finishes. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and A/D Interrupt enable bit, ADE, must first be set. When the interrupt is enabled, the stack is not full and the A/D conversion process has ended, a subroutine call to the A/D Converter Interrupt vector, will take place. When the interrupt is serviced, the A/D Converter Interrupt flag, ADF, will be automatically cleared. The EMI bit will also be automatically cleared to disable other interrupts.

### Time Base Interrupts

The function of the Time Base Interrupts is to provide regular time signal in the form of an internal interrupt. They are controlled by the overflow signals from their respective timer functions. When these happens their respective interrupt request flags, TBnF will be set. To allow the program to branch to their respective interrupt vector addresses, the global interrupt enable bit, EMI and Time Base enable bits, TBnE, must first be set. When the interrupt is enabled, the stack is not full and the Time Base overflows, a subroutine call to their respective vector locations will take place. When the interrupt is serviced, the respective interrupt request flag, TBnF, will be automatically reset and the EMI bit will be cleared to disable other interrupts.

The purpose of the Time Base Interrupt is to provide an interrupt signal at fixed time periods. Its clock source,  $f_{PSC}$ , originates from the internal clock source  $f_{SYS}$ ,  $f_{SYS}/4$  or  $f_{SUB}$  and then passes through a divider, the division ratio of which is selected by programming the appropriate bits in the TBnC register to obtain longer interrupt periods whose value ranges. The clock source which in turn controls the Time Base interrupt period is selected using the CLKSEL1~CLKSEL0 bits in the PSCR register.



**Time Base Interrupt (n=0 or 1)**

### PSCR Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	—	—	—	—	CLKSEL1	CLKSEL0
R/W	—	—	—	—	—	—	R/W	R/W
POR	—	—	—	—	—	—	0	0

Bit 7~2 Unimplemented, read as "0"

Bit 1~0 **CLKSEL1~CLKSEL0**: Prescaler clock source selection  
 00:  $f_{SYS}$   
 01:  $f_{SYS}/4$   
 1x:  $f_{SUB}$

### TBnC Register (n=0 or 1)

Bit	7	6	5	4	3	2	1	0
Name	TBnON	—	—	—	—	TBn2	TBn1	TBn0
R/W	R/W	—	—	—	—	R/W	R/W	R/W
POR	0	—	—	—	—	0	0	0

Bit 7 **TBnON**: Time Base n Control  
 0: Disable  
 1: Enable

Bit 6~3 Unimplemented, read as "0"

Bit 2~0 **TBn2~TBn0**: Select Time Base n Time-out Period  
 000:  $2^8/f_{PSC}$   
 001:  $2^9/f_{PSC}$   
 010:  $2^{10}/f_{PSC}$   
 011:  $2^{11}/f_{PSC}$   
 100:  $2^{12}/f_{PSC}$   
 101:  $2^{13}/f_{PSC}$   
 110:  $2^{14}/f_{PSC}$   
 111:  $2^{15}/f_{PSC}$

### EEPROM Write Interrupt

An EEPROM Interrupt request will take place when the EEPROM Interrupt request flag, DEF, is set, which occurs when an EEPROM Write cycle ends. To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and EEPROM Interrupt enable bit, DEE, must first be set. When the interrupt is enabled, the stack is not full and an EEPROM Write cycle ends, a subroutine call to the respective EEPROM Interrupt vector will take place. When the EEPROM Interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts and the EEPROM interrupt request flag also will be automatically cleared.

### STM Interrupts

The two Standard Type TMs each have two interrupts, one comes from the comparator A match situation and the other comes from the comparator P match situation. For all of the TM types there are two interrupt request flags and two enable control bits. A TM interrupt request will take place when any of the TM request flags are set, a situation which occurs when a TM comparator P or A match situation happens.

To allow the program to branch to its respective interrupt vector address, the global interrupt enable bit, EMI, and respective TM Interrupt enable bit must first be set. When the interrupt is enabled, the stack is not full and a TM comparator match situation occurs, a subroutine call to the respective STM CCRA or CCRP Interrupt vector location, will take place. When the TM interrupt is serviced, the EMI bit will be automatically cleared to disable other interrupts and the TM interrupt request flag will also be automatically cleared.

## **Interrupt Wake-up Function**

Each of the interrupt functions has the capability of waking up the microcontroller when in the SLEEP or IDLE Mode. A wake-up is generated when an interrupt request flag changes from low to high and is independent of whether the interrupt is enabled or not. Therefore, even though the device is in the SLEEP or IDLE Mode and its system oscillator stopped, situations such as external edge transitions on the external interrupt pin may cause their respective interrupt flag to be set high and consequently generate an interrupt.

Care must therefore be taken if spurious wake-up situations are to be avoided. If an interrupt wake-up function is to be disabled then the corresponding interrupt request flag should be set high before the device enters the SLEEP or IDLE Mode. The interrupt enable bits have no effect on the interrupt wake-up function.

## **Programming Considerations**

By disabling the relevant interrupt enable bits, a requested interrupt can be prevented from being serviced, however, once an interrupt request flag is set, it will remain in this condition in the interrupt register until the corresponding interrupt is serviced or until the request flag is cleared by the application program.

It is recommended that programs do not use the "CALL" instruction within the interrupt service subroutine. Interrupts often occur in an unpredictable manner or need to be serviced immediately. If only one stack is left and the interrupt is not well controlled, the original control sequence will be damaged once a CALL subroutine is executed in the interrupt subroutine.

