EM77950

BB Controller

Product Specification

DOC. VERSION 1.0

ELAN MICROELECTRONICS CORP.

October 2007

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APPENDIX

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Specification Revision History

Doc. Version	Revision Description	Date
1.0	Initial released version	2007/10/09

1 General Description

The EM77950 from ELAN Electronics is a low-cost and high performance 8-bit CMOS advance RISC architecture microcontroller device. It has an on-chip 1-Mbps RF driver module/Base Band (BB), Serial Peripheral Interface (SPI), dual Pulse Width Modulation (PWM) with 16-bit resolution, an 8-bit Timer Clock Counter (TCC) and a 16-bit Free Run Timer, multi-channel Analog to Digital Converter (ADC) with 8-bit resolution, Key Wake-up function (KWU), Power-on Reset (POR), Watchdog Timer (WDT), and power saving Sleep Mode. All these features combine to ensure applications require the least external components, hence, not only reduce system cost, but also have the advantage of low power consumption and enhanced device reliability.

The 52-pin EM77950 is available in a very cost-effective version that provides a single chip solution in designing wireless products.

2 Features

2.1 Core

- Operating Voltage Range: 2.2V ~ 3.6V DC (ADC reference volt 3V)
- Operating Temperature Range: 0°C ~ 70°C
- Operating Frequency Range: DC ~ 48MHz (1 clock/cycle)
  - 6MHz external clock source
  - 6/12/24/48 MHz to Core clock
  - 6/12/24/48 MHz to clock
- Internal Memory
  - 12K x 16 bits of on-chip Program ROM
  - 896 x 8 bits of on-chip Register (SRAM)
- Watchdog Timer (WDT)
- 32 level stacks for both CALL and interrupt subroutine
- Internal Power-on Reset (POR) function
- Code protection function available
- All single cycle (1 clock) instruction except for conditional branches which are two or three cycles.
- Direct, indirect and relative addressing modes
- Low power, high speed CMOS technology

- Power consumption:
  - < 4 mA @ 3.3V, 6 MHz
  - < 60 μA @ 3.0V, (RC = 32.768 kHz)
  - < 1 μA standby current
- 52/44-pin QFP package

2.2 Oscillators/System Clocks

- Three oscillator options:
  - Crystal/Resonate oscillator of high frequency
  - PLL oscillator: 6MHz, 12 MHz, 24 MHz, and 48 MHz (External crystal should be 6 MHz)
  - External RC oscillator
- Three modes of system clocks:
  - Sleep mode
  - Green mode
  - Normal mode
- Internal RC oscillator for Power-on Reset (POR) and Watchdog Timer (WDT)

2.3 Input and Output (I/O) Pins

- 40 I/O pins max.
- Pull-up resistor options
- Key Wake-up function
- Open drain output options

2.4 Timers and Counters

- Programmable 8-bit real Time Clock/Counter (TCC) with prescaler and overflow interrupt
- 16-bit Free Run Counter (FRC) with overflow interrupt

2.5 Interrupt Sources and Features

- Hardware priority check
- Different interrupt vectors
- Interrupts
  - Key Wake-up function
  - External pin interrupt
  - 16-bit Free Run Counter Overflow
  - TCC (time-base) overflow;
  - Read Buffer Full Interrupt in Serial Peripheral Interface (SPI)
  - An analog to digital converting (ADC) complete
  - One period of Pulse Width Modulation (PWM) complete

- Base Band (BB) function interrupts:
  - CSD: carrier sense detection
  - TX_AE: TX_FIFO almost full
  - RX_AF: RX_FIFO almost full
  - TX_ EMPTY: finish a transmitting a package
  - RX_OF: RX_FIFO overflow
  - LINK_DIS: zero counter capacitor discharge mechanism
  - LOCK_OUT: finish receiving a package
  - LOCK_IN: start receiving a package

2.6 Baseband (BB)

- Serial to Parallel conversion of RFW102 interface
- Parallel interface to RFW102 modem
- Serial to Parallel conversion of RFW102 interface
- Input FIFO (RX_FIFO)
- Output FIFO (TX_FIFO)
- Preamble Correlation
- Packet Address Filter (Network and unique)
- CRC calculation
- Inter-RFWAVES networks Carrier-sense
- Discharge of RFW-102 reference capacitor
- Compensate for clock drifts between the transmitting EM77950 and the receiving EM77950 up to 1000ppm. Hence, the EM77950 requires low performance crystal.
- Interrupt Driver – connected to the EM77950's internal interrupt and informs the EM77950 about BB events.

2.7 Serial Peripheral Interface (SPI)

- Either MSB or LBS can be transmitted/received first
- Both Master and Slave modes available

2.8 Pulse Width Modulation (PWM)

- Dual Pulse Width Modulation (PWM) with 16-bit resolution

2.9 Analog to Digital Converter (ADC)

- 16 multi-channel Analog to Digital Converter with 8-bit resolution

3 Pins Assignment

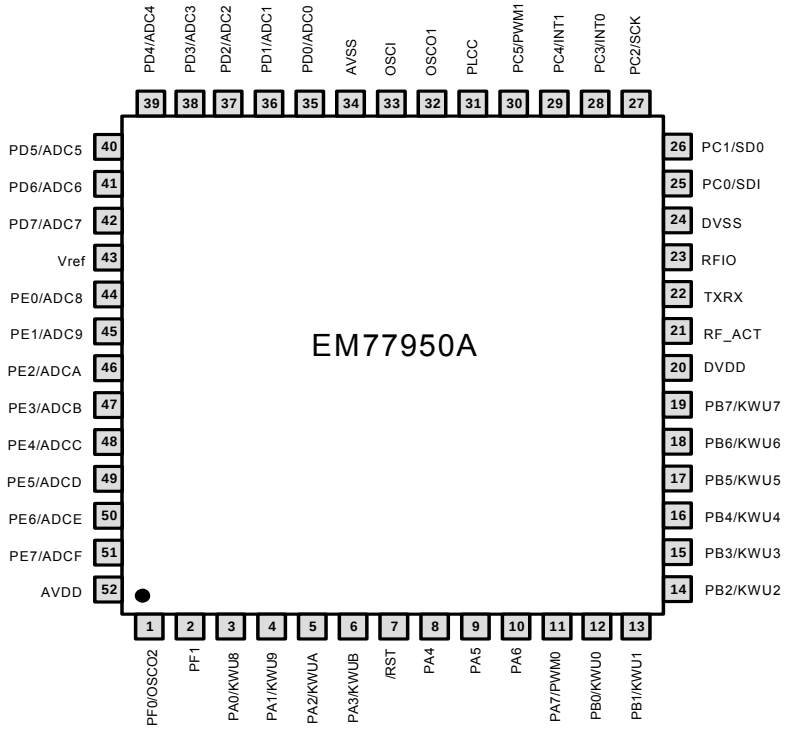


Fig. 3-1 Pin Configuration of EM77950A

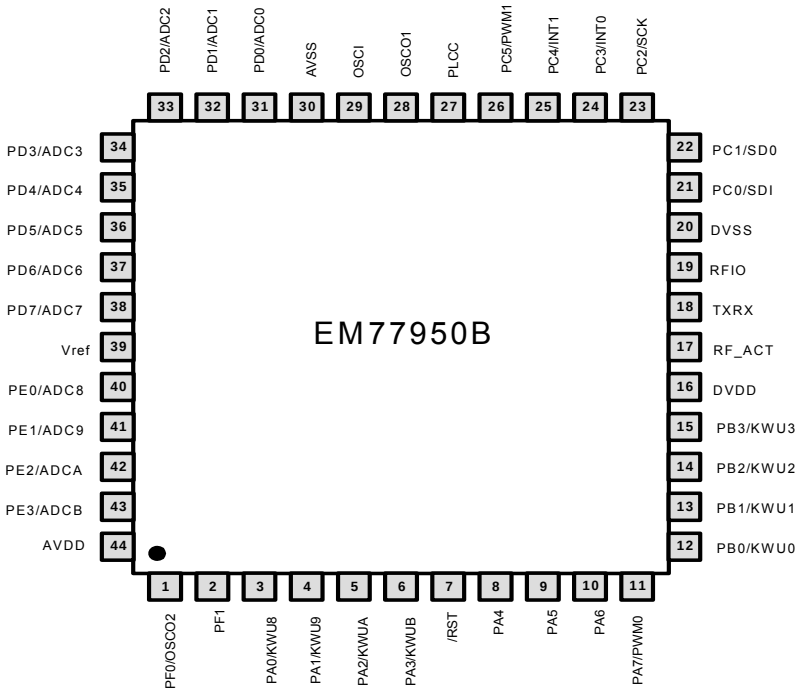


Fig. 3-2 Pins Configuration of EM77950B

4 Pin Description

The Table below shows the corresponding relationship between the pad and pins of EM77950A

Pin #	Symbol	Type	Schmitt Trigger	Pull High /50KΩ	Open Drain	Function Description
1	PTF0/OSCO2	I/O	–	√	–	Pin 0 of Port F Selected PLL clock out
2	PF1	I/O	–	√	–	Pin 1 of Port F
3~6	KWU8~B, PA0~3	I/O	–	√	–	Pins 0~3 of Port A (default). Key Wake-up 8~B
7	/RST	–	√	–	–	Reset pin
8~10	PTA4~6	I/O	–	√	–	Pins 4~6 of Port A.
11	PWM0/PTA7	I/O	–	√	–	Pin 7 of Port A. PWM0 output
12~19	PB0 ~ PB7	I/O	–	√	√	Pins 0~7 of Port B (default). Key Wake-up 0~7
20	DVDD	–	–	–	–	Power supply for digital circuit. The power source value should be within the range of the operating voltage.
21	RF_ACT	O	–	–	–	BB/RF Active
22	TXRX	O	–	–	–	Transceiver modes control
23	RFIO	I/O	–	–	–	Transceiver to/from RF modem
24	DVSS	–	–	–	–	Ground Pin for Digital circuit
25	SDI/PTC0	I/O	√	√	√	Data in of SPI Pin 0 of Port C
26	SDO/PTC1	I/O	√	√	√	Data out of SPI Pin 1 of Port C
27	SCK/PTC2	I/O	√	√	√	Clock of SPI Pin 2 of Port C
28	EINT0/ PTC3	I/O	–	√	√	External interrupt Pin 0 Pin 3 of Port C
29	EINT1/ PTC4	I/O	–	√	√	External interrupt Pin 1 Pin 4 of Port C
30	PWM1/PTC5	I/O	–	√	√	Pin 5 of Port C. PWM1 output
31	PLLC	–	–	–	–	External capacitor for PLL circuit
32	OSCO1	O	–	–	–	Output of crystal oscillator
33	OSCI	I	–	–	–	Input of crystal oscillator
34	AVSS	–	–	–	–	Ground Pin for Analog circuit

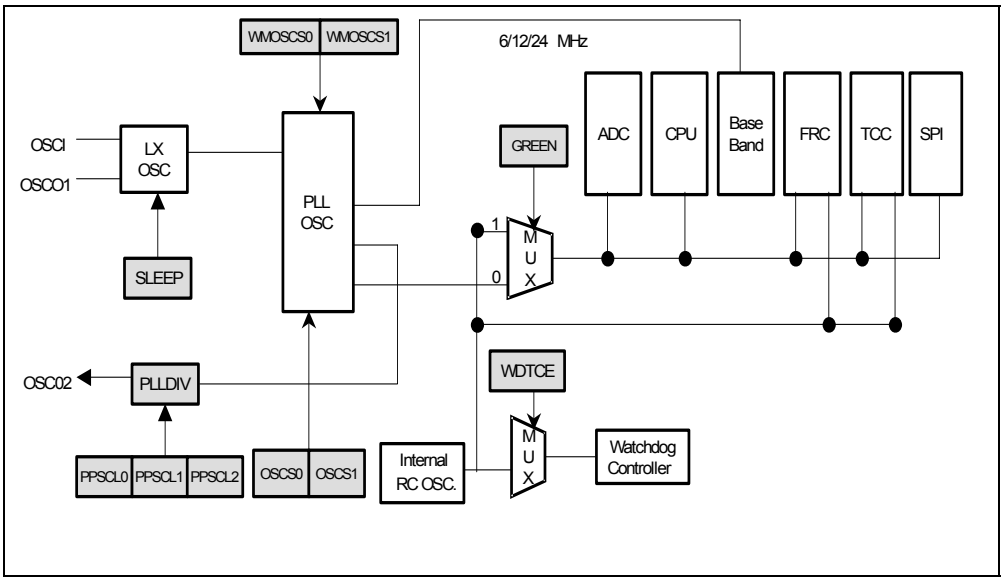
Pin #	Symbol	Type	Schmitt Trigger	Pull High /50KΩ	Open Drain	Function Description
35~42	PTD0~7, ADC0~7	I/O	–	√	–	Pins 0~7 of Port D Inputs 0~7 of ADC
43	VREF	I	–	–	–	Reference voltage for ADC
44~51	PTE0~7, ADC8~F	I/O	–	√	–	Pins 0~7 of Port E Inputs 8~F of ADC
52	AVDD	–	–	–	–	Power supply for analog circuit. The power source value should be within the range of the operating voltage.

The Table below shows the corresponding relationship between the pad and pins of EM77950B

Pin #	Symbol	Type	Schmitt Trigger	Pull High /50KΩ	Open Drain	Function Description
1	PTF0/OSCO2	I/O	–	√	–	Pin 0 of Port F Selected PLL clock out
2	PF1	I/O	–	√	–	Pin 1 of Port F
3~6	KWU8~B, PA0~3	I/O	–	√	–	Pins 0~3 of Port A (default) Key Wake-up 8~B
7	/RST	–	√	–	–	Reset pin
8~10	PTA4~6	I/O	–	√	–	Pins 4~6 of Port A
11	PWM0/PTA7	I/O	–	√	–	Pin 7 of Port A. PWM0 output
12~15	PB0 ~ PB3	I/O	–	√	√	Pins 0~3 of Port B (default) Key Wake-up 0~7
16	DVDD	–	–	–	–	Power supply for digital circuit. The power source value should be within the range of the operating voltage.
17	RF_ACT	O	–	–	–	BB/RF Active
18	TXRX	O	–	–	–	Transceiver modes control
19	RFIO	I/O	–	–	–	Transceiver to/from RF modem
20	DVSS	–	–	–	–	Ground Pin for Digital circuit
21	SDI/PTC0	I/O	√	√	√	Data in of SPI Pin 0 of Port C
22	SDO/PTC1	I/O	√	√	√	Data out of SPI Pin 1 of Port C

Pin #	Symbol	Type	Schmitt Trigger	Pull High /50KΩ	Open Drain	Function Description
23	SCK/PTC2	I/O	√	√	√	Clock of SPI Pin 2 of Port C
24	EINT0/ PTC3	I/O	–	√	√	External interrupt Pin 0 Pin 3 of Port C
25	EINT1/ PTC4	I/O	–	√	√	External interrupt Pin 1 Pin 4 of Port C
26	PWM1/PTC5	I/O	–	√	√	Pin 5 of Port C PWM1 output
27	PLLC	–	–	–	–	External capacitor for PLL circuit
28	OSCO1	O	–	–	–	Output of crystal oscillator
29	OSCI	I	–	–	–	Input of crystal oscillator
31~38	PTD0~7, ADC0~7	I/O	–	√	–	Pins 0~7 of Port D Inputs 0~7 of ADC
39	VREF	I	–	–	–	Reference voltage for ADC
40~43	PTE0~3, ADC8~B	I/O	–	√	–	Pins 0~3 of Port E Inputs 8~B of ADC
44	AVDD	–	–	–	–	Power supply for analog circuit. The power source value should be within the range of the operating voltage.

5 Block Diagram



6 Memory

6.1 Program Memory

The EM77950 has a 14-bit program counter (PC). The space of program memory, which is partitioned into 2 pages can address up to 12K. One page has 8K in length, and the other is 4K. Fig. 6-1 depicts the profile of the program memory and stack. The initial address is 0x0000. The table of interrupt-vectors starts from 0x10 to 0x80 with every other eight-address space.

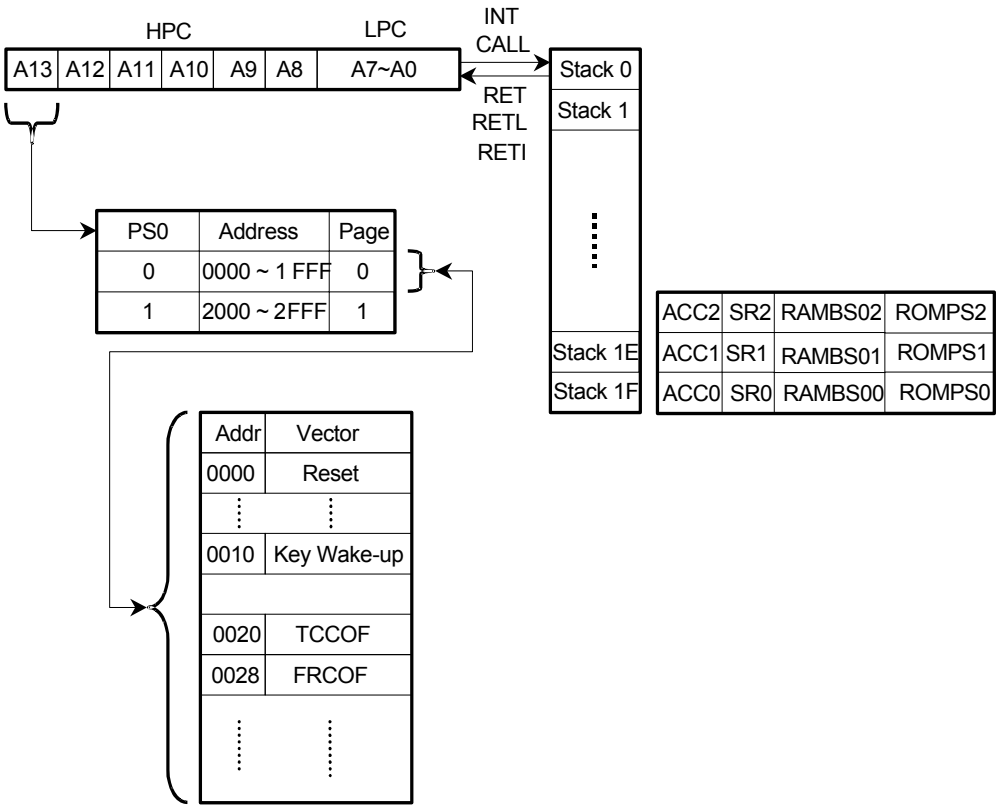


Fig. 6-1 Configuration of Program Memory (ROM) for EM77950

6.2 RAM–Register

A total of 896 accessible bytes of data memory are available for the EM77950. By function, they are classified into general purpose registers, system control/configuration registers, specific purpose registers, Baseband (BB) control/status registers, SPI control/status registers, timer/counter registers, and IO port status/control registers. All of the mentioned registers except I/O ports and their related control registers are implemented as static RAM. The RAM configurations are shown in Fig. 6-2.

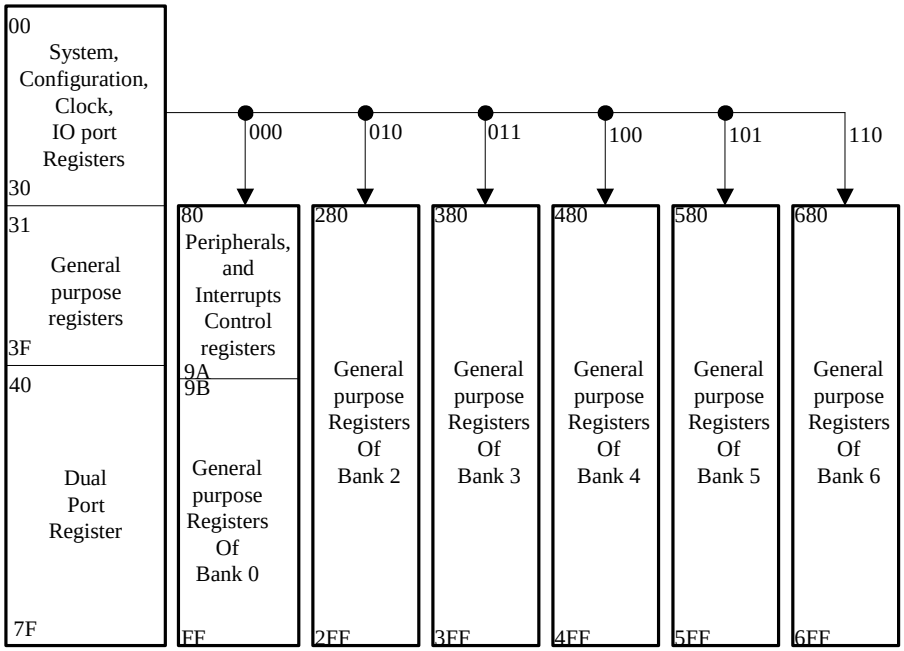


Fig. 6-2 of Data Memory (RAM) Configuration

The table is a summary of all registers except general purpose registers.

