SONiX Technology Co., Ltd.

SN8F5702 Series
Datasheet

8051-based Microcontroller

SN8F5702
SN8F570200
SN8F570202
SN8F570210
SN8F570211
SN8F570212
SN8F570213

1 Device Overview

1.1 Features

- **Enhanced 8051 microcontroller** with reduced instruction cycle time (up to 12 times 80C51)
- Up to 32 MHz flexible CPU frequency
- Internal 32 MHz Clock Generator (IHRC)
- **4 KB non-volatile flash memory (IROM)** with in-system program support
- **256 bytes internal RAM (IRAM)**
- **13 interrupt sources with priority levels control and unique interrupt vectors**
- 12 internal interrupts
- 1 external interrupts: INT0
- 1 set of DPTR
- 2 set 8/16-bit timers with 4 operation modes
- 1 set 16-bit timers with 4 comparison output (PWM) and capture channels
- **1 set 16-bit PWM generators**:
- each PWM generator has 4 output channels with inverters and dead-band control
- **12-bit SAR ADC** with 10 external and 2 internal channels, and 4 internal reference voltages
- **SPI, UART, I2C** interface with SMBus Support
- **On-Chip Debug Support**:
  Single-wire debug interface
  2 hardware breakpoints
  Unlimited software breakpoints
  ROM data security/protection
- Watchdog and programmable external reset
- 1.8/2.4/3.3-V low voltage detectors
- Wide supply voltage (1.8 V – 5.5 V) and temperature (-40 °C to 85 °C) range

1.2 Applications

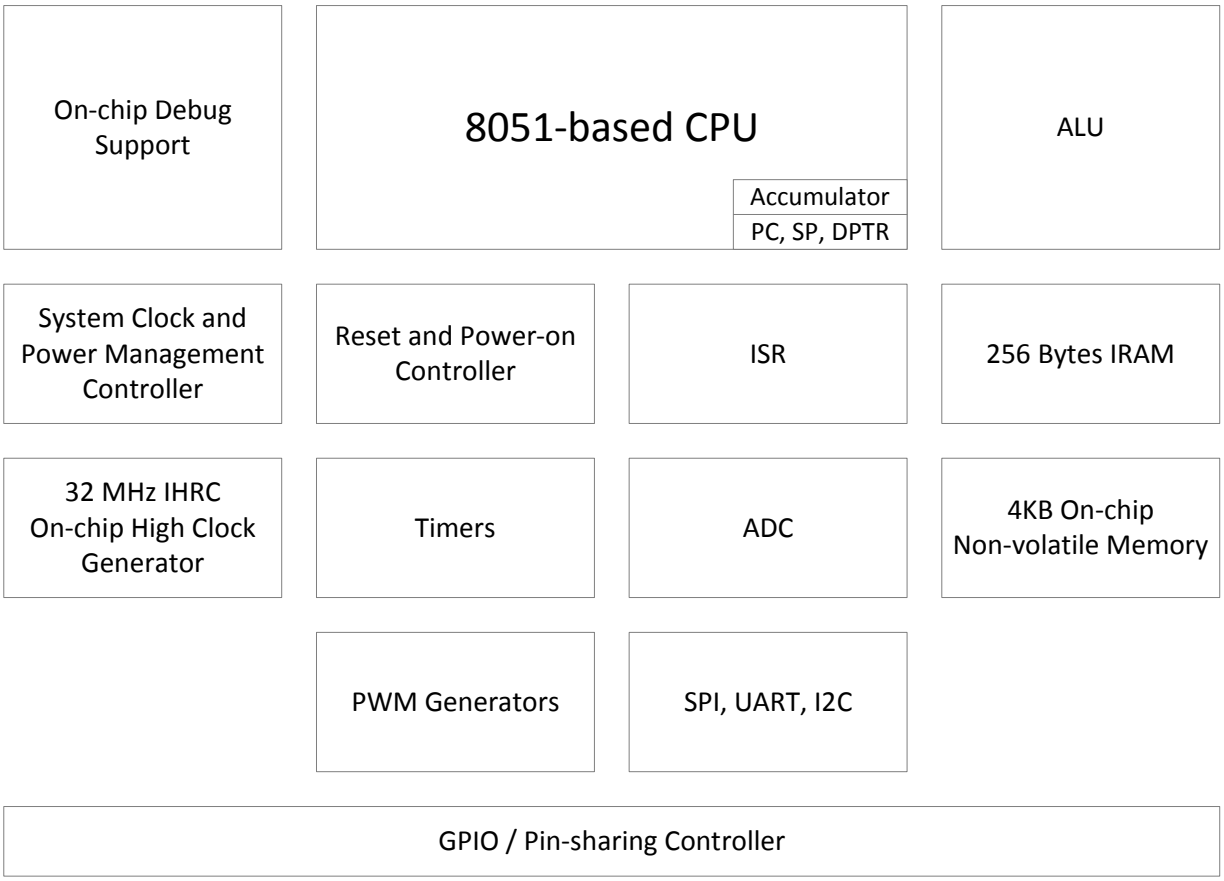
- Brushless DC motor
- Home automation
- Household
- Other

1.3 Features Selection Table

	I/O	PWM Channels	I2C	SPI	UART	ADC ext. Channels	OPA	CMP	Ext. INT	Package Types
SN8F5702	18	8	V	V	V	10	-	-	1	DIP20,SOP20 TSSOP20, QFN20
SN8F570212	14	6	V	V	TX*(1)	8	-	-	1	SOP16,TSSOP16, QFN16
SN8F570210	12	5	-	-	V	6	-	-	1	SOP14
SN8F570211	12	5	V	-	TX*(1)	6	-	-	1	SOP14
SN8F570213	12	5	-	-	V	6	-	-	1	SOP14
SN8F570200	8	3	-	-	TX*(1)	5	-	-	1	MSOP10
SN8F570202	6	3	-	-	TX*(1)	4	-	-	1	SOP8

*(1) Only support UART TX mode.

1.4 Block Diagram



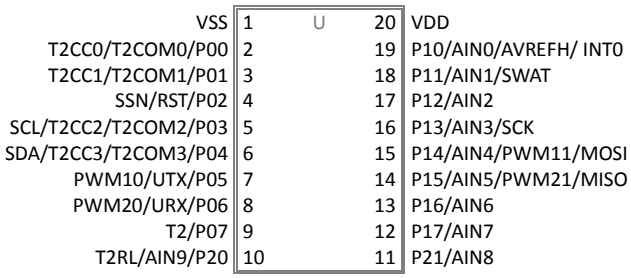
2 Table of Contents

3 Revision History

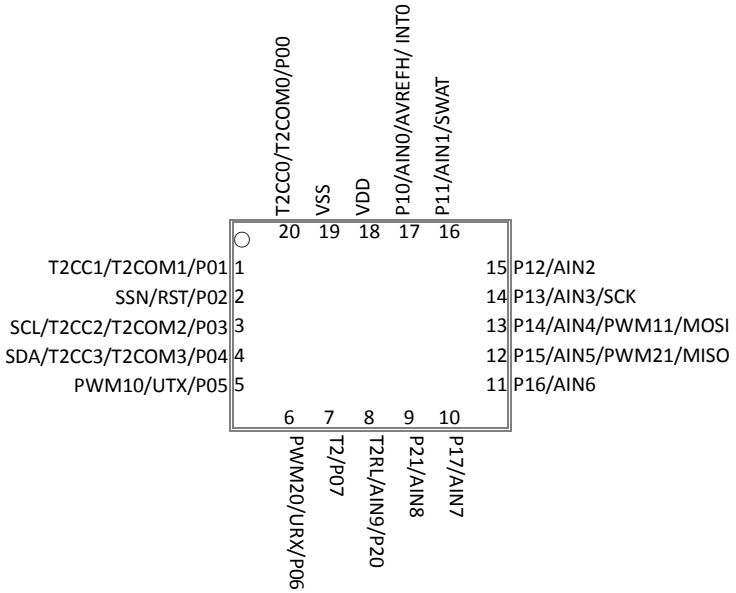
Revision	Date	Description
1.0	Sep. 2015	First issue
1.1	Oct. 2015	1. Modify timer section and electrical characteristic section. 2. Modify SN8F57023/SN8F57024 pin assignment. 3. Add program memory security section, special function register section and noise filter section. 4. Modify minimum requirement in debug interface section. 5. Update electrical characteristics
1.2	Nov. 2015	1. Update package type
1.3	Nov. 2015	1. SN8F57021 was renamed SN8F570210. 2. SN8F57022 was renamed SN8F570200. 3. SN8F57023 was renamed SN8F570211. 4. SN8F57024 was renamed SN8F570212.
1.4	Nov. 2015	1. Modify SN8F570200 pin assignment
1.5	Dec. 2015	1. Modify electrical characteristic in IHRC section. 2. Add power saving description in UART/SPI/I2C section.
1.6	Apr. 2016	1. Add Timer 2 capture function waveform to illustrate operation. 2. Special Function Registers adds Register Declaration section. 3. Add Appendix: Reference Document chapter. 4. Add ROM Programming Pin chapter. 5. Add QFN20 and SOP14 package type.
1.7	Aug. 2016	1. I2C example modify. 2. Modify Power Management section and In-System Program section. 3. Modify PW1M & PW1YH/L registers description. 4. Add SOP8 package type. 5. Add ADC internal reference range.
1.8	Nov. 2016	1. Modify feature table and I2C status code. 2. Add UART Baud Rate Table, WDT description in watchdog reset section and QFN16 package type.
1.9	Dec. 2016	1. Modify electrical characteristic section.

4 Pin Assignments

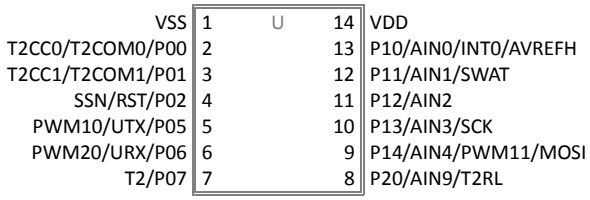
4.1 SN8F5702P/S/T (DIP20/SOP20/TSSOP20)



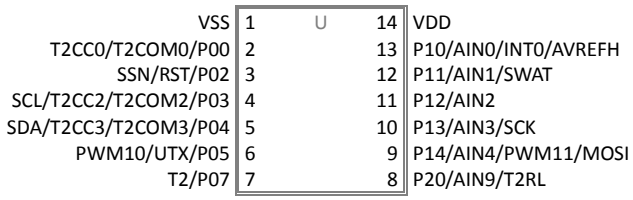
4.2 SN8F5702J (QFN20)



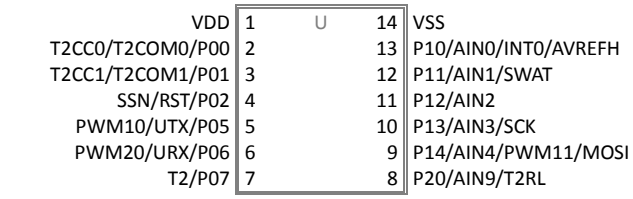
4.3 SN8F570210S (SOP14)



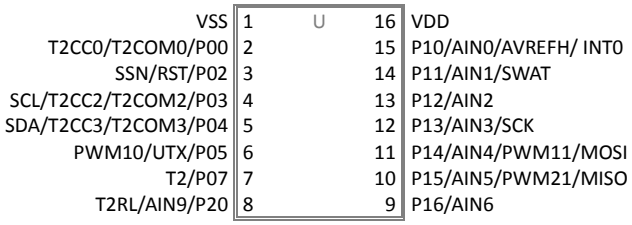
4.4 SN8F570211S (SOP14)



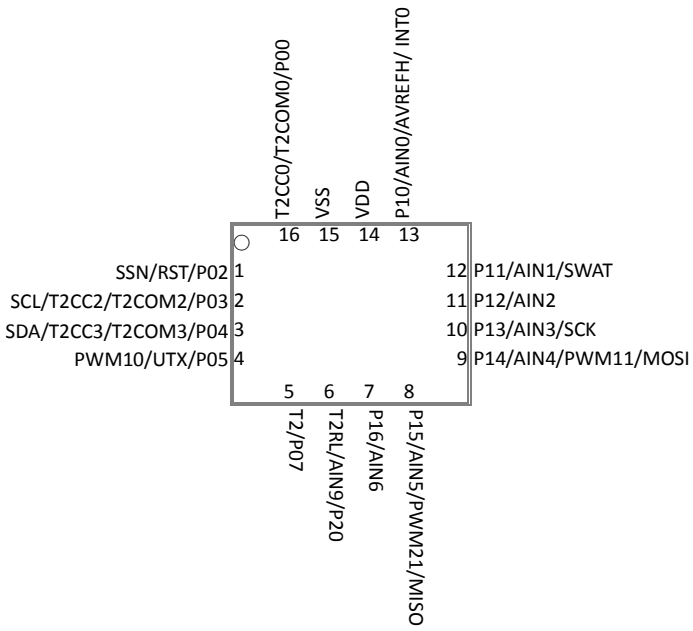
4.5 SN8F570213S (SOP14)



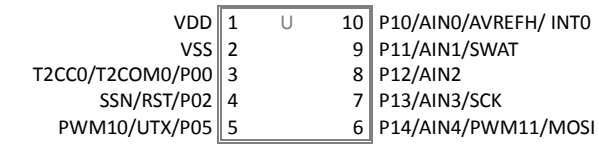
4.6 SN8F570212S/T (SOP16/TSSOP16)



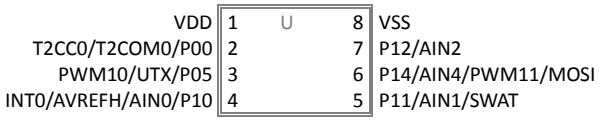
4.7 SN8F570212J (QFN16)



4.8 SN8F570200A (MSOP10)



4.9 SN8F570202S (SOP8)



4.10 Pin Descriptions

Power Pins

Pin Name	Type	Description
VDD	Power	Power supply
VSS	Power	Ground (0 V)

Port 0

Pin Name	Type	Description
P0.0	Digital I/O	GPIO
T2COM0	Digital Output	Timer 2: compare 0 output
T2CC0	Digital Input	Timer 2: capture 0 input
P0.1	Digital I/O	GPIO
T2COM1	Digital Output	Timer 2: compare 1 output
T2CC1	Digital Input	Timer 2: capture 1 input
P0.2	Digital I/O	GPIO
Reset	Digital Input	System reset (active low)
SSN	Digital Input	SPI: salve selection pin (slave mode)
P0.3	Digital I/O	GPIO
T2COM2	Digital Output	Timer 2: compare 2 output
T2CC2	Digital Input	Timer 2: capture 2 input
SCL	Digital I/O	I2C: clock output (master) clock input (slave)
P0.4	Digital I/O	GPIO
T2COM3	Digital Output	Timer 2: compare 3 output
T2CC3	Digital Input	Timer 2: capture 3 input
SDA	Digital I/O	I2C: data pin
P0.5	Digital I/O	GPIO
UTX	Digital Output	UART: transmission pin
PWM10	Digital Output	PWM: programmable PWM output
P0.6	Digital I/O	GPIO
URX	Digital Input	UART: reception pin
PWM20	Digital Output	PWM: programmable PWM output
P0.7	Digital I/O	GPIO
T2	Digital Input	Timer 2: event counter input

Port 1

Pin Name	Type	Description
P1.0	Digital I/O	GPIO
AIN0	Analog Input	ADC: input channel 0
INT0	Digital Input	INT0: external interrupt 0
AVREFH	Analog Input	ADC: external reference voltage
P1.1	Digital I/O	GPIO
AIN1	Analog Input	ADC: input channel 1
SWAT	Digital I/O	Debug interface
P1.2	Digital I/O	GPIO
AIN2	Analog Input	ADC: input channel 2
P1.3	Digital I/O	GPIO
AIN3	Analog Input	ADC: input channel 3
SCK	Digital I/O	SPI: clock output (master) clock input (slave)
P1.4	Digital I/O	GPIO
AIN4	Analog Input	ADC: input channel 4
MOSI	Digital I/O	SPI: transmission pin (master) reception pin (slave)
PWM11	Digital Output	PWM: programmable PWM output
P1.5	Digital I/O	GPIO
AIN5	Analog Input	ADC: input channel 5
MISO	Digital I/O	SPI: reception pin (master) transmission pin (slave)
PWM21	Digital Output	PWM: programmable PWM output
P1.6	Digital I/O	GPIO
AIN6	Analog Input	ADC: input channel 6
P1.7	Digital I/O	GPIO
AIN7	Analog Input	ADC: input channel 7

Port 2

Pin Name	Type	Description
P2.0	Digital I/O	GPIO
AIN9	Analog Input	ADC: input channel 9
T2RL	Digital Input	Timer 2: reload trigger input
P2.1	Digital I/O	GPIO
AIN8	Analog Input	ADC: input channel 8

5 CPU

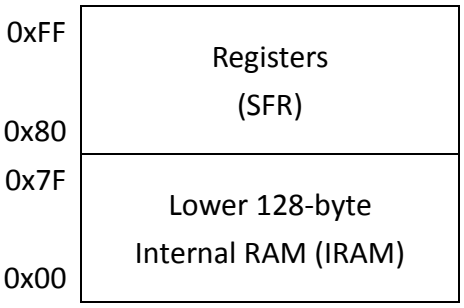
SN8F5000 family is an enhanced 8051 microcontroller (MCU). It is fully compatible with MCS-51 instructions, hence the ability to cooperate with modern development environment (e.g. Keil C51). Generally speaking, SN8F5000 CPU has 9.4 to 12.1 times faster than the original 8051 at the same frequency.

5.1 Memory Organization

SN8F5702 builds in two on-chip memories: internal RAM (IRAM), and program memory (IROM). The internal RAM is a 256-byte RAM which has higher access performance (direct and indirect addressing). The program memory is a 4 KB non-volatile memory and has a maximum 8 MHz speed limitation.

5.2 Direct Addressing: IRAM and SFR

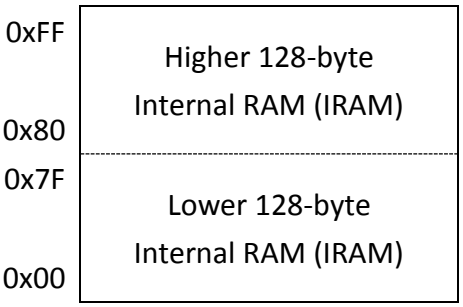
Direct addressing instructions (e.g. MOV A, direct) can access the lower 128-byte internal RAM (address range: 0x00 – 0x7F) and all registers (SFR, address range: 0x80 – 0xFF).



Moreover, the lowest 32 bytes of internal RAM (0x00 – 0x1F) can be seen as four set of R0 – R7 working registers which are addressable by fastest assembly instructions like MOV A, R0. Internal RAM from 0x20 to 0x2F and every 0x0/0x8-ending SFR addresses are bit-addressable.

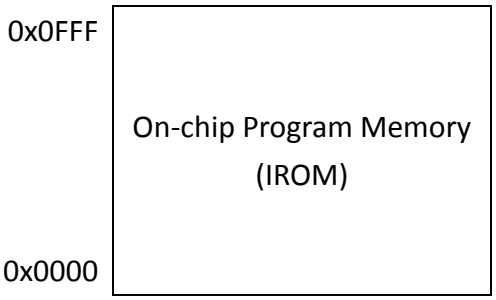
5.3 Indirect Addressing: IRAM

Although direct addressing instructions take fewer period to access internal RAM than indirect addressing, the second addressing type has the full range accessibility to internal RAM and is the only method to access the higher 128-byte internal RAM (0x80 – 0xFF).



5.4 Program Memory (IROM)

The program memory is a non-volatile storage area where stores code, look-up ROM table, and other data with occasional modification. It can be updated by debug tools like SN-Link Adapter II, and a program can also self-update via in-system program process (refer to In-system Program).



5.5 Program Memory Security

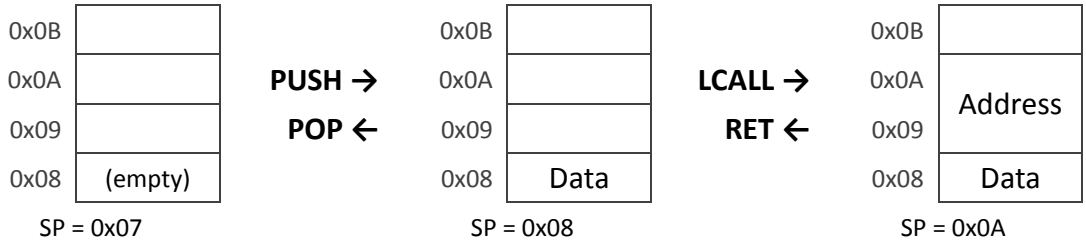
The SN8F5702 provides security options at the disposal of the designer to prevent unauthorized access to information stored in FLASH memory. When enable security option, the ROM code is secured and not dumped complete ROM contents. ROM security rule is all address ROM data protected and outputs 0x00.

5.6 Data Pointer

A data pointer helps to specify the IROM address while performing MOVC instructions. The microcontroller has one set of data pointer (DPH/DPL).

5.7 Stack

Stack can be assigned to any area of internal RAM (IRAM). However, it requires manual assignment to ensure its area does not overlap other RAM's variables. An overflow and underflow stack could also mistakenly overwrite other RAM's variables; thus, these factors should be considered while arrange the size of stack.



By default, stack pointer (SP register) points to 0x07 which means the stack area begin at IRAM address 0x08. In other word, if a planned stack area is assigned from IRAM address 0xC0, the appropriate SP register is anticipated to set at 0xBF after system reset.

An assembly PUSH instruction costs one byte of stack. LCALL, ACALL instructions and interrupt respectively costs two bytes stack. POP-instruction decreases one count, and a RET/RETI subtract two counts of stack pointer.

5.8 Stack and Data Pointer Register

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SP	SP7	SP6	SP5	SP4	SP3	SP2	SP1	SP0
DPL	DPL7	DPL6	DPL5	DPL4	DPL3	DPL2	DPL1	DPL0
DPH	DPH7	DPH6	DPH5	DPH4	DPH3	DPH2	DPH1	DPH0

SP Register (0x81)

Bit	Field	Type	Initial	Description
7..0	SP	R/W	0x07	Stack pointer

DPL Register (0x82)

Bit	Field	Type	Initial	Description
7..0	DPL[7:0]	R/W	0x00	Low byte of DPTR0

DPH Register (0x83)

Bit	Field	Type	Initial	Description
7..0	DPH[7:0]	R/W	0x00	High byte of DPTR0

6 Special Function Registers

6.1 Special Function Register Memory Map

BIN / HEX	000	001	010	011	100	101	110	111
F8	-	P0M	P1M	P2M	-	-	-	PFLAG
F0	B	P0UR	P1UR	P2UR	-	-	-	SRST
E8	-	-	-	-	-	-	-	-
E0	ACC	SPSTA	SPCON	SPDAT	P0OC	CLKSEL	CLKCMD	TCON0
D8	S0CON2	-	I2CDAT	I2CADR	I2CCON	I2CSTA	SMBSEL	SMBDST
D0	PSW	IEN4	ADM	ADB	ADR	VREFH	P1CON	-
C8	T2CON	-	CRCL	CRCH	TL2	TH2	-	-
C0	IRCON	CCEN	CCL1	CCH1	CCL2	CCH2	CCL3	CCH3
B8	IEN1	IP1	S0RELH	PW1DH	PW1DL	PW1A	PW1CH	IRCON2
B0	-	-	-	-	-	-	-	-
A8	IEN0	IP0	S0RELL	PW1M	PW1YL	PW1YH	PW1BL	PW1BH
A0	P2	-	-	-	-	-	-	-
98	S0CON	S0BUF	IEN2	-	-	P0CON	P2CON	-
90	P1	P1W	-	-	PECMD	PEROML	PEROMH	PERAM
88	TCON	TMOD	TL0	TL1	TH0	TH1	CKCON	PEDGE
80	P0	SP	DPL	DPH	-	-	WDTR	PCON

6.2 Special Function register Description

0x80 - 0x9F Registers Description

Register	Address	Description
P0	0x80	Port 0 data buffer.
SP	0x81	Stack pointer register.
DPL	0x82	Data pointer 0 low byte register.
DPH	0x83	Data pointer 0 high byte register.
-	0x84	-
-	0x85	-
WDTR	0x86	Watchdog timer clear register.
PCON	0x87	System mode register.
TCON	0x88	Timer 0 / 1 controls register.
TMOD	0x89	Timer 0 / 1 mode register.
TL0	0x8A	Timer 0 counting low byte register.
TL1	0x8B	Timer 1 counting low byte register.
TH0	0x8C	Timer 0 counting high byte register.
TH1	0x8D	Timer 1 counting high byte register.
CKCON	0x8E	Extended cycle controls register.
PEDGE	0x8F	External interrupt edge controls register.
P1	0x90	Port 1 data buffer.
P1W	0x91	Port 1 wake-up controls register.
-	0x92	-
-	0x93	-
PECMD	0x94	In-System Program command register.
PEROML	0x95	In-System Program ROM address low byte
PEROMH	0x96	In-System Program ROM address high byte
PERAM	0x97	In-System Program RAM mapping address
S0CON	0x98	UART control register.
S0BUF	0x99	UART data buffer.
IEN2	0x9A	Interrupts enable register
-	0x9B	-
-	0x9C	-
P0CON	0x9D	Port 0 configuration controls register.
P2CON	0x9E	Port 2 configuration controls register.
-	0x9F	-

0xA0 - 0xBF Registers Description

Register	Address	Description
P2	0xA0	Port 2 data buffer
-	0xA1	-
-	0xA2	-
-	0xA3	-
-	0xA4	-
-	0xA5	-
-	0xA6	-
-	0xA7	-
IEN0	0xA8	Interrupts enable register
IP0	0xA9	Interrupts priority register.
S0RELL	0xAA	UART reload low byte register.
PW1M	0xAB	PW1 controls register.
PW1YL	0xAC	PW1 cycle controls buffer low byte.
PW1YH	0xAD	PW1 cycle controls buffer high byte.
PW1BL	0xAE	PW1 B point dead band controls buffer low byte.
PW1BH	0xAF	PW1 B point dead band controls buffer high byte.
-	0xB0	-
-	0xB1	-
-	0xB2	-
-	0xB3	-
-	0xB4	-
-	0xB5	-
-	0xB6	-
-	0xB7	-
IEN1	0xB8	Interrupts enable register
IP1	0xB9	Interrupts priority register.
S0RELH	0xBA	UART reload high byte register.
PW1DL	0xBB	PW1 duty controls buffer low byte.
PW1DH	0xBC	PW1 duty controls buffer high byte.
PW1A	0xBD	PW1 A point dead band controls buffer.
PW1CH	0xBE	PW1 channel control buffer.
IRCON2	0xBF	Interrupts request register.