Every interrupt has the capability of waking up the microcontroller when it is in the SLEEP or IDLE Mode, the wake up being generated when the interrupt request flag changes from low to high. If it is required to prevent a certain interrupt from waking up the microcontroller then its respective request flag should be first set high before enter the SLEEP or IDLE Mode.

As only the Program Counter is pushed onto the stack, then when the interrupt is serviced, if the contents of the accumulator, status register or other registers are altered by the interrupt service program, their contents should be saved to the memory at the beginning of the interrupt service routine.

To return from an interrupt subroutine, either a RET or RETI instruction may be executed. The RETI instruction in addition to executing a return to the main program also automatically sets the EMI bit high to allow further interrupts. The RET instruction however only executes a return to the main program leaving the EMI bit in its present zero state and therefore disabling the execution of further interrupts.

## Low Voltage Detector – LVD

The device has a Low Voltage Detector function, also known as LVD. This enabled the device to monitor the power supply voltage,  $V_{DD}$ , and provide a warning signal should it fall below a certain level. This function may be especially useful in battery applications where the supply voltage will gradually reduce as the battery ages, as it allows an early warning battery low signal to be generated. The Low Voltage Detector also has the capability of generating an interrupt signal.

### LVD Register

The Low Voltage Detector function is controlled using a single register with the name LVDC. Three bits in this register, VLVD2~VLVD0, are used to select one of eight fixed voltages below which a low voltage condition will be determined. A low voltage condition is indicated when the LVDO bit is set. If the LVDO bit is low, this indicates that the  $V_{DD}$  voltage is above the preset low voltage value. The LVDEN bit is used to control the overall on/off function of the low voltage detector. Setting the bit high will enable the low voltage detector. Clearing the bit to zero will switch off the internal low voltage detector circuits. As the low voltage detector will consume a certain amount of power, it may be desirable to switch off the circuit when not in use, an important consideration in power sensitive battery powered applications.

### LVDC Register

Bit	7	6	5	4	3	2	1	0
Name	—	—	LVDO	LVDEN	VBGEN	VLVD2	VLVD1	VLVD0
R/W	—	—	R	R/W	R/W	R/W	R/W	R/W
POR	—	—	0	0	0	0	0	0

Bit 7~6 Unimplemented, read as "0"

Bit 5 **LVDO**: LVD Output Flag  
0: No Low Voltage Detected  
1: Low Voltage Detected

Bit 4 **LVDEN**: Low Voltage Detector Control  
0: Disable  
1: Enable

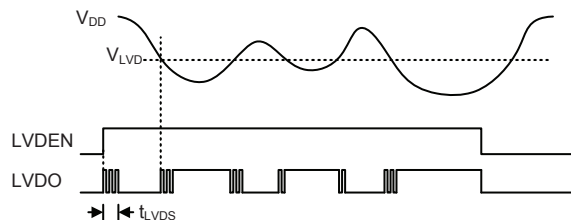
Bit 3 **VBGEN**: Bandgap Buffer Control  
0: Disable  
1: Enable

Note that the Bandgap circuit is enabled when the LVD or the LVR function is enabled or when the VBGEN bit is set high.

Bit 2~0 **VLVD2~VLVD0**: Select LVD Voltage  
000: 2.0V  
001: 2.2V  
010: 2.4V  
011: 2.7V  
100: 3.0V  
101: 3.3V  
110: 3.6V  
111: 4.0V

## LVD Operation

The Low Voltage Detector function operates by comparing the power supply voltage,  $V_{DD}$ , with a pre-specified voltage level stored in the LVDC register. This has a range of between 2.0V and 4.0V. When the power supply voltage,  $V_{DD}$ , falls below this pre-determined value, the LVDO bit will be set high indicating a low power supply voltage condition. The Low Voltage Detector function is supplied by a reference voltage which will be automatically enabled. When the device is in the SLEEP mode, the low voltage detector will be disabled even if the LVDEN bit is high. After enabling the Low Voltage Detector, a time delay  $t_{LVDs}$  should be allowed for the circuitry to stabilise before reading the LVDO bit. Note also that as the  $V_{DD}$  voltage may rise and fall rather slowly, at the voltage nears that of  $V_{LVD}$ , there may be multiple bit LVDO transitions.



**LVD Operation**

The Low Voltage Detector also has its own interrupt, providing an alternative means of low voltage detection, in addition to polling the LVDO bit. The interrupt will only be generated after a delay of  $t_{LVD}$  after the LVDO bit has been set high by a low voltage condition. In this case, the LVF interrupt request flag will be set, causing an interrupt to be generated if  $V_{DD}$  falls below the preset LVD voltage. This will cause the device to wake-up from the IDLE Mode, however if the Low Voltage Detector wake up function is not required then the LVF flag should be first set high before the device enter the IDLE Mode. The LVD function is always disabled in the SLEEP mode.

## Instruction Set

### Introduction

Central to the successful operation of any microcontroller is its instruction set, which is a set of program instruction codes that directs the microcontroller to perform certain operations. In the case of Holtek microcontroller, a comprehensive and flexible set of over 60 instructions is provided to enable programmers to implement their application with the minimum of programming overheads.

For easier understanding of the various instruction codes, they have been subdivided into several functional groupings.