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x00	IAC0	Full Name	Indirect Addressing Register contents							
		Bit Name	IAC07	IAC06	IAC05	IAC04	IAC03	IAC02	IAC01	IAC00
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x01	HPC	Full Name	Most Significant Byte of Programming Counter							
		Bit Name	PC7	PC6	PC5	PC4	PC3	PC2	PC1	PC0
		Read / Write (R/W)	R	R	R	R	R	R	R	R
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	Jump to corresponding interrupt vector or continue to execute next instruction							
0x02	LPC	Full Name	Least Significant Byte of Programming Counter							
		Bit Name	PCF	PCE	PCD	PCC	PCB	PCA	PC9	PC8
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	Jump to corresponding interrupt vector or continue to execute next instruction							
0x03	SR	Full Name	Status Register							
		Bit Name	-	-	RST	T	P	Z	DC	C
		Read / Write (R/W)	-	-	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	-	-	0	1	1	U	U	U
		/RESET and WDT	-	-	P	T	T	P	P	P
		Wake-up from Int	-	-	P	T	T	P	P	P
0x04	RAMBS 0	Full Name	RAM Bank Selector 0							
		Bit Name	-	-	-	-	-	RBS02	RBS01	RBS00
		Read / Write (R/W)	-	-	-	-	-	R	R	R
		Power-on	-	-	-	-	-	0	0	0
		/RESET and WDT	-	-	-	-	-	0	0	0
		Wake-up from Int	-	-	-	-	-	P	P	P
0x05	ROMPS	Full Name	ROM Page Selector							
		Bit Name	-	-	-	-	-	-	-	RPS0
		Read / Write (R/W)	-	-	-	-	-	-	-	R/W
		Power-on	-	-	-	-	-	-	-	0
		/RESET and WDT	-	-	-	-	-	-	-	0
		Wake-up from Int	-	-	-	-	-	-	-	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x06	IAP0	Full Name	Indirect Addressing Pointer 0							
		Bit Name	IAP07	IAP06	IAP05	IAP04	IAP03	IAP02	IAP01	IAP00
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x07	RAMBS1	Full Name	RAM Bank Selector 1							
		Bit Name	-	-	-	-	-	RBS12	RBS11	RBS10
		Read / Write (R/W)	-	-	-	-	-	R/W	R/W	R/W
		Power-on	-	-	-	-	-	0	0	0
		/RESET and WDT	-	-	-	-	-	0	0	0
		Wake-up from Int	-	-	-	-	-	P	P	P
0x08	IAP1	Full Name	Indirect Addressing Pointer 1							
		Bit Name	IAP17	IAP16	IAP15	IAP14	IAP13	IAP12	IAP11	IAP10
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x09	IAC1	Full Name	Indirect Addressing Contents 1							
		Bit Name	IAC17	IAC16	IAC15	IAC14	IAC13	IAC12	IAC11	IAC10
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x0A	IAPDR	Full Name	Indirect Address Pointer Direction Control Register							
		Bit Name	-	-	-	-	IAP1_D	IAP0_D	IAP1_D_E	IAP0_D_E
		Read / Write (R/W)	-	-	-	-	R/W	R/W	R/W	R/W
		Power-on	-	-	-	-	0	0	0	0
		/RESET and WDT	-	-	-	-	0	0	0	0
		Wake-up from Int	-	-	-	-	P	P	P	P
0x0B	LTBL	Full Name	Least Significant Byte of Table Look-up							
		Bit Name	TBL7	TBL6	TBL5	TBL4	TBL3	TBL2	TBL1	TBL0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x0C	HTBL	Full Name	Most Significant Byte of Table Look-up							
		Bit Name	TBLF	TBLE	TBLD	TBLC	TBLB	TBLA	TBL9	TBL8
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x0D	STKPTR	Full Name	Stack Pointer							
		Bit Name	STKPT7	STKPT6	STKPT5	STKPT4	STKPT3	STKPT2	STKPT1	STKPT0
		Read / Write (R/W)	R	R	R	R	R	R	R	R
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	1	1	1	1	1	1	1	1
		Wake-up from Int	P	P	P	P	P	P	P	P
0x0E	RPTC	Full Name	Repeat Pointer							
		Bit Name	RPTC7	RPTC6	RPTC5	RPTC4	RPTC3	RPTC2	RPTC1	RPTC0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x0F	PRC	Full Name	Prescaler Counter							
		Bit Name	PRC7	PRC6	PRC5	PRC4	PRC3	PRC2	PRC1	PRC0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	0	0	0	0	0	0	0	0
0x10	TCC	Full Name	Time Clock/Counter							
		Bit Name	TCC7	TCC6	TCC5	TCC4	TCC3	TCC2	TCC1	TCC0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	0	0	0	0	0	0	0	0
0x11	INTF	Full Name	Interrupt Flag							
		Bit Name	ADIF	RBFIF	PWM1IF	PWM0IF	EINT1F	EINT0F	TCCOF	FRCOF
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x12	KWUAIF	Full Name	Port A Key Wake up Interrupt Flag							
		Bit Name	-	-	-	-	KWUBIF	KWUAIF	KWU9IF	KWU8IF
		Read / Write (R/W)	-	-	-	-	R/W	R/W	R/W	R/W
		Power-on	-	-	-	-	0	0	0	0
		/RESET and WDT	-	-	-	-	0	0	0	0
		Wake-up from Int	-	-	-	-	P	P	P	P
0x13	KWUBIF	Full Name	Port B Key Wake up Interrupt Flag							
		Bit Name	KWU7IF	KWU6IF	KWU5IF	KWU4IF	KWU3IF	KWU2IF	KWU1IF	KWU0IF
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x14	PTA	Full Name	General Purpose I/O port, Port A							
		Bit Name	PTA7	PTA6	PTA5	PTA4	PTA3	PTA2	PTA1	PTA0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	U	U	U	U	U	U	U	U
		/RESET and WDT	U	U	U	U	U	U	U	U
		Wake-up from Int	P	P	P	P	P	P	P	P
0x15	PTB	Full Name	General Purpose I/O port, Port B							
		Bit Name	PTB7	PTB6	PTB5	PTB4	PTB3	PTB2	PTB1	PTB0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	U	U	U	U	U	U	U	U
		/RESET and WDT	U	U	U	U	U	U	U	U
		Wake-up from Int	P	P	P	P	P	P	P	P
0x16	PTC	Full Name	General Purpose I/O port, Port C							
		Bit Name	-	-	PTC5	PTC4	PTC3	PTC2	PTC1	PTC0
		Read / Write (R/W)	-	-	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	-	-	U	U	U	U	U	U
		/RESET and WDT	-	-	U	U	U	U	U	U
		Wake-up from Int	-	-	P	P	P	P	P	P
0x17	PTD	Full Name	General Purpose I/O port, Port D							
		Bit Name	PTD7	PTD6	PTD5	PTD4	PTD3	PTD2	PTD1	PTD0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	U	U	U	U	U	U	U	U
		/RESET and WDT	U	U	U	U	U	U	U	U
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x18	PTE	Full Name	General Purpose I/O port, Port E							
		Bit Name	PTE7	PTE6	PTE5	PTE4	PTE3	PTE2	PTE1	PTE0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	U	U	U	U	U	U	U	U
		/RESET and WDT	U	U	U	U	U	U	U	U
		Wake-up from Int	P	P	P	P	P	P	P	P
0x19	PTF	Full Name	General Purpose I/O port, Port F							
		Bit Name	-	-	-	-	-	-	PTF1	PTF0
		Read / Write (R/W)	-	-	-	-	-	-	R/W	R/W
		Power-on	-	-	-	-	-	-	U	U
		/RESET and WDT	-	-	-	-	-	-	U	U
		Wake-up from Int	-	-	-	-	-	-	P	P
0x1A	LFRC	Full Name	Least significant Byte of 16-bit Free Run Counter							
		Bit Name	FRC7	FRC6	FRC5	FRC4	FRC3	FRC2	FRC1	FRC0
		Read / Write (R/W)	R	R	R	R	R	R	R	R
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	0	0	0	0	0	0	0	0
0x1B	HFRC	Full Name	Most significant Byte of 16-bit Free Run Counter							
		Bit Name	FRCF	FRCE	FRCD	FRCC	FRCB	FRCA	FRC9	FRC8
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	0	0	0	0	0	0	0	0
0x1C	LFRCB	Full Name	Least significant Byte Buffer of 16-bit Free Run Counter							
		Bit Name	FRCB7	FRCB6	FRCB5	FRCB4	FRCB3	FRCB2	FRCB1	FRCB0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	0	0	0	0	0	0	0	0
0x1D	SPIRB	Full Name	Serial Peripheral Interface Read Register							
		Bit Name	SPIR7	SPIR6	SPIR5	SPIR4	SPIR3	SPIR2	SPIR1	SPIR0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x1E	SPIWB	Full Name	Serial Peripheral Interface Write Register							
		Bit Name	SPIW7	SPIW6	SPIW5	SPIW4	SPIW3	SPIW2	SPIW1	SPIW0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x1F	ADDATA	Full Name	Converting Value of ADC							
		Bit Name	ADD7	ADD6	ADD5	ADD4	ADD3	ADD2	ADD1	ADD0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x20	NC	Full Name								
		Bit Name			-	-	-	-	-	-
		Read / Write (R/W)	-	-	-	-	-	-	-	-
		Power-on	-	-	-	-	-	-	-	-
		/RESET and WDT	-	-	-	-	-	-	-	-
		Wake-up from Int	-	-	-	-	-	-	-	-
0x21	DT0L	Full Name	Duty of PWM0-Low Byte							
		Bit Name	DT07	DT06	DT05	DT04	DT03	DT02	DT01	DT00
		Read / Write (R/W)	R	R	R	R	R	R	R	R
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x22	DT0H	Full Name	Duty of PWM0-High Byte							
		Bit Name	DT0F	DT0E	DT0D	DT0C	DT0B	DT0A	DT09	DT08
		Read / Write (R/W)	R	R	R	R	R	R	R	R
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x23	PRD0L	Full Name	Period of PWM0- Low Byte							
		Bit Name	PRD07	PRD06	PRD05	PRD04	PRD03	PRD02	PRD01	PRD00
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x24	PRD0H	Full Name	Period of PWM0- High Byte							
		Bit Name	PRD0F	PRD0E	PRD0D	PRD0C	PRD0B	PRD0A	PRD09	PRD08
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x25	DL0L	Full Name	Duty Latch of PWM0-Low Byte							
		Bit Name	DL07	DL06	DL05	DL04	DL03	DL02	DL01	DL00
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x26	DL0H	Full Name	Duty Latch of PWM0-High Byte							
		Bit Name	DL0F	DL0E	DL0D	DL0C	DL0B	DL0A	DL019	DL08
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x27	DT1L	Full Name	Duty of PWM1-Low Byte							
		Bit Name	DT17	DT16	DT15	DT14	DT13	DT12	DT11	DT10
		Read / Write (R/W)	R	R	R	R	R	R	R	R
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x28	DT1H	Full Name	Duty of PWM1-High Byte							
		Bit Name	DT1F	DT1E	DT1D	DT1C	DT1B	DT1A	DT19	DT18
		Read / Write (R/W)	R	R/	R	R	R	R	R	R
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x29	PRD1L	Full Name	Period of PWM1- Low Byte							
		Bit Name	PRD17	PRD16	PRD15	PRD14	PRD13	PRD12	PRD1	PRD10
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x2A	PRD1H	Full Name	Period of PWM1- High Byte							
		Bit Name	PRD1F	PRD1E	PRD1D	PRD1C	PRD1B	PRD1A	PRD19	PRD18
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x2B	DL1L	Full Name	Duty Latch of PWM1-Low Byte							
		Bit Name	DL17	DL16	DL15	DL14	DL13	DL12	DL11	DL10
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x2C	DL1H	Full Name	Duty Latch of PWM1-High Byte							
		Bit Name	DL1F	DL1E	DL1D	DL1C	DL1B	DL1A	DL19	DL18
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x2D	RFAAR	Full Name	BB Address Register							
		Bit Name	-	-	-	AAR4	AAR3	AAAR2	AAR1	AAR0
		Read / Write (R/W)	-	-	-	R/W	R/W	R/W	R/W	R/W
		Power-on	-	-	-	0	0	0	0	0
		/RESET and WDT	-	-	-	0	0	0	0	0
		Wake-up from Int	-	-	-	P	P	P	P	P
0x2E	RFDB	Full Name	BB Data Buffer							
		Bit Name	RFDB7	RFDB6	RFDB5	RFDB4	RFDB3	RFDB2	RFDB1	RFDB0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x2F	RFACR	Full Name	BB Data Read/Write Control Register							
		Bit Name	-	-	-	-	-	RRST	RFRD	RFWR
		Read / Write (R/W)	-	-	-	-	-	R/W	R/W	R/W
		Power-on	-	-	-	-	-	0	1	1
		/RESET and WDT	-	-	-	-	-	0	1	1
		Wake-up from Int	-	-	-	-	-	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x30	RFINTF	Full Name	BB Interrupt Flag Register							
		Bit Name	CSDF	TX_AEF	RX_AFF	TX_EMPTYF	RX_OFF	LINK_DISF	LOCK_OUTF	LOCK_INF
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x40 ~ 0x7F	DPR	Full Name	Dual Port Registers (64 in total)							
		Bit Name	DPR7	DPR6	DPR5	DPR4	DPR3	DPR2	DPR1	DPR0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	×	×	×	×	×	×	×	×
		/RESET and WDT	×	×	×	×	×	×	×	×
		Wake-up from Int	P	P	P	P	P	P	P	P
0x80	PRIE	Full Name	Peripheral Function Enable							
		Bit Name	SPIE	-	BBE	ADE	PWM1E	PWM0E	TCCE	FRCE
		Read / Write (R/W)	R/W	-	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	-	0	0	0	0	0	0
		/RESET and WDT	0	-	0	0	0	0	0	0
		Wake-up from Int	P	-	P	P	P	P	P	P
0x81	INTE	Full Name	Interrupt Enable Control Register							
		Bit Name	GIE	RBFIE	PWM1IE	PWM0IE	EINT1E	EINT0E	TCCOE	FRCOE
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x82	KWUAIE	Full Name	Port A Key Wake up Interrupt Enable Control Register							
		Bit Name	-	-	-	-	KWUBE	KWUAE	KWU9E	KWU8E
		Read / Write (R/W)	-	-	-	-	R/W	R/W	R/W	R/W
		Power-on	-	-	-	-	0	0	0	0
		/RESET and WDT	-	-	-	-	0	0	0	0
		Wake-up from Int	-	-	-	-	P	P	P	P
0x83	KWUBIE	Full Name	Port B Key Wake up Interrupt Enable Control Register							
		Bit Name	KWU7E	KWU6E	KWU5E	KWU4E	KWU3E	KWU2E	KWU1E	KWU0E
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x84	EINTED	Full Name	External Interrupt Edge Control							
		Bit Name		-	-	-	-	-	EINT1ED	EINT0ED
		Read / Write (R/W)		-	-	-	-	-	R/W	R/W
		Power-on		-	-	-	-	-	0	0
		/RESET and WDT		-	-	-	-	-	0	0
		Wake-up from Int		-	-	-	-	-	P	P
0x85	SPIC	Full Name	Serial Peripheral Serial (SPI) Enable Control Register							
		Bit Name	SPI_RBF	CES	SBR2	SBR1	SBR0	SDID	SDOD	SPIS
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	0	0	0	0	0
0x86	IOCA	Full Name	I/O Control of Port A							
		Bit Name	IOCA7	IOCA6	IOCA5	IOCA4	IOCA3	IOCA2	IOCA1	IOCA0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	1	1	1	1	1	1	1	1
		Wake-up from Int	P	P	P	P	P	P	P	P
0x87	IOCB	Full Name	I/O Control of Port B							
		Bit Name	IOCB7	IOCB5	IOCB5	IOCB4	IOCB3	IOCB2	IOCB1	IOCB0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	1	1	1	1	1	1	1	1
		Wake-up from Int	P	P	P	P	P	P	P	P
0x88	IOCC	Full Name	I/O Control of Port C							
		Bit Name	-	-	IOCC5	IOCC4	IOCC3	IOCC2	IOCC1	IOCC0
		Read / Write (R/W)	-	-	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	-	-	1	1	1	1	1	1
		/RESET and WDT	-	-	1	1	1	1	1	1
		Wake-up from Int	-	-	P	P	P	P	P	P
0x89	IOCD	Full Name	I/O Control of Port D							
		Bit Name	IOCD7	IOCD6	IOCD5	IOCD4	IOCD3	IOCD2	IOCD1	IOCD0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	1	1	1	1	1	1	1	1
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x8A	IOCE	Full Name	I/O Control of Port E							
		Bit Name	IOCE7	IOCE6	IOCE5	IOCE4	IOCE3	IOCE2	IOCE1	IOCE0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	1	1	1	1	1	1	1	1
		/RESET and WDT	1	1	1	1	1	1	1	1
		Wake-up from Int	P	P	P	P	P	P	P	P
0x8B	IOCF	Full Name	I/O Control of Port F							
		Bit Name	-	-	-	-	-	-	IOCF1	IOCF0
		Read / Write (R/W)	-	-	-	-	-	-	R/W	R/W
		Power-on	-	-	-	-	-	-	1	1
		/RESET and WDT	-	-	-	-	-	-	1	1
		Wake-up from Int	-	-	-	-	-	-	P	P
0x8C	PUCA	Full Name	Pull-up Control of Port A							
		Bit Name	PUCA7	PUCA6	PUCA5	PUCA4	PUCA3	PUCA2	PUCA1	PUCA0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x8D	PUCB	Full Name	Pull-up Control of Port B							
		Bit Name	PUCB7	PUCB6	PUCB5	PUCB4	PUCB3	PUCB2	PUCB1	PUCB0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x8E	PUCC	Full Name	Pull-up Control of Port C							
		Bit Name	-	-	PUCC5	PUCC4	PUCC3	PUCC2	PUCC1	PUCC0
		Read / Write (R/W)	-	-	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	-	-	0	0	0	0	0	0
		/RESET and WDT	-	-	0	0	0	0	0	0
		Wake-up from Int	-	-	P	P	P	P	P	P
0x8F	PUCD	Full Name	Pull-up Control of Port D							
		Bit Name	PUCD7	PUCD6	PUCD5	PUCD4	PUCD3	PUCD2	PUCD1	PUCD0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x90	PUCE	Full Name	Pull-up Control of Port E							
		Bit Name	PUCE7	PUCE6	PUCE5	PUCE2	PUCE3	PUCE2	PUCE1	PUCE0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x91	PUCF	Full Name	Pull-up Control of Port F							
		Bit Name	-	-	-	-	-	-	PUCF1	PUCF0
		Read / Write (R/W)	-	-	-	-	-	-	R/W	R/W
		Power-on	-	-	-	-	-	-	0	0
		/RESET and WDT	-	-	-	-	-	-	0	0
		Wake-up from Int	-	-	-	-	-	-	P	P
0x92	ODCB	Full Name	Open Drain Control of Port B							
		Bit Name	OPCB7	OPCB6	OPCB5	OPCB4	OPCB3	OPCB2	OPCB1	OPCB0
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	0	0	0
0x93	TCCC	Full Name	Time Clock/Counter Control							
		Bit Name	-	-	-	-	TCCS0	PS2	PS1	PS0
		Read / Write (R/W)	-	-	-	-	R/W	R/W	R/W	R/W
		Power-on	-	-	-	-	0	0	0	0
		/RESET and WDT	-	-	-	-	0	0	0	0
		Wake-up from Int	-	-	-	-	P	P	P	P
0x94	FRCC	Full Name	Free Run Counter Control							
		Bit Name	-	OSCO2E	OSCO2SL1	OSCO2SL0	PPSCL2	PPSCL1	PPSCL0	FRCCS
		Read / Write (R/W)	-	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	-	0	0	0	0	0	0	0
		/RESET and WDT	-	0	0	0	0	0	0	0
		Wake-up from Int	-	P	P	P	P	P	P	P
0x95	WDTC	Full Name	Watchdog Timer Control							
		Bit Name	GREEN	-	-	WDTCE	-	RAT2	RAT1	RAT0
		Read / Write (R/W)	R/W	-	-	R/W	-	R/W	R/W	R/W
		Power-on	0	-	-	0	-	0	0	0
		/RESET and WDT	0	-	-	0	-	0	0	0
		Wake-up from Int	0	-	-	P	-	P	P	P

Addr	Name	Reset Type	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x96	ADCAIS	Full Name	ADC Analog Input Pin Select							
		Bit Name	-	-	IMS2	IMS1	IMS0	CKR2	CKR1	CKR0
		Read / Write (R/W)	-	-	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	-	-	0	0	0	0	0	0
		/RESET and WDT	-	-	0	0	0	0	0	0
		Wake-up from Int	-	-	P	P	P	P	P	P
0x97	ADCCR	Full Name	ADC Configuration Register							
		Bit Name	ADRUN	ADIE	-	-	AIPS3	AIPS2	AIPS1	AIPS0
		Read / Write (R/W)	R/W	R/W	-	-	R/W	R/W	R/W	R/W
		Power-on	0	0	-	-	0	0	0	0
		/RESET and WDT	0	0	-	-	0	0	0	0
		Wake-up from Int	P	P	-	-	P	P	P	P
0x98	PWMCR	Full Name	PWM Control Register							
		Bit Name	-	-	-	-	S_PWM1	S_PWM0	-	-
		Read / Write (R/W)	-	-	-	-	R/W	R/W	-	-
		Power-on	-	-	-	-	0	0	-	-
		/RESET and WDT	-	-	-	-	0	0	-	-
		Wake-up from Int	-	-	-	-	P	P	-	-
0x99	RFINTE	Full Name	BB Interrupt Enable Control Register							
		Bit Name	CSDE	TX_AEE	RX_AFE	TX_EMPTYE	RX_OFE	LINK_DISE	LOCK_OUTE	LOCK_INE
		Read / Write (R/W)	R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	0	0	0	0	0	0	0	0
		/RESET and WDT	0	0	0	0	0	0	0	0
		Wake-up from Int	P	P	P	P	P	P	P	P
0x9A	ODCC	Full Name	Open Drain Control of Port C							
		Bit Name	-	-	OPCC5	OPCC4	OPCC3	OPCC2	OPCC1	OPCC0
		Read / Write (R/W)	-	-	R/W	R/W	R/W	R/W	R/W	R/W
		Power-on	-	-	0	0	0	0	0	0
		/RESET and WDT	-	-	0	0	0	0	0	0
		Wake-up from Int	-	-	P	P	P	P	P	P

7 Function Description

7.1 Special Purpose Registers

The special purpose registers are function-oriented registers used by the CPU to access memory, record execution results, and carry out the desired operation. The functions of the registers related to the core are described in the following subsections

7.1.1 Accumulator – ACC

Internal data transfer operation, or instruction operand holding usually involves the temporary storage function of the Accumulator, which is not an addressable register.