0xC0 - 0xDF Registers Description

Register	Address	Description
IRCON	0xC0	Interrupts request register.
CCEN	0xC1	Timer 2 Compare /capture enable register.
CCL1	0xC2	Timer 2 Compare /capture module 1 low byte register.
CCH1	0xC3	Timer 2 Compare /capture module 1 high byte register.
CCL2	0xC4	Timer 2 Compare /capture module 2 low byte register.
CCH2	0xC5	Timer 2 Compare /capture module 2 high byte register.
CCL3	0xC6	Timer 2 Compare /capture module 3 low byte register.
CCH3	0xC7	Timer 2 Compare /capture module 3 high byte register.
T2CON	0xC8	Timer 2 controls register.
-	0xC9	-
CRCL	0xCA	Timer 2 Compare/capture module 0 & reload function low byte register.
CRCH	0xCB	Timer 2 Compare/capture module 0 & reload function high byte register.
TL2	0xCC	Timer 2 counting low byte register.
TH2	0xCD	Timer 2 counting high byte register.
-	0xCE	-
-	0xCF	-
PSW	0xD0	System flag register.
IEN4	0xD1	Interrupts enable register
ADM	0xD2	ADC controls register.
ADB	0xD3	ADC data buffer.
ADR	0xD4	ADC resolution selects register.
VREFH	0xD5	ADC reference voltage controls register.
P1CON	0xD6	Port 1 configuration controls register.
-	0xD7	-
S0CON2	0xD8	UART baud rate controls register.
-	0xD9	-
I2CDAT	0xDA	I2C data buffer.
I2CADR	0xDB	Own I2C slave address.
I2CCON	0xDC	I2C interface operation control register.
I2CSTA	0xDD	I2C Status Code.
SMBSEL	0xDE	SMBus mode controls register.
SMBDST	0xDF	SMBus internal timeout register.

0xE0 - 0xFF Registers Description

Register	Address	Description
ACC	0xE0	Accumulator register.
SPSTA	0xE1	SPI statuses register.
SPCON	0xE2	SPI control register.
SPDAT	0xE3	SPI data buffer.
P0OC	0xE4	Open drain controls register.
CLKSEL	0xE5	Clock switch selects register.
CLKCMD	0xE6	Clock switch controls Register.
TCON0	0xE7	Timer 0 / 1 clock controls register.
-	0xE8	-
-	0xE9	-
-	0xEA	-
-	0xEB	-
-	0xEC	-
-	0xED	-
-	0xEE	-
-	0xEF	-
B	0xF0	Multiplication/ division instruction data buffer.
P0UR	0xF1	Port 0 pull-up resister controls register.
P1UR	0xF2	Port 1 pull-up resister controls register.
P2UR	0xF3	Port 2 pull-up resister controls register.
-	0xF4	-
-	0xF5	-
-	0xF6	-
SRST	0xF7	Software reset controls register.
-	0xF8	-
P0M	0xF9	Port 0 input/output mode register.
P1M	0xFA	Port 1 input/output mode register.
P2M	0xFB	Port 2 input/output mode register.
-	0xFC	-
-	0xFD	-
-	0xFE	-
PFLAG	0xFF	Reset flag register.

6.3 System Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ACC	ACC7	ACC6	ACC5	ACC4	ACC3	ACC2	ACC1	ACC0
B	B7	B6	B5	B4	B3	B2	B1	B0
PSW	CY	AC	F0	RS1	RS0	OV	F1	P

ACC Register (0xE0)

Bit	Field	Type	Initial	Description
7..0	ACC[7:0]	R/W	0x00	The ACC is an 8-bit data register responsible for transferring or manipulating data between ALU and data memory. If the result of operating is overflow (OV) or there is carry (C or AC) and parity (P) occurrence, then these flags will be set to PSW register.

B Register (0xF0)

Bit	Field	Type	Initial	Description
7..0	B[7:0]	R/W	0x00	The B register is used during multiplying and division instructions. It can also be used as a scratch-pad register to hold temporary data.

PSW Register (0xD0)

Bit	Field	Type	Initial	Description
7	CY	R/W	0	Carry flag. 0: Addition without carry, subtraction with borrowing signal, rotation with shifting out logic “0”, comparison result < 0. 1: Addition with carry, subtraction without borrowing, rotation with shifting out logic “1”, comparison result ≥ 0.
6	AC	R/W	0	Auxiliary carry flag. 0: If there is no a carry-out from 3rd bit of Accumulator in BCD operations. 1: If there is a carry-out from 3rd bit of Accumulator in BCD operations.
5	F0	R/W	0	General purpose flag 0. General purpose flag available for user.
4..3	RS[1:0]	R/W	00	Register bank select control bit, used to select working register bank. 00: 00H – 07H (Bnak0) 01: 08H – 0FH (Bnak1) 10: 10H – 17H (Bnak2) 11: 18H – 1FH (Bnak3)
2	OV	R/W	0	Overflow flag. 0: Non-overflow in Accumulator during arithmetic Operations. 1: overflow in Accumulator during arithmetic Operations.
1	F1	R/W	0	General purpose flag 1. General purpose flag available for user.
0	P	R	0	Parity flag. Reflects the number of ‘1’s in the Accumulator. 0: if Accumulator contains an even number of ‘1’s. 1: Accumulator contains an odd number of ‘1’s.

6.4 Register Declaration

SN8F5702 has many registers to control various functions, but SFR name is not predefined in the C51 / A51 compiler. To make programming easier and therefore need to add header files to declare SFR name.

When using the assembly code programs, please add the following sentence.

```
1 $NOMOD51 ;Do not recognize the 8051-specific predefined special register.
2 #include <SN8F5702.H>
```

When using the C code programs, please add the following sentence.

```
1 #include <SN8F5702.H>
```

After adding the header file, user can use name of registers to program. During compilation, the compiler will register name translate into register position through the header file.

Different devices need to use a different header file to declare, but the option file is to use the same.

Device	Header file	Options file
SN8F5702	SN8F5702.h	OPTIONS_SN8F5702.A51
SN8F570200	SN8F570200.h	
SN8F570202	SN8F570202.h	
SN8F570210	SN8F570210.h	
SN8F570211	SN8F570211.h	
SN8F570212	SN8F570212.h	
SN8F570213	SN8F570213.h	

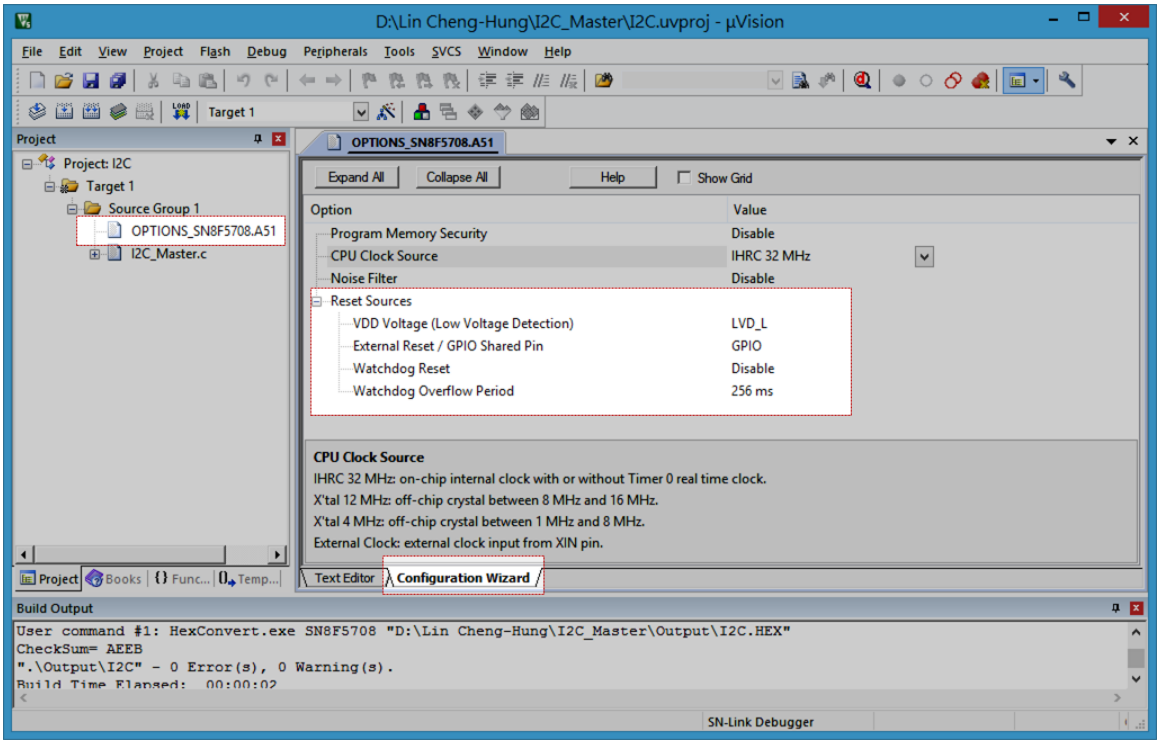
7 Reset and Power-on Controller

The reset and power-on controller has four reset sources: low voltage detectors (LVDs), watchdog, programmable external reset pin, and software reset. The first three sources would trigger an additional power-on sequence. Subsequently, the microcontroller initializes all registers and starts program execution with its reset vector (ROM address 0x0000).

7.1 Configuration of Reset and Power-on Controller

SONiX publishes an *OPTIONS_SN8F5702.A51 file* in *SN-Link Driver for Keil C51.exe* (downloadable on cooperative website: www.sonix.com.tw). This *options file* contains appropriate parameters of reset sources and CPU clock source selection, and is strongly recommended to add to Keil project. *SN8F5000 Debug Tool Manual* provides the further detail of this configuration.

- Program Memory Security
- CPU Clock Source
- Noise Filter
- Reset Source : VDD Voltage (Low Voltage Detection)
- Reset Source : External Reset / GPIO Shared Pin
- Reset Source : Watchdog Reset & Overflow Period



7.2 Power-on Sequence

A power-on sequence would be triggered by LVD, watchdog, and external reset pin. It takes place between the end of reset signal and program execution. Overall, it includes two stages: power stabilization period, and clock stabilization period.

The power stabilization period spends 4.5 ms in typical condition. Afterward the microcontroller fetches CPU Clock Source selection automatically. The selected clock source would be driven, and the system counts 4096 times of the clock period to ensure its reliability.

7.3 LVD Reset

The low voltage detectors monitor VDD pin's voltage at three levels: 1.8 V, 2.4 V and 3.3 V. Depend on low voltage detection configuration, the comparison result can be seen as a system reset signal, or simply as LVD24/LVD33 register flags. The table below lists four different low voltage detection configurations, from LVD_Max to LVD_L, and the respectively results of VDD pin's condition.

Condition	LVD_Max	LVD_H	LVD_M	LVD_L
VDD ≤ 3.3 V	Reset	LVD33 = 1	-	-
VDD ≤ 2.4 V	Reset	Reset	LVD24 = 1	-
VDD ≤ 1.8 V	Reset	Reset	Reset	Reset

7.4 Watchdog Reset

Watchdog is a periodic reset signal generator for the purpose of monitoring the execution flow. Its internal timer is expected to be cleared in a check point of program flow; therefore, the actual reset signal would be generated only after a software problem occurs. Writing 0x5A to WDTR is the proper method to place a check point in program.

```
1     WDTR = 0x5A;
```

Watchdog timer interval time = 256 * 1/ (Internal Low-Speed oscillator frequency/WDT Pre-scalar)
= 256 / (F_{ILRC}/WDT Pre-scaler) …sec

Internal low-speed oscillator	WDT pre-scaler	Watchdog interval time
F_{ILRC}=16 kHz	F_{ILRC} /4	256/(16000/4)=64ms
	F_{ILRC} /8	256/(16000/8)=128ms
	F_{ILRC} /16	256/(16000/16)=256ms
	F_{ILRC} /32	256/(16000/32)=512ms

The operation mode of watchdog is configurable in options file:
Always mode counts its internal timer in all CPU operation modes (normal, IDLE, SLEEP);
Enable mode counts its internal timer during CPU stays in normal mode, and it would not trigger watchdog reset in IDLE and STOP modes;
Disable mode suspends its internal timer at all CPU modes, and the watchdog would not trigger in this condition.

When watchdog is operating in always mode, the system will consume additional power.

7.5 External Reset Pin

Programmable external reset pin is configurable in *options file*. Once it is enabled, it monitors its shared pin's logic level. A logical low (lower than 30% of VDD) would immediately trigger system reset until the input is recovered to high (lager than 70% of VDD).

An optional de-bounce period can improve reset signal's stability. Instead of immediate reset, the system reset requires an 8-ms-long logic low to avoid bouncing from a button key. Any signal lower than de-bounce period would not affect the CPU's execution.

7.6 Software Reset

A software reset would be generated after consecutively set SRSTREQ register. As a result, this procedure enables firmware's ability to reset microcontroller (e.g. reset after firmware update). The following sample C code repeatedly set the least bit of SRST register to perform software reset.

```
1   SRST = 0x01;
2   SRST = 0x01;
```

7.7 Reset and Power-on Controller Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PFLAG	POR	WDT	RST	-	-	LVD24	LVD33	-
SRST	-	-	-	-	-	-	-	SRSTREQ
WDTR	WDTR7	WDTR6	WDTR5	WDTR4	WDTR3	WDTR2	WDTR1	WDTR0

PFLAG Register

Bit	Field	Type	Initial	Description
7	POR	R	0	This bit is automatically set if the microcontroller has been reset by LVD.
6	WDT	R	0	This bit is automatically set if the microcontroller has been reset by watchdog.
5	RST	R	0	This bit is automatically set if the microcontroller has

				been reset by external reset pin.
4..3	Reserved	R	0	
2	LVD24	R	0	This bit is automatically set if the currently VDD pin is lower than 2.4 V
1	LVD33	R	0	This bit is automatically set if the currently VDD pin is lower than 3.3 V
0	Reserved	R	0	

SRST Register

Bit	Field	Type	Initial	Description
7..1	Reserved	R	0	
0	SRSTREQ	R/W	0	Consecutively set this bit for two times to trigger software reset.

WDTR Register (0x86)

Bit	Field	Type	Initial	Description
7..0	WDTR[7:0]	W	-	Watchdog clear is controlled by WDTR register. Moving 0x5A data into WDTR is to reset watchdog timer.

8 System Clock and Power Management

For power saving purpose, the microcontroller built in three different operation modes: normal, IDLE, and STOP mode.

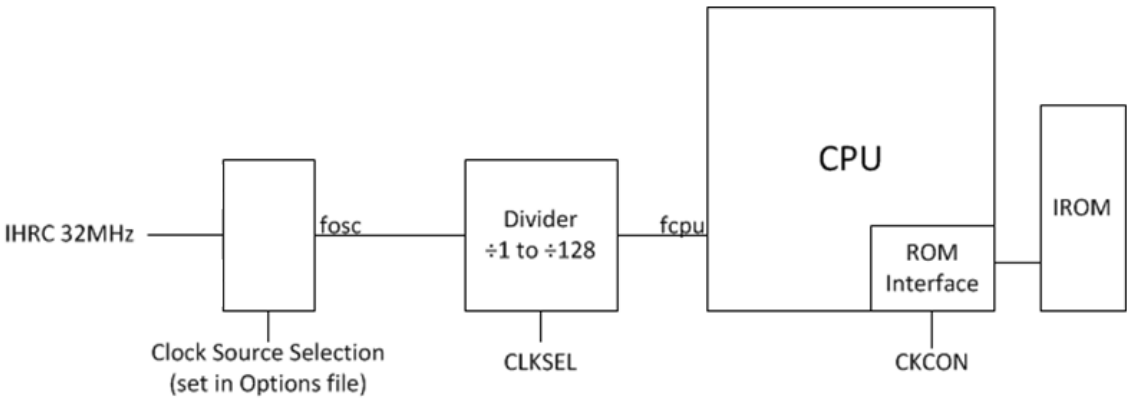
The normal mode means that CPU and peripheral functions are under normally execution. The system clock is based on the combination of source selection, clock divider, and program memory wait state. IDLE mode is the situation that temporarily suspends CPU clock and its execution, yet it remains peripherals' functionality (e.g. timers, PWM, SPI, UART, and I2C). By contrast, STOP mode disables all functions and clock generator until a wakeup signal to return normal mode.

8.1 System Clock

The microcontroller includes an on-chip clock generator (IHRC 32MHz). The reset and power-on controller automatically loads clock source selection during power-on sequence. Therefore, the selected clock source is seen as 'fosc' domain which is a fixed frequency at any time.

Subsequently, the selected clock source (fosc) is divided by 1 to 128 times which is controlled by CLKSEL register. The CPU input the divided clock as its operation base (named fcpu). Applying CLKSEL's setting when CLKCMD register be written 0x69.

```
1     CLKSEL = 0x04;    // set fcpu = fosc / 8
2     CLKCMD = 0x69;    // Apply CLKSEL's setting
```



ROM interface is built in between CPU and IROM (program memory). It optionally extends the data fetching cycle in order to support lower speed program memory. For example if the CPU is anticipated to run at 32 MHz and the IROM has to run at 8 MHz, three extended cycle must be placed by CKCON register.

$$\text{IROM fetching cycle} = \frac{\text{fcpu}}{\text{PWSC[2:0]}+1} \leq 8\text{MHz, PWSC[2:0]} = 0\sim7$$

8.2 Power Management

After the end of reset signal and power-on sequence, the CPU starts program execution at the speed of fcpu. Overall, the CPU and all peripherals are functional in this situation (categorized as normal mode).

The least two bits of PCON register (IDLE at bit 0 and STOP at bit 1) control the microcontroller's power management unit.

If IDLE bit is set by program, only CPU clock source would be gated. Consequently, peripheral functions (such as timers, PWM, and I2C) and clock generator (IHRC 32 MHz) remain execution in this status. Any change from P0/P1 input and interrupt events can make the microcontroller turns back to normal mode, and the IDLE bit would be cleared automatically.

- Any function can work in IDLE mode. Only CPU is suspended
- The IDLE mode wake-up sources are P0/P1 level change trigger and any interrupt event.

If STOP bit is set, by contrast, CPU, peripheral functions, and clock generator are suspended. Data storage in registers and RAM would be kept in this mode. Any change from P0/P1 can wake up the microcontroller and resume system's execution. STOP bit would be cleared automatically.

- CPU, peripheral functions, and clock generator are suspended.
- The STOP mode wake-up source is P0/P1 level change trigger.

For user who is develop program in C language, IDLE and STOP macros is strongly recommended to control the microcontroller's system mode, instead of set IDLE and STOP bits directly.

```
1    IDLE();
2    STOP();
```

8.3 System Clock and Power Management Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
CKCON	-	PWSC2	PWSC1	PWSC0	ESYN	EWSC2	EWSC1	EWSC0
CLKSEL	-	-	-	-	-	CLKSEL2	CLKSEL1	CLKSEL0
CLKCMD	CMD7	CMD6	CMD5	CMD4	CMD3	CMD2	CMD1	CMD0
PCON	SMOD	-	-	-	-	GF0	STOP	IDLE
P1W	P17W	P16W	P15W	P14W	P13W	P12W	P11W	P10W

CKCON Register (0x8E)

Bit	Field	Type	Initial	Description
7	Reserved	R	0	
6..4	PWSC[2:0]	R/W	111	Extended cycle(s) applied to reading program memory 000: non 001: 1 cycle 010: 2 cycles 011: 3 cycles 100: 4 cycles 101: 5 cycles 110: 6 cycles 111: 7 cycles
Else	Reserved	R	0001	

CLKSEL Register (0xE5)

Bit	Field	Type	Initial	Description
7..3	Reserved	R	0x00	
2..0	CLKSEL[2:0]	R/W	111	CLKSEL would be applied by writing CLKCMD. 000: fcpu = fosc / 128 001: fcpu = fosc / 64 010: fcpu = fosc / 32 011: fcpu = fosc / 16 100: fcpu = fosc / 8 101: fcpu = fosc / 4 110: fcpu = fosc / 2 111: fcpu = fosc / 1

CLKCMD Register (0xE6)

Bit	Field	Type	Initial	Description
7..0	CMD[7:0]	W	0x00	Writing 0x69 to apply CLKSEL's setting.

PCON Register (0x87)

Bit	Field	Type	Initial	Description
7				Refer to other chapter(s)
6..3	Reserved	R	0x00	

2	GF0	R/W	0	General Purpose Flag
1	STOP	R/W	0	1: Microcontroller switch to STOP mode
0	IDLE	R/W	0	1: Microcontroller switch to IDLE mode

P1W Register (0x91)

Bit	Field	Type	Initial	Description
7..0	P1nW	R/W	0	0: Disable P1.n wakeup functionality 1: Enable P1.n wakeup functionality

9 Interrupt

The MCU provides 13 interrupt sources (1 external and 12 interrupt) with 4 priority levels. Each interrupt source includes one or more interrupt request flag(s). When interrupt event occurs, the associated interrupt flag is set to logic 1. If both interrupt enable bit and global interrupt (EAL=1) are enabled, the interrupt request is generated and interrupt service routine (ISR) will be started. Most interrupt request flags must be cleared by software. However, some interrupt request flags can be cleared by hardware automatically. In the end, ISR is finished after complete the RETI instruction. The summary of interrupt source, interrupt vector, priority order and control bit are shown as the table below.

Interrupt	Enable Interrupt	Request (IRQ)	IRQ Clearance	Priority / Vector
System Reset	-	-	-	0 / 0x0000
INT0	EX0	IE0	Automatically	1 / 0x0003
PWM1	EPWM1	PWM1F	By firmware	2 / 0x0083
I2C	EI2C	SI	By firmware	3 / 0x0043
Timer 0	ET0	TF0	Automatically	4 / 0x000B
ADC	EADC	ADCF	By firmware	5 / 0x008B
SPI	ESPI	SPIF / MODF	By firmware	6 / 0x004B
T2COM0	ET2C0	TF2C0	Automatically	7 / 0x0053
Timer 1	ET1	TF1	Automatically	8 / 0x001B
T2COM1	ET2C1	TF2C1	Automatically	9 / 0x005B
UART	ES0	TI0 / RI0	By firmware	10 / 0x0023
T2COM2	ET2C1	TF2C2	Automatically	11 / 0x0063
Timer 2	ET2 / ET2RL	TF2 / TF2RL	By firmware	12 / 0x002B
T2COM3	ET2C3	TF2C3	Automatically	13 / 0x006B

9.1 Interrupt Operation

Interrupt operation is controlled by interrupt request flag and interrupt enable bits. Interrupt request flag is interrupt source event indicator, no matter what interrupt function status (enable or disable). Both interrupt enable bit and global interrupt (EAL=1) are enabled, the system executes interrupt operation when each of interrupt request flags actives. The program counter points to interrupt vector (0x03 – 0x8B) and execute ISR.

9.2 Interrupt Priority

Each interrupt source has its specific default priority order. If two interrupts occurs simultaneously, the higher priority ISR will be service first. The lower priority ISR will be serviced after the higher priority ISR completes. The next ISR will be service after the previous ISR complete, no matter the

priority order.

For special priority needs, 4-level priority levels (Level 0 – Level 3) are used. All interrupt sources are classified into 6 priority groups (Group0 – Group5). Each group can be set one specific priority level. Priority level is selected by IP0/IP1 registers. Level 3 is the highest priority and Level 0 is the lowest. The interrupt sources inside the same group will share the same priority level. With the same priority level, the priority rule follows default priority.

Priority Level	IP1.x	IP0.x
Level 0	0	0
Level 1	0	1
Level 2	1	0
Level 3	1	1

The ISR with the higher priority level can be serviced first; even can break the on-going ISR with the lower priority level. The ISR with the lower priority level will be pending until the ISR with the higher priority level completes.