### Instruction Timing

Most instructions are implemented within one instruction cycle. The exceptions to this are branch, call, or table read instructions where two instruction cycles are required. One instruction cycle is equal to 4 system clock cycles, therefore in the case of an 4MHz system oscillator, most instructions would be implemented within 0.5 $\mu$ s and branch or call instructions would be implemented within 1 $\mu$ s. Although instructions which require one more cycle to implement are generally limited to the JMP, CALL, RET, RETI and table read instructions, it is important to realize that any other instructions which involve manipulation of the Program Counter Low register or PCL will also take one more cycle to implement. As instructions which change the contents of the PCL will imply a direct jump to that new address, one more cycle will be required. Examples of such instructions would be "CLR PCL" or "MOV PCL, A". For the case of skip instructions, it must be noted that if the result of the comparison involves a skip operation then this will also take one more cycle, if no skip is involved then only one cycle is required.

### Moving and Transferring Data

The transfer of data within the microcontroller program is one of the most frequently used operations. Making use of three kinds of MOV instructions, data can be transferred from registers to the Accumulator and vice-versa as well as being able to move specific immediate data directly into the Accumulator. One of the most important data transfer applications is to receive data from the input ports and transfer data to the output ports.

### Arithmetic Operations

The ability to perform certain arithmetic operations and data manipulation is a necessary feature of most microcontroller applications. Within the Holtek microcontroller instruction set are a range of add and subtract instruction mnemonics to enable the necessary arithmetic to be carried out. Care must be taken to ensure correct handling of carry and borrow data when results exceed 255 for addition and less than 0 for subtraction. The increment and decrement instructions INC, INCA, DEC and DECA provide a simple means of increasing or decreasing by a value of one of the values in the destination specified.

## Logical and Rotate Operation

The standard logical operations such as AND, OR, XOR and CPL all have their own instruction within the Holtek microcontroller instruction set. As with the case of most instructions involving data manipulation, data must pass through the Accumulator which may involve additional programming steps. In all logical data operations, the zero flag may be set if the result of the operation is zero. Another form of logical data manipulation comes from the rotate instructions such as RR, RL, RRC and RLC which provide a simple means of rotating one bit right or left. Different rotate instructions exist depending on program requirements. Rotate instructions are useful for serial port programming applications where data can be rotated from an internal register into the Carry bit from where it can be examined and the necessary serial bit set high or low. Another application which rotate data operations are used is to implement multiplication and division calculations.

## Branches and Control Transfer

Program branching takes the form of either jumps to specified locations using the JMP instruction or to a subroutine using the CALL instruction. They differ in the sense that in the case of a subroutine call, the program must return to the instruction immediately when the subroutine has been carried out. This is done by placing a return instruction "RET" in the subroutine which will cause the program to jump back to the address right after the CALL instruction. In the case of a JMP instruction, the program simply jumps to the desired location. There is no requirement to jump back to the original jumping off point as in the case of the CALL instruction. One special and extremely useful set of branch instructions are the conditional branches. Here a decision is first made regarding the condition of a certain data memory or individual bits. Depending upon the conditions, the program will continue with the next instruction or skip over it and jump to the following instruction. These instructions are the key to decision making and branching within the program perhaps determined by the condition of certain input switches or by the condition of internal data bits.

## Bit Operations

The ability to provide single bit operations on Data Memory is an extremely flexible feature of all Holtek microcontrollers. This feature is especially useful for output port bit programming where individual bits or port pins can be directly set high or low using either the "SET [m].i" or "CLR [m].i" instructions respectively. The feature removes the need for programmers to first read the 8-bit output port, manipulate the input data to ensure that other bits are not changed and then output the port with the correct new data. This read-modify-write process is taken care of automatically when these bit operation instructions are used.

## Table Read Operations

Data storage is normally implemented by using registers. However, when working with large amounts of fixed data, the volume involved often makes it inconvenient to store the fixed data in the Data Memory. To overcome this problem, Holtek microcontrollers allow an area of Program Memory to be set as a table where data can be directly stored. A set of easy to use instructions provides the means by which this fixed data can be referenced and retrieved from the Program Memory.

## Other Operations

In addition to the above functional instructions, a range of other instructions also exist such as the "HALT" instruction for Power-down operations and instructions to control the operation of the Watchdog Timer for reliable program operations under extreme electric or electromagnetic environments. For their relevant operations, refer to the functional related sections.

## Instruction Set Summary

The following table depicts a summary of the instruction set categorised according to function and can be consulted as a basic instruction reference using the following listed conventions.