7.1.2 Indirect Addressing Contents – IAC0 (0x00), and IAC1 (0x09)

The contents of R0 and R9 are implemented as indirect addressing pointers if any instruction uses R6 and R8 as registers.

7.1.3 High Byte Program Counter HPC (0x01) and Low Byte Program Counter LPC (0x02)

- Program Counter (PC) is composed of registers HPC and LPC.
- PC and the hardware stacks are 14 bits wide.
- The structure is depicted in Fig. 6-1.
- Generates 12K × 16 on-chip ROM addresses to the corresponding program memory (ROM).

- All the bits of PC are set "0"s as a reset condition occurs.
- "RET" ("RETL k", "RETI") instruction loads the program counter with the contents at the top of stack.
- "MOV R2, A" allows the loading of an address from the "A" register to the lower 8 bits of the PC, and the high byte (A8~A14) of the PC remain unchanged.
- "ADD R2, A" & "TBL" allows a corresponding address / offset be added to the current PC.

7.1.4 Status Register – SR (0x03)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	RST	T	P	Z	DC	C

Bit 0 (C): Carry flag. This bit indicates that a carry out of ALU occurred during the last arithmetic operation. This bit is also affected during bit test, branch instruction and bit shifts.

Bit 1 (DC): Auxiliary carry flag. This bit is set during ADD and ADC operations to indicate that a carry occurred between Bit 3 and Bit 4.

Bit 2 (Z): Zero flag. Set to "1" if the result of the last arithmetic, data or logic operation is zero.

Bit 3 (P): Power down bit. Set to 1 during power on or by a "WDTC" command and reset to 0 by a "SLEP" command.

Bit 4 (T): Time-out bit. Set to 1 by the "SLEP" command and the "WDTC" command, or during power up and reset to 0 by WDT timeout.

Bit 5 (RST): Set if the CPU wakes up by keying Wake-up pins. Reset if the chip wakes up from other ways.

Bits 6 and 7 are reserved.

7.1.5 RAM Bank Selector – RAMBS0 (0x04), and RAMBS1 (0x07)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	-	RAMBSX2	RAMBSX1	RAMBSX0

As depicted in Fig. 6-2, there are seven available banks in the MCU. Each of them have 128 registers and can be accessed by defining the bits, RAMBSX0 ~ RAMBSX2, as shown below.

RAMBSX (0x04/0x07)	Bank
000	0
010	2
011	3
100	4
101	5
110	6

7.1.6 ROM Page Selector – ROMPS (0x05)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	-	-	-	RPS0

As depicted in Fig. 6-1, there are two available pages in MCU. The first page has 8K×16 ROM size and the second page has 4K×16 ROM size. Both of them can be accessed by defining the bits, RPS0, as shown below.

As depicted in Fig. 6-1, there are two available pages in the MCU. Each page has 12K×16 ROM size and can be accessed by defining the bits, RPS0, as shown below.

RPS0	Page (Address)
0	0 (0x0000~0×1FFF)
1	1 (0x2000~0×2FFF)

7.1.7 Indirect Addressing Pointers – IAP0 (0×06), and IAP1 (0×08)

Both R6 and R8 are not physically implemented registers. They are useful as indirect addressing pointers. Any instruction using R6/R4 and R8/R7 as registers actually access data pointed by R0 and R9 individually.

7.1.8 Indirect Address Pointer Direction Control Register – IAPDR (0x0A)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	IAP1_D	IAP0_D	IAP1_D_E	IAP0_D_E

Bit 0/1 (IAP0_D_E/IAP1_D_E) Indirect addressing pointer0/1 direction function enable bit.

0: Disable

1: Enable

Bit 2/3 (IAP0_D/IAP1_D) Indirect addressing pointer0/1 direction control bit.

0: Minus direction

1: Plus direction

7.1.9 Table Look-up Pointer – LTBL (0x0B), and HTBL (0x0C)

The maximum length of a table is 64K, and can be accessed through registers LTBL and HTBL. HTBL is the high byte of the pointer, whereas LTBL is the low byte.

7.1.10 Stack Pointer – STKPTR (0x0D)

Register RD indicates how many stacks the current free run program uses. It is a read only register.

7.1.11 Repeat Counter – RPTC (0x0E)

The RE register is used to set how many times the "RPT" instruction is going to read the table.

7.1.12 Prescaler Counter – PRC (0x0F)

Prescaler counter for TCC.

7.1.13 Real Time Clock Counter – RTCC (0x10)

TCC counter.

7.1.14 Interrupt Flag Register – INTF (0x11)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADIF	RBFIF	PWM1IF	PWM0IF	EINT1F	EINT0F	TCCOF	FRCOF

Bit 0 (FRCOF): FRC Overflow interrupt. Set as the contents of the FRC counter change from 0xFFFF to 0x0000, reset by software.

Bit 1 (TCCOF): TCC Overflow interrupt. Set as the contents of the TCC counter change from 0xFF to 0x00, reset by software.

Bits 2 ~ 3 (EINT0F & EINTIF): External input pin interrupt flag. Interrupt occurs at a defined edge of the external input pin, reset by software.

Bits 4 ~ 5 (PWM0IF & PWM1IF): PWM interrupt flag. Interrupt occurs when TMRX is equal to PRDX, reset by software.

Bit 6 (RBFIF): SPI receiving buffer full Interrupt flag. Interrupt occurs when an 8-bit data is received, reset by software.

Bit 7 (ADIF): ADC conversion complete interrupt flag.

Each bit can function independently regardless whether its related interrupt mask bit is enabled or not.

7.1.15 Key Wake-up Flag Register – KWUAIF (0x12) & KWUBIF (0x13)

KWUAIF: Port A Key Wake-up Interrupt Flag

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	KWUBIF	KWUAIF	KWU9IF	KWU8IF

KWUBIF: Port B Key Wake-up Interrupt Flag

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
KWU7IF	KWU6IF	KWU5IF	KWU4IF	KWU3IF	KWU2IF	KWU1IF	KWU0IF

7.1.16 I/O Port Registers – PTA ~ PTF (0x14 ~ 0x19)

PTX can be operated by related instructions, as any other general purpose registers. That is, PTX is an 8-bit, bidirectional, general purpose port. Its corresponding I/O control bit determines the data direction of a PTX pin.

7.1.17 16-bit Free Run Counter (FRC) – LFRC (0x1A), HFRC (0x1B) & LFRCB (0x1C)

R1A is 16-bit FRC low byte; R1B is high byte; R1C is low byte buffer.

7.1.18 Serial Peripheral Interface Read Register – SPIRB (0x1D)

Register R1D indicates SPI received data.

7.1.19 Serial Peripheral Interface Write Register – SPIWB (0x1E)

Register R1E indicates SPI transmitted data.

7.1.20 ADC Converting Value – ADDATA (0x1F)

ADDATA: Converting Value of ADC.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADD7	ADD6	ADD5	ADD4	ADD3	ADD2	ADD1	ADD0

7.1.21 PWM Duty – DT0L (0x21)/DT0H (0x22) & DT1L (0x27) / DT1H (0x28)

R22 : R21 16-bit PWM0 output duty cycle. R28 : R27 16-bit PWM1 output duty cycle.

7.1.22 PWM Period – PRD0L (0x23)/PRD0H (0x24) & PRD1L (0x29)/PRD1H (0x2A)

R24 : R23 16-bit PWM0 output period cycle. R2A : R29 16-bit PWM1 output period cycle.

7.1.23 PWM Duty Latch – DL0L (0x25)/DL0H (0x26) & DL1L (0x2B)/DL1H (0x2C)

R26 : R25 16-bit PWM0 output duty cycle buffer. R2C : R2B 16-bit PWM1 output duty cycle buffer.

7.1.24 BB Address Register – RFAAR (0x2D)

Register R2D indicates BB indirect RAM address.

7.1.25 BB Data Buffer Register – RFDB (0x2E)

Register R2E indicates BB indirect RAM data.

7.1.26 BB Data Read/Write Control Register – RFACR (0x2F)

Register R2F indicates BB RAM access control.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	-	RRST	RFRD	RFWR

Bit 0 (RFWR): Write BB register.

Bit 1 (RFRD): Read BB register

Bit 2 (RRST): BB S/W reset.

Bit 3 ~ Bit 7: reserved

7.1.27 BB Interrupt Flag Register – RFINTF (0x30)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CSDF	TX_AEF	RX_AFF	TX_ EMPTYF	RX_OFF	LINK_ DISF	LOCK_OUTF	LOCK_ INF

Bit 0 (LOCK_INF): This bit reflects the LOCK IN flag interrupt.

Bit 1 (LOCK_OUTF): This bit reflects the LOCK OUT flag interrupt.

Bit 2 (LINK_DISF): This interrupt is invoked by the zero counter capacitor discharge mechanism.

Bit 3 (RX_OFF): This bit reflects the RX FIFO full flag interrupt.

Bit 4 (TX_EMPTYF): This bit reflects the TX EMPTY flag interrupt.

Bit 5 (RX_AFF): This bit reflects the RX FIFO almost full flag interrupt.

Bit 6 (TX_AEF): This bit reflects the TX FIFO almost empty flag interrupt.

Bit 7 (CSDF): This flag indicates that a carrier-sense interrupt has occurred.

7.2 Dual Port Register (0x40 ~ 0x7F)

R 40 ~ R7F are dual port registers.

7.3 System Status, Control and Configuration Registers

These registers are function-oriented registers used by the CPU to record, enable or disable the peripheral modules, interrupts, and the operation clock modes.

7.3.1 Peripherals Enable Control – PRIE (0x80)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPIE	-	BBE	ADE	PWM1E	PWM0E	TCCE	FRCE

Bit 0 (FRCE): Free Run Counter 0 (FRC0) Enable bit.

Bit 1 (TCCE): Timer Clock/Counter (TCC) Enable bit.

Bit 2 (PWM0E): PWM0 function Enable bit.

Bit 3 (PWM1E): PWM1 function Enable bit.

Bit 4 (ADE): ADC Enable bit.

Bit 5 (BBE): Base Band (BB) Enable bit.

Bit 7 (SPIE): Serial Peripheral Interface Enable bit.

0: disable function

1: enable function

7.3.2 Interrupts Enable Control – INTE (0x81)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GIE	RBFIE	PWM1IE	PWM0IE	EINT1E	EINT0E	TCCOE	FRCOE

Bit 0 (FRC0OE): Free Run Counter (FRC) Overflow interrupt enable bit.

Bit 1 (TCCOE): TCC (TCC) Overflow interrupt enable bit.

Bit 2 (EINT0E): External pin (EINT0) interrupt enable bit.

Bit 3 (EINT1E): External pin (EINT1) interrupt enable bit.

Bits 4 (PWM0IE): PWM0 period complete enable bit.

Bits 5 (PWM1IE): PWM1 period complete enable bit.

Bit 6 (RBFIE): SPI Read Buffer Full (EINT) interrupt enable bit.

0: disable function interrupt

1: enable function interrupt

Bit 7 (GIE): Global interrupt control bit. Global interrupt is enabled by the ENI and RETI instructions and is disabled by the DISI instruction.

0: disable Global interrupt function

1: enable Global interrupt function

7.3.3 Key Wake-up Enable Control – KWUAIE (0x82) & KWUBIE (0x83)

KWUAIE: Port A Key Wake-up Interrupt Enable Control Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	KWUBE	KWUAE	KWU9E	KWU8E

Bit 0 ~bit 3 (KWU8E ~ KWUBE): Enable or disable the PTA0 ~ PTA3 Key Wake-up function.

0: disable key wake-up function

1: enable key wake-up function

KWUBIE: Port B Key Wake-up Interrupt Enable Control Register

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
KWU7E	KWU6E	KWU5E	KWU4E	KWU3E	KWU2E	KWU1E	KWU0E

Bit 0 ~bit 7 (KWU0 ~ KWU7): Enable or disable the PTB0 ~ PTB7 Key Wake Up function.

0: disable key wake-up function

1: enable key wake-up function

7.3.4 External Interrupts Edge Control – EINTED (0x84)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	-	-	EINT1ED	EINT0ED

Bit 0 (EINT0ED): Define which edge as an interrupt source for EINT0.

Bit 1 (EINT1ED): Define which edge as an interrupt source for EINT1.

0: Falling Edge

1: Rising Edge

Bit 2 ~ Bit 7 reserved

7.3.5 Serial Peripheral Serial (SPI) Enable Control Register – SPIC (0x85)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPI_RBF	CES	SBR2	SBR1	SBR0	SDID	SDOD	SPIS

Bit 0 (SPIS): SPI start.

Bit 1 (SDOD): SPI data shift out direction.

0: Most significant bit (MSB) transmitted first

1: Least significant bit (LSB) transmitted first

Bit 2 (SDID): SPI data shift in direction.

0: Most significant bit (MSB) received first

1: Least significant bit (LSB) received first

Bit 3 ~ 5 (SBR0 ~ SBR2): Configure the transmission mode and the clock rate.

SBR2 (Bit5)	SBR1 (Bit4)	SBR0 (Bit3)	Mode	Baud Rate
0	0	0	Master	Fosc/2
0	0	1	Master	Fosc/4
0	1	0	Master	Fosc/8
0	1	1	Master	Fosc/16
1	0	0	Master	Fosc/32
1	0	1	Slave	N/A
1	1	0	N/A	N/A
1	1	1	N/A	N/A

Bit 6 (CES): Clock edge select bit.

0 : Data shifts out on a rising edge, and shifts in on a falling edge. Data is held during a low level

1 : Data shifts out on falling edge, and shifts in on rising edge. Data is hold during the high level

Bit 7 (SPI_RBF): SPI read buffer full flag.

7.3.6 I/O Control Registers – IOCA~IOCF (0x86~0x8B)

IOCX is used to determine the data direction of its corresponding I/O port bit.

0 : configure a selected I/O pin as output

1 : configure a selected I/O pin as input

The only four least significant bits of port F, and the only five least significant bits of port C are available.

7.3.7 Pull-up Resistance Control Registers for Ports A~F – PUCA~PUCF (0x8C ~ 0x91)

Each bit of PUCX is used to control the pull-up resistors attached to its corresponding pin respectively. The theoretical value of the resistor is 64 KΩ. However, due to process variation, ±35% variation in resistance must be taken into consideration.

PUCX:

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PUCX7	PUCX6	PUCX5	PUCX4	PUCX3	PUCX2	PUCX1	PUCX0

0 : Pull-up Resistors disconnected

1 : Pull-up Resistors attached

7.3.8 Open Drain Control Registers of Port B/Port C – ODCB/ODCC (0x92/0x9A)

ODCB/ODCC: Open drain control of Port B/Port C.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
OPCX7	OPCX6	OPCX5	OPCX4	OPCX3	OPCX2	OPCX1	OPCX0

0 : Open drain disable

1 : Open drain enable

7.3.9 Timer Clock Counter Controller – TCCC (0x93)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	TCCS0	PSR2	PSR1	PSR0

Bit 0 ~ 2 (PSR0 ~ PSR2): Prescaler for TCC.

PSR2	PSR1	PSR0	Clock Rate
0	0	0	1:2
0	0	1	1:4
0	1	0	1:8
0	1	1	1:16
1	0	0	1:32
1	0	1	1:64
1	1	0	1:128
1	1	1	1:256

Bit 3 (TCCS0): Clock Source Select.

TCCS0	Clock Source
0	Selected PLL Clock Source
1	Selected IRC Clock Source

Bits 4 ~ 7 are reserved.

7.3.10 Free Run Counter Controller – FRCC (0x94)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	OSCO2E	OSCO2SL1	OSCO2SL0	PPSCL2	PPSCL1	PPSCL0	FRCCS

Bit 0 (FRCCS): Clock Source Select.

FRCCS	Clock Source
0	Selected PLL Clock Source
1	Selected IRC Clock Source

Bits 1 ~ 3 (PSR0 ~ PSR2): Prescaler for the OSCO2 clock output.

PPSCL2	PPSCL1	PPSCL0	Clock Rate
0	0	0	1:2
0	0	1	1:4
0	1	0	1:8
0	1	1	1:16
1	0	0	1:32
1	0	1	1:64
1	1	0	1:128
1	1	1	1:256

Bit 4 and Bit 5 (OSCO2SL0 and OSCO1SL1): System Clock Frequency Select Control Bits

OSCO2SL0	OSCO2SL1	Output Frequency (MHz)
0	0	6
0	1	12
1	0	24
1	1	48

Bit 6 (OSCO2E): OSCO2 output function mask. .

0: OSCO2 disabled, function as pin PF0;

1: OSCO2 enabled.

Bit 7 Reserved.

7.3.11 Watchdog Timer Controller – WDTC (0x95)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GREEN	-	-	WDTCE	-	RAT2	RAT1	RAT0

Bit 0 ~ 2 (RAT0 ~ RAT2): Prescaler of WDT.

RAT2	RAT1	RAT0	Clock Rate
0	0	0	1:2
0	0	1	1:4
0	1	0	1:8
0	1	1	1:16
1	0	0	1:32
1	0	1	1:64
1	1	0	1:128
1	1	1	1:256

Bit 4 (WDTCE): Enable the WDT Counter

0 : WDT disabled;

1 : WDT enabled.

Bits 7 (GREEN): for the reason of power saving, the system clock can be changed to internal RC mode.

1 : Green Mode

0 : Normal Mode

Bits 3, 5 and 6 are reserved.

7.3.12 ADC Analog Input Pin Select – ADCAIS (0x96)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	IMS2	IMS1	IMS0	CKR1	CKR0

CKR0 ~ CKR2 (Bit 0 ~ Bit 2): AD conversion Rate control bits.

IMS2~IMS0 (Bit 2 ~ Bit 4): ADC configuration definition bit.

Bits 5 ~ 7 are reserved.

7.3.13 ADC Configuration Register – ADCCR (0x97)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADRUN	ADIE	-	-	AIPS3	AIPS2	AIPS1	AIPS0

Bit 0 ~ Bit3 (AIPS0~AIPS3): Analog Input Select.

Bit 6 ~ Bit 7 (ADIE): ADC interrupt enable.

0 : ADC interrupt disable

1 : ADC interrupt enable

Bit 7 (ADRUN): ADC starts to RUN

0 : reset on completion of the conversion; this bit cannot be reset by software.

1 : A/D conversion is started; this bit can be set by software.

Bits 4 and 5 are reserved.

7.3.14 PWM Control Register – PWMCR (0x98)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	S_PWM1	S_PWM0	-	-

Bit 2 (S_PWM0): Selected PWM0 output enable.

Bit 3 (S_PWM1): Selected PWM1 output enable.

0: disable PWM output

1: enable enable PWM output

Bits 0, 1 and 4 ~ 7 are reserved.

7.3.15 BB Interrupt Control Register – RFINTE (0x99)

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CSDE	TX_AEE	RX_AFE	TX_ EMPTYE	RX_OFE	LINK_ DISE	LOCK_OU TE	LOCK_ INE

Bit 0 (LOCK_INE): LOCK IN interrupt enable bit.

Bit 1 (LOCK_OUTE): LOCK OUT interrupt enable bit.

Bit 2 (LINK_DISE): LINK_DIS interrupt enable bit.

Bit 3 (RX_OFE): RX FIFO full interrupt enable bit.

Bit 4 (TX_EMPTYE): TX EMPTY interrupt enable bit.

Bit 5 (RX_AFE): RX FIFO almost full interrupt enable bit.

Bit 6 (TX_AEE): TX FIFO almost empty interrupt enable bit.

Bit 7 (CSDE): carrier-sense interrupt enable bit.

0: disable interrupt function

1: enable interrupt function

7.4 Code Option (ROM-0x2FFF)

Register SCLK is located on the very last bit of EM77950's 12K program ROM. These values will be fetched first to be the system initial values as power-on.

SCLKC: System Clock Control Register

SCLKC	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
0x2FFF	-	-	-		RFCLK1	RFCLK0	SCLK1	SCLK0

SCLKC	Bit 15	Bit 14	Bit 13	Bit 12	Bit 11	Bit 10	Bit 9	Bit 8
0x2FFF	-	-	-	-	-	-	-	-

Bit 1 ~ Bit 2 (SCLKS1 ~ SCLKS0): System Clock Frequency Select Control Bits

SCLK1	SCLK0	System Clock (MHz)
0	0	6
0	1	12
1	0	24
1	1	48

Bit 3 ~ Bit 4 (RFCK1 ~ RFCK0): Wireless Modem Clock Frequency Select Control Bits

RFCLK1	RFCLK0	System Clock (MHz)
0	0	6
0	1	12
1	0	24
1	1	48

Bit5 ~ 15: Reserved

SCLK [1:0]	RFCLK [1:0]	WDT_CON.GREEN	SYS CLK	RF CLK	Note
00	00	0	Bypass	Bypass	1~20MHz (6MHz)
00/01/10/11	01/10/11	0	6/12/24/48	12/24/48	
01/10/11	00/01/10/11	0	12/24/48	6/12/24/48	
00/01/10/11	00/01/10/11	1	IRC	6/12/24/48	BB enable

8 Baseband (BB)

8.1 BB: Standard Interface for the RFW102 Series

8.1.1 Features

- Parallel interface to RFW102 modem
- Serial to Parallel conversion of RFW102 interface
- Input FIFO (RX_FIFO)
- Output FIFO (TX_FIFO)
- Preamble Correlation
- Packet Address Filter (Network and unique)
- CRC calculation
- Working Frequencies: 6-24MHz
- Power Save modes: Idle, Power-down
- Inter-RFWAVES networks Carrier-sense
- Discharge of the RFW-102 reference capacitor
- Compensate for clock drifts between transmitting and the receiving the EM77950 up to 1000ppm. Hence, the EM77950 requires low performance crystal.
- Interrupt Driver – connected to the EM77950's internal interrupt and informs the EM77950 about BB events.