Group	Interrupt Source			
Group 0	INT0	PWM1	I2C	
Group 1	T0	ADC	SPI	
Group 2			T2 COM0	
Group 3	T1		T2 COM1	
Group 4	UART		T2 COM2	
Group 5	T2		T2 COM3	

IP0, IP1 Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IP0	-	-	IP05	IP04	IP03	IP02	IP01	IP00
IP1	-	-	IP15	IP14	IP13	IP12	IP11	IP10

IP0 Register (0XA9)

Bit	Field	Type	Initial	Description
5..0	IP0[5:0]	R/W	0	Interrupt priority. Each bit together with corresponding bit from IP1 register specifies the priority level of the respective interrupt priority group.
Else	Reserved	R	0	

IP1 Register (0XB9)

Bit	Field	Type	Initial	Description
5..0	IP1[5:0]	R/W	0	Interrupt priority. Each bit together with corresponding bit from IP0 register specifies the priority level of the respective interrupt priority group.
Else	Reserved	R	0	

9.3 Interrupt Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
IEN0	EAL	-	ET2	ES0	ET1	-	ET0	EX0
IEN1	ET2RL	-	ET2C3	ET2C2	ET2C1	ET2C0	ESPI	EI2C
IEN2	-	-	-	-	-	-	EADC	-
IEN4	EPWM1	-	-	-	PWM1F	-	-	-
IRCON	TF2RL	TF2	TF2C3	TF2C2	TF2C1	TF2C0	-	-
IRCON2	-	-	-		-	-	-	ADCF
TCON	TF1	TR1	TF0	TR0	-	-	IE0	-
S0CON	SM0	SM1	SM20	REN0	TB80	RB80	TI0	RI0
SPSTA	SPIF	WCOL	SSERR	MODF	-	-	-	-
I2CCON	CR2	ENS1	STA	STO	SI	AA	CR1	CR0

IEN0 Register (0XA8)

Bit	Field	Type	Initial	Description
7	EAL	R/W	0	Enable all interrupt control bit. 0: Disable all interrupt function. 1: Enable all interrupt function.
5	ET2	R/W	0	T2 timer interrupt control bit 0: Disable T2 interrupt function. 1: Enable T2 interrupt function.
4	ES0	R/W	0	UART interrupt control bit. 0: Disable UART interrupt function. 1: Enable UART interrupt function.
3	ET1	R/W	0	T1 timer interrupt control bit. 0: Disable T1 interrupt function. 1: Enable T1 interrupt function.
1	ET0	R/W	0	T0 timer interrupt control bit. 0: Disable T0 interrupt function. 1: Enable T0 interrupt function
0	EX0	R/W	0	External P1.0 interrupt (INT0) control bit. 0: Disable INT0 interrupt function. 1: Enable INT0 interrupt function.
Else	Reserved	R	0	

IEN1 Register (0XB8)

Bit	Field	Type	Initial	Description
7	ET2RL	R/W	0	T2 Timer external reload interrupt control bit. 0: Disable T2 external reload interrupt function. 1: Enable T2 external reload interrupt function.
5	ET2C3	R/W	0	T2 Timer COM3 interrupt control bit. 0: Disable T2COM3 interrupt function. 1: Enable T2COM3 interrupt function.
4	ET2C2	R/W	0	T2 Timer COM2 interrupt control bit. 0: Disable T2COM2 interrupt function. 1: Enable T2COM2 interrupt function.
3	ET2C1	R/W	0	T2 Timer COM1 interrupt control bit. 0: Disable T2COM1 interrupt function. 1: Enable T2COM1 interrupt function.
2	ET2C0	R/W	0	T2 Timer COM0 interrupt control bit. 0: Disable T2COM0 interrupt function. 1: Enable T2COM0 interrupt function.
1	ESPI	R/W	0	SPI interrupt control bit 0: Disable SPI interrupt function. 1: Enable SPI interrupt function.
0	EI2C	R/W	0	I2C interrupt control bit. 0: Disable I2C interrupt function. 1: Enable I2C interrupt function.
Else	Reserved	R	0	

IEN2 Register (0X9A)

Bit	Field	Type	Initial	Description
1	EADC	R/W	0	ADC interrupt control bit. 0: Disable ADC interrupt function. 1: Enable ADC interrupt function.
Else	Reserved	R	0	

IEN4 Register (0XD1)

Bit	Field	Type	Initial	Description
7	EPWM1	R/W	0	PWM1 interrupt control bit. 0 = Disable PWM1 interrupt function. 1 = Enable PWM1 interrupt function.
3	PWM1F	R/W	0	PWM1 interrupt request flag. 0: None PWM1 interrupt request 1: PWM1 interrupt request.
Else	Reserved	R	0	

IRCON Register (0xC0)

Bit	Field	Type	Initial	Description
7	TF2RL	R/W	0	T2 timer external reload interrupt request flag. 0: None TF2RL interrupt request 1: TF2RL interrupt request.
6	TF2	R/W	0	T2 timer interrupt request flag. 0: None T2 interrupt request. 1: T2 interrupt request.
5	TF2C3	R/W	0	T2 Timer COM3 interrupt request flag. 0: None T2COM3 interrupt request. 1: T2COM3 interrupt request.
4	TF2C2	R/W	0	T2 Timer COM2 interrupt request flag. 0: None T2COM2 interrupt request. 1: T2COM2 interrupt request.
3	TF2C1	R/W	0	T2 Timer COM1 interrupt request flag. 0: None T2COM1 interrupt request. 1: T2COM1 interrupt request.
2	TF2C0	R/W	0	T2 Timer COM0 interrupt request flag. 0: None T2COM0 interrupt request. 1: T2COM0 interrupt request.
Else	Reserved	R	0	

IRCON2 Register (0XBF)

Bit	Field	Type	Initial	Description
0	ADCF	R/W	0	ADC interrupt request flag. 0: None ADC interrupt request. 1: ADC interrupt request.
Else	Reserved	R	0	

TCON Register (0X88)

Bit	Field	Type	Initial	Description
7	TF1	R/W	0	T1 timer external reload interrupt request flag. 0: None T1 interrupt request 1: T1 interrupt request.
5	TF0	R/W	0	T0 timer external reload interrupt request flag. 0: None T0 interrupt request 1: T0 interrupt request.
1	IE0	R	0	External P1.0 interrupt (INT0) request flag 0: None INT0 interrupt request. 1: INT0 interrupt request.
Else				Refer to other chapter(s)

S0CON Register (0X98)

Bit	Field	Type	Initial	Description
1	TI0	R/W	0	UART transmit interrupt request flag. It indicates completion of a serial transmission at UART. It is set by hardware at the end of bit 8 in mode 0 or at the beginning of a stop bit in other modes. It must be cleared by software. 0: None UART transmit interrupt request. 1: UART transmit interrupt request.
0	RI0	R/W	0	UART receive interrupt request flag. It is set by hardware after completion of a serial reception at UART. It is set by hardware at the end of bit 8 in mode 0 or in the middle of a stop bit in other modes. It must be cleared by software. 0: None UART receive interrupt request. 1: UART receive interrupt request.
Else				Refer to other chapter(s)

SPSTA Register (0XE1)

Bit	Field	Type	Initial	Description
7	SPIF	R	0	SPI complete communication flag Set automatically at the end of communication Cleared automatically by reading SPSTA, SPDAT registers
4	MODF	R	0	Mode fault flag
Else				Refer to other chapter(s)

I2CCON Register (0XDC)

Bit	Field	Type	Initial	Description
7	SI	R/W	0	Serial interrupt flag The SI is set by hardware when one of 25 out of 26 possible I2C states is entered. The only state that does not set the SI is state F8h, which indicates that no relevant state information is available. The SI flag must be cleared by software. In order to clear the SI bit, ‘0’ must be written to this bit. Writing a ‘1’ to SI bit does not change value of the SI.
Else				Refer to other chapter(s)

10 GPIO

The microcontroller has up to 18 bidirectional general purpose I/O pin (GPIO). Unlike the original 8051 only has open-drain output, SN8F5702 builds in push-pull output structure to improve its driving performance.

10.1 Input and Output Control

The input and output direction control is configurable through P0M to P2M registers. These bits specify each pin that is either input mode or output mode.

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
P0M	P07M	P06M	P05M	P04M	P03M	P02M	P01M	P00M
P1M	P17M	P16M	P15M	P14M	P13M	P12M	P11M	P10M
P2M	-	-	-	-	-	-	P21M	P20M
P0OC	-	-	-	P15OC	P14OC	P13OC	P06OC	P05OC

P0M: 0xF9, P1M: 0xFA, P2M: 0xFB

Bit	Field	Type	Initial	Description
7	P07M	R/W	0	Mode selection of P0.7 0: Input mode 1: Output mode
6	P06M	R/W	0	Mode selection of P0.6 0: Input mode 1: Output mode
5	P05M	R/W	0	Mode selection of P0.5 0: Input mode 1: Output mode
4..0				et cetera

P0OC Register (0xE4)

Bit	Field	Type	Initial	Description
7..5		R/W	000	Refer to PWM chapter
4	P15OC	R/W	0	P1.5 open-drain output mode 0: Disable 1: Enable, output high status becomes to input mode
3	P14OC	R/W	0	P1.4 open-drain output mode 0: Disable 1: Enable, output high status becomes to input mode
2	P13OC	R/W	0	P1.3 open-drain output mode 0: Disable 1: Enable, output high status becomes to input mode
1	P06OC	R/W	0	P0.6 open-drain output mode 0: Disable 1: Enable, output high status becomes to input mode
0	P05OC	R/W	0	P0.5 open-drain output mode 0: Disable 1: Enable, output high status becomes to input mode

10.2 Input Data and Output Data

By a read operation from any registers of P0 to P2, the current pin's logic level would be fetch to represent its external status. This operation remains functional even the pin is shared with other function like UART and I2C which can monitor the bus condition in some case.

A write P0 to P2 register value would be latched immediately, yet the value would be outputted until the mapped P0M – P2M is set to output mode. If the pin is currently in output mode, any value set to P0 to P2 register would be presented on the pin immediately.

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
P0	P07	P06	P05	P04	P03	P02	P01	P00
P1	P17	P16	P15	P14	P13	P12	P11	P10
P2	-	-	-	-	-	-	P21	P20

P0: 0x80, P1: 0x90, P2: 0xA0

Bit	Field	Type	Initial	Description
7	P07	R/W	1	Read: P0.7 pin's logic level Write 1/0: Output logic high or low (applied if P07M = 1)
6	P06	R/W	1	Read: P0.6 pin's logic level Write 1/0: Output logic high or low (applied if P06M = 1)
5	P05	R/W	1	Read: P0.5 pin's logic level Write 1/0: Output logic high or low (applied if P05M = 1)
4..0				et cetera

10.3 On-chip Pull-up Resisters

The P0UR to P2UR registers are mapped to each pins' internal 100 kΩ (in typical value) pull-up resister.

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
P0UR	P07UR	P06UR	P05UR	P04UR	P03UR	P02UR	P01UR	P00UR
P1UR	P17UR	P16UR	P15UR	P14UR	P13UR	P12UR	P11UR	P10UR
P2UR	-	-	-	-	-	-	P21UR	P20UR

P0UR: 0xF1, P1UR: 0xF2, P2UR: 0xF3

Bit	Field	Type	Initial	Description
7	P07UR	R/W	0	On-chip pull-up resister control of P0.7 0: Disable* 1: Enable
6	P06UR	R/W	0	On-chip pull-up resister control of P0.6 0: Disable* 1: Enable
5	P05UR	R/W	0	On-chip pull-up resister control of P0.5 0: Disable* 1: Enable
4..0				et cetera

* Recommended disable pull-up resister if the pin is output mode or analog function

10.4 Pin Shared with Analog Function

The microcontroller builds in analog functions, such as ADC. The Schmitt trigger of input channel is strongly recommended to switch off if the pin's shared analog function is enabled.

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
P0CON	P0CON7							
P1CON	P1CON7	P1CON6	P1CON5	P1CON4	P1CON3	P1CON2	P1CON1	P1CON0
P2CON	-	-	-	-	-	-	P2CON1	P2CON0

P2CON: 0x9E, P1CON: 0xD6, P0CON: 0x9D

Bit	Field	Type	Initial	Description
7	P1CON7	R/W	0	Schmitt trigger control of P1.7 0: Enable 1: Disable
6	P1CON6	R/W	0	Schmitt trigger control of P1.6 0: Enable 1: Disable
5	P1CON5	R/W	0	Schmitt trigger control of P1.5 0: Enable 1: Disable
4..0				et cetera

11 External Interrupt

INT0 is external interrupt trigger sources. Build in edge trigger configuration function and edge direction is selected by PEDGE register. When both external interrupt (EX0) and global interrupt (EAL) are enabled, the external interrupt request flag (IE0) will be set to “1” as edge trigger event occurs. The program counter will jump to the interrupt vector (ORG 0x0003) and execute interrupt service routine. Interrupt request flag will be cleared by hardware before ISR is executed.

11.1 External Interrupt Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PEDGE	-	-	-	-	-	-	EX0G1	EX0G0
IEN0	EAL	-	ET2	ES0	ET1	-	ET0	EX0

PEDGE Register (0X8F)

Bit	Field	Type	Initial	Description
1..0	EX0G[1:0]	R/W	10	External interrupt 0 trigger edge control register. 00: Reserved. 01: Rising edge trigger. 10: Falling edge trigger (default) 11: Both rising and falling edge trigger
Else	Reserved	R	0	

11.2 Sample Code

The following sample code demonstrates how to perform INT0 with interrupt.

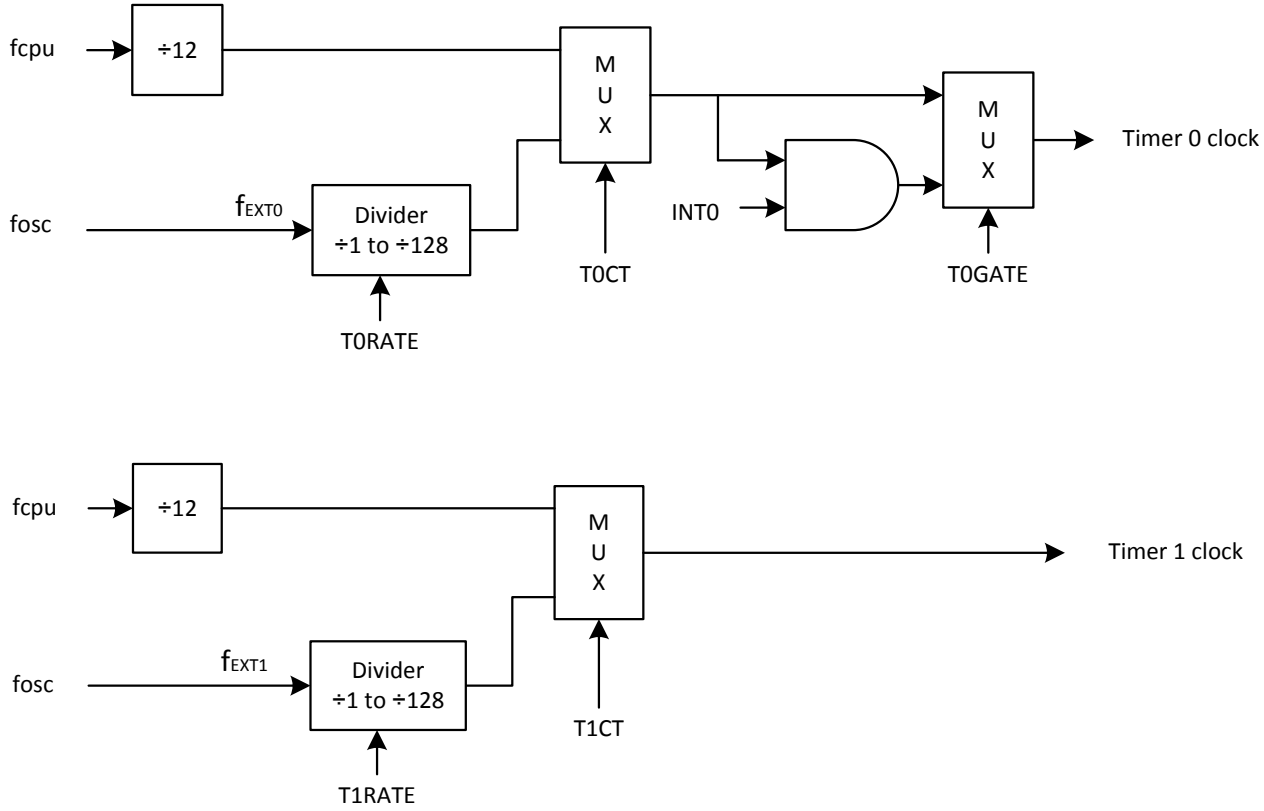
```
#define INT0Rsing      (1 << 0)  //INT0 trigger edge is rising edge
#define INT0Falling    (2 << 0)  //INT0 trigger edge is falling edge
#define INT0LeChge     (3 << 0)  //INT0 trigger edge is level chagne
#define EINT0          (1 << 0)  //INT0 interrupt enable

void EnableINT(void)
{
  // INT0 rising edge
  PEDGE = INT0Rising;

  // Enable INT0 interrupt
  IEN0 |= EINT0;
  // Enable total interrupt
  IEN0 |= 0x80;

  P0 = 0x00;
  P0M = 0x07;
}

void INT0Interrupt(void) interrupt ISRInt0  //0x03
{ //IE0 clear by hardware
  P00 = ~P00;
}

```

12 Timer 0 and Timer 1

Timer 0 and Timer 1 are two independent binary up timers. Timer 0 has four different operation modes: (1) 13-bit up counting timer, (2) 16-bit up counting timer, (3) 8-bit up counting timer with specified reload value support, and (4) separated two 8-bit up counting timer. By contrast, Timer 1 has only mode 0 to mode 2 which are same as Timer 0. Timer 0 and Timer 1 respectively support ET0 and ET1 interrupt function.

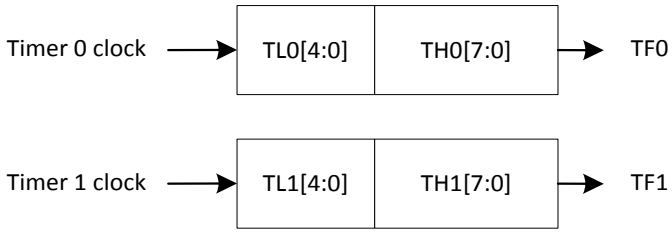
12.1 Timer 0 and Timer 1 Clock Selection

The figures below illustrate the clock selection circuit of Timer 0 and Timer 1. Timer 0 has two clock sources selection: fcpu and fosc. All clock sources can be gated (pause) by INT0 pin if T0GATE is applied. Timer 1 clock sources selection: fcpu and fosc.



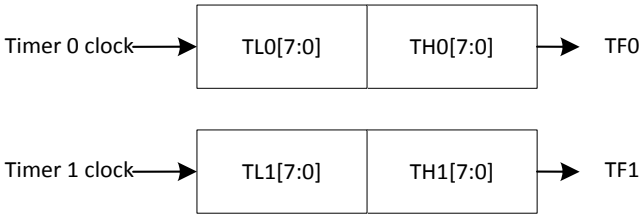
12.2 Mode 0: 13-bit Up Counting Timer

Mode 0 is a 13-bit up counting timer (the upper 3 bits of TL0 is suspended). Once the timer's counter is overflow (counts from 0xFF1F to 0x0000), TF0/TF1 flag would be issued immediately. This flag is readable and writable by firmware if ET0/ET1 does not apply, or can be handled by interrupt controller if ET0/ET1 is applied.



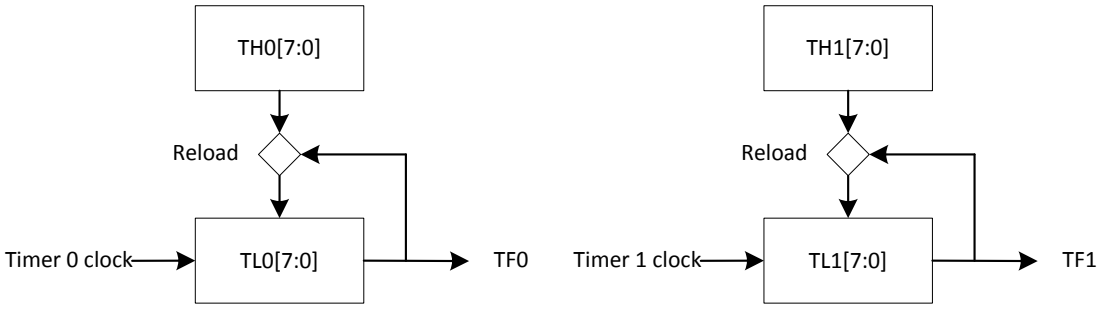
12.3 Mode 1: 16-bit Up Counting Timer

Mode 1 is a 16-bit up counting timer. Once the timer's counter overflow is occurred (from 0xFFFF to 0x0000), TF0/TF1 would be issued which is readable and writable by firmware or can be handled by interrupt controller (if ET0/ET1 applied).



12.4 Mode 2: 8-bit Up Counting Timer with Specified Reload Value Support

Mode 2 is an 8-bit up counting timer (TL0/TL1) with a specifiable reload value. An overflow event (TL0/TL1 counts from 0xFF to 0x00) issues its TF0/TF1 flag for firmware or interrupt controller; meanwhile, the timer duplicates TH0/TH1 value to TL0/TL1 register in the same time. As a result, the timer is actually counts from 0xFF to the value of TH0/TH1.

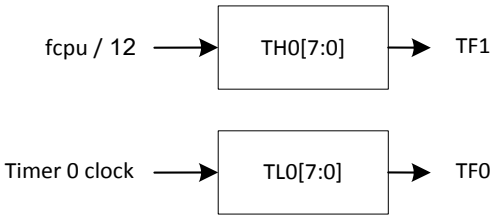


12.5 Mode 3 (Timer 0 only): Separated Two 8-bit Up Counting Timer

Mode 3 treats TH0 and TL0 as two separated 8-bit timers. TL0 is an 8-bit up counting timer with two clock sources selection (fcpu and fosc), whereas TH0 clock source is fixed at fcpu/12. Only TL0 clock source can be gated (pause) by INT0 pin if T0GATE is applied.

In this mode TL0 counter is enabled by TR0, and its overflow signal is reflected in TF0 flag. TH0 counter is controlled by TR1, and TF1 flag is also occupied by TH0 overflow signal.

Timer 1 cannot issue any overflow event in this situation, and it can be seen as a self-counting timer without flag support.



12.6 Timer 0 and Timer 1 Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
TCON	TF1	TR1	TF0	TR0	-	-	IE0	-
TCON0	-	T0RATE2	T0RATE1	T0RATE0	-	T1RATE2	T1RATE1	T1RATE0
TMOD	-	T1CT	T1M1	T1M0	T0GATE	T0CT	T0M1	T0M0
TH0	TH07	TH06	TH05	TH04	TH03	TH02	TH01	TH00
TL0	TL07	TL06	TL05	TL04	TL03	TL02	TL01	TL00
TH1	TH17	TH16	TH15	TH14	TH13	TH12	TH11	TH10
TL1	TL17	TL16	TL15	TL14	TL13	TL12	TL11	TL10
IEN0	EAL	-	ET2	ES0	ET1	-	ET0	EX0

TCON Register (0x88)

Bit	Field	Type	Initial	Description
7	TF1	R/W	0	Timer 1 overflow event 0: Timer 1 does not have any overflow event 1: Timer 1 has overflowed This bit can be cleared automatically by interrupt handler, or manually by firmware
6	TR1	R/W	0	Timer 1 function 0: Disable 1: Enable
5	TF0	R/W	0	Timer 0 overflow event 0: Timer 0 does not have any overflow event 1: Timer 0 has overflowed This bit can be cleared automatically by interrupt handler, or manually by firmware
4	TR0	R/W	0	Timer 0 function 0: Disable 1: Enable
3..2	Reserved	R	0	
1	IE0	R/W	0	Refer to INT0
0	Reserved	R	0	

IEN0 Register (0xA8)

Bit	Field	Type	Initial	Description
7	EAL	R/W	0	Interrupts enable. Refer to Chapter Interrupt
3	ET1	R/W	0	Timer 1 interrupt 0: Disable 1: Enable
1	ET0	R/W	0	Timer 0 interrupt 0: Disable 1: Enable

TCON0 Register (0xE7)

Bit	Field	Type	Initial	Description
7	Reserved	R	0	
6..4	T0RATE[2:0]	R/W	000	Clock divider of Timer 0 external clock source 000: f_{EXT0} / 128 001: f_{EXT0} / 64 010: f_{EXT0} / 32 011: f_{EXT0} / 16 100: f_{EXT0} / 8 101: f_{EXT0} / 4 110: f_{EXT0} / 2 111: f_{EXT0} / 1
3	Reserved	R	0	
2..0	T1RATE[2:0]	R/W	000	Clock divider of Timer 0 external clock source 000: f_{EXT1} / 128 001: f_{EXT1} / 64 010: f_{EXT1} / 32 011: f_{EXT1} / 16 100: f_{EXT1} / 8 101: f_{EXT1} / 4 110: f_{EXT1} / 2 111: f_{EXT1} / 1

TH0 / TH1 Registers (TH0: 0x8C, TH1: 0x8D)

Bit	Field	Type	Initial	Description
7..0	TH0/TH1	R/W	0x00	High byte of Timer 0 and Timer 1 counter

TL0 / TL1 Register (TL0: 0x8A, TL1: 0x8B)

Bit	Field	Type	Initial	Description
7..0	TL0/TL1	R/W	0x00	Low byte of Timer 0 and Timer 1 counter

TMOD Register (0x89)

Bit	Field	Type	Initial	Description
7	Reserved	R	0	
6	T1CT	R/W	0	Timer 1 clock source selection 0: f_{Timer1} = fcpu / 12 1: $f_{Timer\ 1}$ = fosc / T1RATE (refer to T1RATE) *(1)
5..4	T1M[1:0]	R/W	00	Timer 1 operation mode 00: 13-bit up counting timer 01: 16-bit up counting timer 10: 8-bit up counting timer with reload support 11: Reserved
3	T0GATE	R/W	0	Timer 0 gate control mode 0: Disable 1: Enable, Timer 0 clock source is gated by INT0
2	T0CT	R/W	0	Timer 0 clock source selection 0: f_{Timer0} = fcpu / 12 1: f_{Timer0} = fosc / T0RATE (refer to T0RATE) *(2)
1..0	T0M[1:0]	R/W	00	Timer 0 operation mode 00: 13-bit up counting timer 01: 16-bit up counting timer 10: 8-bit up counting timer with reload support 11: Separated two 8-bit up counting timer

*(1) f_{EXT1} = fosc.