### Table Conventions

x: Bits immediate data  
 m: Data Memory address  
 A: Accumulator  
 i: 0~7 number of bits  
 addr: Program memory address

Mnemonic	Description	Cycles	Flag Affected
<b>Arithmetic</b>			
ADD A,[m]	Add Data Memory to ACC	1	Z, C, AC, OV
ADDM A,[m]	Add ACC to Data Memory	1 <sup>Note</sup>	Z, C, AC, OV
ADD A,x	Add immediate data to ACC	1	Z, C, AC, OV
ADC A,[m]	Add Data Memory to ACC with Carry	1	Z, C, AC, OV
ADCM A,[m]	Add ACC to Data memory with Carry	1 <sup>Note</sup>	Z, C, AC, OV
SUB A,x	Subtract immediate data from the ACC	1	Z, C, AC, OV
SUB A,[m]	Subtract Data Memory from ACC	1	Z, C, AC, OV
SUBM A,[m]	Subtract Data Memory from ACC with result in Data Memory	1 <sup>Note</sup>	Z, C, AC, OV
SBC A,[m]	Subtract Data Memory from ACC with Carry	1	Z, C, AC, OV
SBCM A,[m]	Subtract Data Memory from ACC with Carry, result in Data Memory	1 <sup>Note</sup>	Z, C, AC, OV
DAA [m]	Decimal adjust ACC for Addition with result in Data Memory	1 <sup>Note</sup>	C
<b>Logic Operation</b>			
AND A,[m]	Logical AND Data Memory to ACC	1	Z
OR A,[m]	Logical OR Data Memory to ACC	1	Z
XOR A,[m]	Logical XOR Data Memory to ACC	1	Z
ANDM A,[m]	Logical AND ACC to Data Memory	1 <sup>Note</sup>	Z
ORM A,[m]	Logical OR ACC to Data Memory	1 <sup>Note</sup>	Z
XORM A,[m]	Logical XOR ACC to Data Memory	1 <sup>Note</sup>	Z
AND A,x	Logical AND immediate Data to ACC	1	Z
OR A,x	Logical OR immediate Data to ACC	1	Z
XOR A,x	Logical XOR immediate Data to ACC	1	Z
CPL [m]	Complement Data Memory	1 <sup>Note</sup>	Z
CPLA [m]	Complement Data Memory with result in ACC	1	Z
<b>Increment &amp; Decrement</b>			
INCA [m]	Increment Data Memory with result in ACC	1	Z
INC [m]	Increment Data Memory	1 <sup>Note</sup>	Z
DECA [m]	Decrement Data Memory with result in ACC	1	Z
DEC [m]	Decrement Data Memory	1 <sup>Note</sup>	Z
<b>Rotate</b>			
RRA [m]	Rotate Data Memory right with result in ACC	1	None
RR [m]	Rotate Data Memory right	1 <sup>Note</sup>	None
RRCA [m]	Rotate Data Memory right through Carry with result in ACC	1	C
RRC [m]	Rotate Data Memory right through Carry	1 <sup>Note</sup>	C
RLA [m]	Rotate Data Memory left with result in ACC	1	None
RL [m]	Rotate Data Memory left	1 <sup>Note</sup>	None
RLCA [m]	Rotate Data Memory left through Carry with result in ACC	1	C
RLC [m]	Rotate Data Memory left through Carry	1 <sup>Note</sup>	C

Mnemonic	Description	Cycles	Flag Affected
<b>Data Move</b>			
MOV A,[m]	Move Data Memory to ACC	1	None
MOV [m],A	Move ACC to Data Memory	1 <sup>Note</sup>	None
MOV A,x	Move immediate data to ACC	1	None
<b>Bit Operation</b>			
CLR [m].i	Clear bit of Data Memory	1 <sup>Note</sup>	None
SET [m].i	Set bit of Data Memory	1 <sup>Note</sup>	None
<b>Branch Operation</b>			
JMP addr	Jump unconditionally	2	None
SZ [m]	Skip if Data Memory is zero	1 <sup>Note</sup>	None
SZA [m]	Skip if Data Memory is zero with data movement to ACC	1 <sup>Note</sup>	None
SZ [m].i	Skip if bit i of Data Memory is zero	1 <sup>Note</sup>	None
SNZ [m].i	Skip if bit i of Data Memory is not zero	1 <sup>Note</sup>	None
SIZ [m]	Skip if increment Data Memory is zero	1 <sup>Note</sup>	None
SDZ [m]	Skip if decrement Data Memory is zero	1 <sup>Note</sup>	None
SIZA [m]	Skip if increment Data Memory is zero with result in ACC	1 <sup>Note</sup>	None
SDZA [m]	Skip if decrement Data Memory is zero with result in ACC	1 <sup>Note</sup>	None
CALL addr	Subroutine call	2	None
RET	Return from subroutine	2	None
RET A,x	Return from subroutine and load immediate data to ACC	2	None
RETI	Return from interrupt	2	None
<b>Table Read Operation</b>			
TABRD [m]	Read table (specific page) to TBLH and Data Memory	2 <sup>Note</sup>	None
TABRDC [m]	Read table (current page) to TBLH and Data Memory	2 <sup>Note</sup>	None
TABRDL [m]	Read table (last page) to TBLH and Data Memory	2 <sup>Note</sup>	None
<b>Miscellaneous</b>			
NOP	No operation	1	None
CLR [m]	Clear Data Memory	1 <sup>Note</sup>	None
SET [m]	Set Data Memory	1 <sup>Note</sup>	None
CLR WDT	Clear Watchdog Timer	1	TO, PDF
CLR WDT1	Pre-clear Watchdog Timer	1	TO, PDF
CLR WDT2	Pre-clear Watchdog Timer	1	TO, PDF
SWAP [m]	Swap nibbles of Data Memory	1 <sup>Note</sup>	None
SWAPA [m]	Swap nibbles of Data Memory with result in ACC	1	None
HALT	Enter power down mode	1	TO, PDF

Note: 1. For skip instructions, if the result of the comparison involves a skip then two cycles are required, if no skip takes place only one cycle is required.