8.1.2 Description

RFWAVES has developed a very low cost wireless modem (RFW102) for short range, cost-sensitive applications. The modem is a physical layer element (PHY) – allowing the transmission and reception of bits from one end to the other.

In an RFWAVES application, the MCU is in charge of the MAC layer protocol. In order to reduce the real-time demands of the MCU handling the MAC protocol, the BB was developed. The BB enables the MCU an easy interface to RFW102 through a parallel interface, similar to memory access. It converts the fast serial input to 8-bit words, which are much easier for an 8-bit MCU to work with, and requires a lower rate oscillator. It buffers the input through a TBD bytes FIFO, enabling the MCU to access the BB more efficiently. Instead of reading one byte per interrupt, the MCU can read up to 16 bytes in each interrupt. This reduces the MCU overhead in reading incoming words, insofar as stack stuffing and pipeline emptying are concerned, in cases where each incoming byte causes an interrupt. When using the FIFO, the MCU pays the same overhead for all the FIFO bytes as it paid for only one byte without a FIFO.

Having a low-cost BB with a built-in state machine that can support basic wireless communication elements presents the following advantages:

- Shorter development time, hence shorter time to market.
- Conserve CPU power and other resources for other applications.
- Offer an easy, standard integrated solution.

8.1.3 I/O and Package Description

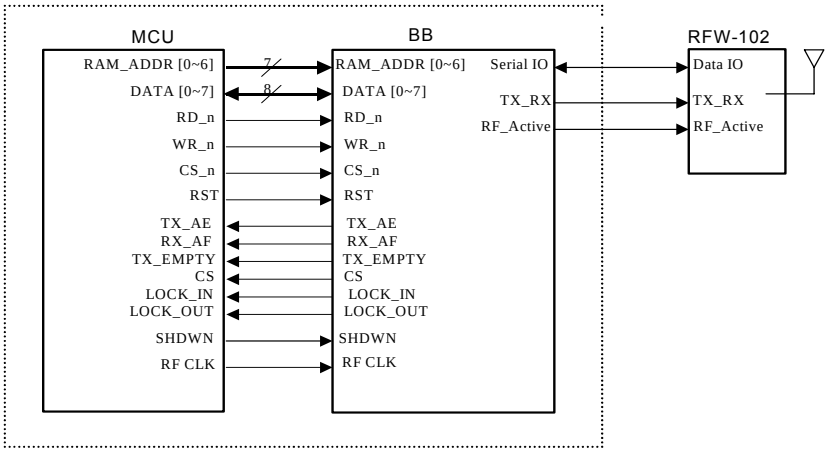


Fig. 8-1 Parallel Interface between the MCU and RFW-102 through BB

Name	Type	Description
DATA [0-7]	I/O	This bus comprises of eight TRI-STATE input/output lines. The bus provides bidirectional communication between the system and the MCU. Data, control words, and status information are transferred via the DATA [0-7] data bus.
RD_n	I	When RD_n is low while the system is enabled, BB outputs one of its internal register values to DATA[0-7] according to RAM_ADDR[0-6].
WR_n	I	When WR_n is low while the system is enabled, BB enables writing to its internal registers. The register is determined by RAM_ADDR [0-6] and the value DATA[0-7].
RAM_ADDR[0-6]	I	These four input signals determine the register to which the MCU writes to or reads from.
CS_n	I	Chip select input pin. When CS_n is low, the chip is selected; when high, the chip is disabled. This pin overrides all pins excluding RST. This enables communication between BB and the MCU. This pin functions as wakeup pin for power-down and idle modes.
TX_AE; TX_EMPTY; RX_AF; CS; LOCK_IN; LOCK_OUT	O	Interrupt driver pins. This pin goes high whenever any of the interrupt sources has an active high condition and is enabled via the IER. The purpose of this pin is to notify the MCU through its external interrupt pin that an event (such as empty TX_FIFO) has occurred. Goes low when IER register is read.
RST	I	Chip's reset pin. When this pin is set high, all registers and FIFOs are cleared to their initial values. All transceiver traffic is disabled and aborted. Reset is asynchronous to system clock. After power-up, a pulse in RST input should be applied (by POR).
SHDWN	I	Shut Down BB
RF_ACTIVE	O	This output pin controls the RFW102 working/shutdown mode. Its values are determined by SCR4(1).
SERIAL_IO	I/O	Serial input or output according to TX_RX mode. It functions as serial interface for the RFW-102 (RFWAVES modem). When SERIAL_IO is input, it is a Schmitt-trigger input.
RX_TX	O	This pin controls RFW-102 operation mode. It should be connected to RFW-102 RX_TX input pin. When RX_TX is low, RFW-102 is in receiving mode. When RX_TX is high, RFW-102 is in transmitting mode. In most cases RX_TX output pin is determined by SCR2(0) register. SCR3(7) and the capacitor discharge mechanism affects this pin.
RF_CLK	I	Clock for RF operation

8.1.4 BB Architecture

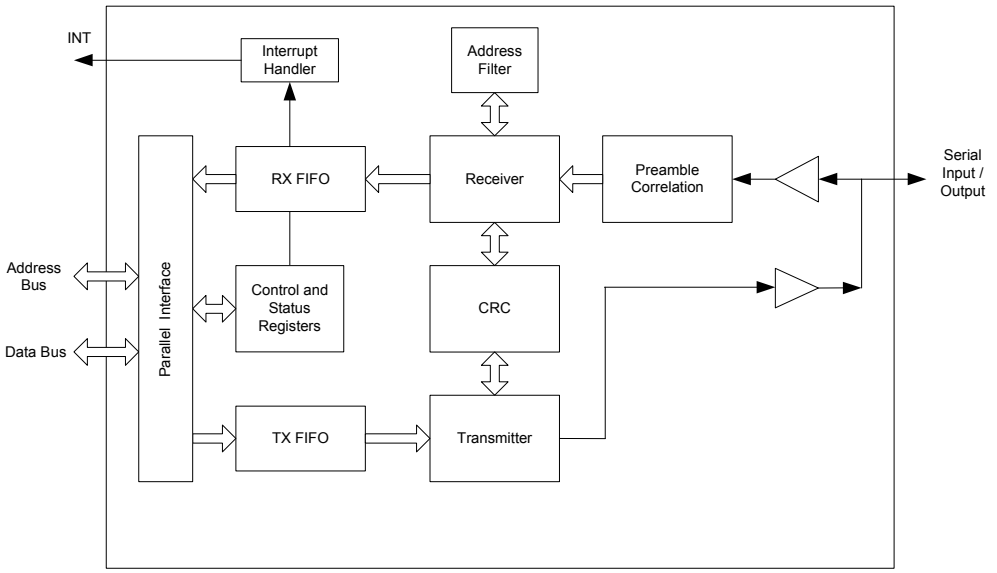


Fig. 8-2 BB Block Diagram

8.2 BB Description

8.2.1 Reset

A reset is achieved by holding the RST pin high for at least TBD oscillator cycles.

To ensure good power-up, a reset should be given to BB after power-up.

8.2.2 Power Saving Modes

The BB was designed to work in similar working modes as a typical MCU.

These modes enable the system to conserve power when the BB is not in use.

8.2.2.1 Power-Down Mode

The MCU is able to halt all activity in BB by stopping its clock. This enables the MCU to reduce the power consumption of the BB to a minimum.

All registers and FIFOs retain their values when BB is in power-down mode.

BB enters power-down mode by setting bit TBD in register TBD to “1”. This bit is set by the MCU and cleared by BB.

BB goes back to working mode by setting CS_n input pin to “0” for TBD msec.

The wake-up time of BB from power-down mode to fully operating mode is TBD msec.

Since BB retains all the register values in power-down mode, special care should be paid to the register values before it enters power-down. For example, the MCU should check that the BB is not in the middle of transmitting or receiving a packet.

The RFACTIVE should be set low to shutdown the RFW-102, before entering power-down mode.

8.2.2.2 Idle Mode

In idle mode, the BB internally blocks the clock input. The external clock is not stopped, but it is not routed to the internal logic. By doing this, the MCU achieves substantial power savings and yet the wake-up time is still relatively short. The power consumption is not minimal since the external clock is still active.

All registers and FIFOs retain their values when BB is in idle mode.

BB enters idle mode by setting bit TBD in register TBD to “1”. This bit is set by the MCU and cleared by BB.

BB goes back to working mode by setting CS_n input pin to “0” for TBD μsec.

Since BB retains all the register values in idle mode, special care should be given to the register values before BB enters idle mode. For example, the MCU should check that the BB is not in the middle of transmission or receiving a packet. In addition, the RFACTIVE should be set low to shutdown the RFW-102.

8.2.3 Preamble Correlation

The transmitting BB sends the PREAMBLE in order to synchronize the receiver to its transmission. BB transmits a fixed size PREAMBLE of 16 bits. The received PREAMBLE has a variable length of 16⇔9 bits, determined by SCR2 [5:7]. The receiver correlates the 16⇔9 bits from its PRE-L and PRE-H registers to the 16⇔9 bits in its input shift-register. If a correlation was found, then BB receiver state machine is enabled.

The purpose of the PREAMBLE is to filter the module packets from white noise or other transmissions on the channel. NODE_ID and NET_ID filter are used to filter packets from other module networks.

The PREAMBLE is transmitted MSB to LSB (PRE-H first and then PRE-L).

The value of the PREAMBLE is determined according to PRE-L and PRE-H registers.

The BB has the same PREAMBLE when it is in transmitting mode (TX_RX=1) as when it is in receiving mode (TX_RX=0).

The value of the PRE-L and PRE-H registers should be identical in the BB in all nodes in the network.

8.2.4 Refresh Bit

When receiving a valid packet, The RFWaves modem (PHY layer) has to receive a “1” symbol each time a certain period has elapsed in order to maintain its sensitivity. The time between adjacent “1” symbols is determined by the value of the reference capacitor. This constraint is transparent to the application layer since the BB adds a “1” symbol (refresh bit) if too many “0” symbols are transmitted consecutively. On the receiver side, these additional “1” symbols (refresh bits) are removed by the BB.

This feature is transparent to the application layer. The application layer has only to initialize the maximum allowed number of consecutive x“00” bytes.

The BB has the flexibility to add a refresh bit every 1 to 7 bytes. This is configured by RB (0:2) bits in PPR register. The value of RB (0:2) bits in PPR register determines the overhead the refresh bit has on the throughput of the link.

The refresh bit does not add substantial overhead on the bit stream, since it is only added when the number of consecutive x”00” bytes exceeds a certain value.

The data that is sent is application dependent, so the application can be adjusted in order that there will be a negligible probability of this event happening.

Typical RFWaves capacitor: C=1nF.

Normal discharge current = 200nA.

Each 10mV on the capacitor represent 1dB in receiving power.

$$\frac{I}{C \cdot V} = \frac{200nA}{1nF \cdot 10mV} = \frac{1dB}{50\mu\sec}$$

The capacitor is charged with each received “1” symbol.

The receiver is allowed to lose 1dB before a new “1” is to be received.

Thus, after each 50 consecutive “0” bits in 1Mbps (50µsec) a “1” symbol should be sent.

In this case, setting RB [0:2] in PPR register to be 5 (“101”) would be sufficient (5 bytes = 40bits).

When RB (0:2) bits are set to “000” a refresh bit is added to every transmitted byte, regardless of its content. This introduces a constant overhead of 12.5%.

8.2.5 Bit Structure

The BB uses an oscillator ranging from 6~24 MHz. In order to determine the output and input bit rate, the BB must be configured to the number of clocks consisting each bit. This gives the applicator the control over the bit rate with certain restrictions. Each bit must have at least 6 clock cycles.

The maximum bit rate is: 1Mbps.

The minimum bit rate is: 10Kbps (TBD)

However it is recommended to work only at 1Mbps since reducing the bit rate does not change the energy of a transmitted bit. Meaning, reducing the bit-rate does not improve the bit error rate or the range between the transmitter and the receiver.

Bit Length Register (BLR) determines the number of clock cycles per bit (bit period).

BLR value is given a fixed offset of 6, since the minimum number of clock cycles in one bit is 6.

Bit Rate = Oscillator/(BLR+6).

The BB outputs (for the RFW-102) the bit structure shown below.

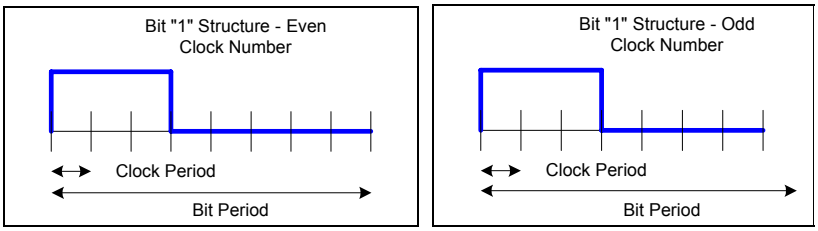


Fig. 8-3 Bit Structure of the BB output to the RFW-102

In the odd number of clocks example BLR=1.

In the even number of clocks example BLR=2.

The number of clocks when the line is “1” is determined as follows:

$$Number\ of\ \text{"1"}s = FLOOR\left[\left(\frac{BLR+6}{2}\right) - 1\right]$$

In case of “0” bit, BB output “0” value for BLR+6 clock pulses.

* FLOOR – Rounds towards zero.

8.2.6 CRC

The BB adds additional CRC information to each packet in the transmitter module, in order to enable the protocol to detect errors. The CRC is a redundant code, which is calculated and added to each packet on the transmitter side. The CRC is also calculated on the receiver side. The CRC calculation results of the receiver and the CRC field in the received packet are compared in the receiver using the CRC module in the chip. If CRC results are equal, then the receiver knows with reasonable probability that the packet was received correctly. If the CRC results are not equal then the receiver knows with probability 1 that the packet was received incorrectly.

The CRC mode is configured in the PPR (3:4) register.

Both the receiving node and the transmitting node in the network have to be in the same CRC mode.

The BB can apply CRC in three different ways:

16-Bit CRC – using polynomial $1+X^2+X^{15}+X^{16}$.

8-Bit CRC – using polynomial $1+X+X^2+X^8$.

No CRC.

This gives each application the flexibility to choose the adequate amount of overhead it adds to each packet and the corresponding level of protection the CRC code has.

If CRC is enabled, then BB calculates the CRC of each incoming packet. It does not put the received CRC value in the RX_FIFO. It just puts the result of its calculation in the RX_FIFO as the last byte of the packet:

0x55 – CRC received correctly.

0xAA – CRC was received incorrectly.

The status bit SSR (0) stores the result of the last received packet.

8.2.7 RX FIFO

All received bytes are transferred to the RX_FIFO. The RX_FIFO stores the input data until the MCU reads the data from it.

CRC and Preamble bytes are not transferred to the RX_FIFO.

The RX_FIFO is accessed just like all the other read-only registers in the BB. The MCU cannot write to RX_FIFO - it can only read from it.

RX_FIFO_SIZE is 16 bytes.

The purpose of having an input FIFO in BB is to reduce the real-time burden from the MCU. The FIFO is used as a buffer, which theoretically enables the MCU to read the incoming data every RX_FIFO_SIZE × 8 bit/byte × 1µsec = 128 µsec, and not every 1µsec in the case of serial input, or every 8µsec in the case where there is a serial to parallel converter.

The actual buffer size for practical use is a bit smaller, since the MCU response time is taken into account.

The MCU has three ways to learn about the RX_FIFO status:

The RX FIFO Status Register (RFSR) contains the number of bytes in the RX_FIFO.

BB INT pin. I f configured appropriately, the INT pin will be “1” each time RX_FIFO is almost full. This invokes an MCU interrupt if the INT pin is connected to the MCU external interrupt pin.

RX_FIFO Overflow Status Bit – bit RX_OF in SSR indicates when an overflow event has occurred. If a received byte is written to a full RX_FIFO, the last byte in the RX_FIFO is override and the RX_OF flag is raised.

The **RX_AF** interrupt should invoke the MCU to read from the RX_FIFO. Using the almost full event gives the MCU 32μsec (4 bytes × 8 μsec) to respond before it loses data, assuming a bit rate of 1Mbps. It uses most of the RX_FIFO size even if the response latency of the MCU is very short.

Should the MCU not respond properly to the almost full event, and an input byte is written to the RX_FIFO when it was full, then this byte would overrun the last byte in the RX_FIFO, meaning the byte that immediately preceded it.

LOCK_OUT interrupt should also trigger the MCU to read from the RX_FIFO. In case a packet has ended and the RX_AF interrupt was not invoked, the MCU should be triggered by the LOCK_OUT interrupt.

8.2.8 TX FIFO

Transmitting data is done by writing it to the TX_FIFO.

The interface to the TX_FIFO is similar to all the other write-only registers in BB.

The purpose of the TX_FIFO is to reduce the real-time from the MCU in a transmitting process. The TX_FIFO enables the MCU, theoretically, to write to the TX_FIFO every 128μsec and not every 8μsec, as is the case with a regular 8-bit shift register.

The TX_FIFO Status Register (TFSR) indicates the number of bytes in the TX_FIFO.

The TX_FIFO can also invoke an MCU interrupt if TX_FIFO almost empty event occurs.

Almost empty flag will rise when there are only 4 empty bytes in the TX_FIFO.

It gives the MCU 32μsec to respond time to reload the TX_FIFO in case the transmitted packet is bigger than the TX_FIFO.

In case the MCU writes to a full TX_FIFO, then this byte overruns the last byte in the TX_FIFO, meaning the byte that was written just before it. Writing to a full TX_FIFO set the TX_OF flag in SSR.

8.2.9 Interrupt Driver

The INT output pin is the summation of all interrupt sources in the BB. Whenever an interrupt event has occurred and this interrupt is enabled (IER), INT will go from low to high. INT will remain high until IIR register is read. The IIR register contains all the interrupts event that have occurred since the last read. It shows the event only for enabled interrupts. If an interrupt is disabled, even if the event that invoked this interrupt has occurred, the interrupt flag will be low. The IER register is used to enable/disable each of the interrupt. SCR4 (0) enables/disables all the interrupts.

There are 8 events in the BB that can cause the INT pin to go from low to high:

1. LOCK_IN – This interrupt indicates that the BB has started receiving a new packet. The Preamble has been identified. If the NET_ID or/and the NODE_ID are enabled, then they have been identified correctly. This event signals the beginning of an incoming packet.
2. LOCK OUT – BB has just finished receiving a packet. This means that if the BB is in fixed packet size mode, then it has finished receiving PSR bytes not including CRC bytes. If BB is not in fixed packet size mode, then it has just finished receiving a packet of size as indicated in the packet header. Although RX_STOP and setting TX_RX=1 (SCR2) terminate the receiving of the packet, they do not cause a LOCK_OUT event, since the MCU is already aware of it (the MCU initiated it). The LOCK_OUT interrupt tells the MCU when to get data out of the RX_FIFO.
3. LINK_DIS – This interrupt indicates that a “Zero counter” capacitor discharge event has occurred. If a consecutive number of zero bits (according to SCR3 (4:6)) have been received, this interrupt is set, even if zero count capacitor discharge is disabled (SCR3 (3) – EN_ZERO_DIS = ’0’). The actual capacitor discharge and its interrupt are two separate registers (IER (2) for the interrupt and SCR3 (3) for the discharge).
4. RX_OF – This interrupt indicates that a byte from an incoming packet was discarded, since the RX_FIFO was already full. The receiver module tried to write a byte to a full RX_FIFO. The MCU should know that the corresponding packet is corrupted, since it is lacking at least one byte.
5. TX_EMPTY – The BB has finished transmitting a packet. Meaning, the transmit shift register is empty and BB is now in RX mode (not TX mode).
6. RX_FIFO_AF – RX_FIFO is almost full. If the MCU does not want the RX_FIFO to overflow, then it should empty it.
7. TX_FIFO_AE – TX_FIFO is almost empty. If the MCU did not finish putting the transmitted packet in the TX_FIFO, then it should continue doing so now.
8. CS – CS status line has gone from “1” to “0” invokes a CS interrupt. This signals the MCU that an unidentified (NET_ID or NODE_ID or Preamble were not identified) packet has ended. If the MCU has a packet to transmit, and CS=”1” than the MCU waits for this event.

All these events can be masked. If an event is masked, then even if that event occurs - it does not set the INT pin to “1”. The masking is done by register IER.

The reason for masking is that in different applications or in different situation in the same application these events have different priorities. The MCU determines which of these events will invoke an MCU interrupt.

Moreover all these events can be masked together by IE in IER register.

If INT pin is set to “1”, the MCU learns which event has occurred by reading IIR register.

INT goes “0” when MCU reads from IIR register.

8.2.10 Packet Size

There are two types of packet structure determined by PPR [5] (FIXED).

Fixed Sized Packet – all packets have the same, fixed size. The packet size is determined in PSR register. The packet size can be 2 ~ 255 bytes.

Variable Sized Packet - the header of the incoming packet determines the packet size. One of the header bytes contains the packet size. Bits SIZE_LOC[0:1] in LCR register determines the location (offset) of the packet size inside each incoming packet header. The BB reads the packet size byte in the packet header according to LCR register.

In both cases the packet size does not include the CRC addition or the Preamble.

8.2.11 NET_ID and NODE_ID Filters

NET_ID and NODE_ID are two filters in the receiver. They filter incoming packets according to their network address and node address.