*(2) f_{EXT0} = fosc.

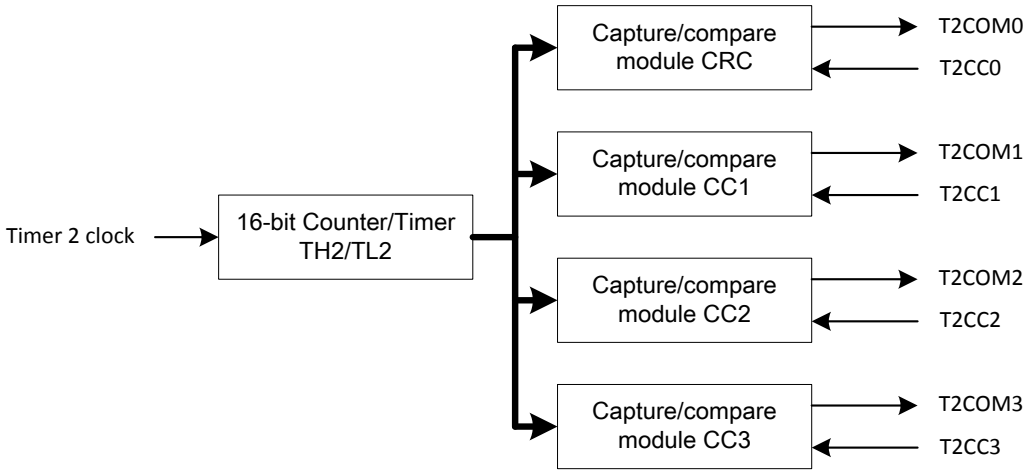
12.7 Sample Code

The following sample code demonstrates how to perform T0/T1 with interrupt.

```
#define T0Mode0     (0 << 0)  //T0 mode0, 13-bit counter
#define T0Mode1     (1 << 0)  //T0 mode1, 16-bit counter
#define T0Mode2     (2 << 0)  //T0 mode2, 8-bit auto-reload counter
#define T0Mode3     (3 << 0)  //T0 mode3, T0 two 8-bit counter/T1 no flag
#define T0GATE      (8 << 0)  //T0 gating clock by INT0
#define T0ClkFcpu    (0 << 0)  //T0 clock source from Fcpu/12
#define T0ClkExt     (4 << 0)  //T0 clock source from Fosc
#define T0ExtFosc    (0 << 4)  //T0 clock source from Fosc

#define T1Mode0     (0 << 4)  //T1 mode0, 13-bit counter
#define T1Mode1     (1 << 4)  //T1 mode1, 16-bit counter
#define T1Mode2     (2 << 4)  //T1 mode2, 8-bit auto-reload counter
#define T1Mode3     (3 << 4)  //T1 mode3, T1 stop
#define T1ClkFcpu    (0 << 4)  //T0 clock source from Fcpu/12
#define T1ClkExt     (4 << 4)  //T0 clock source from Fosc

void InitT0T1(void)
{
  // T0/T1_Initial
  TH0 = 0x00;
  TL0 = 0x00;
  TH1 = 0x00;
  TL1 = 0x00;
  // T0 mode0 with gating clock by INT0, clock source from Fosc
  TMOD |= T0Mode0 | T0GATE | T0ClkExT;
  // T0 clock source = Fosc/1
  TCON0 |= 0x70;
  // T1 mode1, clock source from Fcpu/12
  TMOD |= T1Mode1 | T1ClkFcpu;
  // Timer 0/1 enable. Clear TF0/TF1
  TCON |= 0x50;
  // Enable T0/T1 interrupt
  IEN0 |= 0x0A;
  // Enable total interrupt
  IEN0 |= 0x80;

  P0 = 0x00;
  P0M = 0x03;
}

void T0Interrupt(void) interrupt ISRTimer0  //0x0B
{ //TF0 clear by hardware
  P00 = ~P00;
}
void T1Interrupt(void) interrupt ISRTimer1  //0x1B
{ //TF1 clear by hardware
  P01 = ~P01;
}
```

13 Timer 2

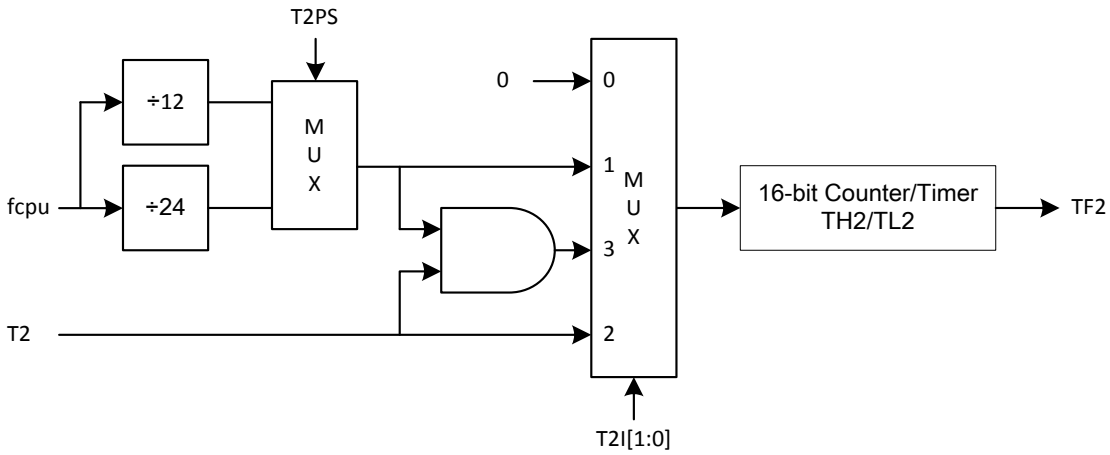
Timer 2 is a 16-bit up counting timer which has several optional extensions: specified reload value, comparison output (PWM) and capture function. Timer 2 consists of a dedicated 16-bit counter/timer and four 16-bit capture/compare modules. Each capture/compare module has its own associated I/O when enabled. Each capture/compare module may be configured to operate independently in one of 3 modes: compare, capture with rising edge, or capture with register be written.



13.1 Timer 2 Up-counting Control

Timer 2 has three operation modes by its clock source: specify fcpu clocks (fcpu/12 and fcpu/24), specify fcpu clocks with a stop control, and external clock input. The table below categorizes these three operation modes and its related registers (T2I1, T2I0 and T2PS). Once the timer's counter is overflow (counts from 0xFFFF to 0x0000), TF2 would be issued immediately which can read/write by firmware. Timer 2 interrupt function is controlled by ET2.

T2I1	T2I0	T2PS	Timer 2 Clock Source
0	0	X	Disable Timer 2
0	1	0	fcpu/12
0	1	1	fcpu/24
1	1	0	fcpu/12 (stop counting when T2 pin is low, resume when T2 is high)
1	1	1	fcpu/24 (stop counting when T2 pin is low, resume when T2 is high)
1	0	X	T2 pin rising edge (T2 pin clock rate ≤ 0.5 * fcpu)

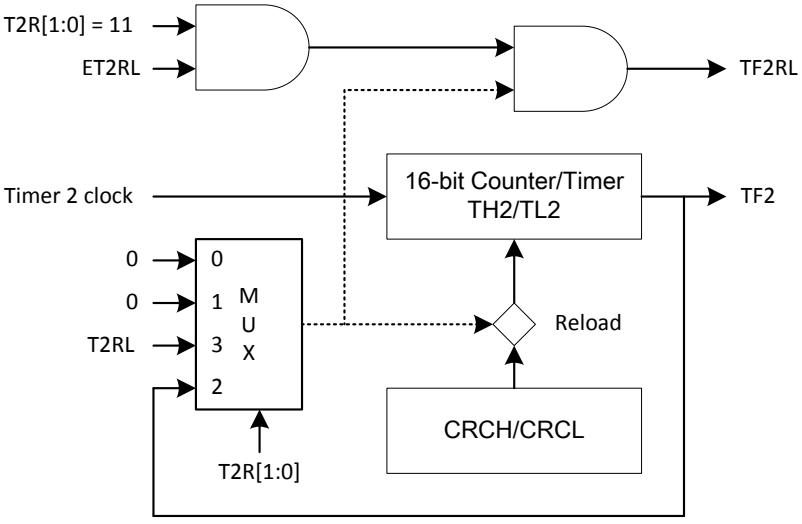


13.2 Specified Timer 2 Reload Value

The specified reload value is an optional function which can reload Timer 2 counter by overflow or external control pin.

If overflow-to-reload is selected, Timer 2 duplicates CRCH/CRCL value to its counter (TH2/TL2) automatically by overflow signal. As a result, Timer 2 would repeatedly counts from CRCH/CRCL value to 0xFFFF.

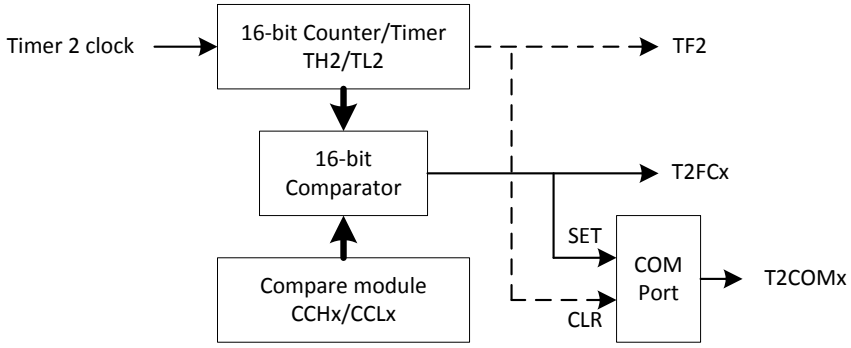
On the other hand, a falling edge of external pin T2RL (shared with P2.0) can also be chosen as a reload signal. In this situation, Timer 2 normally counts its counter from 0x0000 to 0xFFFF if T2RL pin remains stable, yet the counter value would be replaced at any time by CRCH/CRCL value as long as T2RL pin has a falling signal. Subsequently, Timer 2 continues its counting routine from CRCH/CRCL value, and external reload flag (TF2RL) would be issued if interrupt function is enabled (both ET2RL and ET2 are set). External reload interrupt vector is shared with Timer 2 interrupt vector and identify event by firmware.

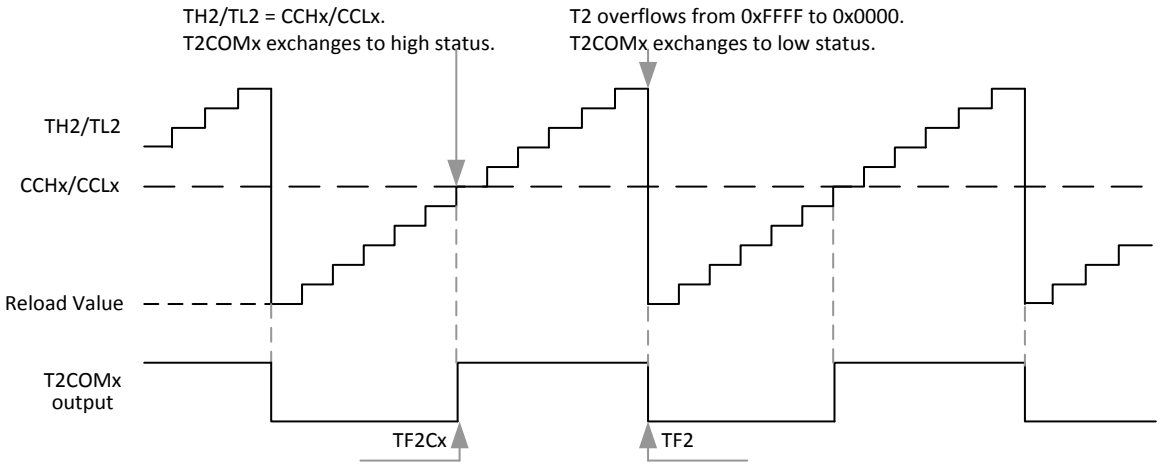


13.3 Comparison Output (PWM)

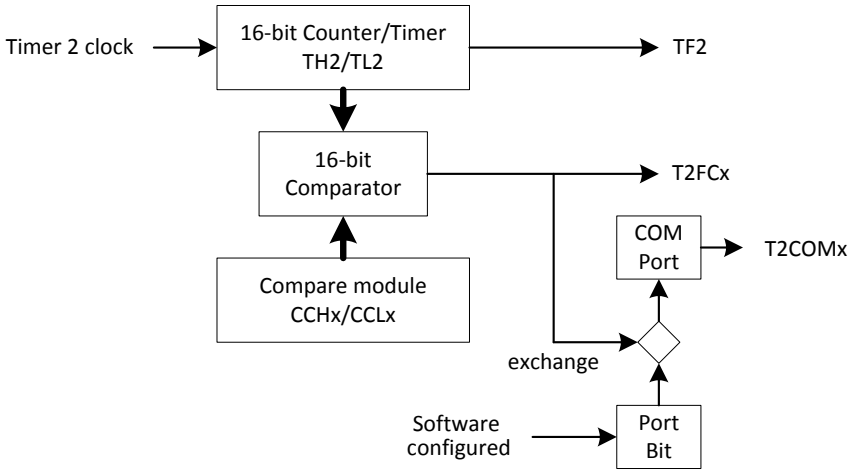
Timer 2 has up to four set of comparison output. Each set (CRC/CC1/CC2/CC3) independently compares its value to Timer 2 counter (TH2/TL2) and outputs the comparison result on T2COM0 to T2COM3 pins (shared with P00, P01, P03 and P0.4). The comparison result has two output methods: directly output and indirectly output.

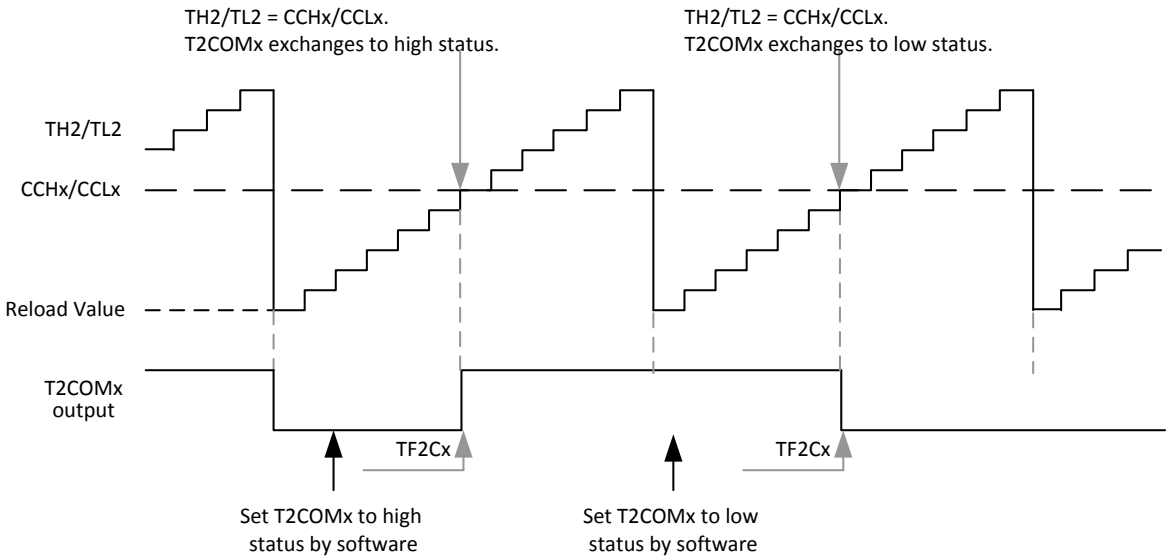
The directly method is that the mapped pin outputs low status if CRC/CC1/CC2/CC3 register is lower than Timer 2 counter, whereas it outputs high status if its register value is equal/lager than Timer 2 counter. Thus, the output status is changed twice at crossover points. As CRC/CC1/CC2/CC3 register is equal to Timer 2 counter, a TF2C0/TF2C1/TF2C2/TF2C3 flag is issued which can read/write by firmware. Compare interrupt function is controlled by ET2C0/ET2C1/ET2C2/ET2C3.





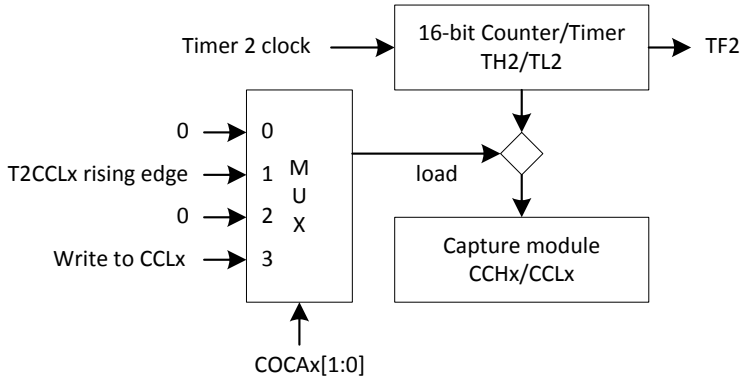
By contrast, the indirectly output method is an event which keep the mapped pin's previous output setting until Timer 2 counter overtakes CRC/CC1/CC2/CC3 register value. In this mode, the transition of the output signal can be configured by software. In other word, the P0.0 register bit would be affect T2COM0/P0.0 pin when TH2/TL2 equal to CRC registers. A Timer 2 overflow causes no output change.



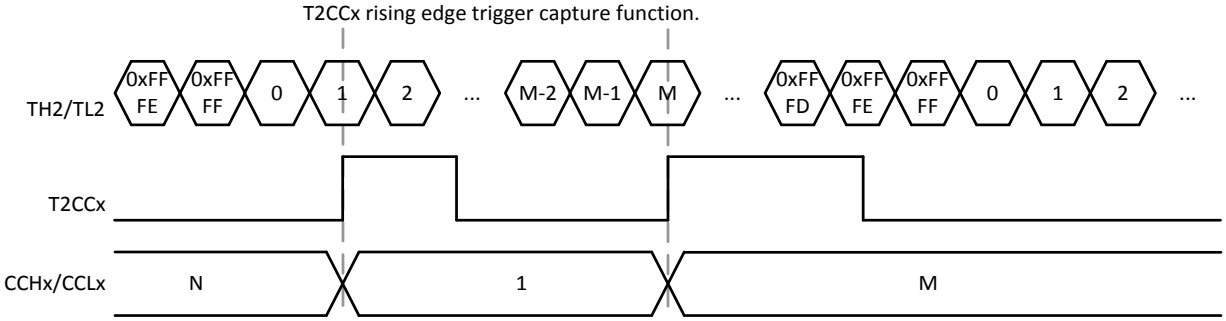


13.4 Capture Function

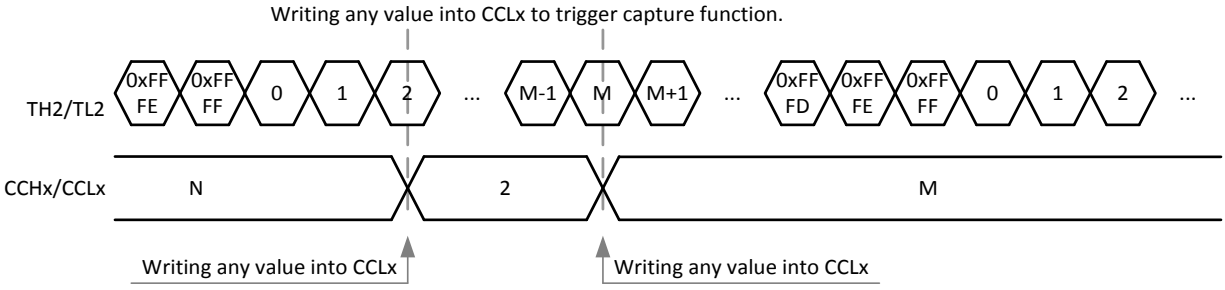
The capture function is similar to split/lap button of a stopwatch. While Timer 2 counter (TH2/TL2) routinely count up, a split event records counter value in CRC/CC1/CC2/CC3 register(s).



The split event can from hardware or software. The T2CC0 pin can trigger a hardware split event that duplicates TH2/TL2 value to CRCH/CRCL registers, whereas T2CC1, T2CC2 and T2CC3 respectively control CC1 to CC3 registers.



A software split event is triggered by writing any value into CRCL/CCL1/CCL2/CCL3 register. While perform a writing instruction to these registers, the present TH2/TL2 value would be record in the paired registers instead.



13.5 Timer 2 Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
T2CON	T2PS	I3FR	-	T2R1	T2R0	T2CM	T2I1	T2I0
CCEN	COCA31	COCA30	COCA21	COCA20	COCA11	COCA10	COCA01	COCA00
TH2	TH27	TH26	TH25	TH24	TH23	TH22	TH21	TH20
TL2	TL27	TL26	TL25	TL24	TL23	TL22	TL21	TL20
CRCH	CRCH7	CRCH6	CRCH5	CRCH4	CRCH3	CRCH2	CRCH1	CRCH0
CRCL	CRCL7	CRCL6	CRCL5	CRCL4	CRCL3	CRCL2	CRCL1	CRCL0
CCH3	CCH37	CCH36	CCH35	CCH34	CCH33	CCH32	CCH31	CCH30
CCL3	CCL37	CCL36	CCL35	CCL34	CCL33	CCL32	CCL31	CCL30
CCH2	CCH27	CCH26	CCH25	CCH24	CCH23	CCH22	CCH21	CCH20
CCL2	CCL27	CCL26	CCL25	CCL24	CCL23	CCL22	CCL21	CCL20
CCH1	CCH17	CCH16	CCH15	CCH14	CCH13	CCH12	CCH11	CCH10
CCL1	CCL17	CCL16	CCL15	CCL14	CCL13	CCL12	CCL11	CCL10

IEN0	EAL	-	ET2	ES0	ET1	-	ET0	EX0
IEN1	ET2RL	-	ET2C3	ET2C2	ET2C1	ET2C0	ESPI	EI2C
IRCON	TF2RL	TF2	TF2C3	TF2C2	TF2C1	TF2C0	-	-

T2CON Register (0xC8)

Bit	Field	Type	Initial	Description
7	T2PS	R/W	0	Timer 2 pre-scalar 0: fcpu/12 1: fcpu/24
6	I3FR	R/W	0	In compare mode: 0: The COM0 interrupt would be generated when the content of Timer2 become not equal to the CRC register. 1: The COM0 interrupt would be generated when the content of Timer2 become equal to the CRC register. In capture mode 0: 0: The timer 2 content would be latched into CRC register by T2CC0 is falling edge. 1: The timer 2 content would be latched into CRC register by T2CC0 is rising edge.
5	Reserved	R/W	0	
4..3	T2R[1:0]	R/W	00	Specified Timer 2 reload value 00: Disable 01: Disable 10: Load CRCH/CRCL to TH2/TL2 by counter overflow 11: Load CRCH/CRCL to TH2/TL2 by T2RL pin
2	T2CM	R/W	0	Timer 2 comparison output 0: Directly output method 1: Indirectly output, next output status can be specified
1..0	T2I[1:0]	R/W	00	Timer 2 up counting control 00: Disable 01: Clock rate is defined by T2PS 10: Clock source is T2 pin 11: Clock rate is defined by T2PS with T2 pin gate control

CCEN Register (0xC1)

Bit	Field	Type	Initial	Description
7..6	COCA3[1:0]	R/W	00	Comparison and capture function of CC3 00: Disable 01: Capture by T2CC3 pin rising edge 10: Comparison function 11: Capture by writing CCL3 register
5..4	COCA2[1:0]	R/W	00	Comparison and capture function of CC2 00: Disable 01: Capture by T2CC2 pin rising edge 10: Comparison function 11: Capture by writing CCL2 register
3..2	COCA1[1:0]	R/W	00	Comparison and capture function of CC1 00: Disable 01: Capture by T2CC1 pin rising edge 10: Comparison function 11: Capture by writing CCL1 register
1..0	COCA0[1:0]	R/W	00	Comparison and capture function of CRC 00: Disable 01: Capture by T2CC0 pin rising edge 10: Comparison function 11: Capture by writing RCCL register

TH2/TL2 Registers (TH2: 0xCD, TL2: 0xCC)

Bit	Field	Type	Initial	Description
7..0	TH2/TL2	R/W	0x00	Timer 2 16-bit counter registers.

CRC Registers (CRCH: 0xCB, CRCL: 0xCA)

Bit	Field	Type	Initial	Description
7..6	CRCH[15:0]	R/W	0x00	16-bit compare/capture registers.

CCH3/CCL3 Registers (CCH3: 0xC7, CCL3: 0xC6)

Bit	Field	Type	Initial	Description
7..6	CCH3/CCL3	R/W	0x00	16-bit compare/capture registers.