- Any instruction which changes the contents of the PCL will also require 2 cycles for execution.
- For the "CLR WDT1" and "CLR WDT2" instructions the TO and PDF flags may be affected by the execution status. The TO and PDF flags are cleared after both "CLR WDT1" and "CLR WDT2" instructions are consecutively executed. Otherwise the TO and PDF flags remain unchanged.

## Instruction Definition

<b>ADC A,[m]</b>	Add Data Memory to ACC with Carry
Description	The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the Accumulator.
Operation	$ACC \leftarrow ACC + [m] + C$
Affected flag(s)	OV, Z, AC, C
<b>ADCM A,[m]</b>	Add ACC to Data Memory with Carry
Description	The contents of the specified Data Memory, Accumulator and the carry flag are added. The result is stored in the specified Data Memory.
Operation	$[m] \leftarrow ACC + [m] + C$
Affected flag(s)	OV, Z, AC, C
<b>ADD A,[m]</b>	Add Data Memory to ACC
Description	The contents of the specified Data Memory and the Accumulator are added. The result is stored in the Accumulator.
Operation	$ACC \leftarrow ACC + [m]$
Affected flag(s)	OV, Z, AC, C
<b>ADD A,x</b>	Add immediate data to ACC
Description	The contents of the Accumulator and the specified immediate data are added. The result is stored in the Accumulator.
Operation	$ACC \leftarrow ACC + x$
Affected flag(s)	OV, Z, AC, C
<b>ADDM A,[m]</b>	Add ACC to Data Memory
Description	The contents of the specified Data Memory and the Accumulator are added. The result is stored in the specified Data Memory.
Operation	$[m] \leftarrow ACC + [m]$
Affected flag(s)	OV, Z, AC, C
<b>AND A,[m]</b>	Logical AND Data Memory to ACC
Description	Data in the Accumulator and the specified Data Memory perform a bitwise logical AND operation. The result is stored in the Accumulator.
Operation	$ACC \leftarrow ACC \text{ "AND" } [m]$
Affected flag(s)	Z
<b>AND A,x</b>	Logical AND immediate data to ACC
Description	Data in the Accumulator and the specified immediate data perform a bit wise logical AND operation. The result is stored in the Accumulator.
Operation	$ACC \leftarrow ACC \text{ "AND" } x$
Affected flag(s)	Z
<b>ANDM A,[m]</b>	Logical AND ACC to Data Memory
Description	Data in the specified Data Memory and the Accumulator perform a bitwise logical AND operation. The result is stored in the Data Memory.
Operation	$[m] \leftarrow ACC \text{ "AND" } [m]$
Affected flag(s)	Z

<b>CALL addr</b>	Subroutine call
Description	Unconditionally calls a subroutine at the specified address. The Program Counter then increments by 1 to obtain the address of the next instruction which is then pushed onto the stack. The specified address is then loaded and the program continues execution from this new address. As this instruction requires an additional operation, it is a two cycle instruction.
Operation	Stack $\leftarrow$ Program Counter + 1 Program Counter $\leftarrow$ addr
Affected flag(s)	None
<b>CLR [m]</b>	Clear Data Memory
Description	Each bit of the specified Data Memory is cleared to 0.
Operation	[m] $\leftarrow$ 00H
Affected flag(s)	None
<b>CLR [m].i</b>	Clear bit of Data Memory
Description	Bit i of the specified Data Memory is cleared to 0.
Operation	[m].i $\leftarrow$ 0
Affected flag(s)	None
<b>CLR WDT</b>	Clear Watchdog Timer
Description	The TO, PDF flags and the WDT are all cleared.
Operation	WDT cleared TO $\leftarrow$ 0 PDF $\leftarrow$ 0
Affected flag(s)	TO, PDF
<b>CLR WDT1</b>	Pre-clear Watchdog Timer
Description	The TO, PDF flags and the WDT are all cleared. Note that this instruction works in conjunction with CLR WDT2 and must be executed alternately with CLR WDT2 to have effect. Repetitively executing this instruction without alternately executing CLR WDT2 will have no effect.
Operation	WDT cleared TO $\leftarrow$ 0 PDF $\leftarrow$ 0
Affected flag(s)	TO, PDF
<b>CLR WDT2</b>	Pre-clear Watchdog Timer
Description	The TO, PDF flags and the WDT are all cleared. Note that this instruction works in conjunction with CLR WDT1 and must be executed alternately with CLR WDT1 to have effect. Repetitively executing this instruction without alternately executing CLR WDT1 will have no effect.
Operation	WDT cleared TO $\leftarrow$ 0 PDF $\leftarrow$ 0
Affected flag(s)	TO, PDF
<b>CPL [m]</b>	Complement Data Memory
Description	Each bit of the specified Data Memory is logically complemented (1's complement). Bits which previously contained a 1 are changed to 0 and vice versa.
Operation	[m] $\leftarrow$ $\overline{[m]}$
Affected flag(s)	Z