The address field in each incoming packet is compared to NET_ID byte and NODE_ID byte. If one of the above comparisons fails, then the packet is discarded and the MCU will not be aware of it.

NET_ID and NODE_ID are both one byte. Their values are stored in NIR and BIR registers accordingly. The byte to which they are compared is set by the LCR register.

Each of them can be enabled or disabled independently (PPR register).

NET_ID is targeted to be a filter on the network address. It is supposed to be common for all nodes in the network.

NODE_ID is targeted to be a filter on the specific node address. It is supposed to be unique to each node in the network.

The purpose of these filters is to conserve MCU power and to reduce its load. In a multi-node network, a node can filter all packets that are not sent to it, while in multi-network environment, a node can filter packets from other RFWaves networks.

In certain network, a multicast ability inside the network is required. Even if NODE_ID filter is applied, Addresses ‘111111XX’ in NODE_ID filter are preserved for multicast transmissions. NODE_ID filter will not discard those 4 addresses in any case.

8.2.12 Carrier-Sense

Carrier-sense protocols are protocols in which a node (station) listens to the common channel before it starts transmitting. The node tries to identify other transmissions in order to avoid collision that might block its own transmission. In a wider perspective, a network that applies carrier-sense protocol utilizes the channel bandwidth more efficiently. A more efficient network enables lower power consumption to each node, shorter delay and higher probability of reaching destination to each packet.

The BB uses one complimentary technique in order to achieve very wide-ranging carrier-sense abilities. It has an internal implementation of RFWaves Network Carrier-Sense algorithm. This enables it to avoid collision with other RFWaves stations on its network or from other networks in the area.

While the Carrier-Sense status bit in SSR (CS) tells the MCU when not to transmit, the two interrupt CS and LINK_DIS gives the MCU a flag when to transmit. LINK_DIS will be invoked whenever any transmission has ended, while CS interrupt will be invoked only when an RFWaves transmission has ended. An application can use some of the above mechanisms though not all of them – according to its needs.

8.2.12.1 RFWaves Carrier-Sense Algorithm

Assuming our bit rate is 1Mbps. According to the described bit structure (Section 8.2.5 Bit Structure), the time difference between two rising on DATA_IO must be an integer number of 1μsec. If we take into account the frequency deviation between the two BB oscillators, the time difference between two rising edges is 1μsec±□. The □ depends on the frequency deviation between the two BB oscillators. The BB uses this quality in its carrier-sense algorithm. If an N (N = (CSR (0:3) * 2) + 2) number of “1” bit, where each is preceded by at least one “0” bit, are received with time difference of an integer number of 1μsec between two consecutive “1” bit, then the CS flag in SSR equals ‘1’. Basically, the BB counts “0” to “1” transits on DATA_IO input, where the time difference between two transits should be an integer number (≥ 2) of 1μsec. The number of consecutive “1” bit that conforms to this rule is counted in the following example (Figure 8-2) in ONE_CNT counter. ONE_CNT is incremented only if a “1” bit that comes after a “0” bit is received, where the time gap between the “1” bit and the preceding “1” bit is as mentioned above. If the time difference between two consecutive “1” bit is out of the allowed deviation, the ONE_CNT is reset. ONE_CNT is also reset if the number of consecutive “0” exceeds (CSR (4:7) * 2) + 2, where CSR is the last “1” bit received is counted in ZERO_CNT. ZERO_CNT is reset each time “1” bit is received.

Both M and N values are determined in CSR register (CSR (7:4) and CSR (3:0) accordingly).

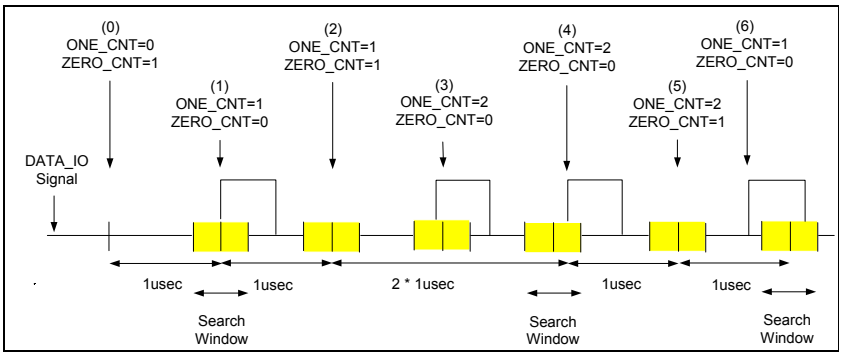


Fig. 8-4 Carrier-Sense Example

In the example shown in Figure 8-2, at time (1) a new “1” bit is received after a “0” bit was received. Thus, ONE_CNT equals 1 and ZERO_CNT is reset to 0. At time (2), a zero bit is received, so the ZERO_CNT is incremented. At time (3), a “1” is received after a “0” bit that was received before it. Thus ONE_CNT is incremented and ZERO_CNT is reset. At time (4) a “1” bit is received after a “1” bit, thus, there is no change in any counter. At time (6) a “1” bit is received out of the allowed window, so ONE_CNT is reset to 1.

The CSR register is used to configure the carrier-sense algorithm sensitivity. The CSR register determines the number of “1” bit required in order to decide that a carrier exists. The CSR also determines the number of successive “0” bits that reset the carrier-sense state machine.

In SSR register, bit CS notifies whether a carrier was identified. Carrier-sense can also be used as an interrupt. When CS in SSR goes from ‘1’ to ‘0’ i.e. the transmission has stopped, a CS interrupt is invoked (if enabled in IER). The purpose of this interrupt is to inform the MCU that the channel is free again.

If the BB identifies a packet, the carrier-sense algorithm halts. When the BB is in RX mode and the LOCK flag in SSR is “0”, the CS mechanism is working. When the LOCK flag in SSR is “1”, the CS mechanism is not working, since the CS flag does not add any information because a Preamble was identified already. After a Preamble was identified the CS in SSR equals ‘1’.

8.2.13 Receiver Reference Capacitor Discharge

BB implements two independent mechanisms for receiver capacitor discharge:

At the end of each received packet.

Zero counter.

Mechanism 1 is enabled/disabled by bit EN_CAP_DISCH in SCR3.

Mechanism 2 is enabled/disabled by bit EN_ZERO_DISCH in SCR3.

The number of “0” bits that will cause a discharge in Mechanism 2 are determined by bits ZERO_DISCH_CNT [0:2].

For both mechanisms, the discharge time is determined by CAP_DIS_PERIOD in SCR3.

Discharge is done by setting RX_TX pin to ‘1’ for a certain time and then setting it back to ‘0’.

(*) More detailed explanations of the reference capacitor discharge algorithms and motivations are can be found in the “RFW - Capacitor Discharge.pdf” document.

8.2.14 Changing BB Configuration

It is not recommended to change the BB configuration while it is in the middle of receiving or transmitting a packet.

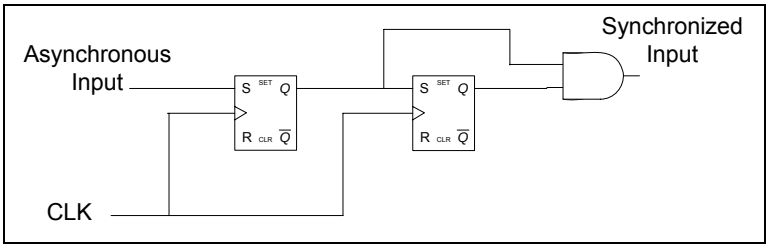
Thus, before writing to any of the BB control registers (such as BLR, PRE-L, PRE-H, PPR etc), do thefollowing:

1. Change TX_RX mode to RX.
2. Disable Preamble search (SEARCH_EN in SCR2)
3. Stop all RX receiving – RX_STOP.

It is then safe to change the BB configuration.

8.2.15 Input Synchronizer

Handling asynchronous inputs to the BB.



8.3 Register Description

The registers in the BB are divided into three groups:

- Read-only registers. Mainly status registers.
- Write-only registers. Mainly control registers.
- Read and write registers.

In case of an RST pulse, all register are set to their default value.

8.3.1 Bit Length Register (BLR)

This register is both a read and a write register.

It determines the length of the bit in terms of clock cycles.

The bit length will be (BLR+6) clocks, since the minimum length of a bit is 6 clocks.

Default Value: 00 (0+6=6).

8.3.2 Preamble Low Register (PRE-L)

This register is a write-only register.

This register contains the 8 least significant bits of the Preamble.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PRE-L	PR-7	PR-6	PR-5	PR-4	PR-3	PR-2	PR-1	PR-0

Default Value: 0xEB.

8.3.3 Preamble High Register (PRE-H)

This register is a write-only register.

This register contains the 8 most significant bits of the Preamble.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PRE-H	PR-15	PR-14	PR-13	PR-12	PR-11	PR-10	PR-9	PR-8

Default Value: 0xFF.

8.3.4 Packet Parameter Register (PPR)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PPR	NET ID_EN	NODE ID_EN	FIXED	CRC1	CRC0	RB-2	RB-1	RB-0

This is a read and a write register.

It contains control bits of the transmitted and received packet structure.

Default Value: 0x3A.

Bits 0-2 (RB-0~RB-2): Refresh Bits

These bits determine the maximum number of successive “zero” bytes allowed before an added “one” bit is stuffed to the packet by the transmitter state machine. The reason for this feature is to keep the RFW-102 reference capacitor charged.

Refresh Bit	Bit 2	Bit 1	Bit 0
Refresh bit is added to every byte.	0	0	0
Refresh bit is added if 1 byte equals x”00”.	0	0	1
Refresh bit is added if 2 successive bytes equal x”00”.	0	1	0
Refresh bit is added if 3 successive bytes equal x”00”.	0	1	1
Refresh bit is added if 4 successive bytes equal x”00”.	1	0	0
Refresh bit is added if 5 successive bytes equal x”00”.	1	0	1
Refresh bit is added if 6 successive bytes equal x”00”.	1	1	0
Refresh bit is added if 7 successive bytes equal x”00”.	1	1	1

The value of the refresh bit is determined by the value of the reference capacitor.

Bits 3, 4: CRC [0:1]

These bits control the CRC operation for both transmit and receive mode:

CRC	Bit 4	Bit 3
No CRC	0	0
CRC8	0	1
CRC8	1	0
CRC16	1	1

Bit 5: FIXED

This controls the packet mode when high system packets are fixed size and the length is specified in the Packet Size Register (PSR).

When FIXED is low, the packet size is variable. The size is specified in the header of the incoming or outgoing packets. The location of the packet size field is specified in the LCR register.

Bit 6: NODE_ID_EN

This is NODE_ID control bit.

0: Disables Node ID search.

1: Enables Node ID search according to LCR, BIR.

Bit 7: NET_ID_EN

This is NET_ID control bit.

0: Disables Net ID search.

1: Enables Net ID search according to LCR, NIR.

8.3.5 System Control Register1 (SCR1)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A

This byte is reserved.

Default Value: 0x00.

8.3.6 System Control Register 2 (SCR2)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SCR2	PRE MASK 2	PRE MASK 1	PRE MASK 0	STOP RX	TX FIFO RESET	RX FIFO RESET	SEARCH EN	TX_RX

This register is a read and a write register.

This register controls the system operation modes.

Bit 0: TX_RX

Controls the transceiver mode: receive mode or transmit mode

When TX_RX is low – BB is in receive mode (default mode). The output pin RX_TX is set to '0'. BB searches for a Preamble. If Preamble is found, it handles the process of receiving a packet.

If SCR3 (7) is set, then the BB goes to RX mode and the output pin RX_TX is TX mode.

The capacitor discharge can change the output pin RX_TX to TX mode even if we are in RX mode in the BB. In this case the output pin RX_TX will be in TX for a short duration and then return to RX mode.

When TX_RX is high – BB is in transmit mode. The output pin RX_TX is set to '1'. BB handles the process of transmitting a packet according to the data in the TX_FIFO. When it finishes transmitting the packet, it automatically goes back to receive mode.

Bit 1: SEARCH_EN

Preamble search enable bit.

When 1: Enables the search for Preamble in receive mode.

When 0: Disables the search for Preamble in receive mode, (used when user configures the system while in default receive mode).

This bit's default value is '0'. It must be set to '1' in order to start receiving a packet.

Bit 2: RX_FIFO_RESET

This bit resets the RX_FIFO address pointers when set to Logic 1. This bit is set by MCU and is cleared automatically by BB.

Bit 3: TX_FIFO_RESET

This bit resets the TX_FIFO address pointers when set to Logic 1. This bit is set by MCU and is cleared automatically by BB.

Bit 4: STOP_RX

This bit stops receiving the current command, resets the RX_FIFO counters and start new searches for preamble. This bit is set by MCU and is cleared automatically by BB.

Bits 5-7: PRE_MASK [0:2]

These bits determine the mask on PRE-H in preamble correlation. Meaning, it determines the size of the Preamble in the receiver.

The PRE-L is always used in the Preamble correlation.

BB cuts off bit from PRE-H register, starting from the MSB.

PRE MASK 0	PRE MASK 1	PRE MASK 2	Preamble Size
0	0	0	16
0	0	1	15
0	1	0	14
0	1	1	13
1	0	0	12
1	0	1	11
1	1	0	10
1	1	1	9

Default Value: 0x60

8.3.7 System Control Register 3 (SCR3)

This register is a read and a write register.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SCR3	LOW MODE	ZERO DISCH CNT 2	ZERO DISCH CNT 1	ZERO DISCH CNT 0	EN ZERO DISCH.	CAP DIS PERIOD	EN CAP DISCH.	-

Bit 1: EN_CAP_DISCH

Enables/disables capacitor discharge mechanism after each received packet:

0: Disables discharge.

1: Enables discharge.

This bit overrides Bit 3.

Bit 2: CAP_DIS_PERIOD

Determines the capacitor discharge duration:

0: The pulse width is 36 clocks, (3 μsec at 12 MHz clock).

1: The pulse width is 72 clocks, (3 μsec at 24 MHz clock).

Bit 3: EN_ZERO_DISCH

Enables/disables zero counter mechanism for capacitor discharge:

0: Disables discharge

1: Enables discharge

Bits 4-6: ZERO_DISCH_CNT [0:2]

Determine the number of zero bits that will trigger a capacitor discharge by the zero counter mechanism.

ZERO DISCH CNT 0	ZERO DISCH CNT 1	ZERO DISCH CNT 2	Number of Zeros
0	0	0	5
0	0	1	10
0	1	0	15
0	1	1	20
1	0	0	25
1	0	1	30
1	1	0	35
1	1	1	40

Bit 7: LOW_MODE

Enables or disables low power mode for RFW-102

0: Disables low mode (normal mode).

1: Enables low mode. BB is in RX mode, while RFW-102 is in TX mode.

User has to put the BB into RX mode to disable RX and Preamble search, before enabling LOW_MODE. This transfers the RFW-102 to TX mode using RX_TX pin, while the BB is still in RX mode.

RFW-102 power consumption is lower in TX mode than in RX mode. BB cannot remain in TX mode, if it is not transmitting. The low mode is the combination of both of the above.

Default Value: 0x01

8.3.8 System Control Register 4 (SCR4)

This register is a read and a write register.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SCR4	N/A	N/A	N/A	N/A	FIFO FLAGS	WIN CONT	RF_ACTIVE	IE

Bit 0: IE

This flag enables all interrupts when set to '1'.

When '0' all interrupts are disabled.

Bit 1: RF_ACTIVE

This bit controls RF_ACTIVE pin. When this bit is high the RF Modem is active.

Bit 2: WIN CONT

This bit determines the size of the WINDOW in the Preamble search module.

IF (BLR+6) > 14 and WIN_CONT=1, then the preamble window size is 5

Bit 3: FIFO FLAGS

Determines the RX_FIFO AF flag and TX_FIFO AE flag:

IF FIFO FLAGS = 0 then AF = 12 and AE = 4.

IF FIFO FLAGS = 1 then AF = 8 and AE = 8.

Default Value: 0x00.

8.3.9 Transmit FIFO Status Register (TFSR)

This register is a read-only register. It contains the number of bytes in the TX_FIFO.

Default Value: 0x00 (TX_FIFO empty).

8.3.10 Receive FIFO Status Register (RFSR)

This register is a read-only register. It contains the number of bytes in the RX_FIFO.

Default Value: 0x00 (TR_FIFO empty).

8.3.11 Location Control Register (LCR)

This is a read and a write register.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
LCR	-	SIZE LOC 2	SIZE LOC 1	SIZE LOC 0	NET LOC1	NET LOC 0	NODE LOC 1	NODE LOC 0

Bits 0, 1: NODE_LOC [0:1]

These bits determine the location of the NODE_ID parameter in the header (the location is specified in bytes excluding preamble). The location should be fixed for all of different kinds of packets transferred by the system. NODE_ID must never be set to be smaller than NET_ID, if both filters are enabled.

Location	NODE LOC 1	NODE LOC 0
2	0	0
3	0	1
4	1	0
5	1	1

Bits 2, 3: NET_LOC [0:1]

These bits determine the location of the NET_ID parameter in the header (the location is specified in bytes excluding the Preamble). The location should be fixed for all the different kinds of packets transferred by the system.

Location	NET LOC 1	NET LOC 0
1	0	0
2	0	1
3	1	0
4	1	1

Bits 4-5: SIZE_LOC [0:2]

These bits determine the location of the Packet Size parameter in the header (the location is specified in bytes excluding the Preamble). The location should be fixed for all the different kinds of packets transferred by the system.

Location	SIZE LOC 2	SIZE LOC 1	SIZE LOC 0
2	0	0	0
3	0	0	1
4	0	1	0
5	0	1	1
6	1	0	0
7	1	0	1
8	1	1	0
9	1	1	1

Default Value: 0x00

8.3.12 Node Identity Register (BIR)

This is a read and a write register.

When the Receiver State Machine builds the incoming packet, it compares the value in the BIR register to the received data at the location specified in LCR.

If received NODE_ID and the expected NODE_ID are not equal, the packet is discarded.

Four multicast NODE_ID addresses are implemented “111111XX”. All packets whose 6 MSBs are “1” are not discarded.

Default Value: 0x00

8.3.13 Net Identity Register (NIR)

This is a read and a write register.

When the Receiver State Machine builds the incoming packet, it compares the value in the NIR to the received data at the location specified in LCR.

If received NET_ID and the expected NET_ID are not equal, the packet is discarded.

Default Value: 0x00

8.3.14 System Status Register (SSR)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SSR	-	TX_UF	BIT_ERROR	LOCK	CS	TX EMPTY	LOCKED	CRC ERROR

This register is a read-only register.

This register provides status information to the MCU concerning the communication line and the data transfer. Bits 1, 2, 3 can trigger the interrupt if enabled in the IER. Bits 0, 5 and 6 are set by H/W and cleared automatically after the MCU reads the register. Bits 1~4 are set and cleared by H/W.

Bit 0: CRC_ERROR

This flag indicates a CRC Error in the packet. The CRC Block sets this flag at the end of each received packet according to the CRC calculation result. BB compares the calculated CRC and the received CRC. When these values differ, the flag goes high.

The flag is cleared only after the MCU reads the SSR register. If the MCU does not read the SSR register, this flag remains “1”.

Bit 1: LOCKED

This flag indicates that a packet is being received.

Bit 1 is set to Logic 1 whenever the system identifies a new incoming packet (triggers LOCK IN interrupt). The bit will reset to Logic 0 when the packet ends (triggers LOCK OUT interrupt) or when one of the IDs fails (NET or BYTE). This indicator is important whenever we want to switch to transmit mode because it can tell us that the line is busy and that in most cases the transmission will not succeed. The Lock triggers interrupt for every change in the bit status.

Bit 2: TX_EMPTY

This bit is the Transmitter Empty flag. When this bit is high the system is available for loading the next packet for transmission and BB is in receive mode. When the flag is low, BB is in the middle of a packet transmission.

When transmitting few successive packets, the MCU should wait to the end of a packet before it reloads the TX_FIFO with the next packet.

Bit 3: CS

Carrier Sense detection bit

When this bit is high, the system has identified a structure of packet transmission in the air according to CSR.

When low, no carrier has been detected. This bit is only valid in receive mode. The conditions for setting or clearing this flag are determined in the CS register.

When LOCKED is high, then CS is meaningless.

Bit 4: LOCK

This signals whether a Preamble was identified or is still searching.

When the flag is “0”, the receiver is searching for Preamble.

When the flag is “1” a Preamble was identified. If a packet was discarded for any reason, the LOCK flag goes to 1.

Bit 5: BIT_ERROR

This flag indicate that there was some error in the received package. The packet was not received according the expected timing specifications.

The packet can still pass CRC verification.

Bit 6: TX_UF

This flag is set whenever the MCU reads a byte from an empty TX_FIFO.

This flag indicates abnormal end of packet transmission. The MCU transmitter’s state machine has expected to find a valid byte in the TX_FIFO according to the packet size, but it found an empty TX_FIFO. When this event occurs, the TX_EMPTY interrupt is invoked and TX_UF (underflow) flag is set to ‘1’.

This flag is set by hardware and cleaned by MCU. It is cleaned whenever the MCU read the SSR register.

Default Value: 0x04.

8.3.15 Packet Size Register (PSR)

This is a read and a write register.

It contains the Packet Size in byte units. When working in fixed size packets (see Control Bit-1), the size will be fixed for all types of packets.

The size in PSR excludes 2 bytes of Preamble and 2, 1 or 0 bytes of CRC.

Default Value: 0x00.

8.3.16 Carrier Sense Register (CSR)

This is both a read and a write register.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CSR	ZERO CNT.3	ZERO CNT.2	ZERO CNT.1	ZERO CNT.0	ONE CNT.3	ONE CNT.2	ONE CNT.1	ONE CNT.0

Bits 0-3: ONE_CNT [0:3]

The number of successive “1” bits that set the carrier sense high.