CCH2/CCL2 Registers (CCH2: 0xC5, CCL2: 0xC4)

Bit	Field	Type	Initial	Description
7..6	CCH2 /CCL2	R/W	0x00	16-bit compare/capture registers.

CCH1/CCL1 Registers (CCH1: 0xC3, CCL1: 0xC2)

Bit	Field	Type	Initial	Description
7..6	CCH1/CCL1	R/W	0x00	16-bit compare/capture registers.

IEN0 Register (0xA8)

Bit	Field	Type	Initial	Description
7	EAL	R/W	0	Interrupts enable. Refer to Chapter Interrupt
5	ET2	R/W	0	Enable Timer 2 interrupt
Else				Refer to other chapter(s)

IEN1 Register (0xB8)

Bit	Field	Type	Initial	Description
7	ET2RL	R/W	0	T2 Timer external reload interrupt control bit 0: Disable 1: Enable
6	Reserved	R	0	
5	ET2C3	R/W	0	T2 Timer COM3 interrupt control bit 0: Disable 1: Enable
4	ET2C2	R/W	0	T2 Timer COM2 interrupt control bit 0: Disable 1: Enable
3	ET2C1	R/W	0	T2 Timer COM1 interrupt control bit 0: Disable 1: Enable
2	ET2C0	R/W	0	T2 Timer COM0 interrupt control bit 0: Disable 1: Enable
Else				Refer to other chapter(s)

13.6 Sample Code

The following sample code demonstrates how to perform T2 compare function with interrupt.

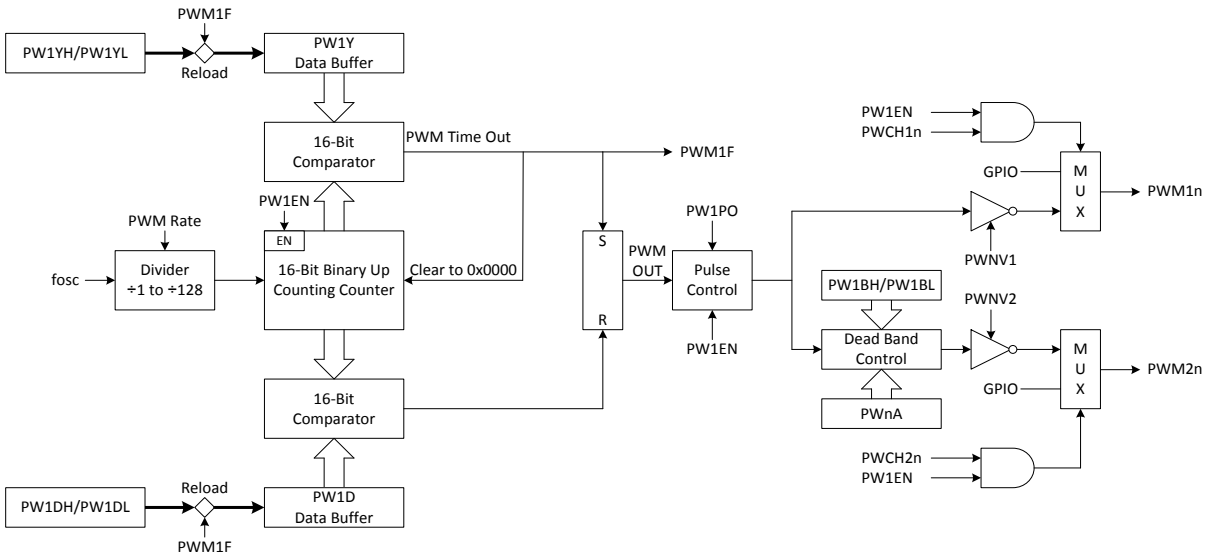
```
#define T2ClkFcpu    (1 << 0)  //T2 clock from Fcpu
#define T2ClkPin     (2 << 0)  //T2 clock from T2 pin
#define T2ClkGate    (3 << 0)  //T2 clock from Fcpu with T2 pin gating
#define T2Fcpu12     (0 << 7)  //T2 clock = Fcpu/12
#define T2Fcpu24     (1 << 7)  //T2 clock = Fcpu/24
#define T2RLMode0    (2 << 3)  //T2 reload mode0 = auto-reload
#define T2RLMode1    (3 << 3)  //T2 reload mode1 = T2RL falling edge trigger
#define ComMode0     (0 << 2)  //Compare mode = directly method
#define ComMode1     (1 << 2)  //Compare mode = indirectly output method
#define T2COM0EdNE   (0 << 6)  //T2COM0 interrupt edge = no equle CRC
#define T2COM0EdE    (1 << 6)  //T2COM0 interrupt edge = equle CRC
#define T2COM0En     (2 << 0)  //T2COM0 compare funcion enable
#define T2COM1En     (2 << 2)  //T2COM1 compare funcion enable
#define T2COM2En     (2 << 4)  //T2COM2 compare funcion enable
#define T2COM3En     (2 << 6)  //T2COM3 compare funcion enable

void InitT2(void)
{
  // T2_Initial
  TH2 = 0x00;
  TL2 = 0x00;
  CRCH = 0x80;
  CRCL = 0x00;
  CCH1 = 0xC0;
  CCL1 = 0x00;
  CCH2 = 0xE0;
  CCL2 = 0x00;
  CCH3 = 0xF0;
  CCL3 = 0x00;

  // T2 clock from Fcpu/24 with T2 pin gating
  // Reload mode1 = T2RL falling edge trigger
  // Compare mode = directly method
  // T2COM0 interrupt trigger = equle CRC
  T2CON |= T2ClkGate | T2Fcpu24 | T2RLMode1 | ComMode0 | T2COM0EdE;

  // Compare function T2COM0/1/2/3 enable
  CCEN |= T2COM0En | T2COM1En | T2COM2En | T2COM3En;

  // P07(T2)/P20(T2RL) is input mode with pull-high resister
  P0M &= 0x7F;
  P2M &= 0xFE;
  P0UR &= 0x80;
  P2UR &= 0x01;

  // Enable T2RL/T2COM0/1/2/3 interrupt
  IEN1 |= 0xBC;

  // Enable total/Timer2 interrupt
  IEN0 |= 0xA0;

  P0 = 0x00;
```

```
}

void T2Interrupt(void) interrupt ISRTimer2  //0x2B
{ //TF2/TF2RL clear by software
  if ((IRCON & 0x40) == 0x40) {
    IRCON  &= 0xBF;   //Clear TF2
    P00 = ~P00;
  }
  if ((IRCON & 0x80) == 0x80) {
    IRCON  &= 0x7F;   //Clear TF2RL
    P01 = ~P01;
  }
}

void T2COM0Interrupt(void) interrupt ISRCom1  //0x53
{ //TF2C0 clear by hardware
  P02 = ~P02;
}

void T2COM1Interrupt(void) interrupt ISRCom2  //0x5B
{ //TF2C1 clear by hardware
  P03 = ~P03;
}

void T2COM2Interrupt(void) interrupt ISRCom3  //0x63
{ //TF2C2 clear by hardware
  P04 = ~P04;
}

void T2COM3Interrupt(void) interrupt ISRCom4  //0x6B
{ //TF2C3 clear by hardware
  P05 = ~P05;
}
```

14 PWM

The PW1 timer includes a 16-bit binary up 4-channel PWM, and one pulse PWM functions. By the counter reaches the up-boundary value (PW1Y), it clears its counter and triggers an interrupt signal. PWM's duty cycle is controlled by PW1D register.

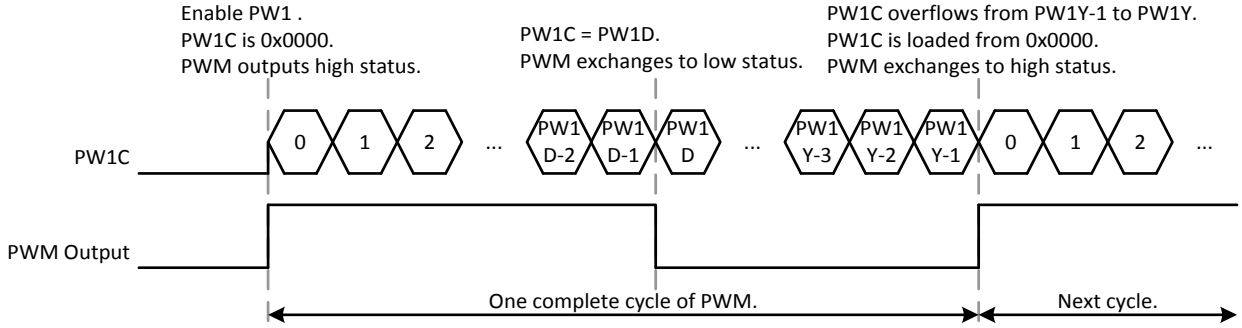
The PWM also support one pulse output signal which can disables itself by the end of first PWM cycle. Thus, only one pulse would be generated in this condition. The PWM has four programmable channels shared with GPIO pins and controlled by PW1CH[5:4, 1:0] bit. The output operation must be through enabled each bit/channel of PW1CH[5:4, 1:0] bits. The enabled PWM channel exchanges from GPIO to PWM output. When the PW1CH[5:4, 1:0] bits disables, the PWM channel returns to last status of GPIO mode. The PWM build in IDLE Mode wake-up function if interrupt enable. When PWM timer overflow occurs (counts from PW1Y-1 to PW1Y), PWM1F would be issued immediately which can read/write by firmware. PWM1 interrupt function is controlled by EPWM1.



14.1 General PWM

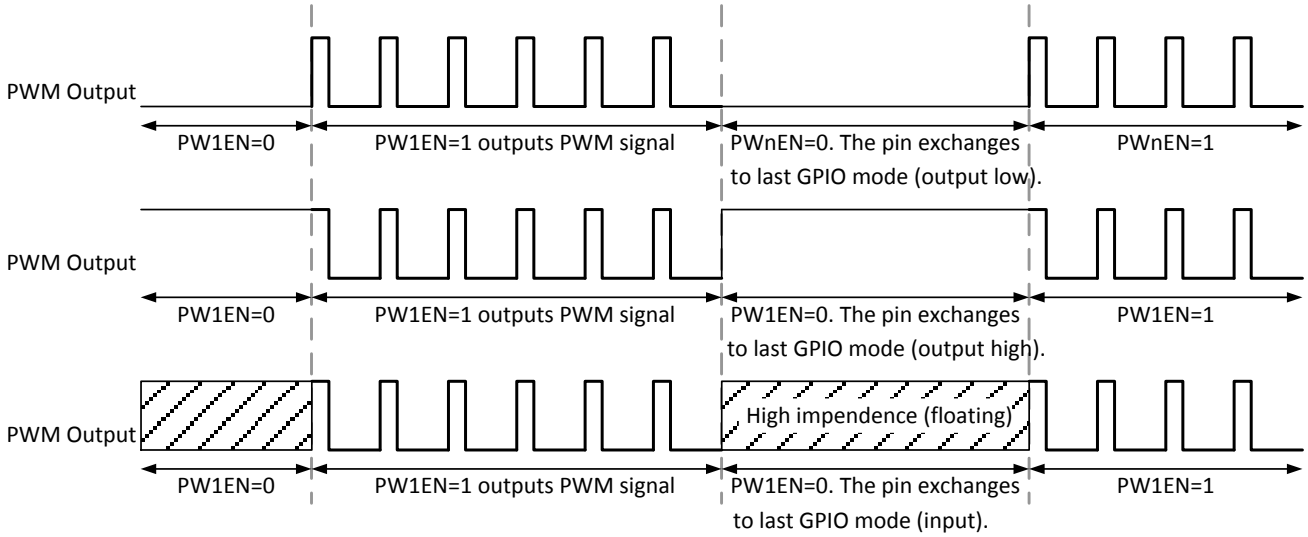
PW1 timer builds in PWM function controlled by PW1EN and PW1CH[5:4, 1:0] bits. PWM10, PWM11, PWM20, PWM21 are output pins. Those output pins are shared with GPIO pin controlled by PW1CH[5:4, 1:0] bits. When output PWM function, we must be set PW1EN =1. When PWM output signal synchronize finishes, the PWM channel exchanges from GPIO to PWM output. When PW1EN = 0, the PWM channel returns to GPIO mode and last status. PWM signal is generated from the result of PW1Y and PW1D comparison combination. When PW1C counts from 0x0000, the PWM outputs high status which is the PWM initial status. PW1C is loaded new data from PW1Y register to decide PWM cycle and resolution. PW1C keeps counting, and the system compares PW1C and PW1D. When PW1C=PW1D, the PWM output status exchanges to low PW1C keeps

counting. When PW1 timer overflow occurs (PW1Y-1 to 0x0000), and one cycle of PWM signal finishes. PW1C is reloaded from 0x0000 automatically, and PWM output status exchanges to high for next cycle. PW1D decides the high duty duration, and PW1Y decides the resolution and cycle of PWM. PW1D can't be larger than PW1Y, or the PWM signal is error. PWM clock source is fosc, PW1RATE[2:0] bits: 000 = fosc/128, 001 = fosc/64, 010 = fosc/32, 011 = fosc/16, 100 = fosc/8, 101 = fosc/4, 110 = fosc/2, 111 = fosc/1.



PWM Period = PW1Y

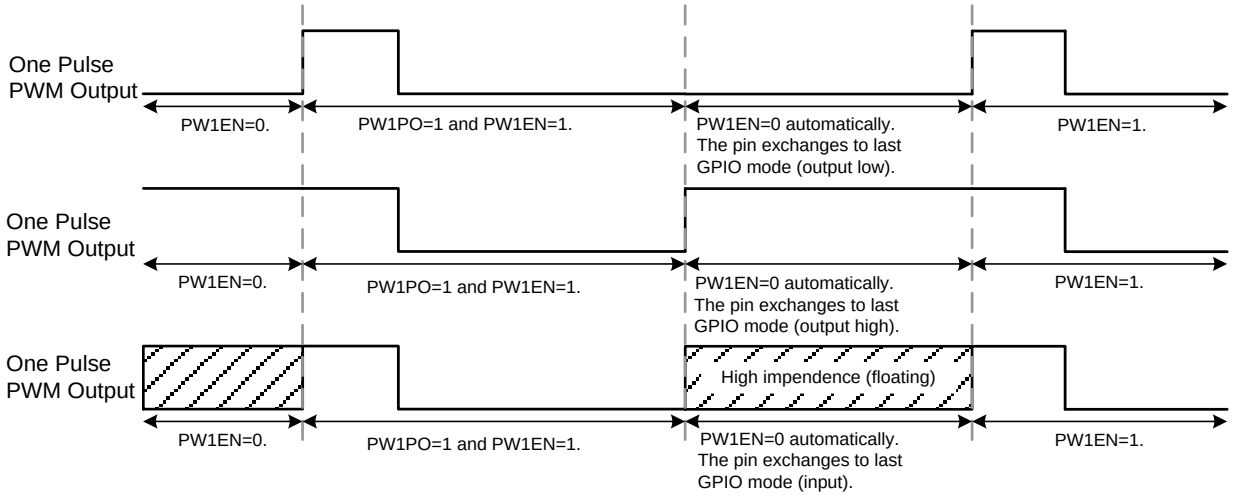
PWM duty = (PW1D): (PW1Y-PW1D)



14.2 One Pulse PWM

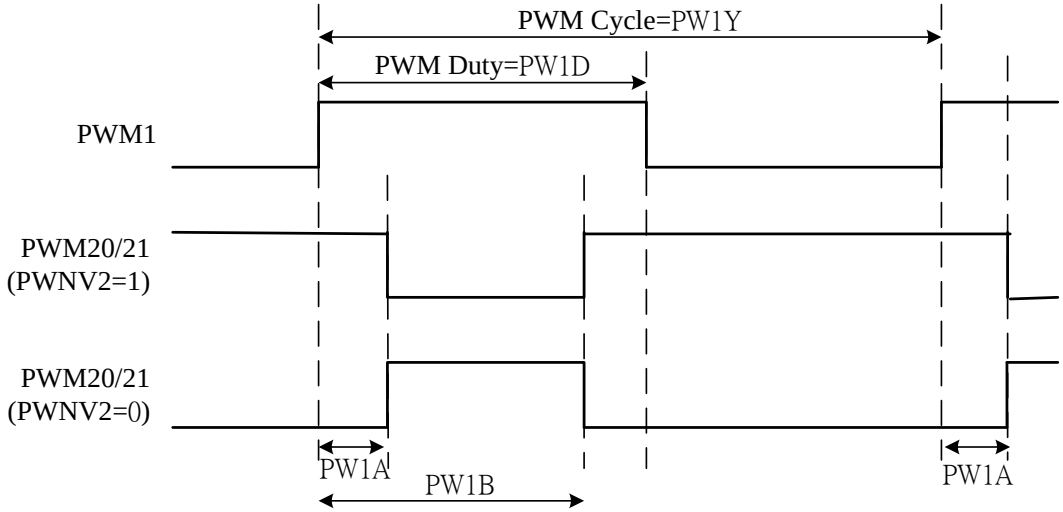
When PW1PO = 0, PW1 is PWM function mode. When PW1PO = 1 and PW1EN=1, PW1 will output one pulse PWM function and the PWM1F is issued as PW1 counter overflow. PW1EN bit is cleared automatically and pulse output pin returns to idle status. To output next pulse is to set PW1EN bit by program again. One pulse PWM channels selected by PW1CH[5:4, 1:0] bits. PWM10, PWM11, PWM20, PWM21 are output pins. Those output pins are shared with GPIO pin controlled by PW1CH[5:4, 1:0] bits. When output one pulse PWM function, we must be set PW1PO=PW1EN=1.

When one pulse PWM output signal synchronize finishes, the PWM channel exchanges from GPIO to PWM output. When one pulse PWM output finishes, PW1EN = 0, the PWM channel returns to GPIO mode and last status.



14.3 Inverse and Dead Band

The PWM builds in inverse output function. The PWM has one inverse PWM signal as PWNVn =1. When PWNVn= 1, the PW1 outputs the inverse PWM signal of PWM1. When PWNVn = 0, the PW1 outputs the non-inverse PWM signal of PWM1. The inverse PWM output waveform is below diagram.



The PWM dead band occurs in PWM high pulse width, and the dead band period is programmable from PW1A and PW1D-PW1B registers. The dead band period is symmetrical at left-right terminal of PWM pulse width or not. If the bead band period is longer than PWM duty, the PWM is no output.

14.4 PWM Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PW1M	PW1EN	PW1rate2	PW1rate1	PW1rate0	PWNV2	PWNV1	-	PW1PO
PW1CH	-	-	PWCH21	PWCH20	-	-	PWCH11	PWCH10
PW1YH	PW1Y15	PW1Y14	PW1Y13	PW1Y12	PW1Y11	PW1Y10	PW1Y9	PW1Y8
PW1YL	PW1Y7	PW1Y6	PW1Y5	PW1Y4	PW1Y3	PW1Y2	PW1Y1	PW10
PW1BH	PW1B15	PW1B14	PW1B13	PW1B12	PW1B11	PW1B10	PW1B9	PW1B8
PW1BL	PW1B7	PW1B6	PW1B5	PW1B4	PW1B3	PW1B2	PW1B1	PW1B0
PW1DH	PW1D15	PW1D14	PW1D13	PW1D12	PW1D11	PW1D10	PW1D9	PW1D8
PW1DL	PW1D7	PW1D6	PW1D5	PW1D4	PW1D3	PW1D2	PW1D1	PW1D0
PW1A	PW1A7	PW1A6	PW1A5	PW1A4	PW1A3	PW1A2	PW1A1	PW1A0

PW1M Registers (PW1M: 0xAB)

Bit	Field	Type	Initial	Description
7	PW1EN	R/W	0	PW1 function 0: Disable 1: Enable*
6..4	PW1RATE	R/W	000	PWM timer clock source 000: fosc / 128 001: fosc / 64 010 fosc / 32 011: fosc / 16 100: fosc / 8 101: fosc / 4 110: fosc / 2 111: fosc / 1
3	PWNV2	R/W	0	PWM20/21 pin output control 0: Non-inverse 1: Inverse
2	PWNV1	R/W	0	PWM10/11 pin output control 0: Non-inverse 1: Inverse
1	Reserved	R/W	0	
0	PW1PO	R/W	0	One pulse function 0: Disable 1: Enable

* When the period is setting 0x0000, after PWM is set enable bit, the PWM will stop and the period can’t update.

PW1CH Register (0xBE)

Bit	Field	Type	Initial	Description
7..6	Reserved	R/W	0	
5	PWCH21	R/W	0	PWM1 shared-pin control
4	PWCH20			0: GPIO
				1: PWM output (shared with P0.6/ P1.5)
3..2	Reserved	R/W	0	
1	PWCH11	R/W	0	PWM1 shared-pin control
0	PWCH10			0: GPIO
				1: PWM output (shared with P0.5/ P1.4)

PW1YH/PW1YL Registers (PW1YH: 0xAD, PW1YL: 0xAC)

Bit	Field	Type	Initial	Description
7..0	PW1YH/L	R/W	0x00	16-bit PWM1 period control*.

* The period configuration must be setup completely before starting PWM function.

PW1DH/PW1DL Registers (PW1DH: 0xBC, PW1DL: 0xBB)

Bit	Field	Type	Initial	Description
7..0	PW1DH/L	R/W	0x00	16-bit PWM1 duty control

PW1BH/PW1BL Registers (PW1BH: 0xAF, PW1BL: 0xAE)

Bit	Field	Type	Initial	Description
7..0	PW1BH/L	R/W	0x00	16-bit PWM1 dead band control

PW1A Registers (PW1A: 0xBD)

Bit	Field	Type	Initial	Description
7..0	PW1A	R/W	0x00	8-bit PWM1 dead band control

IEN0 Register (0xA8)

Bit	Field	Type	Initial	Description
7	EAL	R/W	0	Interrupts enable. Refer to Chapter Interrupt
Else				Refer to other chapter(s)

IEN4 Register (0XD1)

Bit	Field	Type	Initial	Description
7	EPWM1	R/W	0	PWM1 interrupt control bit. 0 = Disable PWM1 interrupt function. 1 = Enable PWM1 interrupt function.
3	PWM1F	R/W	0	PWM1 interrupt request flag. 0: None PWM1 interrupt request 1: PWM1 interrupt request.
Else	Reserved	R	0	

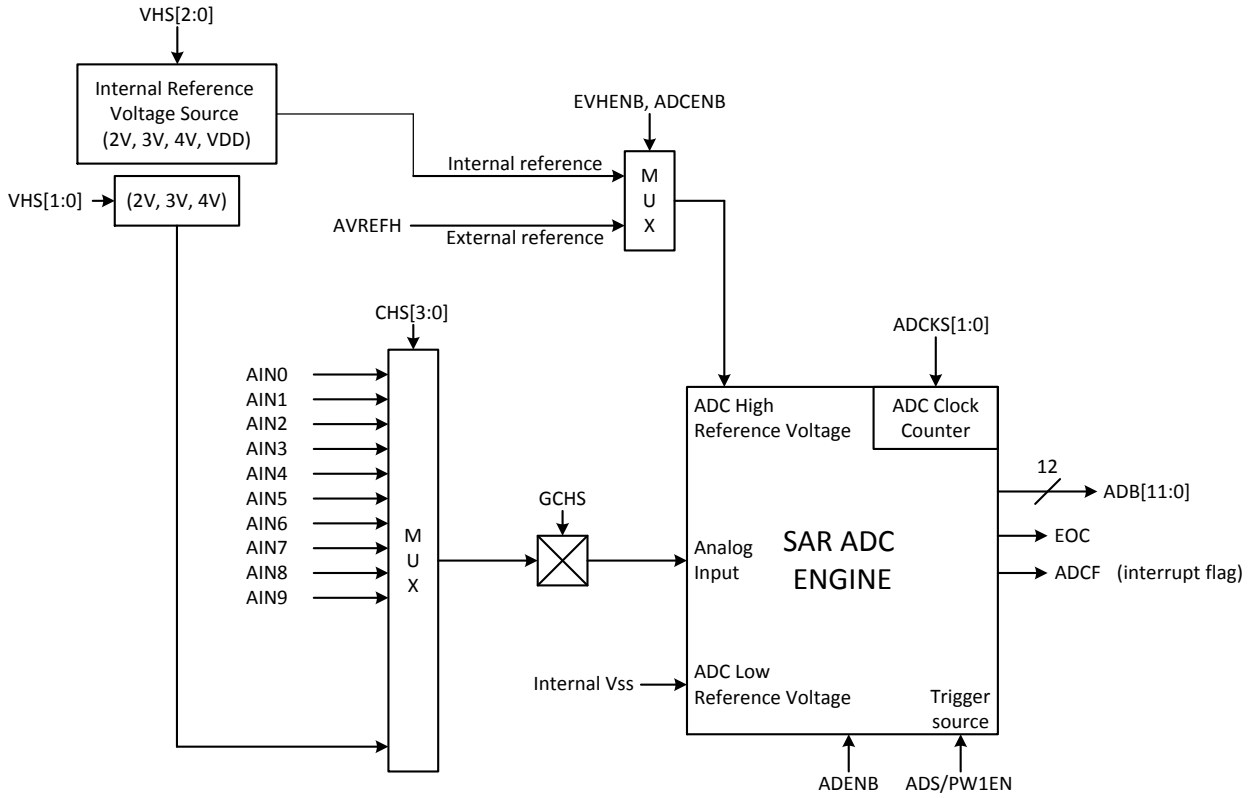
14.5 Sample Code

The following sample code demonstrates how to perform PW1 with interrupt.

```
#define PW1Inv1      (1 << 2)  //PWM10/11 output inverse
#define PW1Inv2      (1 << 3)  //PWM20/21 output inverse
#define PW1OnePu     (1 << 0)  //Enable PW1 pulse output function
#define PWM10En      (1 << 0)  //Enable PWM10 output function
#define PWM11En      (2 << 0)  //Enable PWM11 output function
#define PWM20En      (1 << 4)  //Enable PWM20 output function
#define PWM21En      (2 << 4)  //Enable PWM21 output function
#define PW1En         (1 << 7)  //Enable PWM1 function

void InitPWM(void)
{
  // PWM1_Initial
  PW1YH = 0x80;
  PW1YL = 0x00;
  PW1DH = 0x40;
  PW1DL = 0x00;
  PW1BH = 0x60;
  PW1BL = 0x00;
  PW1A = 0x80;

  // PW10/11/20/21 channel enable
  PW1CH = PWM10En | PWM11En | PWM20En | PWM21En ;

  // PWM1 enable, P10/11 output inverse, clock = Fosc/32
  PW1M = PW1En | PW1Inv1 | 0x20;

  // Enable PWM1 interrupt & clear PWM1F
  IEN4 = 0x80;

  // Enable total interrupt
  IEN0 |= 0x80;

  P0 = 0x00;
  P0M |= 0x01;
}

void PW1Interrupt(void) interrupt ISRPwm1  //0x83
{ //PWM1F clear by software
  if ((IEN4 & 0x08) == 0x08) {
    IEN4  &= 0xF7;   //Clear PWM1F
    P00 = ~P00;
  }
}
```

15 ADC

The analog to digital converter (ADC) is SAR structure with 10-input sources and up to 4096-step resolution to transfer analog signal into 12-bits digital buffers. The ADC builds in 10-channel input source to measure 10 different analog signal sources. The ADC resolution is 12-bit. The ADC has four clock rates to decide ADC converting rate. The ADC reference high voltage includes 5 sources. Four internal power source including VDD, 4V, 3V and 2V. The other one is external reference voltage input pin from AVREFH pin. The ADC builds in P1CON/P2CON registers to set pure analog input pin. After setup ADENB and ADS bits, the ADC starts to convert analog signal to digital data. Besides ADS bit can start to convert analog signal, PW1EN also have convert analog signal ADC function. ADC can work in idle mode. After ADC operating, the system would be waked up from green mode to normal mode if interrupt enable.