<b>CPLA [m]</b>	Complement Data Memory with result in ACC
Description	Each bit of the specified Data Memory is logically complemented (1's complement). Bits which previously contained a 1 are changed to 0 and vice versa. The complemented result is stored in the Accumulator and the contents of the Data Memory remain unchanged.
Operation	$ACC \leftarrow \overline{[m]}$
Affected flag(s)	Z
<b>DAA [m]</b>	Decimal-Adjust ACC for addition with result in Data Memory
Description	Convert the contents of the Accumulator value to a BCD (Binary Coded Decimal) value resulting from the previous addition of two BCD variables. If the low nibble is greater than 9 or if AC flag is set, then a value of 6 will be added to the low nibble. Otherwise the low nibble remains unchanged. If the high nibble is greater than 9 or if the C flag is set, then a value of 6 will be added to the high nibble. Essentially, the decimal conversion is performed by adding 00H, 06H, 60H or 66H depending on the Accumulator and flag conditions. Only the C flag may be affected by this instruction which indicates that if the original BCD sum is greater than 100, it allows multiple precision decimal addition.
Operation	$[m] \leftarrow ACC + 00H$ or $[m] \leftarrow ACC + 06H$ or $[m] \leftarrow ACC + 60H$ or $[m] \leftarrow ACC + 66H$
Affected flag(s)	C
<b>DEC [m]</b>	Decrement Data Memory
Description	Data in the specified Data Memory is decremented by 1.
Operation	$[m] \leftarrow [m] - 1$
Affected flag(s)	Z
<b>DECA [m]</b>	Decrement Data Memory with result in ACC
Description	Data in the specified Data Memory is decremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.
Operation	$ACC \leftarrow [m] - 1$
Affected flag(s)	Z
<b>HALT</b>	Enter power down mode
Description	This instruction stops the program execution and turns off the system clock. The contents of the Data Memory and registers are retained. The WDT and prescaler are cleared. The power down flag PDF is set and the WDT time-out flag TO is cleared.
Operation	TO $\leftarrow$ 0 PDF $\leftarrow$ 1
Affected flag(s)	TO, PDF
<b>INC [m]</b>	Increment Data Memory
Description	Data in the specified Data Memory is incremented by 1.
Operation	$[m] \leftarrow [m] + 1$
Affected flag(s)	Z
<b>INCA [m]</b>	Increment Data Memory with result in ACC
Description	Data in the specified Data Memory is incremented by 1. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.
Operation	$ACC \leftarrow [m] + 1$
Affected flag(s)	Z

<b>JMP addr</b>	Jump unconditionally
Description	The contents of the Program Counter are replaced with the specified address. Program execution then continues from this new address. As this requires the insertion of a dummy instruction while the new address is loaded, it is a two cycle instruction.
Operation	Program Counter $\leftarrow$ addr
Affected flag(s)	None
<b>MOV A,[m]</b>	Move Data Memory to ACC
Description	The contents of the specified Data Memory are copied to the Accumulator.
Operation	ACC $\leftarrow$ [m]
Affected flag(s)	None
<b>MOV A,x</b>	Move immediate data to ACC
Description	The immediate data specified is loaded into the Accumulator.
Operation	ACC $\leftarrow$ x
Affected flag(s)	None
<b>MOV [m],A</b>	Move ACC to Data Memory
Description	The contents of the Accumulator are copied to the specified Data Memory.
Operation	[m] $\leftarrow$ ACC
Affected flag(s)	None
<b>NOP</b>	No operation
Description	No operation is performed. Execution continues with the next instruction.
Operation	No operation
Affected flag(s)	None
<b>OR A,[m]</b>	Logical OR Data Memory to ACC
Description	Data in the Accumulator and the specified Data Memory perform a bitwise logical OR operation. The result is stored in the Accumulator.
Operation	ACC $\leftarrow$ ACC "OR" [m]
Affected flag(s)	Z
<b>OR A,x</b>	Logical OR immediate data to ACC
Description	Data in the Accumulator and the specified immediate data perform a bitwise logical OR operation. The result is stored in the Accumulator.
Operation	ACC $\leftarrow$ ACC "OR" x
Affected flag(s)	Z
<b>ORM A,[m]</b>	Logical OR ACC to Data Memory
Description	Data in the specified Data Memory and the Accumulator perform a bitwise logical OR operation. The result is stored in the Data Memory.
Operation	[m] $\leftarrow$ ACC "OR" [m]
Affected flag(s)	Z
<b>RET</b>	Return from subroutine
Description	The Program Counter is restored from the stack. Program execution continues at the restored address.
Operation	Program Counter $\leftarrow$ Stack
Affected flag(s)	None

<b>RET A,x</b>	Return from subroutine and load immediate data to ACC
Description	The Program Counter is restored from the stack and the Accumulator loaded with the specified immediate data. Program execution continues at the restored address.
Operation	Program Counter ← Stack ACC ← x
Affected flag(s)	None
<b>RETI</b>	Return from interrupt
Description	The Program Counter is restored from the stack and the interrupts are re-enabled by setting the EMI bit. EMI is the master interrupt global enable bit. If an interrupt was pending when the RETI instruction is executed, the pending Interrupt routine will be processed before returning to the main program.
Operation	Program Counter ← Stack EMI ← 1
Affected flag(s)	None
<b>RL [m]</b>	Rotate Data Memory left
Description	The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0.
Operation	[m].(i+1) ← [m].i; (i=0~6) [m].0 ← [m].7
Affected flag(s)	None
<b>RLA [m]</b>	Rotate Data Memory left with result in ACC
Description	The contents of the specified Data Memory are rotated left by 1 bit with bit 7 rotated into bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.
Operation	ACC.(i+1) ← [m].i; (i=0~6) ACC.0 ← [m].7
Affected flag(s)	None
<b>RLC [m]</b>	Rotate Data Memory left through Carry
Description	The contents of the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into bit 0.
Operation	[m].(i+1) ← [m].i; (i=0~6) [m].0 ← C C ← [m].7
Affected flag(s)	C
<b>RLCA [m]</b>	Rotate Data Memory left through Carry with result in ACC
Description	Data in the specified Data Memory and the carry flag are rotated left by 1 bit. Bit 7 replaces the Carry bit and the original carry flag is rotated into the bit 0. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.
Operation	ACC.(i+1) ← [m].i; (i=0~6) ACC.0 ← C C ← [m].7
Affected flag(s)	C
<b>RR [m]</b>	Rotate Data Memory right
Description	The contents of the specified Data Memory are rotated right by 1 bit with bit 0 rotated into bit 7.
Operation	[m].i ← [m].(i+1); (i=0~6) [m].7 ← [m].0
Affected flag(s)	None