Bits 4-7: ZERO_CNT [0:3]

The number of successive “0” bits that reset the carrier sense (CS=’0’).

Default Value: 0x44

8.4 Interrupt Registers

8.4.1 Interrupt Enable Register (IER)

This register is a write and a read register.

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IER	CS	TX_AE	RX AF	TX EMPTY	RX_OF	LINK_ DIS	LOCK OUT	LOCK IN

Default Value: 0x00.

For all flags in this register, **0** : Disable

1 : Enable

Bit 0: LOCK_IN

This flag enables/disables the LOCK IN interrupt.

PREAMBLE + NODE_ID + NET_ID identified correctly triggers LOCK IN interrupt.

Bit 1: LOCK_OUT

This flag enables/disables the LOCK OUT interrupt.

End of received packet triggers LOCK_OUT interrupt.

Bit 2: LINK_DIS

This flag enables/disables the LINK_DIS interrupt.

The zero counter capacitor discharge triggers the LINK_DIS interrupt.

Bit 3: RX_OF

This flag enables/disables the RX_OF interrupt.

End of received packet triggers RX_OF interrupt.

Bit 4: TX_EMPTY

This flag enables/disables the TX_EMPTY (Transmitter Empty) interrupt.

X_EMPTY interrupt tells the MCU that the transmitter has just finished transmitting a packet. BB goes to RX mode after finishing the transmission of a packet.

Bit 5: RX_AF

This flag enables/disables the RX_AF interrupt.

The RX_AF interrupt is triggered when RX_FIFO AF flag goes from ‘0’ to ‘1’.

Bit 6: TX_AE

This flag enables/disables the TX_AE interrupt.

The TX_AE interrupt is triggered when TX_FIFO AE flag goes from ‘0’ to ‘1’.

Bit 7: CS

This flag enables/disables the CS interrupt.

CS flag in SSR negative edge triggers CS interrupt.

8.4.2 Interrupt Identification Register (IIR)

Name	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IIR	CS	TX AE	RX AF	TX EMPTY	RX_OF	LINK_ DIS	LOCK OUT	LOCK IN

This is a read only register.

When the MCU accesses the IIR, all interrupts freeze. While the MCU access is occurring, the system records the changes in the interrupts but waits until the MCU access is complete before updating the register. A flag is active only when the matching interrupt enable bit is set, and does not depend on the IE bit value. The flags are set by H/W and cleared after the MCU reads the register.

Bit 0: This bit reflects the LOCK IN flag interrupt when enabled by IER.

This bit reflects the LOCK IN flag interrupt when enabled by IER.

LOCK_IN interrupt is invoke whenever a PREAMBLE+NET_ID+NODE_ID where recognized.

If NET_ID is disabled, then a received PREAMBLE+ NODE_ID invokes the interrupt.

If NODE_ID is disabled, then a received PREAMBLE+ NET_ID invokes the interrupt.

If NET_ID and NODE_ID are disabled, then a received PREAMBLE invokes the interrupt.

Bit 1: This bit reflects the LOCK OUT flag interrupt when enabled by IER.

This bit reflects the LOCK OUT flag interrupt when enabled by IER.

LOCK_OUT interrupt is invoked whenever RFW-D100 has finished receiving a packet. The end of the packet is determined according to the packet size.

Bit 2: This bit reflects the LINK_DIS flag interrupt when enabled by IER.

This interrupt is invoked by the zero counter capacitor discharge mechanism.

Bit 3: This bit reflects the RX_OF flag interrupt when enabled by IER.

Bit 4: This bit reflects the TX EMPTY flag interrupt when enabled by IER.

Bit 5: This bit reflects the RX FIFO AF flag interrupt when enabled by IER.

Bit 6: This bit reflects the TX FIFO AE flag interrupt when enabled by IER.

Bit 7: CS – when CS flag goes from “1” to “0”, an interrupt is invoked.

8.5 List of BB Register Mapping

Register Address	Write	Read	Default Values	
0 (00000)	TX_FIFO	RX_FIFO	–	–
1 (00001)	PRE_L		0xFF	
2 (00010)	PRE_H		0xFF	
3 (00011)	FRC_L		0xFF	
4 (00100)	FRC_H		0xFF	
5 (00101)	SCR1		0x00	
6 (00110)	SCR2		0x60	
7 (00111)	SCR3		0x01	
8 (01000)	SCR4		0x00	
9 (01001)	LCR		0x00	
10 (01010)	BIR		0x00	
11 (01011)	NIR		0x00	
12 (01100)	PSR		0x00	
13 (01101)	PPR		0x3A	
14 (01110)	BLR		0x00	
15 (01111)	CSR		0x44	
16 (10000)	IER		0x00	
17 (10001)	–	IIR	–	–
18 (10010)	–	SSR	–	0x04
19 (10011)	–	TFR	–	0x00
20 (10100)	–	RFR	–	0x00

8.6 MCU BB Control Registers

8.6.1 Control Registers List

RFAAR (0x2D): Register R2D indicates WM indirect RAM address.

RFDB (0x2E): Register R2E indicates WM indirect RAM data.

RFACR (0x2F): Register R2F indicates WM RAM access control.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	-	RRST	RFRD	RFWR

RFINTF (0x30): BB interrupt flags.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CSDF	TX_AEF	RX_AFF	TX_ EMPTYF	RX_OFF	LINK_ DISF	LOCK_OU TF	LOCK_ INF

RFINTE (0x99): BB interrupt enable.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CSDE	TX_AEE	RX_AFE	TX_ EMPTYE	RX_OFE	LINK_ DISE	LOCK_OU TE	LOCK_ INE

PRIE (0x80): Peripherals enable control.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPIE	-	BBE	ADE	PWM1E	PWM0E	TCCE	FRCE

8.6.2 BB Control Example

```
ORG    0X0060               // TX_EMPTY INT address
BC     RFINTF, TX_EMPTYF    // RF data send out, clear INT flag.
RETI

ORG    0X0100
START:
BS     RFACR, RRST          // BB reset.
NOP
BC     RFACR, RRST
BS     PRIE, WME            // BB power enable.
MOV    A, #0x10
MOV    RFINTE, A            // BB INT.TX_EMPTY enable.
ENI                         // enable all INT.

RF_TX_INITIAL:
WRITE  #SCR2, #8            // Reset TX_FIFO, RX mode.
WRITE  #BLR, #10            // Set bit rate.
WRITE  #PPR, #33            // Set package size to be fixed.
                            // Refresh bit mode 1. CRC disabled
WRITE  #PSR, #6             // Set package size to 6.
WRITE  #PRE_H, #0xDC        // Set preamble High byte value.
WRITE  #PRE_L, #0xA7        // Set preamble Low byte value.

RF_SEND_DATA:
WRITE  #TX_FIFO, #0x01      // Write first byte of package to
                            // TX_FIFO.
WRITE  #TX_FIFO, #0x02
WRITE  #TX_FIFO, #0x03
WRITE  #TX_FIFO, #0x04
WRITE  #TX_FIFO, #0x05

WRITE  #TX_FIFO, #0x06      // Write last byte of package to
                            // TX_FIFO.
READ   #TFR, 0x60           // Read TFR register data
WRITE  #IER, #16            // enable TX_EMPTY INT
WRITE  #SCR4, #0x03         // enable all INT.
WRITE  #SCR2, #1            // move from RX to TX mode.
```

```
LOOP:
JMP     LOOP

WRITE_DATA_TO_RF:           // BB register write SUB
BC      RFACR, RFWR
NOP
NOP
BS      RFACR, RFWR
RET

READ_DATA_FROM_RF:          // BB register read SUB
NOP
NOP
NOP
NOP
BC      RFACR, RFRD
NOP
NOP
NOP

NOP
NOP                         // Note the access time
MOV     A, RFDB
NOP
NOP
NOP
BS      RFACR, RFRD
RET

; ============================================
WRITE   MACRO#CON1, #CON2   // BB register write MACRO
MOV     A, #CON2
MOV     RFDB, A
MOV     A, #CON1
MOV     RFAAR, A
CALL    WRITE_DATA_TO_RF
ENDM
; ============================================

READMACRO#CON, REG          // BB register read MACRO
MOV     A, #CON
MOV     RFAAR, A
CALL    READ_DATA_FROM_RF
MOV     REG, A
ENDM
```

9 Direction Serial Peripheral Interface (SPI)

9.1 Introduction

The EM77950 communicates with other devices via SPI (Direction Serial Peripheral Interface) module, as shown in Fig. 9-1. To accomplish communication, SPI uses three wire synchronous protocols: Serial Clock, Serial Data Output, and Serial Data. If the EM77950 is a master controller, it sends clock through the SCK pin. An 8-bit data is transmitted and received at the same time. If the EM77950, however, is defined as a slave, its SCK pin could be programmed as an input pin. Data will continue to be shifted on the basis of both the clock rate and the selected edge.

9.2 Features

- 3-wire, full duplex synchronous transceiver
- Operation in either Master mode or Slave mode
- Programmable baud rates of communication
- Programming clock polarity
- Programmable data transmission order
- Interrupt flag available for read buffer full
- Up to 8 MHz (maximum) bit frequency

9.3 Block Diagram

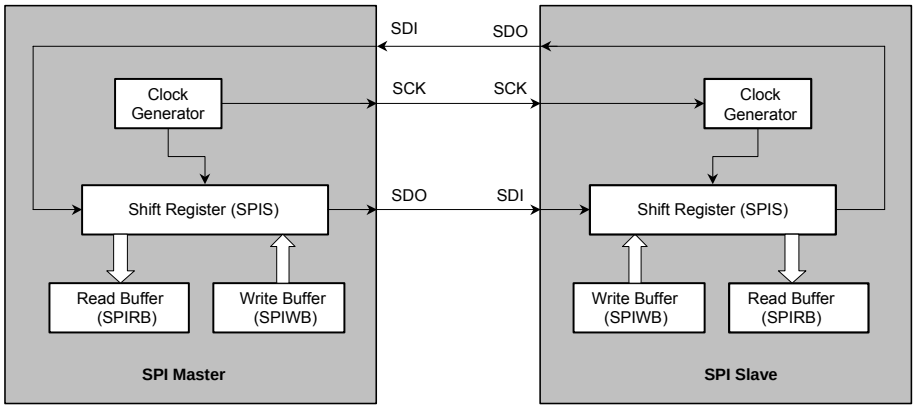


Fig. 9-1 Typical SPI Transceiver Mode

9.4 Transceiver Timing

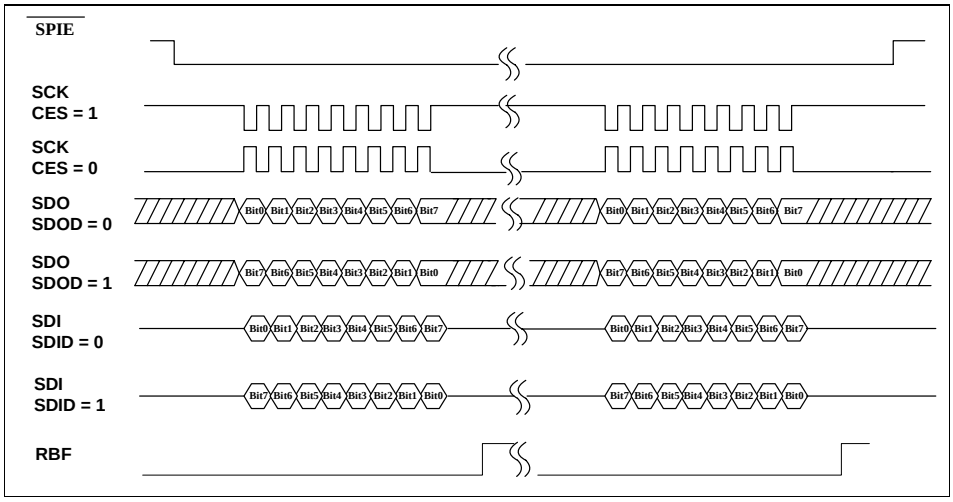


Fig. 9-2 SPI Transceiver Timing

9.5 Related Registers with SPI

As the SPI mode is defined, the related registers of this operation are shown below:

SPIRB (0x1D): Serial peripheral interface read Register

SPIWB (0x1E): Serial peripheral interface write Register

INTF (0X11): Interrupt flag

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADIF	RBFIF	PWM1IF	PWM0IF	EINT1F	EINT0F	TCCOF	FRCOF

PRIE (0x80): Peripherals enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPIE	-	BBE	ADE	PWM1E	PWM0E	TCCE	FRCE

INTE (0X81): Interrupt enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GIE	RBFIE	PWM1IE	PWM0IE	EINT1E	EINT0E	TCCOE	FRCOE

SPIC (0X85): SPI control.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPI_RBF	CES	SBR2	SBR1	SBR0	SDID	SDOD	SPIS

9.6 Function Description

9.6.1 Block Diagram Description

The following subsections describe the function of each blocks and signals. Fig. 9.2 depicts how the SPI communication is carried out.

SDI: Serial Data In

SCK: Serial clock

SDO: Serial Data Out

RBFIF: Set by Buffer Full Detector, and reset by software

SPIS: Loads the data in SPIWB register, and begin to shift

Shift reg.: Shifting byte out and in. The order is defined by bit SDOD. Both the Shift register and the SPIWB registers are loaded at the same time. Once data are written to, SPIS starts transmission / reception. The received data will be moved to the SPIRB register, as the shifting of the 8-bit data is completed. The RBFIF (Read Buffer Full) flag is equal to 1.

SPIRB: Read buffer. The buffer will be updated, as the 8-bit shifting is completed. The data must be read before the next reception is finished. The RBF flag is cleared as the SPIRB register is read.

SPIWB: Write buffer. The buffer will deny any write until the 8-bit shifting is completed. The SPIS bit will be kept in 1 if the communication is still undergoing. This flag must be cleared as the shifting is finished. Users can determine if the next write attempt is available.

SBR2~SBR0: Programming the clock frequency/rates and sources.

Edge Select: Selecting the appropriate clock edges by programming the CES bit.

9.6.2 Signal & Pin Description

The three pins, SDI, SDO, and SCK, which are shown in Fig. 9-1, will be explained in details as follows:

SDI:

- SDI: Serial Data In
- Serial Data In
- Receive serially
- Defined as high-impedance, if not selected.

- Programmed the same clock rate and the same clock edge to latch on both the master device and slave device.
- The received byte will replace the corresponding transmitted byte.
- The RBFIF bit will be set, as the SPI operation is completed.
- Timing is shown in Fig. 9-2.

SCK:

- Serial Clock.
- Generated by a master device.
- Synchronize the data communication on both the SDI pin and the SDO pin.
- The CES used to select the edge to communicate.
- The SBR0~SBR2 used to determine the baud rate of communication.
- The ES, SBR0, SBR1, and SBR2 bit have no effect in the slave mode.
- Timing is shown in Fig. 9-2

SDO:

- Serial Data Out
- Transmit serially
- Programmed the same clock rate and the same clock edge to latch on both the master device and slave device.
- The received byte will replace the transmitted byte.
- The SPIS bit will be reset, as the SPI operation is completed.
- Timing is shown in Fig. 9-2.

10 Analog to Digital Converter (ADC)

The analog-to-digital circuitry consists of one 16-to-1 multiplexer, two control registers (ADCAIS and ADCCR), one data register (ADDATA) and one ADC calculator with 8-bit resolution. The functional block diagram of the ADC is shown in Fig. 10. Port D [7:0] and Port E [7:0] can be selected as either normal digital I/O ports or analog input ports. A maximum of 16 analog input pins can be selected by ADCAIS register [5:3], IMS3 ~IMS0 bits. Control bits, AIPS3 ~ AIPS0, of ADCCR [3:0] are then used to select the ADC input channel that will supply analog signal to ADC calculator. CKR2 ~ CKR0 control bits are used to select the desired conversion rate. The ADC module, then, utilizes successive approximation to convert the unknown analog signal into an 8-bit digital output value. Finally, the 8-bit result is fed to the ADDATA register. If the ADC interrupt is enabled, the ADC interrupt flag will be set to “1” as the analog-to-digital conversion is completed.

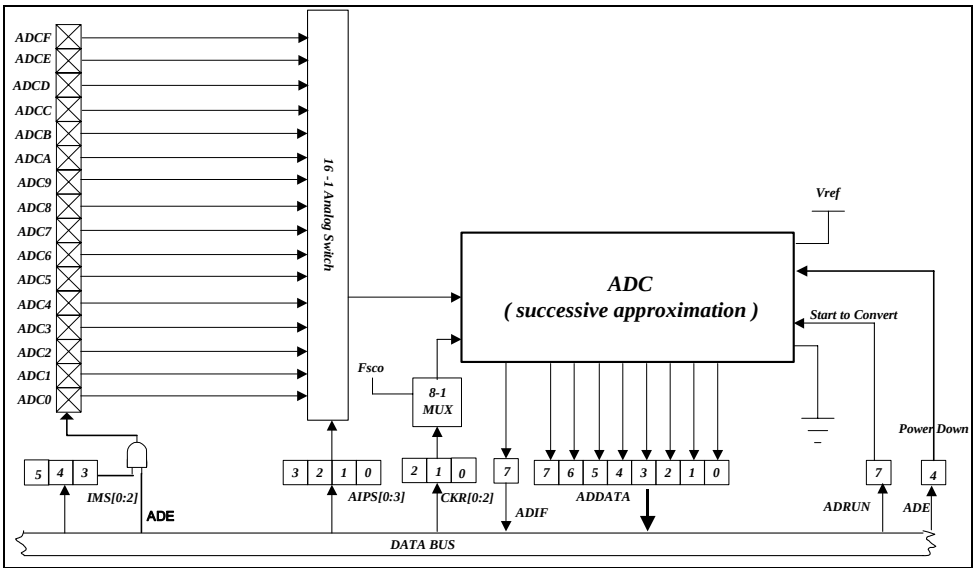


Fig.10 Analog-to-Digital Conversion Functional Block Diagram

10.1 ADC Control Registers

As the ADC mode is defined, the related registers of this operation are shown below:

INTF (0X11): Interrupt flag,

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADIF	RBFIF	PWM1IF	PWM0IF	EINT1F	EINT0F	TCCOF	FRCOF

ADDATA (0x1F): ADC 8-bit data.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADD7	ADD6	ADD5	ADD4	ADD3	ADD2	ADD1	ADD0

When the A/D conversion is completed, Bit 7 ~ Bit 0 are loaded to the ADDATA [7:0]. The ADCRUN bit is cleared, and the ADIF is set.

PRIE (0x80): Peripherals enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPIE	-	BBE	ADE	PWM1E	PWM0E	TCCE	FRCE

ADCAIS (0x96): ADC analog input pin select and conversion rate select.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	IMS2	IMS1	IMS0	CKR2	CKR1	CKR0

IMS2~IMS0 (Bit 2 ~ Bit 4): ADC configuration definition bit.

IMS	PTE 7	PTE 6	PTE 5	PTE 4	PTE 3	PTE 2	PTE 1	PTE 0	PTD 7	PTD 6	PTD 5	PTD 4	PTD 3	PTD 2	PTD 1	PTD 0
ADC	F	E	D	C	B	A	9	8	7	6	5	4	3	2	1	0
000	A	A	D	D	D	D	D	D	D	D	D	D	D	D	D	D
001	A	A	A	A	D	D	D	D	D	D	D	D	D	D	D	D
010	A	A	A	A	A	A	D	D	D	D	D	D	D	D	D	D
011	A	A	A	A	A	A	A	A	D	D	D	D	D	D	D	D
100	A	A	A	A	A	A	A	A	A	A	D	D	D	D	D	D
101	A	A	A	A	A	A	A	A	A	A	A	A	D	D	D	D
110	A	A	A	A	A	A	A	A	A	A	A	A	A	A	D	D
111	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A	A

CKR2~CKR0 (Bit 2 ~ Bit 0): AD conversion Rate control bits.

CKR2: CKR1: CKR0	Divided Rate	A/D Conversion Rate Unit: kHz			
		6MHz Clock Source	12MHz Clock Source	24MHz Clock Source	48MHz Clock Source
000	÷ 2	250	500	1000	2000
001	÷ 4	125	250	500	1000
010	÷ 8	62.5	125	250	500
011	÷ 16	31.3	62.5	125	250
100	÷ 32	15.6	31.3	62.5	125
101	÷ 64	7.8	15.6	31.3	62.5
110	÷ 128	3.9	7.8	15.6	31.3
111	÷ 256	2.0	3.9	7.8	15.6

ADCCRR (0x97): ADC configuration register.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADRUN	ADIE	-	-	AIPS3	SIPA2	AIPS1	AIPS0

AIPS0~AIPS3 (Bits 0~3): Analog Input Select.

0000 = AN0;0001 = AN1; 0010 = AN2;0011 = AN3

0100 = AN4;0101 = AN5; 0110 = AN6;0111 = AN7

1000 = AN8;1001 = AN9; 1010 = ANA;1011 = ANB

1100 = ANC;1101 = AND; 1110 = ANE;1111 = ANF

They can only be changed when the ADIF bit and the ADRUN bit are both LOW.

ADIE (Bit 6): ADC interrupt enable.

ADRUN (Bit 7): ADC starts to RUN

0 = reset on completion of the conversion; this bit cannot be reset by software.

1 = an A/D conversion is started; this bit can be set by software.

10.2 Programming Steps/Considerations

Follow these steps to obtain data from the ADC:

1. Set ADC function power on (PRIE.ADE).
2. Write to the three bits (IMS2:IMS0) on the ADCCR register to define the characteristics of PD and PF: Digital I/O, analog channels, and voltage reference pin;
3. Write to the ADCAIS register to configure ADC module:
   i Select ADC input channel (AIPS3: AIPS0)
   ii Define ADC conversion clock rate (CKR2: CKR1: CKR0)
4. Set ADC interrupt enable (ADCCR.ADIE). Include the “ENI” instruction, if the interrupt function is employed.
5. Set the ADRUN bit to 1 to begin sampling.
6. Wait for either the interrupt flag to be set or the ADC interrupt to occur.
7. Read the conversion data register ADDATA.
8. Clear the interrupt flag bit (INTF.ADIF).
9. For next conversion, go to Step 2 or Step 3 as required. At least 2Tct is required before the next acquisition starts.