15.1 Configurations of Operation

These configurations must be setup completely before starting ADC converting. ADC is configured using the following steps:

1. Choose and enable the start of conversion ADC input channel. (By CHS[3:0] bits and GCHS bit)
2. The GPIO mode of ADC input channel must be set as input mode. (By PnM register)
3. The internal pull-up resistor of ADC input channel must be disabled. (By PnUR register)
4. The configuration control bit of ADC input channel must be set. (By PnCON register)
5. Choose ADC high reference voltage. (By VREFH register)
6. Choose ADC Clock Rate. (By ADCKS[1:0] bits)
7. After setup ADENB bits, the ADC ready to convert analog signal to digital data.

15.1.1 Start to Conversion

When ADC IP is enabled by ADENB bit, it is necessary to make a ADC start-up by program. Besides ADS bit can start to convert analog signal, PW1EN also have convert analog signal ADC function. Conversions may be initiated by one of the following:

- Writing a 1 to the ADS bit of register ADM
- PWM1 was enabled when ADPWS bit is “1”

After setup ADENB and ADS bits, the ADC starts to convert analog signal to digital data. The ADS bit is reset to logic 0 when the conversion is complete. When the conversion is complete, the ADC circuit will set EOC and ADCF bits to “1” and the digital data outputs in ADB and ADR registers. If ADC interrupt function is enabled (EADC = 1), the ADC interrupt request occurs and executes interrupt service routine when ADCF is “1” after ADC converting. Clear ADCF by program is necessary in interrupt procedure. Note that when ADPWS bit is “1”, if PWM enable trigger be used as the conversion source, the ADC will continuous conversions until PWM is disabled.

15.2 ADC input channel

The ADC builds in 10-channel input source (AIN0 – AIN9) to measure 10 different analog signal sources controlled by CHS[3:0] and GCHS bits. The AIN10 is internal 2V or 3V or 4V input channel. There is no any input pin from outside. In this time ADC reference voltage must be internal VDD and External voltage, not internal 2V or 3V or 4V. AIN10 can be a good battery detector for battery system. To select appropriate internal AVREFH level and compare value, a high performance and cheaper low battery detector is built in the system.

ADC input channel

CHS[3:0]	Channel	Pin name	Remark
0000	AIN0	P1.0	
0001	AIN1	P1.1	
0010	AIN2	P1.2	
0011	AIN3	P1.3	
0100	AIN4	P1.4	
0101	AIN5	P1.5	
0110	AIN6	P1.6	
0111	AIN7	P1.7	
1000	AIN8	P2.1	
1001	AIN9	P2.0	
1010	AIN10	Internal 2V or 3V or 4V	Battery detector channel
1011 – 1111	-	-	Reserved

15.2.1 Pin Configuration

ADC input channels are shared with Port1 and Port2. ADC channel selection is through CHS[3:0] bit. Only one pin of Port1 and Port2 can be configured as ADC input in the same time. The pins of Port1 and Port2 configured as ADC input channel must be set input mode, disable internal pull-up and enable P1CON/P2CON first by program. After selecting ADC input channel through CHS[3:0], set GCHS bit as “1” to enable ADC channel function.

ADC input pins are shared with digital I/O pins. Connect an analog signal to COMS digital input pin, especially, the analog signal level is about 1/2 VDD will cause extra current leakage. In the power down mode, the above leakage current will be a big problem. Unfortunately, if users connect more than one analog input signal to Port1 or Port2 will encounter above current leakage situation. Write “1” into PnCON register will configure related pin as pure analog input pin to avoid current leakage.

Note that When ADC pin is general I/O mode, the bit of P1CON and P2CON must be set to “0”, or the digital I/O signal would be isolated.

15.3 Reference Voltage

The ADC builds in five high reference voltage source controlled through VREFH register. There are one external voltage source and four internal voltage source (VDD, 4V, 3V, 2V). When EVHENB bit is “1”, ADC reference voltage is external voltage source from AVREFH/P1.0. In the condition, P1.0 GPIO mode must be set as input mode and disable internal pull-up resistor.

If EVHENB bit is “0”, ADC reference high voltage is from internal voltage source selected by VHS[1:0] bits. If VHS[1:0] is “11”, ADC reference high voltage is VDD. If VHS[1:0] is “10”, ADC reference high voltage is 4V. If VHS[1:0] is “01”, ADC reference high voltage is 3V. If VHS[1:0] is “00”, ADC reference high voltage is 2V. The limitation of internal high reference voltage application is VDD can’t below each of internal high voltage level, or the level is equal to VDD. If AIN10 channel is selected as internal 2V or 3V or 4V input channel. There is no any input pin from outside. In this time ADC reference high voltage must be internal VDD or External voltage, not internal 2V/3V/4V.

15.3.1 Signal Format

ADC sampling voltage range is limited by high/low reference voltage. The ADC low reference voltage is Vss and not changeable. The ADC high reference voltage includes internal VDD/4V/3V/2V and external reference voltage source from P1.0/AVREFH pin controlled by EVHENB bit. ADC reference voltage range limitation is “(ADC high reference voltage - low reference voltage) ≥ 2V”. ADC low reference voltage is Vss = 0V. So ADC high reference voltage range is 2V to VDD. The range is ADC external high reference voltage range.

- ADC Internal Low Reference Voltage = 0V.
- ADC Internal High Reference Voltage = VDD/4V/3V/2V. (EVHENB=0)
- ADC External High Reference Voltage = 2V to VDD. (EVHENB=1)

ADC sampled input signal voltage must be from ADC low reference voltage to ADC high reference. If the ADC input signal voltage is over the range, the ADC converting result is error (full scale or zero).

- ADC Low Reference Voltage ≤ ADC Sampled Input Voltage ≤ ADC High Reference Voltage

15.4 Converting Time

The ADC converting time is from ADS=1 (Start to ADC convert) to EOC=1 (End of ADC convert). The converting time duration is depend on ADC clock rate. 12-bit ADC’s converting time is
1/ (ADC clock /4)*16 sec. ADC clock source is fosc and includes fosc/1, fosc/2, fosc/8 and fosc/16 controlled by ADCKS[1:0] bits.

The ADC converting time affects ADC performance. If input high rate analog signal, it is necessary to select a high ADC converting rate. If the ADC converting time is slower than analog signal variation rate, the ADC result would be error. So to select a correct ADC clock rate to decide a right ADC converting rate is very important.

$$12\text{ bits ADC conversion time} = \frac{16}{\text{ADC clock rate}/4}$$

ADC converting time

ADCKS[1:0]	ADC clock rate	fosc = 16MHz		fosc = 32MHz	
		Converting time	Converting rate	Converting time	Converting rate
00	fosc/16	1/(16MHz/16/4)*16 = 64us	15.625kHz	1/(32MHz/16/4)*16 = 32us	31.25kHz
01	fosc/8	1/(16MHz/8/4)*16 = 32us	31.25kHz	1/(32MHz/8/4)*16 = 16us	62.5kHz
10	fosc	1/(16MHz/4)*16 = 4us	250kHz	1/(32MHz/4)*16 = 2us	500kHz
11	fosc/2	1/(16MHz/2/4)*16 = 8us	125kHz	1/(32MHz/2/4)*16 = 4us	250kHz

15.5 Data Buffer

ADC data buffer is 12-bit length to store ADC converter result. The high byte is ADB register, and the low-nibble is ADR[3:0] bits. The ADB register is only 8-bit register including bit 4 – bit 11 ADC data. To combine ADB register and the low-nibble of ADR will get full 12-bit ADC data buffer. The ADC data buffer is a read-only register and the initial status is unknown after system reset.

Table 15-1 The AIN input voltage vs. ADB output data

AIN n	ADB11	ADB10	ADB9	ADB8	ADB7	ADB6	ADB5	ADB4	ADB3	ADB2	ADB1	ADB0
0/4096*VREFH	0	0	0	0	0	0	0	0	0	0	0	0
1/4096*VREFH	0	0	0	0	0	0	0	0	0	0	0	1
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
.	.	.	.	.	.	.	.	.	.	.	.	.
4094/4096*VREFH	1	1	1	1	1	1	1	1	1	1	1	0
4095/4096*VREFH	1	1	1	1	1	1	1	1	1	1	1	1

15.6 ADC Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
ADM	ADENB	ADS	EOC	-	CHS3	CHS2	CHS1	CHS0
ADB	ADB11	ADB10	ADB9	ADB8	ADB7	ADB6	ADB5	ADB4
ADR	-	GCHS	ADCKS1	ADCKS0	ADB3	ADB2	ADB1	ADB0
VREFH	EVHENB	-	-	ADPWS	-	VHS2	VHS1	VHS0
P1CON	P1CON7	P1CON6	P1CON5	P1CON4	P1CON3	P1CON2	P1CON1	P1CON0
P2CON	-	-	-	-	-	-	P2CON1	P2CON0
IEN2	-	-	-	-	-	-	EADC	-
IRCON2	-	-	-		-	-	-	ADCF

ADM Register (0xD2)

Bit	Field	Type	Initial	Description
7	ADENB	R/W	0	ADC control bit. In stop mode, disable ADC to reduce power consumption. 0: Disable 1: Enable
6	ADS	R/W	0	ADC conversion control Write 1: Start ADC conversion (automatically cleared by the end of conversion)
5	EOC	R/W	0	ADC status bit. 0: ADC progressing 1: End of conversion (automatically set by hardware; manually cleared by firmware)
3..0	CHS[3:0]	R/W	0x00	ADC input channel select bit. 0000: AIN0, 0001: AIN1, 0010: AIN2, 0011: AIN3, 0100: AIN4, 0101: AIN5, 0110: AIN6, 0111: AIN7, 1000: AIN8, 1001: AIN9, 1010: AIN10*(1), others: Reserved.

*(1) The AIN10 is internal 2V or 3V or 4V input channel. There is no any input pin from outside. In this time ADC reference voltage must be internal VDD and External voltage, not internal 2V or 3V or 4V.

ADB Register (0xD3)

Bit	Field	Type	Initial	Description
7..0	ADB[11:4]	R	-	ADC Result Bit [11:4]* in 12-bit ADC resolution mode.

* ADC data buffer is 12-bit length to store ADC converter result. The high byte is ADB register, and the low-nibble is ADR[3:0] bits.

ADR Register (0xD4)

Bit	Field	Type	Initial	Description
6	GCHS	R/W	0	ADC global channel select bit. 0: Disable AIN channel. 1: Enable AIN channel.
5..4	ADCKS[1:0]	R/W	00	ADC's clock source select bit. 00 = fosc/16, 01 = fosc/8, 10 = fosc/1, 11 = fosc/2
3..0	ADB[3:0]	R	-	ADC Result Bit [3:0]* in 12-bit ADC resolution mode.

* ADC data buffer is 12-bit length to store ADC converter result. The high byte is ADB register, and the low-nibble is ADR[3:0] bits.

VREFH Register (0xD5)

Bit	Field	Type	Initial	Description
7	EVHENB	R/W	0	ADC internal reference high voltage control bit. 0: Enable ADC internal VREFH function. AVREFH/P1.0 pin is GPIO. 1: Disable ADC internal VREFH function. AVREFH/P1.0 pin is external AVREFH*(1) input pin.
4	ADPWS	R/W	0	PWM trigger ADC start control bit. 0: Disable PWM trigger ADC start. 1: Enable PWM trigger ADC start.
2	VHS[2]	R/W	0	ADC internal reference high voltage select bit for AIN10. 0: ADC internal VREFH function is depend on VHS[1:0]*(2). 1: ADC internal VREFH function is internal VDD.
1..0	VHS[1:0]	R/W	00	ADC internal reference high voltage selects bits. 00: 2.0V 01: 3.0V 10: 4.0V 11: VDD

*(1) The AVREFH level must be between the VDD and 2.0V.

*(2) If AIN10 channel is selected as internal 2V or 3V or 4V input channel. There is no any input pin from outside. In this time ADC reference high voltage must be internal VDD or External voltage, not internal 2V/3V/4V.

P1CON Register (0xD6)

Bit	Field	Type	Initial	Description
7..0	P1CON[7:0]	R/W	0x00	P1 configuration control bit*. 0: P1 can be analog input pin (ADC input pin) or digital GPIO pin. 1: P1 is pure analog input pin and can't be a digital GPIO pin.

* P1CON [7:0] will configure related Port1 pin as pure analog input pin to avoid current leakage.

P2CON Register (0x9E)

Bit	Field	Type	Initial	Description
1..0	P2CON[1:0]	R/W	0x0	P2 configuration control bit*. 0: P2 can be analog input pin (ADC input pin) or digital GPIO pin. 1: P2 is pure analog input pin and can't be a digital GPIO pin.

* P2CON [1:0] will configure related Port2 pin as pure analog input pin to avoid current leakage.

IEN2 Register (0x9A)

Bit	Field	Type	Initial	Description
1	EADC	R/W	0	ADC interrupt control bit. 0: Disable ADC interrupt function. 1: Enable ADC interrupt function.
Else				Refer to other chapter(s)

IRCON2 Register (0xBF)

Bit	Field	Type	Initial	Description
0	ADCF	R/W	0	ADC interrupt request flag. 0 = None ADC interrupt request. 1 = ADC interrupt request.
Else				Refer to other chapter(s)

15.7 Sample Code

The following sample code demonstrates how to perform ADC to convert AIN5 with interrupt.

```
#define ADCAIN12_VDD   (3 << 0)  //AIN12 = VDD
#define ADCAIN12_4V    (2 << 0)  //AIN12 = 4.0V
#define ADCAIN12_3V    (1 << 0)  //AIN12 = 3.0V
#define ADCAIN12_2V    (0 << 0)  //AIN12 = 2.0V
#define ADCInRefVDD    (1 << 2)  //internal reference from VDD
#define ADCExHighRef   (1 << 7)  //high reference from AVREFH/P2.0
#define ADCSpeedDiv16  (0 << 4)  //ADC clock = fosc/16
#define ADCSpeedDiv8   (1 << 4)  //ADC clock = fosc/8
#define ADCSpeedDiv1   (2 << 4)  //ADC clock = fosc/1
#define ADCSpeedDiv2   (3 << 4)  //ADC clock = fosc/2
#define ADCChannelEn   (1 << 6)  //enable ADC channel
#define SelAIN5        (5 << 0)  //select ADC channel 5
#define ADCStart       (1 << 6)  //start ADC conversion
#define ADCEn          (1 << 7)  //enable ADC
#define EADC           (1 << 1)  //enable ADC interrupt
#define ClearEOC       0xDF;

unsigned int  ADCBuffer;    // data buffer

void ADCInit(void)
{
  P1  = 0x00;
  P1M = 0x80;

  // set AIN5 pin's mode at pure analog pin
  P1CON |= 0x20;     //AIN5/P15
  P1M   &= 0xDF;    //input mode
  P1UR  &= 0xDF;    //disable pull-high

  // configure ADC channel and enable ADC.
  ADM = ADCEn | SelAIN5;

  // enable channel and select conversion speed
  ADR = ADCChannelEn | ADCSpeedDiv1;

  // configure reference voltage
  VREFH = ADCInRefVDD;

  // enable gobal interrupt
  IEN0  |= 0x80;    //enable global interrupt

  // enable ADC interrupt
  IEN2  |= EADC;

  // start ADC conversion
  ADM   |= ADCStart;
}

void ADCInterrupt(void) interrupt ISRAdc
{
  if ((IRCON2 & 0x01) == 0x01) {
    P17 = ~P17;
    IRCON2  &= 0xFE;   //Clear ADCF
```

```
    ADCBuffer = (ADB << 4) + (ADR & 0x0F);
    ADM &= ClearEOC;
    ADM |= ADCStart;
  }
}
```

16 UART

The universal synchronous/asynchronous receiver/transmitter, or UART, provides an up to 1 MHz flexible full-duplex transmission. It has four operate modes: one synchronous, and three asynchronous. The synchronous mode transmits 8 bits data without start/stop bits, whereas the other modes respectively support 8 and 9 bits data transmission with start/stop bits appended.

16.1 UART Mode 0: Synchronous 8-bit Receiver/Transmitter

In mode 0, the UART transmits/receives an 8-bit-length data without start and stop bits. It handles the first bit of the bus as LSB (least significant bit), and its baud rate is fixed at fcpu/12. The reception is started by setting REN0 and clearing RI0 bits, whereas the transmission is started by writing data to S0BUF.

16.2 UART Mode 1: Asynchronous 8-bit Receiver/Transmitter

In mode 1, the UART operates typical format protocol which has a start bit, 8 data bits, and one stop bit. Its baud rate is controlled by S0RELH/S0RELL registers, or Timer 1 overflow period depending on BD register.

A Transmission is started by writing S0BUF register. The first bit of transmission is a start bit (always 0), then data from S0BUF proceed (LSB first). After which a stop bit (always 1) is transmitted, and TI0 bit is automatically set as a notification/interrupt.

The UART synchronizes with the start bit from master if the reception is enabled (REN0 = 1). The first data bit would be seen as LSB (least significant bit), and S0BUF would be updated after the completion of a reception.

16.3 UART Mode 2/3: Asynchronous 9-bit Receiver/Transmitter

Both mode 2 and 3 have a start bit, 9 data bits, and one stop bit. The mode 2 has only two baud rate selections, fcpu/32 and fcpu/64, but the mode 3 can control its baud rate by S0RELH/S0RELL registers or Timer 1 overflow period.

The 9th data bit (after the MSB of S0BUF register proceed) is writable in TB80 register for its transmission, and readable in RB80 for a reception. By always setting TB80 register, it is an alternative method to transmit two stop bits with 8 data bits. Another common application of 9th bit is parity check.

Furthermore, the 9th bit can also be seen as identification for multiprocessor communication. If

SM20 register is set, the receive interrupt is generated only when the 9th received bit is high. To utilize this feature to multiprocessor communication, on the other word, all slave processors set SM20 to 1. The master processor transmits the slave's address, with the 9th bit set to 1, causing reception interrupt in all of the slaves. The slave processors' software compares the received byte with their network address. If there is a match, the addressed slave clears its SM20 flag and the rest of the message is transmitted from the master with the 9th bit set to 0. The other slaves keep their SM20 to 1 so that they ignore the rest of the message sent by the master.

16.4 Baud Rate Control

The UART mode 0 has a fixed baud rate at fcpu/12, and the mode 2 has two baud rate selection which is chosen by SMOD register: fcpu/32 (SMOD = 0) and fcpu/64 (SMOD = 1).

The baud rate of UART mode 1 and mode 3 is generated by either S0RELH/S0RELL registers (BD = 1) or Timer 1 overflow period (BD = 0). The SMOD bit doubles the frequency from the generator.

If the S0RELH/S0RELL is selected (BD = 1) in mode 1 and 3, the baud rate is generated as following equation.

$$\text{Baud Rate} = 2^{\text{SMOD}} \times \frac{\text{fcpu}}{64 \times (1024 - \text{S0REL})}$$

Table 16-1 Recommended Setting for Common UART Baud Rates (fcpu = 32 MHz)

Baud Rate	SMOD	S0RELH	S0RELL	Accuracy
4800 Hz	0	0x03	0x98	-0.16 %
9600 Hz	0	0x03	0xCC	-0.16 %
19200 Hz	0	0x03	0xE6	-0.16 %
38400 Hz	0	0x03	0xF3	-0.16 %
56000 Hz	1	0x03	0xEE	0.79 %
57600 Hz	1	0x03	0xEF	-2.12 %
115200 Hz	1	0x03	0xF7	3.55 %
128 kHz	1	0x03	0xF8	2.34 %
250 kHz	1	0x03	0xFC	0 %
500 kHz	1	0x03	0xFE	0 %
1 MHz	1	0x03	0xFF	0 %

If the Timer 1 overflow period is selected (BD = 0) in mode 1 and 3, the baud rate is generated as following equation. The Timer 1 must be in 8-bit auto-reload mode which can generate periodically

overflow signals.

$$\text{Baud Rate} = 2^{\text{SMOD}} \times \frac{1}{32 \times \text{Timer 1 period}}$$

Table 16-2 Recommended Setting T1 overflow period (T1 clock=32M) for Common UART Baud Rates (fcpu = 32 MHz)

Baud Rate	SMOD	Timer Period	TH1/TL1	Accuracy
4800 Hz	0	6.510 us	0x30	0.16 %
9600 Hz	1	6.510 us	0x30	0.16 %
19200 Hz	1	3.255 us	0x98	0.16 %
38400 Hz	1	1.628 us	0xCC	0.16 %
56000 Hz	1	1.116 us	0xDC	-0.80 %
57600 Hz	1	1.085 us	0xDD	-0.80 %
115200 Hz	1	0.543 us	0xEF	2.08 %
128 kHz	1	0.488 us	0xF0	-2.40 %
250 kHz	1	0.250 us	0xF8	0 %
500 kHz	1	0.125 us	0xFC	0 %
1 MHz	1	0.063 us	0xFE	0 %

When clock generator source is T1 overflow rate, the system clock Fcpu minimum setting value follow Fcpu<= Timer Period Value.

16.5 Power Saving

The UART module has clock gating function for saving power. When REN0 bit is 0, the UART module internal clocks are halted to reduce power consumption. UART relevant register (S0CON, S0CON2, S0BUF, S0RELL, S0RELH and SMOD bit) are unable to access.

Conversely, when REN0 bit is 1, UART internal clocks are run, and registers can access. The REN0 bit must be set to 1, before the initial setting UART.

16.6 UART Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
S0CON	SM0	SM1	SM20	REN0	TB80	RB80	TI0	RI0
S0CON2	BD	-	-	-	-	-	-	-
S0BUF	S0BUF7	S0BUF6	S0BUF5	S0BUF4	S0BUF3	S0BUF2	S0BUF1	S0BUF0
PCON	SMOD	-	-	-	P2SEL	GF0	STOP	IDLE
S0RELH	-	-	-	-	-	-	S0REL9	S0REL8
S0RELL	S0REL7	S0REL6	S0REL5	S0REL4	S0REL3	S0REL2	S0REL1	R0REL0
IEN0	EAL	-	ET2	ES0	ET1	EX1	ET0	EX0

P0OC	-	-	-	P06OC	P05OC	P04OC	P01OC	P00OC
P0M	P07M	P06M	P05M	P04M	P03M	P02M	P01M	P00M
P0	P07	P06	P05	P04	P03	P02	P01	P00

S0CON Register (0x98)

Bit	Field	Type	Initial	Description
7..6	SM[0:1]	R/W	00	UART mode selection 00: Mode 0 01: Mode 1 10: Mode 2 11: Mode 3
5	SM20	R/W	0	Multiprocessor communication (mode 2, 3) 0: Disable 1: Enable
4	REN0	R/W	0	UART module (and reception function) 0: Disable for power saving* 1: Enable for UART operating
3	TB0	R/W	0	The 9th bit transmission data (mode 2, 3)
2	RB0	R/W	0	The 9th bit data from reception
1	TI0	R/W	0	UART interrupt flag of transmission
0	RI0	R/W	0	UART interrupt flag of reception

* When REN0 bit is 0, UART relevant register are unable to access, and the module internal clocks are halted.