<b>RRA [m]</b>	Rotate Data Memory right with result in ACC
Description	Data in the specified Data Memory is rotated right by 1 bit with bit 0 rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.
Operation	$ACC.i \leftarrow [m].(i+1); (i=0\sim6)$ $ACC.7 \leftarrow [m].0$
Affected flag(s)	None
<b>RRC [m]</b>	Rotate Data Memory right through Carry
Description	The contents of the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7.
Operation	$[m].i \leftarrow [m].(i+1); (i=0\sim6)$ $[m].7 \leftarrow C$ $C \leftarrow [m].0$
Affected flag(s)	C
<b>RRCA [m]</b>	Rotate Data Memory right through Carry with result in ACC
Description	Data in the specified Data Memory and the carry flag are rotated right by 1 bit. Bit 0 replaces the Carry bit and the original carry flag is rotated into bit 7. The rotated result is stored in the Accumulator and the contents of the Data Memory remain unchanged.
Operation	$ACC.i \leftarrow [m].(i+1); (i=0\sim6)$ $ACC.7 \leftarrow C$ $C \leftarrow [m].0$
Affected flag(s)	C
<b>SBC A,[m]</b>	Subtract Data Memory from ACC with Carry
Description	The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.
Operation	$ACC \leftarrow ACC - [m] - C$
Affected flag(s)	OV, Z, AC, C
<b>SBCM A,[m]</b>	Subtract Data Memory from ACC with Carry and result in Data Memory
Description	The contents of the specified Data Memory and the complement of the carry flag are subtracted from the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.
Operation	$[m] \leftarrow ACC - [m] - C$
Affected flag(s)	OV, Z, AC, C
<b>SDZ [m]</b>	Skip if decrement Data Memory is 0
Description	The contents of the specified Data Memory are first decremented by 1. If the result is 0 the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.
Operation	$[m] \leftarrow [m] - 1$ Skip if $[m]=0$
Affected flag(s)	None

<b>SDZA [m]</b>	Skip if decrement Data Memory is zero with result in ACC
Description	The contents of the specified Data Memory are first decremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.
Operation	$ACC \leftarrow [m] - 1$ Skip if $ACC=0$
Affected flag(s)	None
<b>SET [m]</b>	Set Data Memory
Description	Each bit of the specified Data Memory is set to 1.
Operation	$[m] \leftarrow FFH$
Affected flag(s)	None
<b>SET [m].i</b>	Set bit of Data Memory
Description	Bit i of the specified Data Memory is set to 1.
Operation	$[m].i \leftarrow 1$
Affected flag(s)	None
<b>SIZ [m]</b>	Skip if increment Data Memory is 0
Description	The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.
Operation	$[m] \leftarrow [m] + 1$ Skip if $[m]=0$
Affected flag(s)	None
<b>SIZA [m]</b>	Skip if increment Data Memory is zero with result in ACC
Description	The contents of the specified Data Memory are first incremented by 1. If the result is 0, the following instruction is skipped. The result is stored in the Accumulator but the specified Data Memory contents remain unchanged. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.
Operation	$ACC \leftarrow [m] + 1$ Skip if $ACC=0$
Affected flag(s)	None
<b>SNZ [m].i</b>	Skip if bit i of Data Memory is not 0
Description	If bit i of the specified Data Memory is not 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is 0 the program proceeds with the following instruction.
Operation	Skip if $[m].i \neq 0$
Affected flag(s)	None
<b>SUB A,[m]</b>	Subtract Data Memory from ACC
Description	The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.
Operation	$ACC \leftarrow ACC - [m]$
Affected flag(s)	OV, Z, AC, C