NOTE

To obtain an accurate value, it is necessary to avoid any data transition on the I/O pins during AD conversion.

11 Dual Pulse Width Modulations (PWM0 and PWM1)

11.1 Overview

The EM77950 has two built-in PWM outputs with 16-bit resolution. Fig.11-1 shows the functional block diagram. A PWM output has a period and a duty cycle, and it keeps the output high. The baud rate of the PWM is the inverse of the period. Fig. 11-2 depicts the relationships between a period and a duty cycle.

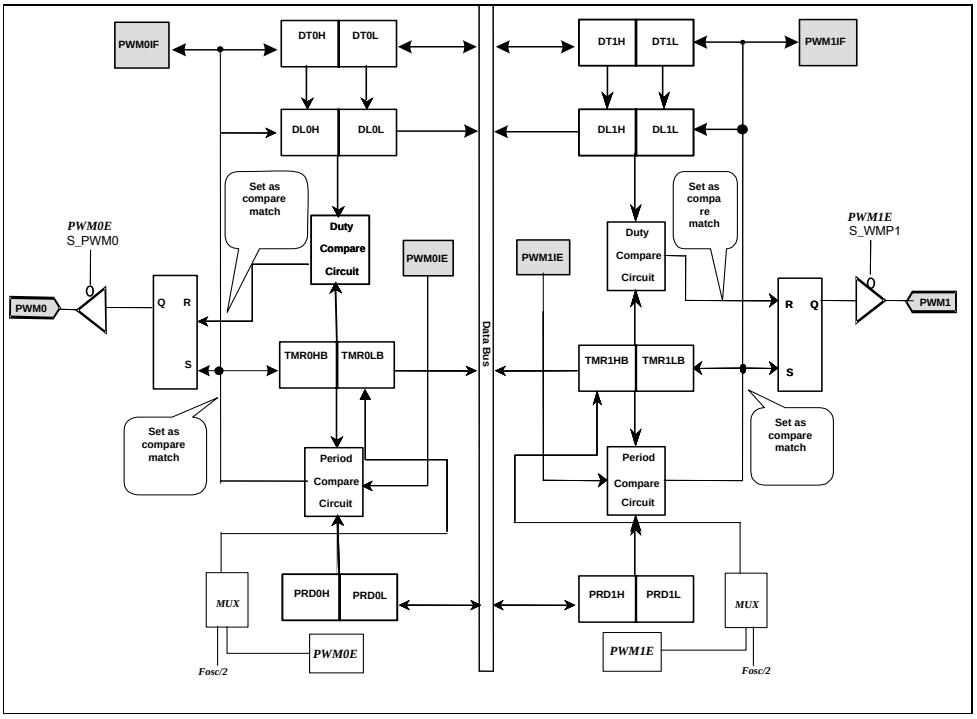


Fig. 11-1 The Functional Block Diagram of the Dual PWM

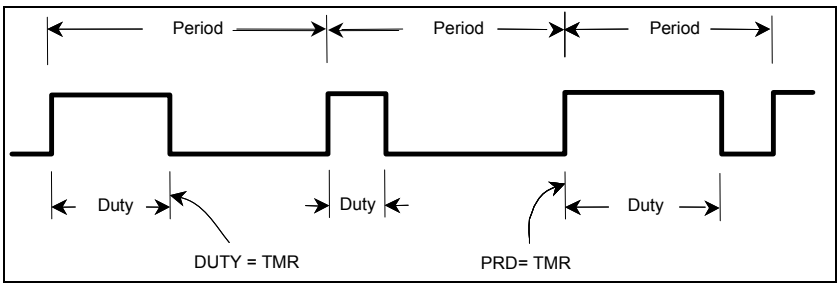


Fig. 11-2 PWM Output Timing Diagram

11.2 PWM Control Registers

As the PWM mode is defined, the related registers of this operation are shown below:

INTF (0x11): Interrupt flag

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADIF	RBFIF	PWM1IF	PWM0IF	EINT1F	EINT0F	TCCOF	FRCOF

DT0L (0x21): Duty of PWM0 low byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DT07	DT06	DT05	DT04	DT03	DT02	DT01	DT00

DT0H (0x22): Duty of PWM0 high byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DT0F	DT0E	DT0D	DT0C	DT0B	DT0A	DT09	DT08

DL0L (0x25): Duty latch of PWM0 low byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DL07	DL06	DL05	DL04	DL03	DL02	DL01	DL00

DL0H (0x26): Duty latch of PWM0 high byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DL0F	DL0E	DL0D	DL0C	DL0B	DL0A	DL09	DL08

DT1L (0x27): Duty of PWM1 low byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DT17	DT16	DT15	DT14	DT13	DT12	DT11	DT10

DT1H (0x28): Duty of PWM1 high byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DT1F	DT1E	DT1D	DT1C	DT1B	DT1A	DT19	DT18

DL1L (0x2B): Duty latch of PWM1low byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DL17	DL16	DL15	DL14	DL13	DL12	DL11	DL10

DL2H (0x2C): Duty latch of PWM1 high byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
DL1F	DL1E	DL1D	DL1C	DL1B	DL1A	DL19	DL18

The PWM duty cycle is defined by writing to the DTX register, and is latched from DTX to DLX while TMRX is cleared. When DLX is equal to TMRX, the PWMX pin is cleared. DTX can be loaded at any time. However, it cannot be latched into DLX until the current value of DLX is equal to TMRX.

The following formula describes how to calculate the PWM duty cycle:

Duty Cycle = (DTX+1) * (2/Fosc)

PRD0L (0x23): Period of PWM0 low byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PRD07	PRD06	PRD05	PRD04	PRD03	PRD02	PRD01	PRD00

PRD0H (0x24): Period of PWM0 high byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PRD0F	PRD0E	PRD0D	PRD0C	PRD0B	PRD0A	PRD09	PRD08

PRD1L (0x29): Period of PWM1 low byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PRD17	PRD16	PRD15	PRD14	PRD13	PRD12	PRD11	PRD10

PRD1H (0x2A): Period of PWM1 high byte

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PRD1F	PRD1E	PRD1D	PRD1C	PRD1B	PRD1A	PRD19	PRD18

The PWM period is defined by writing to PRDX. When TMRX is equal to PRDX, the following events occur on the next increment cycle:

- TMRX is cleared.
- The PWMX pin is set to 1.
- The PWMX duty cycle is latched from DTPS to DUTY.

NOTE

The PWMX will not be set, if the duty cycle is 0;

- The PWMXIF pin is set to 1.
- The following formula describes how to calculate the PWM period:

Period = (PRD +2) * (2/Fosc)

The function of PWM must be disabled before a new period being executed. In other word, bit PWMXE has to be reset by advance, if the contents of PRDX are reloaded.

PRIE (0x80): Peripherals enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPIE	-	BBE	ADE	PWM1E	PWM0E	TCCE	FRCE

INTE (0x81): Interrupt enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GIE	RBFIE	PWM1IE	PWM0IE	EINT1E	EINT0E	TCCOE	FRCOE

PWMCR (0x98): PWM control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	S_PWM1	S_PWM0	-	-

11.3 PWM Programming Procedures/Steps

(1) Load PRDX with the PWMX period.

(2) Load DTX with the PWMX Duty Cycle.

(3) Enable the interrupt function by setting PWMXIE in the INTE register, if required.

(4) Set the PWM pin as output by setting PWMCR.S_PWMX.

(5) Enable the PWM function by setting PWMXE bit in the PRIE register.

(6) Write the desired new duty to DTX before TMRX is equal to PRDX, then this new DTX will be latched into DLX if various duty cycle is required for the next PWMX operation.

(7) Clear PWMXE bit and write the desired new period to PRDX, then enable it again if various periods are required for the next PWMX operation.

(8) Clear the PWMXIF before the next operation if interrupt PWMXIE is employed.

12 Interrupts

12.1 Introduction

The EM77950 has 15 interrupt sources. By priority, these interrupts are classified into two levels, namely; peripherals and base band, as described in the following:

The interrupt status registers record the interrupt requests in the corresponding control bits in the interrupt control registers. The global interrupt (GIE) is enabled by the ENI instruction and is disabled by the DISI instruction. The interrupt flag bit must be cleared by instructions before leaving the interrupt service routine to avoid recursive interrupts.

The flags in the Interrupt Status Register are set regardless of the status of their corresponding mask bits or the execution of DISI. Note that the logic AND of an interrupt flag and its corresponding interrupt control bit is 1 which makes the program counter point to the right interrupt vector. Refer to Fig. 12-1. The RETI instruction ends the interrupt routine and enables the global interrupt (the execution of ENI).

Before the interrupt subroutine is executed, the contents of ACC, SR and ROMPS will be saved by the hardware. After the interrupt service routine is finished, ACC, SR and ROMPS will be pushed back.

In EM77950, individual interrupt sources have their own interrupt vectors, depicted in the following table:

No	Mnemonic		Priority	Vector	Function	Mask		Status	
	Mask	Status				Register	Bit	Register	Bit
1	KWUAE KWUBE	KWUAIF KWUBIF	1	0x10	Key Wake up	0x82 0x83	3~0 All	0x12 013	3~0 All
2	EINT0E EINT1E	EINT0F EINT1F	1	0x18	External Interrupt	0x81	2 3	0x11	2 3
3	FRCOE	FRCOF	1	0x20	FRC Overflow	0x81	0	0x11	0
4	TCCOE	TCCOF	1	0x28	TCC Overflow	0x81	1	0x11	1
5	RBFIE	RBFIF	1	0x30	Read Buffer Full of SPI	0x81	6	0x11	6
6	ADCIE	ADCIF	1	0x38	ADC complete	0x80	4	0x11	7
7	PWM0IE PWM1IE	PWM0IF PWM1IF	1	0x40	PWM period complete	0x81	4 5	0x11	4 5
8	CSDE	CSDF	2	0x48	Carrier sense interrupt	0x99	7	0x30	7
9	TX_AEE	TX_AEF	2	0x50	TX FIFO almost empty	0x99	6	0x30	6
10	RX_AFE	RX_AFF	2	0x58	RX FIFO almost full	0x99	5	0x30	5
11	TX_EMPTY	TX_EMPTYF	2	0x60	TX FIFO empty	0x99	4	0x30	4
12	RX_OFE	RX_OFF	2	0x68	RX FIFO overflow	0x99	3	0x30	3
13	LINK_DIS	LINK_DIS	2	0x70	LINK_DIS interrupt	0x99	2	0x30	2
14	LOCK_OUTE	LOCK_OUTF	2	0x78	Lock out interrupt	0x99	1	0x30	1
15	LOCK_INE	LOCK_INF	2	0x80	Lock in interrupt	0x99	0	0x30	0

The interrupt priority is another useful feature provided by this IC. The latest interrupt, which has the highest priority than the others, will override and hold the currently executed interrupt until the interrupt is finished. Otherwise, the latest interrupt will be in queue right after all its peers.

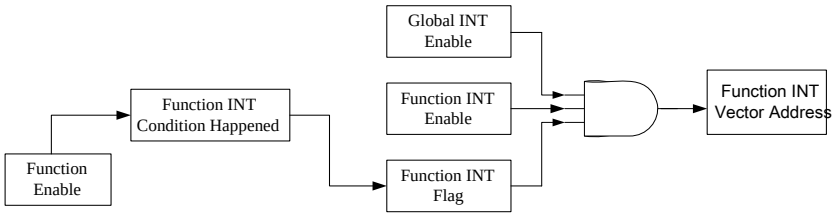


Fig. 12 Block Diagram of Interrupts

13 Circuitry of Input and Output Pins

13.1 Introduction

The EM77950 has six parallel ports, namely Port A, Port B, Port C, Port D, Port E and Port F. There are 40 available I/O pins. A control bit defines the configuration of its corresponding pin. Refer to Fig. 3.1 for the Pin Assignment.

The I/O registers, from Port A to Port F, are bidirectional tri-state I/O ports. The I/O ports can be defined as "input" or "output" pins by the I/O control registers (IOCA, IOCB, IOCD, IOCE and IOCF) under program control. The I/O registers and I/O control registers are both readable and writable.

14 Timer/Counter System

14.1 Introduction

The EM77950 provides two timer modules: 8-bit TCC (Timer Clock/Counter), and 16-bit FRC (Free Run Counter). The clock sources of TCC come from one of the instruction cycles and low frequency oscillator (IRC). The clock source of FRC is from either the instruction cycle or low frequency oscillator (IRC).

14.2 Time Clock Counter (TCC)

An 8-bit counter is available as prescaler for the TCC. The prescaler ratio is determined by the PS0~PS2 bits. When in TCC mode, the prescaler is cleared each time an instruction writes to the TCC.

- TCC is an 8-bit timer/counter. If the TCC signal source is from the system clock, TCC will be incremented by 1 for every instruction cycle (without prescaler).
- If the TCC signal source is from the IRC clock input, TCC will be incremented by 1 on every falling edge or rising edge of the TCC pin.
- The prescaler counter (PRC) can be read from Address 0x0F. In other words, the combination of TCC and PRC can be used as a 16-bit counter without prescaler

14.2.1 Block Diagram of TCC

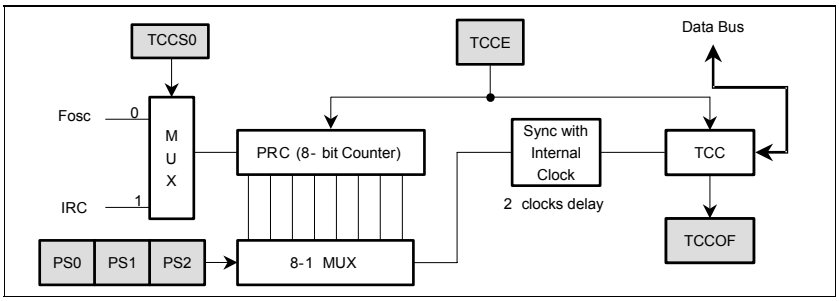


Fig. 14-1 Function Block Diagram of TCC

14.2.2 TCC Control Registers

As the TCC mode is defined, the related registers involved in this operation are shown below:

PRC (0x0F): Prescale counter.

TCC (0x10): Timer clock/counter.

INTF (0x11): Interrupt flag.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADIF	RBFIF	PWM1IF	PWM0IF	EINT1F	EINT0F	TCCOF	FRCOF

PRIE (0x80): Peripherals enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPIE	-	BBE	ADE	PWM1E	PWM0E	TCCE	FRCE

INTE (0x81): Interrupt enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GIE	RBFIE	PWM1IE	PWM0IE	EINT1E	EINT0E	TCCOE	FRCOE

TCCC (0x93): Timer clock/counter control.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	-	-	-	TCCS0	PS2	PS1	PS0

14.2.3 TCC Programming Procedures/Steps

(1) Load TCCC with the prescaler and TCC clock source.

(2) Load TCC with the TCC overflow period.

(3) Enable the interrupt function by setting TCCOE in the INTE register, if required.

(4) Enable the TCC function by setting the TCCE bit in the PRIE register.

(5) Wait for either the interrupt flag to be set (TCCOF) or the TCC interrupt to occur.

(6) The following formula describes how to calculate the TCC overflow period:

$$TCC\ \ Timer = \left(0 \times 100 - TCC\right)\ \times\ \Pr escaler\ \left(\frac{1}{ClockSource}\right)$$

where ***Clock Source = Fosc or IRC***

14.3 Free Run Counter

Dual 8-bit counters, high byte register and low byte register, make up the 16-bit software programmable counter. The driving clock source is either the system clock divided by 2 or the low frequency oscillator. A read of the low byte register allows full control of the corresponding timer function. On the contrary, accessing a high byte register will inhibit the specific timer function until the corresponding low byte is read as well.

14.3.1 Block Diagram of FRC

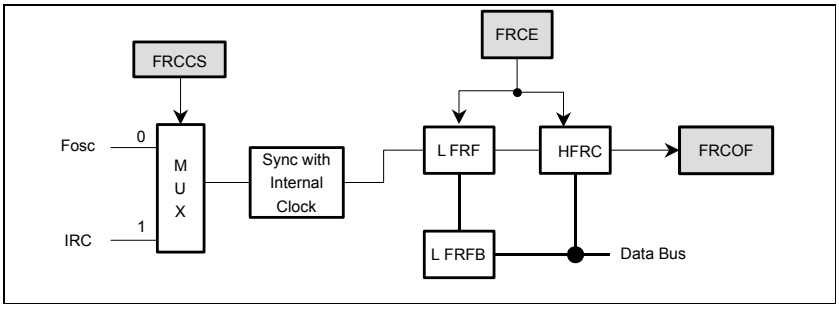


Fig. 14-2 Function Block Diagram of Timer 1

14.3.2 FRC Control Registers

As the FRC mode is defined, the related registers of this operation are shown below:

INTF (0x11): Interrupt flag.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADIF	RBFIF	PWM1IF	PWM0IF	EINT1F	EINT0F	TCCOF	FRCOF

LFRC (0x1A): Least significant byte of 16-bit free run counter.

HFRC (0x1B): Most significant byte of 16-bit free run counter.

LFRCB (0x1C): Least significant byte buffer of 16-bit free run counter.

PRIE (0x80): Peripherals enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPIE	-	BBE	ADE	PWM1E	PWM0E	TCCE	FRCE

INTE (0x81): Interrupt enable control

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
GIE	RBFIE	PWM1IE	PWM0IE	EINT1E	EINT0E	TCCOE	FRCOE

FRCC (0x94): Free run counter control.

Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
-	OSCO2E	OSCO2SL1	OSCO2SL0	PPSCL2	PPSCL1	PPSCL0	FRCCS

14.3.3 FRC Programming Procedures/Steps

(1) Load LFRCB with the FRC overflow period low byte.

(2) Load HFRC with the TCC overflow period high byte. Then LFRC will load with the LFRCB automatically.

(3) Enable interrupt function by setting FRCOE in the INTE register, if required.

(4) Enable FRC function by setting FRCE bit in the PRIE register.

(5) Wait for either the interrupt flag to be set (FRCOF) or the FRC interrupt to occur.

(6) An access of low byte of a 16-bit counter receives the count value at the moment of the read. However, the contents of low byte will transfer to the buffer, the LFRCB register, if a high byte is read first. The value in the LFRCB register remains unchanged until the corresponding low byte is read.

(7) The following formula describes how to calculate the FRC overflow period:

$$FRC\ Timer = \left(\ 0 \times 10000 - HFRC \ : \ LFRC \ \right) \times \left(\frac{1}{ClockSource} \right)$$

where Clock Source = Fosc or IRC

15 Reset and Wake up

15.1 Reset

A reset can be caused by one of the following:

(1) Power-on reset

(2) /RESET pin input "low", or

(3) Watchdog timer time-out (if enabled)

The device will remain in a reset condition for a period of 8-bit external RC ripple counter (one oscillator start-up timer period) after the reset is detected. **The initial Address is 000h.**

15.2 The Status of RST, T, and P of the STATUS Register

A reset condition can be caused by the following events:

(1) A power-on condition (external);

(2) A high-low-high pulse on the /RESET pin (external); and

(3) Watchdog timer time-out (internal).

The values of bits RST, T and P, listed in Table 17.1 can be used to check how the processor wakes up.

Table 17.1 Values of RST, T and P after a reset

Condition	RST	T	P
Power on	0	1	1
WDTC instruction	*P	1	*P
WDT timeout	*P	0	*P
SLEP instruction	*P	*P	0
Wake-Up on pin change during SLEEP mode	1	1	0

*P: Previous status before reset

15.3 System Set-up Time (SST)

In order to have a successful start up, System Set-up Time (SSU) is employed to guarantee a stable clock for IC operation. It is made up of two delay sources:

(1) Internal RC Oscillation Set-up Delay (IRCOSUD): Internal RC oscillation shared with a watchdog timer divided by an 8-bit ripple counter.

(2) Main Oscillation Set-up Delay (MOSUD): A 10-bit ripple counter is used to filter unstable main clocks at the beginning of power-on before the chip starts to run. This delay is performed right after IRCOSUD, if enabled

$$SST = \left(\frac{1}{32.768K}\right) \times 2^8 + \left(\frac{1}{Main\ Clock}\right) \times 2^{10}$$

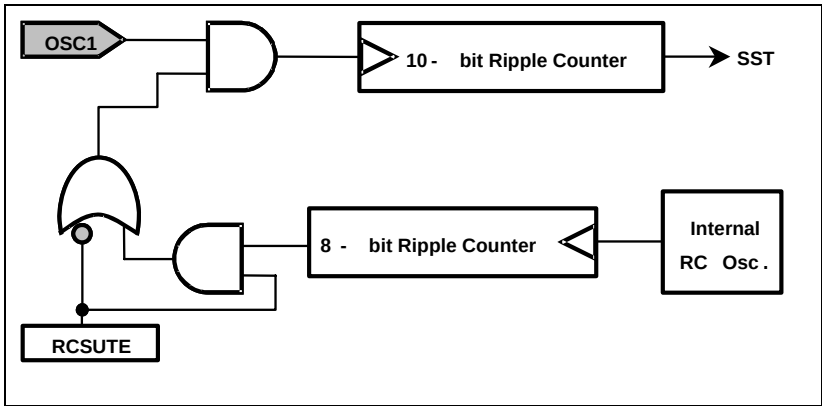


Fig. 15 System Set-up Time

15.4 Wake-up Procedure on Power-on Reset

Power-on Voltage Detector (POVD) will allow the VDD whose value is over the default threshold voltage (2.0 V for the EM77950) to enter the IC, and the SST delay starts.