S0CON2 Register (0xD8)

Bit	Field	Type	Initial	Description
7	BD	R/W	0	Baud rate generators selection (mode 1, 3) 0: Timer 1 overflow period 1: Controlled by S0RELH, S0RELL registers
6..0	Reserved	R	0x00	

S0BUF Register (0x99)

Bit	Field	Type	Initial	Description
7..0	S0BUF	R/W	0x00	Action of writing data triggers UART communication (LSB first). Reception data is available to read by the end of packages.

PCON Register (0x87)

Bit	Field	Type	Initial	Description
7	SMOD	R/W	0	UART baud rate control (UART mode 0, 2) 0: fcpu/64 1: fcpu/32
6..0				Refer to other chapter(s)

IEN0 Register (0xA8)

Bit	Field	Type	Initial	Description
7	EAL	R/W	0	Interrupts enable. Refer to Chapter Interrupt
4	ES0	R/W	0	Enable UART interrupt
Else				Refer to other chapter(s)

P0OC Register (0xE4)

Bit	Field	Type	Initial	Description
1	P06OC	R/W	0	0: Switch P0.6 (URX) to input mode (required) ~~1: Switch P0.6 (URX) to open-drain mode~~*
0	P05OC	R/W	0	0: Switch P0.5 (UTX) to push-pull mode 1: Switch P0.5 (UTX) to open-drain mode
Else				Refer to other chapter(s)

* Setting P06OC as high causes URX cannot receive data.

P0M Register (0xF9)

Bit	Field	Type	Initial	Description
6	P06M	R/W	0	0: Set P0.6 (URX) as input mode (required) ~~1: Set P0.6 (URX) as output mode~~*
5	P05M	R/W	0	~~0: Set P0.5 (UTX) as input mode~~* 1: Set P0.5 (UTX) as output mode (required)
Else				Refer to other chapter(s)

* The URX and UTX respectively require input and output mode selection to receive/transmit data appropriately.

P0 Register (0x80)

Bit	Field	Type	Initial	Description

6	P06	R/W	0	This bit is available to read at any time for monitoring the bus statue.
5	P05	R/W	0	~~0: Set P0.5 (UTX) always low~~ * 1: Make P0.5 (UTX) can output UART data (required)
Else				Refer to other chapter(s)

* Setting P05 initially high because UART block drive the shared pin low signal only.

16.7 Sample Code

The following sample code demonstrates how to perform UART mode 1 with interrupt.

```
#define SYSUartSM0    (0 << 6)
#define SYSUartSM1    (1 << 6)
#define SYSUartSM2    (2 << 6)
#define SYSUartSM3    (3 << 6)
#define SYSUartREN    (1 << 4)
#define SYSUartSMOD   (1 << 7)
#define SYSUartES0    (1 << 4)

void SYSUartInit(void)
{
  // set UTX, URX pins' mode at here or at GPIO initialization
  P05 = 1;
  P0M = P0M | 0x20 & ~0x40;

  // configure UART mode between SM0 and SM3, enable URX
  S0CON = SYSUartSM1 | SYSUartREN;

  // configure UART baud rate
  PCON = SYSUartSMODE1;
  S0CON2 = SYSUartBD1;
  S0RELH = 0x03;
  S0RELL = 0xFE;

  // enable UART interrupt
  IEN0 |= SYSUartES0;

  // send first UTX data
  S0BUF = uartTxBuf;
}

void SYSUartInterrupt(void) interrupt ISRUart
{
  if (TI0 == 1) {
    S0BUF = uartTxBuf;
    TI0 = 0;
  } else if (RI0 == 1) {
    uartRxBuf = S0BUF;
    RI0 = 0;
  }
}
```

17 SPI

The serial peripheral interface, aka SPI, has two operation modes: master and slave. A master proactively outputs bus clock through SCK pin, whereas slave device(s) handle communication based on SCK pin's clock input. An optional slave select pin (SSN) can be enabled by register in slave mode.

17.1 SPI Master

The SPI master mode has seven types of clock generator from fcpu/2 to fcpu/128. Generated clock is outputted through SCK pin (shared with P1.3) and its idle status is controlled by CPOL.

The phase of data input and output is automatically specified by CPHA register. In master mode MOSI pin (shared with P1.4) plays the role of data output, and MISO pin (shared with P1.5) fetches data from slave device. A SPI communication is started by writing SPDAT register; the received data from MISO is available to read after the end of data transmission.

The master mode has two status flags with interrupt function:
SPIF register indicates the end of one byte data communication. An interrupt would be issued at the same time if ESPI bit is enabled.
MODF is issued by SSN (shared with P0.2) low status while transmission. This interrupt source can be masked by setting SSDIS bit.

17.2 SPI Slave

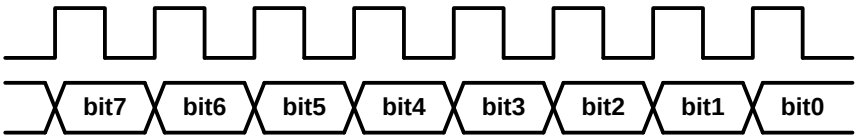
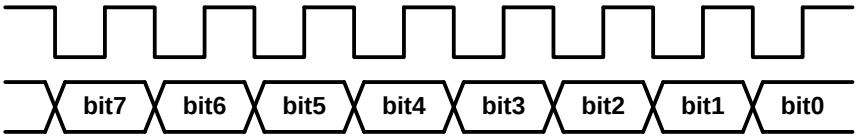
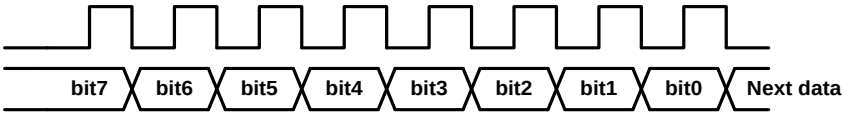
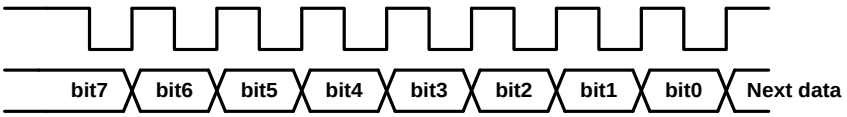
The SPI slave mode monitors SCK pin to control its MISO and MOSI communication. However, the maximum clock rate is limited at fcpu/8. Slave device(s) are expected to specify its CPOL and CPHA setting as the same configuration of the connected SPI bus.

The slave mode treats MOSI pin as its data input, and MISO pin as its data transmission. By default, the SSDIS register is low which means the slave select pin (SSN) is functional. A SPI communication would be processed if the SSN is low status. Thus, a slave device is suspended if its SSN is high status.

The slave mode has two status flags with interrupt function:
SPIF indicates the end of one byte data communication. The original SPDAT's value has been transmitted, and the received data from MOSI is ready to be read on SPDAT.
MODF indicates that the slave select pin (SSN) has turned high before a completion of one byte communication. In other word, the last time of SPI communication is broken.

17.3 SPI Operation

The table below illustrates four different setting of CPOL and CPHA, and the bus operation in each combination.

CPOL	CPHA	Diagrams	Description
0	1		SCK idle low Data latch at falling edges
1	1		SCK idle high Data latch at rising edges
0	0		SCK idle low Data latch at rising edges
1	0		SCL idle high Data latch at falling edges

17.4 Power Saving

The SPI module has clock gating function for saving power. When SPEN bit is 0, the SPI module internal clocks are halted to reduce power consumption. SPI relevant register (SPCON, SPSTA and SPDAT) are unable to access. Conversely, when SPEN bit is 1, SPI internal clocks are run, and registers can access. The SPEN bit must be set to 1, before the initial setting SPI.

17.5 SPI Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
SPCON	SPR2	SPEN	SSDIS	MATR	CPOL	CPHA	SPR1	SPR0
SPSTA	SPIF	WCOL	SSERR	MODF	-	-	-	-
SPDAT	SPDAT7	SPDAT6	SPDAT5	SPDAT4	SPDAT3	SPDAT2	SPDAT1	SPDAT0
IEN0	EAL	-	ET2	ES0	ET1	-	ET0	EX0
IEN1	ET2RL	-	ET2C3	ET2C2	ET2C1	ET2C0	ESPI	EI2C
P0OC	-	-	-	P15OC	P14OC	P13OC	P06OC	P05OC
P1M	P17M	P16M	P15M	P14M	P13M	P12M	P11M	P10M

SPCON Register (0xE2)

Bit	Field	Type	Initial	Description
7,1,0	SM[2:0]	R/W	000	SPI baud rate generator (master mode only) 000: fcpu/2 001: fcpu/4 010: fcpu/8 011: fcpu/16 100: fcpu/32 101: fcpu/64 110: fcpu/128 ~~111: reserved~~
6	SPEN	R/W	0	SPI communication function 0: Disable for power saving* 1: Enable for SPI operating
5	SSDIS	R/W	0	Slave select pin function (MSTR = 0, CPHA = 0 only) 0: Enable slave selection pin (SSN) function 1: Disable slave select pin (SSN) function
4	MSTR	R/W	1	SPI mode 0: Slave mode 1: Master mode
3	CPOL	R/W	0	SCK pin idle status 0: SCK idle low 1: SCK idle high
2	CPHA	R/W	1	Clock phase of data latch control 0: Data latched by the first of clock edge 1: Data latched by the second of clock edge

* When SPEN bit is 0, SPI relevant register are unable to access, and the module internal clocks are halted.

SPSTA Register (0xE1)

Bit	Field	Type	Initial	Description
7	SPIF	R	0	SPI complete communication flag Set automatically at the end of communication Cleared automatically by reading SPSTA, SPDAT registers
6	WCOL	R	0	Write collision flag Set automatically if write SPDAT during communication Cleared automatically by reading SPSTA, SPDAT registers
5	SSERR	R	0	Synchronous slave select pin error Set automatically if SSN error controlling Cleared automatically by clear SPEN
4	MODF	R	0	Mode fault flag
3..0	Reserved	R	0x00	

SPDAT Register (0xE3)

Bit	Field	Type	Initial	Description
7..0	SPDAT	R/W	0x00	Master mode: action of writing data triggers SPI communication; reception data is readable after the end of one byte communication (SPIF automatically set). Slave mode: written data would be transmitted by SCK input; reception data is available to read after the end of one byte communication (SPIF automatically set).

IEN0 Register (0xA8)

Bit	Field	Type	Initial	Description
7	EAL	R/W	0	Interrupts enable. Refer to Chapter Interrupt
Else				Refer to other chapter(s)

IEN1 Register (0xB8)

Bit	Field	Type	Initial	Description
1	ESPI	R/W	0	Enable SPI interrupt
Else				Refer to other chapter(s)

P0OC Register (0xE4)

Bit	Field	Type	Initial	Description
2	P13OC	R/W	0	0: Switch P1.3 (SCK) to input or output mode 1: Switch P1.3 (SCK) to open-drain mod
3	P14OC	R/W	0	0: Switch P1.4 (MOSI) to input or output mode 1: Switch P1.4 (MOSI) to open-drain mode
4	P15OC	R/W	0	0: Switch P1.5 (MISO) to input or output mode 1: Switch P1.5 (MISO) to open-drain mod
Else				Refer to other chapter(s)

P1M Register (0xFA)

Bit	Field	Type	Initial	Description
3	P13M	R/W	0	0: Set P1.3 (SCK) as input mode [1] slave mode 1: Set P1.3 (SCK) as output mode [1] master mode
4	P14M	R/W	0	0: Set P1.4 (MOSI) as input mode [2] master mode 1: Set P1.4 (MOSI) as output mode [2] slave mode
5	P15M	R/W	0	0: Set P1.5 (MISO) as input mode [3] slave mode 1: Set P1.5 (MISO) as output mode [3] master mode
Else				Refer to other chapter(s)

[1]Setting SCK as input mode is essential in slave mode; setting as output mode is recommended in master mode.

[2]Setting MISO as input mode is essential in master mode; setting as output mode is recommended in slave mode.

[3]Setting MOSI as input mode is essential is slave mode; setting as output mode is recommended in master mode.

P0M Register (0xF9)

Bit	Field	Type	Initial	Description
2	P02M	R/W	0	0: Set P0.2 (SSN) as input mode* 1: Set P0.2 (SSN) as output mode*

*If slave mode with SSN function: essentially to set SSN as input mode.

17.6 Sample Code

The following sample code demonstrates how to perform SPI Master with interrupt.

```
#define SpiMaster     (1 << 4)  //SPI = Master mode
#define SpiSlave      (1 << 4)  //SPI = Slave mode
#define SpiMode0      (0 << 2)  //SCK idle low, data latch at rising edge
#define SpiMode1      (1 << 2)  //SCK idle low, data latch at falling edge
#define SpiMode2      (2 << 2)  //SCK idle high, data latch at falling edge
#define SpiMode3      (3 << 2)  //SCK idle high, data latch at rising edge
#define SpiEn         (1 << 6)  //Enable SPI
#define SpiSSNEn      (0 << 5)  //SSN pin function enable
#define SpiSSNDis     (1 << 5)  //SSN pin function disable

unsigned char  u8SpiData = 0;    // data buffer
unsigned char  u8TxCompleted = 0;

void SpiMaster(void)
{
  unsigned char u8RcvData = 0;

  //SCK & MOSI = output, MISO = input
  P1M |= 0x18;
  //Enable Spi, Master mode, SSN pin disable, Fclk/128
  //SCK idle low, data latch at falling edge
  SPCON = SpiEn | SpiMaster | SpiMode1 | SpiSSNDis | 0x82;
  //Enable Global/SPI interrupt
  IEN1  |= 0x02;
  IEN0  |= 0x80;    //enable global interrupt

  while (1) {
    SPDAT = 0x55;
    while(!u8TxCompleted);      // wait end of transmition
    u8TxCompleted = 0;         // clear sw flag
    u8RcvData = u8SpiData;      // receive 0x66

    SPDAT = 0x99;
    while(!u8TxCompleted);      // wait end of transmition
    u8TxCompleted = 0;         // clear sw flag
    u8RcvData = u8SpiData;      // receive 0xAA
  }
}

void SpiInterrupt(void) interrupt ISRSpi //0x4B
{
  switch ( SPSTA )              // Clear SPI flag (SPIF) by reading
  {
    case 0x80:
      u8SpiData = SPDAT;
      u8TxCompleted = 1;
      break;
    case 0x10:
      // Mode Fault
      break;
  }
}
```

18 I2C

The I2C is a serial communication interface for data exchanging from one MCU to one MCU or other hardware peripherals. The device can transmit data as a master or a slave with two bi-directional IO, SDA (Serial data output) and SCL (Serial clock input).

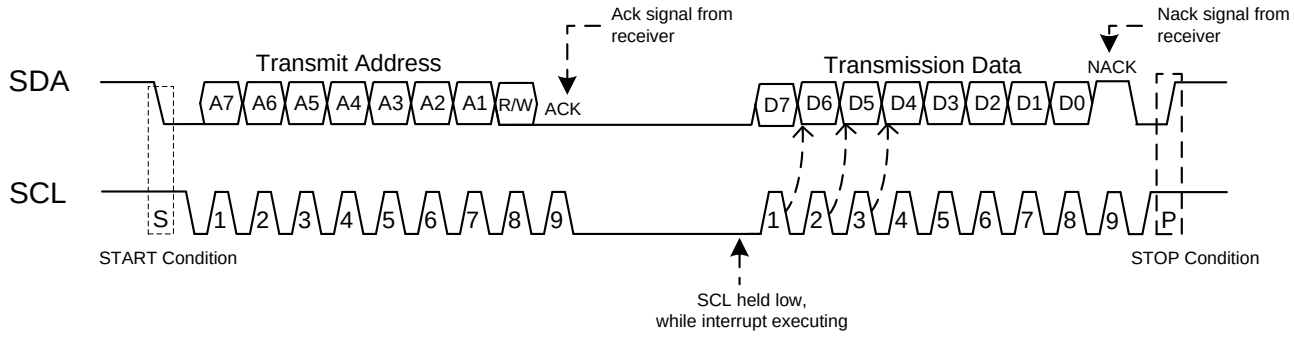
When a master transmit data to a slave, it's called "WRITE" operation; when a slave transmit data to a master, it's called "READ" operation. It also supports multi-master communication and keeps data transmission correctly by an arbitration method to decide one master has the control on bus and transmit its data.

18.1 I2C Protocol

I2C transmission structure includes a START(S) condition, 8-bit address byte, one or more data byte and a STOP (P) condition. START condition is generated by master to initial any transmission.

Data is transmitted with the Most Significant Bit (MSB) first. In address byte, the higher 7-bit is address bit and the lowest bit is data direction (R/W) bit. When R/W=0, it assigns a "WRITR" operation. When R/W=1, it assigns a "READ" operation.

After each byte is received, the receiver (a master or a slave) must send an acknowledge (ACK). If transmitter can't receive an ACK, it will recognize a not acknowledge (NACK). In WRITE operation, the master will transmit data to the slave and then waits for ACK from slave. In READ operation, the slave will transmit data to the master and then waits for ACK from master. In the end, the master will generate a STOP condition to finish transmission.



18.2 I2C Transfer Modes

The I2C can operate as a master/slave to execute the 8-bit serial data transmission/reception operation. Thus, the module can operate in one of four modes: Master Transmitter, Master Receiver, Slave Transmitter and Slave Receiver.

18.2.1 Master Transmitter Mode

The master transmits information to the slave. The serial data is output via SDA while the serial clock is output on SCL. Data transmission starts via generate a START(S) signal. After the START signal, the specific address byte of slave device is sent. The address byte includes 7-bit address bit and an 8th data direction (R/W) bit. The R/W is set “0” to enable the master transmission. In the following, the master transmits one or more data byte to the slaver. After each data is transmitted, the master waits for the acknowledge (ACK) from the slave. In the end, the master generates a STOP (P) signal to terminate the data transmission.

18.2.2 Master Receiver Mode

The master receives the information from the slave. The serial data input via SDA while the serial clock output on SCL. Data reception starts via generate a START(S) signal. After the START signal, the specific address byte of slave device is sent. The address byte includes 7-bit address bit and an 8th data direction (R/W) bit. The R/W is set “1” to enable the master reception. In the following, the master receives one or more data byte from the slaver. After each data is received, the master generates the acknowledge (ACK) or not acknowledge (NACK) to the slave via the status of AA bit. In the end, the master generates a STOP (P) signal to terminate the data transmission.

18.2.3 Slave Transmitter Mode

The slave transmits information to the master. The serial data output via SDA while the serial clock input on SCL. Data transmission starts via receive a START(S) signal from the master. After the START signal, the specific address byte of slave device is received. The address byte includes 7-bit address bit and an 8th data direction (R/W) bit. The R/W is set “1” to enable the slave transmission. If the received address byte match the address in I2CADR register, the slave generate an acknowledge (ACK). Otherwise, if general call address condition is set (GC=1), the slave also generate an acknowledge (ACK) after general call address (0x00) is received. In the following, the slave transmits one or more data byte to the master. After each data is transmitted, the slave waits for the acknowledge (ACK) from the master. In the end, the slave receives a STOP (P) signal from the master to terminate the data transmission.

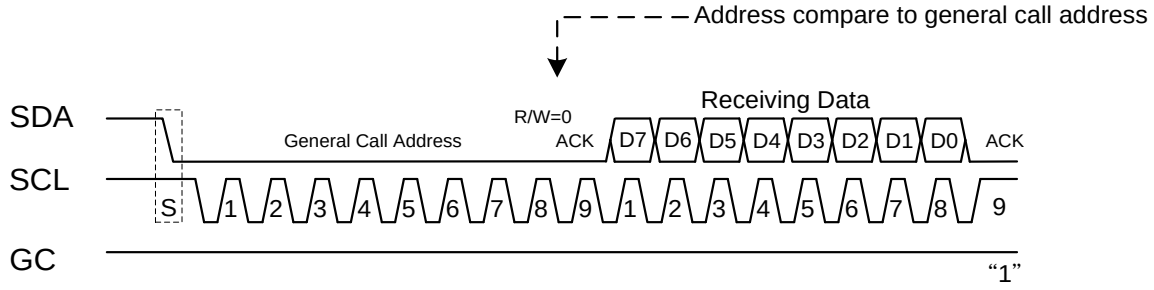
18.2.4 Slave Receiver Mode

The slave receives information from the master. Both the serial data and the serial clock are input on SDA and SCL. Data reception starts via receive a START(S) signal from the master. After the START signal, the specific address byte of slave device is received. The address byte includes 7-bit address bit and an 8th data direction (R/W) bit. The R/W is set “0” to enable the slave reception. If the received address byte match the address in I2CADR register, the slave generate an acknowledge (ACK). Otherwise, if general call address condition is set (GC=1), the slave also generate an acknowledge (ACK) after general call address (0x00) is received. In the following, the

slave receives one or more data byte from the master. After each data is receives, the slave generates the acknowledge (ACK) or not acknowledge (NACK) to the master via the status of AA bit. In the end, the slave receives a STOP (P) signal from the master to terminate the data transmission.

18.3 General Call Address

In I2C bus, the first 7-bit is the slave address. Only the address matches slave address, the slave will response an ACK. The exception is the general call address which can address all slave devices. When this address occur, all devices should response an acknowledge (ACK). The general call address is a special address which is reserved as all “0” of 7-bit address. The general call address function is control by GC bit. Set this bit will enable general call address and clear it will disable. When GC=1, the general call address will be recognized. When GC=0, the general call address will be ignored.



18.4 Serial Clock Generator

In master mode, the SCL clock rate generator’s is controlled by CR[2:0] bit of I2CCON register.

When CR[2:0]=000~110, SCL clock rate is from internal clock generator.

$$\text{SCL Clock Rate} = \frac{\text{Fcpu}}{\text{Prescaler}} (\text{Prescaler} = 256\sim60)$$

When CR[2:0]=111, SCL clock rate is from Timer 1 overflow rate .

$$\text{SCL Clock Rate} = \frac{\text{Timer 1 Overflow}}{8}$$

The table below shows the clock rate under different setting.

CR2	CR1	CR0	I2C	Bit Frequency (kHz)			
			Prescaler	6MHz	12MHz	16MHz	24MHz
0	0	0	256	23	47	63	92
0	0	1	224	27	54	71	108
0	1	0	192	31	63	83	124
0	1	1	160	37	75	100	148
1	0	0	960	6.25	12.5	17	25
1	0	1	120	50	100	133	200
1	1	0	60	100	200	266	400
1	1	1	(Timer 1 overflow rate)/8				

When clock generator source is T1 overflow rate, the max counter value is 0xFB (Only supports 0x00~0xFB). And in this time if T1 clock rate is IHRC_32MHz, SCL maximum clock rate is 800kHz. If user wants to generate SCL clock rate is 100kHz/400kHz, you can set T1 counter value is 0xD8/0xF6 easily.

18.5 Synchronization and Arbitration

In multi-master condition, more than one master may transmit on bus in the same time. It must be decided which master has the control of bus and complete its transmission. Clock synchronization and arbitration are used to configure multi-master transmission. Clock synchronization is executed by synchronizing the SCL signal with anther devices.

When two masters want to transmit in the same, the clock synchronization will start by the High to Low transition on the SCL. If master 1 clock set LOW first, it holds the SCL in LOW status until the clock transit to HIGH status. However, if anther master clock still keep LOW status, the Low to High transition of master 1 may not change SCL status (SCL keep LOW). In the other word, SCL keep LOW by the master with the longest clock time in LOW status. The SCL will transit from LOW to HIGH when the all devices clock transit to HIGH status. In the duration, the master1 will keep in HIGH status and wait for SCL transition (from LOW to HIGH), then continue its transmission. After clock synchronization, all devices clock and SCL clock are the same. Arbitration is used to decide which master can complete its transmission by SDA signal. Two masters may send out a START condition and transmit data on bus in the same time. They may influence by each other. Arbitration will force one master to lose the control on bus. Data transmission will keep until master output different data signal. If one master transmits HIGH status and anther master transmits LOW status, the SDA will be pull low. The master output High will detect the different with SDA and lose the control on bus. The mater with LOW status wins the bus control and continues its transmission. There is no data miss during arbitration.

18.6 System Management Bus Extension

The optional System Management Bus (SMBus) protocol hardware supports 3 types timeout detection: (1) Tmext Timeout Detection: The cumulative stretch clock cycles within one byte. (2)Tsext Timeout Detection: The cumulative stretch clock cycles between start and stop condition. (3)Timeout Detection: The clock low measurement.

Timeout detection is controlled by SMBSEL and SMBDST registers. The SMBEXE bit of SMBSEL is SMBus extension function enable bit. When SMBEXE=1, SMBus extension function is enabled. Otherwise, Disable SMBus extension function. Timeout type and period setting is controlled by SMBTOP[2:0] and SMBDST. The period of SMBus timeout is controlled by three 16-bit buffers of Tmex, Tsext and Tout. The equation is as following.

$$\text{Tmext/Tsext/Tout} = \frac{\text{Timeout Period(sec)xFcpu(Hz)}}{1024}$$

Tmext is support by two 8-bit register of Tmext_L and Tmext_H . Tmext_L hold the low byte and Tmext_H hold high byte. Tsext is support by two 8-bit register of Tsext_L and Tsext_H . Tsext_L hold the low byte and Tsext_H hold high byte. Tout is support by two 8-bit register of Tout_L and Tout_H . Tout_L hold the low byte and Tout_H hold high byte.

Type	Time out period	Fcpu=24MHz		Fcpu=32MHz	
		DEC	HEX	DEC	HEX
Tmext	5ms	118	76	157	9D
Tsext	25ms	586	24A	782	30E
Tout	35ms	821	335	1094	446

By the setting of SMBTOP[2:0] to choose register type (as the table below), and write to register by write data to SMBDST register.