<b>SUBM A,[m]</b>	Subtract Data Memory from ACC with result in Data Memory
Description	The specified Data Memory is subtracted from the contents of the Accumulator. The result is stored in the Data Memory. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.
Operation	$[m] \leftarrow ACC - [m]$
Affected flag(s)	OV, Z, AC, C
<b>SUB A,x</b>	Subtract immediate data from ACC
Description	The immediate data specified by the code is subtracted from the contents of the Accumulator. The result is stored in the Accumulator. Note that if the result of subtraction is negative, the C flag will be cleared to 0, otherwise if the result is positive or zero, the C flag will be set to 1.
Operation	$ACC \leftarrow ACC - x$
Affected flag(s)	OV, Z, AC, C
<b>SWAP [m]</b>	Swap nibbles of Data Memory
Description	The low-order and high-order nibbles of the specified Data Memory are interchanged.
Operation	$[m].3 \sim [m].0 \leftrightarrow [m].7 \sim [m].4$
Affected flag(s)	None
<b>SWAPA [m]</b>	Swap nibbles of Data Memory with result in ACC
Description	The low-order and high-order nibbles of the specified Data Memory are interchanged. The result is stored in the Accumulator. The contents of the Data Memory remain unchanged.
Operation	$ACC.3 \sim ACC.0 \leftarrow [m].7 \sim [m].4$ $ACC.7 \sim ACC.4 \leftarrow [m].3 \sim [m].0$
Affected flag(s)	None
<b>SZ [m]</b>	Skip if Data Memory is 0
Description	If the contents of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.
Operation	Skip if $[m]=0$
Affected flag(s)	None
<b>SZA [m]</b>	Skip if Data Memory is 0 with data movement to ACC
Description	The contents of the specified Data Memory are copied to the Accumulator. If the value is zero, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0 the program proceeds with the following instruction.
Operation	$ACC \leftarrow [m]$ Skip if $[m]=0$
Affected flag(s)	None
<b>SZ [m].i</b>	Skip if bit i of Data Memory is 0
Description	If bit i of the specified Data Memory is 0, the following instruction is skipped. As this requires the insertion of a dummy instruction while the next instruction is fetched, it is a two cycle instruction. If the result is not 0, the program proceeds with the following instruction.
Operation	Skip if $[m].i=0$
Affected flag(s)	None

<b>TABRD [m]</b>	Read table (specific page) to TBLH and Data Memory
Description	The low byte of the program code (specific page) addressed by the table pointer pair (TBHP and TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.
Operation	[m] ← program code (low byte) TBLH ← program code (high byte)
Affected flag(s)	None
<b>TABRDC [m]</b>	Read table (current page) to TBLH and Data Memory
Description	The low byte of the program code (current page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.
Operation	[m] ← program code (low byte) TBLH ← program code (high byte)
Affected flag(s)	None
<b>TABRDL [m]</b>	Read table (last page) to TBLH and Data Memory
Description	The low byte of the program code (last page) addressed by the table pointer (TBLP) is moved to the specified Data Memory and the high byte moved to TBLH.
Operation	[m] ← program code (low byte) TBLH ← program code (high byte)
Affected flag(s)	None
<b>XOR A,[m]</b>	Logical XOR Data Memory to ACC
Description	Data in the Accumulator and the specified Data Memory perform a bitwise logical XOR operation. The result is stored in the Accumulator.
Operation	ACC ← ACC "XOR" [m]
Affected flag(s)	Z
<b>XORM A,[m]</b>	Logical XOR ACC to Data Memory
Description	Data in the specified Data Memory and the Accumulator perform a bitwise logical XOR operation. The result is stored in the Data Memory.
Operation	[m] ← ACC "XOR" [m]
Affected flag(s)	Z
<b>XOR A,x</b>	Logical XOR immediate data to ACC
Description	Data in the Accumulator and the specified immediate data perform a bitwise logical XOR operation. The result is stored in the Accumulator.
Operation	ACC ← ACC "XOR" x
Affected flag(s)	Z

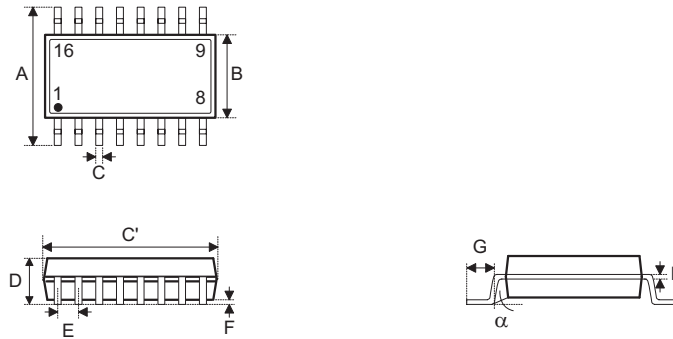
## Package Information

Note that the package information provided here is for consultation purposes only. As this information may be updated at regular intervals users are reminded to consult the [Holtek website](#) for the latest version of the [Package/Carton Information](#).

Additional supplementary information with regard to packaging is listed below. Click on the relevant section to be transferred to the relevant website page.

- Further Package Information (include Outline Dimensions, Product Tape and Reel Specifications)
- Packing Materials Information
- Carton information

**16-pin NSOP (150mil) Outline Dimensions**



Symbol	Dimensions in inch		
	Min.	Nom.	Max.
A	—	0.236 BSC	—
B	—	0.154 BSC	—
C	0.012	—	0.020
C'	—	0.390 BSC	—
D	—	—	0.069
E	—	0.050 BSC	—
F	0.004	—	0.010
G	0.016	—	0.050
H	0.004	—	0.010
α	0°	—	8°

Symbol	Dimensions in mm		
	Min.	Nom.	Max.
A	—	6 BSC	—
B	—	3.9 BSC	—
C	0.31	—	0.51
C'	—	9.9 BSC	—
D	—	—	1.75
E	—	1.27 BSC	—
F	0.10	—	0.25
G	0.40	—	1.27
H	0.10	—	0.25
α	0°	—	8°

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