The following three cases may be taken into consideration:

(1) /RESET pin goes high with VDD at the same time. In hardware, this pin and VDD are tied together. The internal reset will remain low until the SST delay is over.

(2) /RESET pin goes high during the SST delay. It is similar to Case 1. The IC will start to operate when the SST delay is over.

/RESET pin goes high after an SST delay. The EM77950 will start program execution immediately

16 Oscillators

16.1 Introduction

The EM77950 provides three main oscillators: One high frequency crystal oscillator (connected to OSCI and OSCO), internal RC, and four PLL (Phase Lock Loop) outputs. Versatile combinations of oscillation are provided for a wide range of applications. On-chip clock sources can be either dual clocks or single clock.

16.2 Clock Signal Distribution

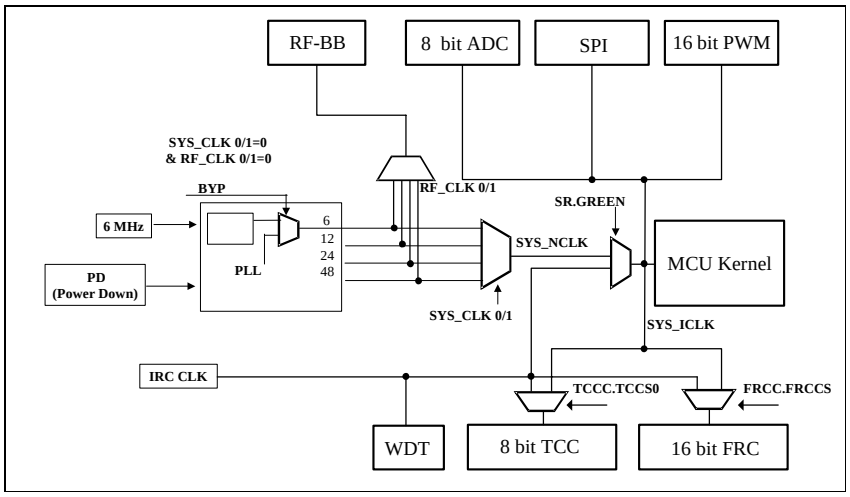


Fig. 16 Clock Tours

16.3 PLL Oscillator

The Phase-locked loop (PLL) technology is employed to produce four different frequencies: 6 MHz, 12MHz, 24MHz and 48 MHz (external 6MHz crystal). Setting the SYS_CLK bits can select the system clock source. PLL is enabled except when entering Green and Sleep mode.

16.4 Selected PLL Oscillation out

As shown in register FRCC (0x94), EM77950 can output the selected PLL frequency divided by the prescaler. Once the pin is enabled as a PLL clock out, the output frequency can be implemented by the peripherals of the chip. If disabled, this pin is used as pin PF0, a general purpose I/O pin.

17 Low-Power Mode

17.1 Introduction

The EM77950 has two power-saving modes, green mode and sleep mode. Figure 17 shows the mode change diagram.

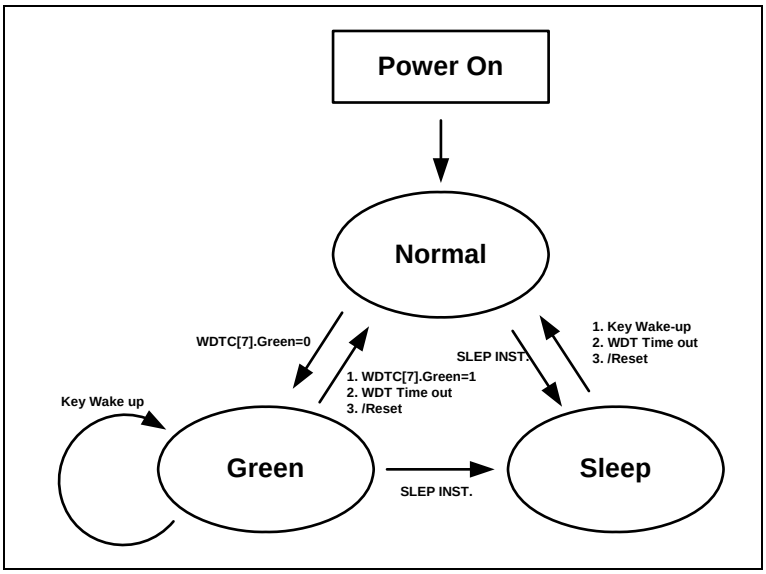


Fig. 17 Three-Mode State

17.2 Green Mode

The “GREEN” bit of WDTC [7] register is the only control bit used for mode switching between normal mode and green mode. Its initial value is “0”, normal mode. When “GREEN” bit is written with a 1, the MCU will switch to green mode from normal mode. In contrast, the MCU will go back to normal mode when the “GREEN” bit is written from 1 to 0. During green mode, the main oscillator and PLL will be turned off. The MCU and all the peripherals are driven by the internal RC oscillator - IRC.

Once BB peripheral is functional and then switched into green mode, the clock source of all other peripherals, except PLL, will be provided by IRC. PLL will keep running as BB circuit’s clock source.

17.3 Sleep Mode

The execution of “SLEP” instruction will turn the whole chip into Sleep mode. The main clock will be shut down. The IRC oscillator is halted also if the watchdog function is disabled. All registers, memory and I/O port remain in their previous states during sleep mode. The overflow of the watchdog timer driven by IRC will generate a reset to resume normal operation. Key Wake up (KWU) interrupt and /RESET pin are other methods to exit sleep mode. It is essential to wait for stable Oscillation start-up time before normal operation. The stabilizing time is SST.

18 Instruction Description

18.1 Instruction Set Summary

Type	Binary Instruction				Mnemonic	Operation	Status Affected	Cycles
System Control	0000	0000	0000	0000	NOP	No operation	None	1
	0000	0000	0000	0001	WDTC	WDT ← 0	None	1
	0000	0000	0000	0010	RET	PC ← (Top of Stack)	None	1
	0000	0000	0000	0011	RETI	PC ← (Top of Stack); Enable Interrupt	None	1
	0000	0000	0000	0100	SLEP	WDT ← 0 Stop oscillator	None	1
	0000	0000	0000	0101	ENI	Enable Interrupt	None	1
	0000	0000	0000	0110	DISI	Disable Interrupt	None	1
	0000	0000	0000	0111	DAA	Decimal Adjust A	C	1
Table Look up	1010	0000	rrrr	rrrr	TBRDP r	r ← ROM[(TABPT[15:1])] TABPT ← TABPT+1	None	2
	1010	0001	rrrr	rrrr	TBRD r	r ← ROM[(TABPT[15:1])]	None	2
	1010	0010	rrrr	rrrr	TBRDM r	r ← ROM[(TABPT[15:1])] TABPT ← TABPT-1	None	2
	0000	0000	0000	1010	TBRDP A	A ← ROM[(TABPT[15:1])] TABPT ← TABPT+1	None	2
	0000	0000	0000	1011	TBRD A	A ← ROM[(TABPT[15:1])]	None	2
	0000	0000	0000	1100	TBRDM A	A ← ROM[(TABPT[15:1])] TABPT ← TABPT-1	None	2
	0011	1101	0000	0010	TBL	R2 ← R2+A	C, DC, Z	1
	1010	1011	kkkk	kkkk	RETL #k	A ← k PC ← [Top of Stack]	None	1
Logic	0000	0001	rrrr	rrrr	OR A, r	A ← A .or. r	Z	1
	0000	0010	rrrr	rrrr	OR r, A	r ← r .or. A	Z	1
	0000	0011	kkkk	kkkk	OR A, #k	A ← A .or. k	Z	1
	0000	0100	Rrrr	rrrr	AND A, r	A ← A .and. r	Z	1
	0000	0101	Rrrr	rrrr	AND r, A	r ← r .and. A	Z	1
	0000	0110	kkkk	kkkk	AND A, #k	A ← A .and. k	Z	1
	0000	0111	Rrrr	rrrr	XOR A, r	A ← A .xor. r	Z	1
	0000	1000	rrrr	rrrr	XOR r, A	r ← r .xor. A	Z	1
	0000	1001	kkkk	kkkk	XOR A, #k	A ← A .xor. k	Z	1
	0000	1010	rrrr	rrrr	COMA r	A ← /r	Z	1
	0000	1011	rrrr	rrrr	COM r	r ← /r	Z	1
	1011	00kk	rrrr	rrrr	RRCA r, #k	[C,r] rotate right k bits to [C,A]	C	1
	1011	01kk	rrrr	rrrr	RRC r, #k	[C,r] rotate right k bits to [C,r]	C	1
	1011	10kk	rrrr	rrrr	RLCA r, #k	[C,r] rotate left k bits to [C,A]	C	1
	1011	11kk	rrrr	rrrr	RLC r, #k	[C,r] rotate left k bits to [C,r]	C	1
	0101	10kk	rrrr	rrrr	SHRA r, #k	[C,r] shift right k bits to A Insert C into high order bits	None	1
	0101	11kk	rrrr	rrrr	SHLA r, #k	[C,r] shift left k bits to A Insert C into low order bits	None	1

Type	Binary Instruction				Mnemonic	Operation	Status Affected	Cycles
Compare Branch	0001 xxaa	0bbb aaaa	rrrr aaaa	rrrr aaaa	JBC r,b,addr	If r(b)=0, jump to addr	None	2/3
	0001 xxaa	1bbb aaaa	rrrr aaaa	rrrr aaaa	JBS r,b,addr	If r(b)=1, jump to addr	None	2/3
	0101 xxaa	0010 aaaa	rrrr aaaa	rrrr aaaa	DJZA r,addr	A ←r-1, jump to addr if zero	None	2/3
	0101 xxaa	0011 aaaa	rrrr aaaa	rrrr aaaa	DJZ r,addr	r ←r-1, jump to addr if zero	None	2/3
	0101 xxaa	0100 aaaa	rrrr aaaa	rrrr aaaa	JZA r,addr	A←r+1, jump to addr if zero	None	2/3
	0101 xxaa	0101 aaaa	rrrr aaaa	rrrr aaaa	JZ r,addr	r ←r+1, jump to addr if zero	None	2/3
Process	0010	0bbb	rrrr	rrrr	BC r,b	r(b) ← 0	None	1
	0010	1bbb	rrrr	rrrr	BS r,b	r(b) ← 1	None	1
	0011	0bbb	rrrr	rrrr	BTG r,b	r(b) ← /r(b)	None	1
	0011	1000	rrrr	rrrr	SWAP r	r(0:3) ↔ r(4:7)	None	1
	0011	1001	rrrr	rrrr	SWAPA r	A(4:7) ← r(0:3) A(0:3) ← r(4:7)	None	1
	1010	1100	rrrr	rrrr	ZCHK r	Z ← 0 if r < > 0 Z ← 1 if r = 0	Z	1
	0000	0000	0000	1101	RPT	Single repeat CS times on next TBRD instruction	None	1
	1010	1111	rrrr	rrrr	CLR r	r ← 0	Z	1
Arithmetic	0011	1100	rrrr	rrrr	ADD A,r	A ← A+r	C, DC, Z	1
	0011	1101	rrrr	rrrr	ADD r,A	r ← r+A	C, DC, Z	1
	0011	1110	kkkk	kkkk	ADD A,#k	A ← A+k	C, DC, Z	1
	0100	0010	rrrr	rrrr	SUB A,r	A ← r-A	C, DC, Z	1
	0100	0011	rrrr	rrrr	SUB r,A	f ← r-A	C, DC, Z	1
	0100	0100	kkkk	kkkk	SUB A,#k	A ← k-A	C, DC, Z	1
	0100	1110	rrrr	rrrr	INCA r	A ← r+1	C, DC, Z	1
	0100	1111	rrrr	rrrr	INC r	r ← r+1	C, DC, Z	1
	0101	0000	rrrr	rrrr	DECA r	A ← r-1	C, DC, Z	1
	0101	0001	rrrr	rrrr	DEC r	r ← r-1	C, DC, Z	1
Move	1010	1000	rrrr	rrrr	MOV A,r	A ← r	Z	1
	1010	1001	rrrr	rrrr	MOV r,A	r ← A	None	1
	0110	r2 r2 r2 r2	r2 r2 r1 r1	r1 r1 r1 r1	MOVRR r1, r2	Register r1 ← Register r2	None	1
	1010	0111	kkkk	kkkk	MOV A,#k	A ← k	None	1
Branch	110a	aaaa	aaaa	aaaa	JMP addr	PC ← addr PC[13..16] unchange	None	1
	111a	aaaa	aaaa	aaaa	CALL addr	[Top of Stack] ← PC + 1 PC ← addr PC [13..16] unchange	None	1
Bank	1010	1110	0000	0kkk	BANK #k	R4(RAMBS0) ← k (0~6)	None	1
Page	1010	1101	0000	000k	PAGE #k	R5(PAGES) ← k (0~1)	None	1

19 Electrical Specification

19.1 Absolute Maximum Ratings

Temperature under Bias	0°C	to	70°C
Storage temperature	-65°C	to	150°C
Input voltage	-0.3V	to	+3.6V
Output voltage	-0.3V	to	+3.6V

19.2 DC Electrical Characteristic

Ta=0°C ~ 70 °C, VDD=3.3V±5%, VSS=0V

Symbol	Parameter	Condition	Min	Typ	Max	Unit
Fxt	Crystal: VDD ~ 2.75V	One cycle with one clock	DC	–	48.0	MHz
IIL	Input Leakage Current for input pins	VIN = VDD, VSS	–	–	±2	μA
VIH	Input High Voltage	Port A ~ Port F	0.8xVDD	–	–	V
VIL	Input Low Voltage	Port A ~ Port F	VSS	–	0.2xVDD	V
VIHT	Input High Threshold Voltage	/RST	2.0	–	–	V
VILT	Input Low Threshold Voltage	/RST	–	–	0.8	V
VIHX	Clock Input High Voltage	OSCI, OSCO	2.5	–	–	V
VILX	Clock Input Low Voltage	OSCI, OSCO	–	–	1.0	V
VOH1	Output High Voltage: PTA, PTC, PTD, PTE, PTF	IOH = -8.0 mA	2.4	–	–	V
VOH2	Output High Voltage: PTB; RFIO	IOH = -8.0 mA	2.4	–	–	V
VOL1	Output Low Voltage: PTA, PTC, PTD, PTE, PTF	IOL = 8.0 mA	–	–	0.4	V
VOL2	Output Low Voltage: PTB; RFIO	IOL = 8.0 mA	–	–	0.4	V
IPH	Pull-high current	Pull-high active, input pin at VSS	–	-6.5	–	μA
ISB	Power down current	All input and I/O pins at VDD, Output pin floating, WDT enabled.	–	–	2	μA
ISB	Power down current	All input and I/O pins at VDD, Output pin floating, WDT and all peripherals disabled.	–	–	1	μA
ICC1	Operating supply current (VDD = 3.3V)	/RESET = 'High', Fosc = 32kHz (RC type), Output pin floating, WDT and all peripherals disabled.	–	60	–	μA
ICC3	Operating supply current (VDD = 3.3V)	/RESET= 'High', Fosc = 6MHz (Crystal type), Output pin floating, and all peripherals disabled.	–	5	–	mA

19.3 Voltage Detector Electrical Characteristic

Ta=25°C

Symbol	Parameter	Condition	Min	Typ	Max	Unit
Vdet	Detect voltage	–	1.8	2.0	2.2	V
Vrel	Release voltage	–	–	Vdet × 1.05	–	V
Iss	Current consumption	VDD = 3V	–	–	0.8	μA
Vop	Operating voltage	–	0.7*	–	3.5	V
ΔVdet/ΔTa	Vdet Temperature characteristic	0°C ≤ Ta ≤ 70°C	–	–	-2	MV/°C

* When the VDD voltage rises between Vop=0.7V and Vdet, the voltage detector output must be "Low".

19.4 AC Electrical Characteristic

19.4.1 MCU

Ta=0°C ~ 70 °C, VDD=3.3 V±5%, VSS=0V

Ta=0°C ~ 70 °C, VDD=3.3 V±5%, VSS=0V

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
Dclk	Input CLK duty cycle	–	45	50	55	%
Tins	Instruction cycle time (CLKS="0")	Crystal type RC type	125 500	–	DC DC	ns ns
Ttcc	TCC input period	–	(Tins+20)/N*	–	–	ns
Tdrh	Device reset hold time	Ta = 25°C	9	18	30	ms
Trst	/RESET pulse width	Ta = 25°C	2000	–	–	ns
Twdt	Watchdog timer period	Ta = 25°C	9	18	30	ms
Tset	Input pin setup time	–	–	0	–	ms
Thold	Input pin hold time	–	–	20	–	ms
Tdelay	Output pin delay time	Cload=20pF	–	50	–	ms

* N= selected prescaler ratio.

19.4.2 BB

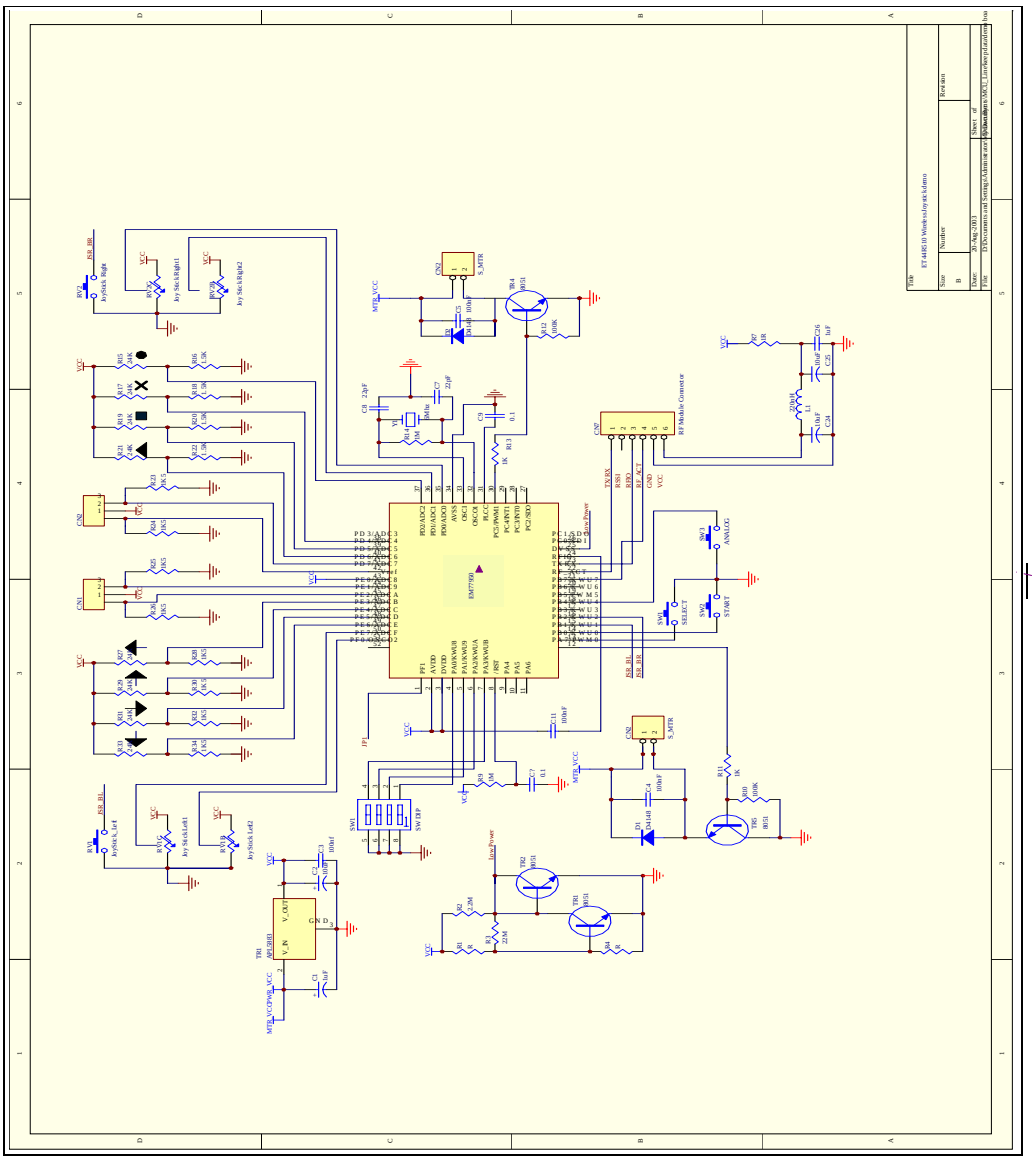
Ta=0°C ~ 70 °C, VDD=3.3 V±5%, VSS=0V

Symbol	Parameter	Min	Max	Unit
1/tOSC	Oscillator frequency	0.1	24	MHz
tRDPW	RD pulse width	3*tOSC+ Δ	–	ns
tCSRD	CS low to RD low	tOSC	–	ns
tADRD	Address valid for RD low	0	–	ns
tRDDV	RD low to Data valid	–	3*tOSC+Δ	ns
tRHDT	Data float after RD.	–	tOSC	ns
tDHAR	Data hold after RD	0	–	ns
tRHDT	Time between consecutive RD pulses	2*tOSC	–	ns
tRDAN	Address valid after RD low	3*tOSC+Δ	–	ns

Δ>0 will be determined according to cell library simulation.

The values above were determined according to behavioral simulations. They take into account only the BB digital state-machine. Thus, such values are for reference only.

20 Application Circuit



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APPENDIX

A Package Type

ET NO	Package Type	Pin count	Package Size
EM77950A	QFP52	52	14×20MM
EM77950B	QFP44	44	10×10MM

B Package Information