SMBTOP[2:0]	SMBDST	Description
000	Tmext_L	Select the low byte of Tmext register.
001	Tmext_H	Select the high byte of Tmext register.
010	Tsext_L	Select the low byte of Tsext register.
011	Tsext_H	Select the high byte of Tsext register.
100	Tout_L	Select the low byte of Tout register.
101	Tout_H	Select the high byte of Tout register.

When the SMBus extension function is enabled the lower 3-bit of I2CSTA hold the information about time out as the table below.

I2CSTA	Description
XXXX X000	No timeout errors.
XXXX XXX1	Tout timeout error.
XXXX XX1X	Tsext timeout error.
XXXX X1XX	Tmext timeout error.

18.7 Power Saving

The I2C module has clock gating function for saving power. When ENS1 bit is 0, the I2C module internal clocks are halted to reduce power consumption. I2C relevant register (I2CDAT, I2CADR, I2CCON, I2CSTA, SMBSEL and SMBDST) are unable to access. Conversely, when ENS1 bit is 1, I2C internal clocks are run, and registers can access. The ENS1 bit must be set to 1, before the initial setting I2C.

18.8 I2C Registers

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
I2CDAT	I2CDAT7	I2CDAT6	I2CDAT5	I2CDAT4	I2CDAT3	I2CDAT2	I2CDAT1	I2CDAT0
I2CADR	ADR6	ADR5	ADR4	ADR3	ADR2	ADR1	ADR0	GC
I2CCON	CR2	ENS1	STA	STO	SI	AA	CR1	CR0
I2CSTA	I2CSTA7	I2CSTA6	I2CSTA5	I2CSTA4	I2CSTA3	I2CSTA2	I2CSTA1	I2CSTA0
SMBSEL	SMBEXE	-	-	-	-	SMBSTP2	SMBSTP1	SMBSTP0
SMBDST	SMBD7	SMBD6	SMBD5	SMBD4	SMBD3	SMBD2	SMBD1	SMBD0
IEN0	EAL	-	ET2	ES0	ET1	-	ET0	EX0
IEN1	ET2RL	-	ET2C3	ET2C2	ET2C1	ET2C0	ESPI	EI2C
P1M	P17M	P16M	P15M	P14M	P13M	P12M	P11M	P10M
P0M	P07M	P16M	P05M	P04M	P03M	P02M	P01M	P00M
P1	P17	P16	P15	P14	P13	P12	P11	P10
P0	P07	P16	P05	P04	P03	P02	P01	P00

I2CDAT Register (0xDA)

Bit	Field	Type	Initial	Description
7:0	I2CDAT[7:0]	R/W	0x00	The I2CDAT register contains a byte to be transmitted through I2C bus or a byte which has just been received through I2C bus. The CPU can read from and write to

				this 8-bit, directly addressable SFR while it is not in the process of byte shifting. The I2CDAT register is not shadowed or double buffered so the user should only read I2CDAT when an I2C interrupt occurs.

I2CADR Register (0xDB)

Bit	Field	Type	Initial	Description
7:1	I2CADR[6:0]	R/W	0x00	I2C slave address
0	GC	R/W	0	General call address (0X00) acknowledgment 0: ignored 1: recognized

I2CCON Register (0xDC)

Bit	Field	Type	Initial	Description
7,1,0	CR[2:0]	R/W	0	I2C clock rate 000: fcpu/256 001: fcpu/224 010: fcpu/192 011: fcpu/160 100: fcpu/960 101: fcpu/120 110: fcpu/60 111: Timer 1 overflow-period/8
6	ENS1	R/W	0	I2C functionality 0: Disable for power saving* 1: Enable for I2C operating
5	STA	R/W	0	START flag 0: No START condition is transmitted. 1: A START condition is transmitted if the bus is free.
4	STO	R/W	0	STOP flag 0: No STOP condition is transmitted. 1: A STOP condition is transmitted to the I2C bus in master mode.
3	SI	R/W	0	Serial interrupt flag The SI is set by hardware when one of 25 out of 26 possible I2C states is entered. The only state that does

				not set the SI is state F8h, which indicates that no relevant state information is available. The SI flag must be cleared by software. In order to clear the SI bit, '0' must be written to this bit. Writing a '1' to SI bit does not change value of the SI.
2	AA	R/W	0	Assert acknowledge flag 0: A NACK will be returned when a byte has received 1: An ACK will be returned when a byte has received

* When ENS1 bit is 0, I2C relevant register are unable to access, and the module internal clocks are halted.

I2CSTA Register (0xDD)

Bit	Field	Type	Initial	Description
7:3	I2CSTA[7:3]	R	11111	I2C Status Code
2..0	I2CSTA[2:0]	R	000	SMBus Status Code

I2C status code and status

Mode	Status Code	Status of the I2C	Application software response					Next action taken by I2C hardware
			To/from I2CDAT	TO I2CCON				
				STA	STO	SI	AA	
Master Transmitter/ Receiver	08H	A START condition has been transmitted	Load SLA+R	X	0	0	X	SLA+R/W will be transmitted; ACK will be received
	10H	A repeated START condition has been transmitted.	Load SLA+R	X	0	0	X	SLA+R/W will be transmitted; ACK will be received
			Load SLA+W					SLA+W will be transmitted; I2C will be switched to MST/TRX mode.
Master Transmitter	18H	SLA+W has been transmitted; ACK has been received	Load data byte	0	0	0	X	Data byte will be transmitted; ACK will be received.
			No action	1	0	0	X	Repeated START will be transmitted.
			No action	0	1	0	X	STOP condition will be transmitted; STO flag will be reset.
			No action	1	1	0	X	STOP condition followed by a START condition will be transmitted; STO flag will be reset.
	20H	SLA+W has been transmitted; not ACK has been received	Load data byte*	0	0	0	X	Data byte will be transmitted; ACK will be received.
			No action	1	0	0	X	Repeated START will be transmitted.
			No action	0	1	0	X	STOP condition will be transmitted; STO flag will be reset.
			No action	1	1	0	X	STOP condition followed by a START condition will be transmitted; STO flag will be reset.
	28H	Data byte in I2CDAT has been transmitted; ACK has been received	Load data byte	0	0	0	X	Data byte will be transmitted; ACK bit will be received.
			No action	1	0	0	X	Repeated START will be transmitted.
			No action	0	1	0	X	STOP condition will be transmitted; STO flag will be reset.
			No action	1	1	0	X	STOP condition followed by a START condition will be transmitted; STO flag will be reset.
	30H	Data byte in I2CDAT has been transmitted; not ACK has been received	Load data byte*	0	0	0	X	Data byte will be transmitted; ACK will be received.
			No action	1	0	0	X	Repeated START will be transmitted.
			No action	0	1	0	X	STOP condition will be transmitted; STO flag will be reset.
			No action	1	1	0	X	STOP condition followed by a START condition will be transmitted; STO flag will be reset.
Master Receiver	40H	SLA+R has been transmitted; ACK has been received	No action	0	0	0	0	Data byte will be received; not ACK will be returned
			No action	0	0	0	1	Data byte will be received; ACK will be returned
	48H	SLA+R has been transmitted; not ACK has been received	No action	1	0	0	X	Repeated START condition will be transmitted
			No action	0	1	0	X	STOP condition will be transmitted; STO flag will be reset
			No action	1	1	0	X	STOP condition followed by a START condition will be transmitted; STO flag will be reset
	50H	Data byte has been received; ACK has been returned	Read data byte	0	0	0	0	Data byte will be received; not ACK will be returned
			Read data byte	0	0	0	1	Data byte will be received; ACK will be returned
	58H	Data byte has been received; not ACK has been returned	Read data byte	1	0	0	X	Repeated START condition will be transmitted
			Read data byte	0	1	0	X	STOP condition will be transmitted; STO flag will be reset
			Read data byte	1	1	0	X	STOP condition followed by a START condition will be transmitted; STO flag will be reset

Mode	Status Code	Status of the I2C	Application software response					Next action taken by I2C hardware
			To/from I2CDAT	TO I2CCON				
				STA	STO	SI	AA	
Slave Receiver	60H	Own SLA+W has been received; ACK has been returned	No action	X	0	0	0/1	Data byte will be received and not ACK/ACK will be returned
	68H	Arbitration lost in SLA+R/W as master; own SLA+W has been received, ACK returned	No action	X	0	0	0/1	Data byte will be received and not ACK/ACK will be returned
	70H	General call address (00H) has been received; ACK has been returned	No action	X	0	0	0/1	Data byte will be received and not ACK/ACK will be returned
	78H	Arbitration lost in SLA+R/W as master; general call address has been received, ACK returned	No action	X	0	0	0/1	Data byte will be received and not ACK/ACK will be returned
	80H	Previously addressed with own SLV address; DATA has been received; ACK returned	Read data byte	X	0	0	0/1	Data byte will be received and not ACK/ACK will be returned
	88H	Previously addressed with own SLA; DATA byte has been received; not ACK returned	Read data byte	0	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address
			Read data byte	0	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized
			Read data byte	1	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address; START condition will be transmitted when the bus becomes free
			Read data byte	1	0	0	1	Switched to not addressed SLV mode; own SLA or general

								call address will be recognized; START condition will be transmitted when the bus becomes free
	90H	Previously addressed with general call address; DATA has been received; ACK returned	Read data byte	X	0	0	0/1	Data byte will be received and not ACK/ACK will be returned
	98H	Previously addressed with general call address; DATA has been received; not ACK returned	Read data byte	0	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address
			Read data byte	0	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized
			Read data byte	1	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address; START condition will be transmitted when the bus becomes free
			Read data byte	1	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized; START condition will be transmitted when the bus becomes free
	A0H	A STOP condition or repeated START condition has been received while still addressed as SLV/REC or SLV/TRX	No action	0	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address
			No action	0	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized
			No action	1	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address; START condition will be transmitted when the bus becomes free
			No action	1	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized; START condition will be transmitted when the bus becomes free
Slave Transmitter	A8H	Own SLA+R has been received; ACK has been returned	Load data byte	X	0	0	0	Last data byte will be transmitted and ACK will be received
			Load data byte	X	0	0	1	Data byte will be transmitted; ACK will be received.
	B0H	Arbitration lost in SLA+R/W as master; own SLA+R has been received, ACK has been returned.	Load data byte	X	0	0	0	Last data byte will be transmitted and ACK will be received
			Load data byte	X	0	0	1	Data byte will be transmitted; ACK will be received.
	B8H	Data byte has been transmitted; ACK will be received.	Load data byte	X	0	0	0	Last data byte will be transmitted and ACK will be received
			Load data byte	X	0	0	1	Data byte will be transmitted; ACK will be received.
	C0H	Data byte has been transmitted; not ACK has been received.	No action	0	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address.
			No action	0	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized.
			No action	1	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address; START condition will be transmitted when the bus becomes free.
			No action	1	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized; START condition will be transmitted when the bus becomes free.
	C8H	Last data byte has been transmitted; ACK has been received.	No action	0	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address.
			No action	0	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized.
			No action	1	0	0	0	Switched to not addressed SLV mode; no recognition of own SLA or general call address; START condition will be transmitted when the bus becomes free.
			No action	1	0	0	1	Switched to not addressed SLV mode; own SLA or general call address will be recognized; START condition will be transmitted when the bus becomes free.
Miscellaneous	F8H	No relevant state information available; SI=0	No action	No action				Wait or proceed current transfer
	38H	Arbitration lost	No action	0	0	0	X	I2C will be released; A start condition will be transmitted.
			No action	1	0	0	X	When the bus becomes free. (enter to a master mode)
	00H	Bus error during MST or selected slave modes	No action	0	1	0	X	Only the internal hardware is affected in the MST or addressed SLV modes. In all cases, the bus is released and I2C is switched to the not addressed SLV mode. STO flag is reset.

"SLA" means slave address, "R" means R/W=1, "W" means R/W=0

*For applications where NACK doesn't mean the end of communication.

SMBSEL Register (0xDE)

Bit	Field	Type	Initial	Description
7	SMBEXE	R/W	0	SMBus extension functionality 0: Disable 1: Enable
2..0	SMBSTP[2:0]	R/W	000	SMBus timeout register

SMBDST Register (0xDF)

Bit	Field	Type	Initial	Description
7..0	SMBD[7:0]	R/W	0x00	This register is used to provide a read/write access port to the SMBus timeout registers. Data read or written to that register is actually read or written to the Timeout Register which is pointed by the SMBSEL register.

IEN0 Register (0xA8)

Bit	Field	Type	Initial	Description
7	EAL	R/W	0	Interrupts enable. Refer to Chapter Interrupt
Else				Refer to other chapter(s)

IEN1 Register (0xB8)

Bit	Field	Type	Initial	Description
0	EI2C	R/W	0	Interrupts enable. Refer to Chapter Interrupt
Else				Refer to other chapter(s)

P1M Register (0xFA)

Bit	Field	Type	Initial	Description
0	P10M	R/W	0	0: Set P1.0 (SDA) as input mode (required) ~~1: Set P1.0 (SDA) as output mode~~*
Else				Refer to other chapter(s)

* The P10M require be set input mode.

P1 Register (0x90)

Bit	Field	Type	Initial	Description
0	P10	R/W	0	0: Set P1.0 (SDA) data is 0 (required) ~~1: Set P1.0 (SDA) data is 1~~
Else				Refer to other chapter(s)

* The P10 require be set 0.

P0M Register (0xF9)

Bit	Field	Type	Initial	Description
7	P07M	R/W	0	0: Set P0.7 (SCL) as input mode (required) ~~1: Set P0.7 (SCL) as output mode~~*
Else				Refer to other chapter(s)

* The P07M require be set input mode.

P0 Register (0x80)

Bit	Field	Type	Initial	Description
7	P07	R/W	0	0: Set P0.7 (SCL) data is 0 (required) ~~1: Set P0.7 (SCL) data is 1~~
Else				Refer to other chapter(s)

* The P07 require be set 0.

18.9 Sample Code

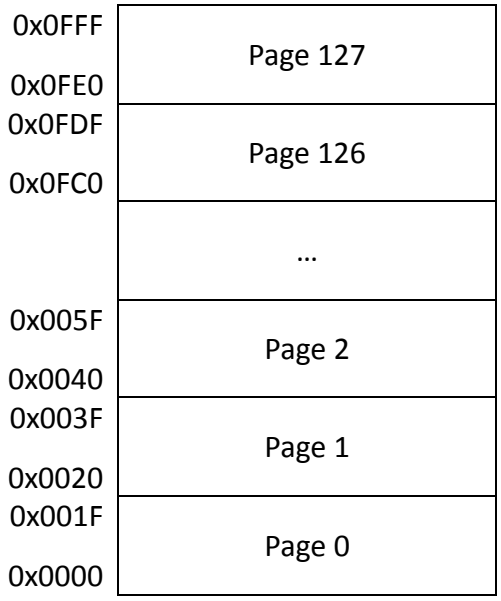
The following sample code demonstrates how to perform I2C with interrupt.

```
unsigned int  I2CAddr;
unsigned int  I2C_TXData0;
unsigned int  I2C_TXDatan;
unsigned int  I2C_RXData0;
unsigned int  I2C_RXDatan;

void I2CInit(void)
{
  P0M &= 0xE7;      // P03 & P04 as input

  // configure I2C clock(T1)and enable I2C.
  I2CCON |= 0xC3;
  TMOD = 0x60;   // auto reload
  TCON0 = 0x07;  // Fosc/1
  TH1 = 0xF6;    //400kHz
  TL1 = 0xF6;    //400kHz or
  TH1 = 0xD8;    //100kHz
  TL1 = 0xD8;    //100kHz
  TR1 = 1;

  // enable I2C interrupt
  EI2C = 1;
  //enable global interrupt
  EAL = 1;

  I2CCON |= 0x20;            // START (STA) = 1
}

void I2cInterrupt(void) interrupt ISRI2c  //0x43
{
    switch (I2CSTA)
    {
        // tx mode
        case 0x08:
            I2CCON &= 0xDF;           // START (STA) = 0
            I2CDAT = I2CAddr;        // Tx/Rx addr
            break;
        case 0x18:                    // write first byte
            I2CDAT = I2C_TXData0;
            break;
        case 0x28:                    // write n byte
            I2CDAT = I2C_TXDatan;
            break;
        case 0x30:                    // STOP (STO)
            I2CCON |= 0x10;
            break;
        //    rx mode
        case 0x40:                    // get slave addr
            I2CCON |= 0x04;           // AA = 1
            break;
        case 0x50:                    // read n byte
            I2C_RXData0 = I2CDAT;
            I2CCON &= 0xFB;           // AA = 0
            break;
```

```
54          case 0x58:                    // read last byte & stop
55              I2C_RXDatan = I2CDAT;
56              I2CCON |= 0x10;           // STOP (STO)
57              break;
58          default:
59              I2CCON |= 0x10;            // STOP (STO)
60      }
61
62      I2CCON &= 0xF7;                    // Clear I2C flag (SI)
63  }
```

19 In-System Program

SN8F5702 builds in an on-chip 4 KB program memory, aka IROM, which is equally divided to 128 pages (32 bytes per page). The in-system program is a procedure that enables a firmware to freely modify every page's data; in other word, it is the channel to store value(s) into the non-volatile memory and/or live update firmware.



Program memory (IROM)

19.1 Page Program

Because each page of the program memory has 32 bytes in length, a page program procedure requires 32 bytes IRAM as its data buffer.

These configurations must be setup completely before starting Page Program. ISP is configured using the following steps:

1. Save program data into IRAM. The data continues for 32 bytes.
2. Set the start address of the content location to PERAM.
3. Set the start address of the anticipated update area to PEROM [15:5]. (By PEROMH/PRROML registers)
4. Write '0xA5A' into PECMD [11:0] to trigger ISP function. Before writing '0x5A' into PECMD[7:0], PECMD[11:8] must be written '0xA'.

As an example, assume the 126th page of program memory (IROM, 0x0FC0 – 0x0FDF) is the anticipated update area; the content is already stored in IRAM address 0x60 – 0x7F. To perform the in-system program, simply write starting IROM address 0x0FC0 to EPROMH/EPROML registers, and then specify buffer starting address 0x60 to EPRAM register. Subsequently, write '0xA5A' into PECMD [11:0] registers to duplicate the buffer's data to 126th page of IROM.

In general, every page has the capability to be modified by in-system program procedure. However, since the first and least pages (page 0 and 127) respectively stores reset vector and information for power-on controller, incorrectly perform page program (such as turn off power while programming) may cause faulty power-on sequence / reset.

19.2 In-system Program Register

Register	Bit 7	Bit 6	Bit 5	Bit 4	Bit 3	Bit 2	Bit 1	Bit 0
PERAM	PERAM7	PERAM6	PERAM5	PERAM4	PERAM3	PERAM2	PERAM1	PERAM0
PEROMH	PEROM15	PEROM14	PEROM13	PEROM12	PEROM11	PEROM10	PEROM9	PEROM8
PEROML	PEROM7	PEROM6	PEROM5	-	PECMD11	PECMD10	PECMD9	PECMD8
PECMD	PECMD7	PECMD6	PECMD5	PECMD4	PECMD3	PECMD2	PECMD1	PECMD0

PERAM Register (0x97)

Bit	Field	Type	Initial	Description
7..0	PERAM[7:0]	R/W	0x00	The first address of data buffer (IRAM)

PEROMH Register (0x96)

Bit	Field	Type	Initial	Description
7..0	PEROM[15:8]	R/W	0x00	The first address (15^{th}– 8^{th} bit) of program page (IROM)

PEROML Register (0x95)

Bit	Field	Type	Initial	Description
7..5	PEROM[7:5]	R/W	000	The first address (7^{th} – 5^{th}) of program page (IROM)
4	Reserved	R	0	
3..0	PECMD[11:8]	R/W	0x0	0xA: Enable in-system program Else values: Disable in-system program*

* Disabling in-system program can avoid mistakenly trigger ISP function.

PECMD Register (0x94)

Bit	Field	Type	Initial	Description
7..0	PECMD[7:0]	W	0x0	0x5A: Start page program procedure*(1) ~~Else values: Reserved~~*(2)

*(1) Before writing '0x5A' into PECMD[7:0], PECMD[11:8] must be written '0xA'.

*(2) Not permitted to write any other to PECMD register.

19.3 Sample Code

```
unsigned cahr idata dataBuffer[32] _at_ 0xE0;  // IRAM 0xE0 to 0xFF

void SYSIspSetDataBuffer(unsigned char address, unsigned char data)
{
  dataBuffer[address & 0x1F] = data;
}

void SYSIspStart(unsigned int pageAddress)
{
  ISP(pageAddress, 0xE0);
}
```

20 Electrical Characteristics

20.1 Absolute Maximum Ratings

Voltage applied at VDD to VSS ..... - 0.3V to 6.0V
Voltage applied at any pin to VSS..... - 0.3V to VDD+0.3V
Operating ambient temperature.....-40°C to 85°C
Storage ambient temperature ..... -40°C to 125°C
Junction Temperature ..... -40°C to 125°C

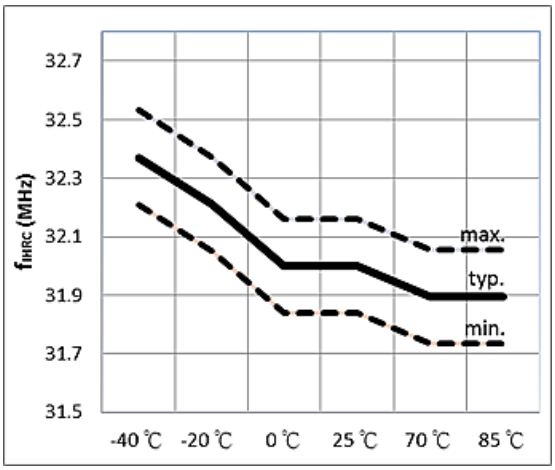
20.2 System Operation Characteristics

	Parameter	Test Condition	Min	TYP	MAX	UNIT
VDD	Operating voltage	fcpu = 1MHz	1.8		5.5	V
V_{DR}	RAM data retention Voltage		1.5			V
V_{POR}	VDD rising rate*		0.05			V/ms
I_{DD1}	Normal mode supply current	VDD = 3V, fcpu = 0.25MHz		2.20		mA
		VDD = 5V, fcpu = 0.25MHz		2.25		mA
		VDD = 3V, fcpu = 1MHz		2.25		mA
		VDD = 5V, fcpu = 1MHz		2.30		mA
		VDD = 3V, fcpu = 4MHz		2.70		mA
		VDD = 5V, fcpu = 4MHz		2.75		mA
		VDD = 3V, fcpu = 8MHz		3.20		mA
		VDD = 5V, fcpu = 8MHz		3.25		mA
		VDD = 3V, fcpu = 32MHz		4.50		mA
		VDD = 5V, fcpu = 32MHz		4.55		mA
I_{DD2}	STOP mode supply current	VDD = 3V		3.5		µA
		VDD = 5V		4.0		µA
I_{DD3}	IDLE mode supply current (fcpu = 1MHz)	VDD = 3V, 32MHz IHRC		0.63		mA
		VDD = 5V, 32MHz IHRC		0.65		mA
F_{IHRC}	Internal high clock generator	VDD = 1.8V to 5.5V, 25°C	31.84	32	32.16	MHz
		VDD = 1.8V to 5.5V, 25°C to 85°C	31.68		31.99	MHz
		VDD = 1.8V to 5.5V, -40°C to 25°C	32.31		32.64	MHz
F_{ILRC}	Internal low clock generator	VDD = 5V, 25°C	12	16	24	kHz
V_{LVD18}	LVD18 detect voltage	25°C	1.7	1.8	1.9	V
		-40°C to 85°C	1.6	1.8	2.0	V
V_{LVD24}	LVD24 detect voltage	25°C	2.3	2.4	2.4	V

		-40°C to 85°C	2.2	2.4	2.6	V
V_{LVD33}	LVD33 detect voltage	25°C	3.2	3.3	3.4	V
		-40°C to 85°C	3.0	3.3	3.6	V

* Parameter(s) with star mark are non-verified design reference. Ambient temperature is 25°C.

- IHRC Frequency - Temperature Graph



20.3 GPIO Characteristics

Parameter		Test Condition	MIN	TYP	MAX	UNIT
V_{IL}	Low-level input voltage		VSS		0.3VSS	V
V_{IH}	High-level input voltage		0.7VDD		VDD	V
I_{LEKG}	I/O port input leakage current	V_{IN} = VDD			2	µA
R_{UP}	Pull-up resister	VDD = 3V	100	200	300	kΩ
		VDD = 5V	50	100	150	kΩ
I_{OH}	I/O output source current	VDD = 5V, V_O = VDD-0.5V	12	16		mA
I_{OL1}	I/O sink current (P1, P07, P2)	VDD = 5V, V_O = VSS+0.5V	15	20		mA
I_{OL2}	I/O sink current (P00-P06)	VDD = 5V, V_O = VSS+1.5V	80	100		mA

* Ambient temperature is 25°C.

20.4 ADC Characteristics

	Parameter	Test Condition	MIN	TYP	MAX	UNIT
V_{ADC}	Operating voltage		2.0		5.5	V
V_{AIN}	AIN channels input voltage	VDD = 5V	0		V_{REFH}	V
V_{REFH}	AVREFH pin input voltage	VDD = 5V	2		VDD	V
V_{EREF}	External reference voltage	VDD = 5V	2		VDD	V
V_{IREF}	Internal VDD reference voltage	VDD = 5V		VDD		V
	Internal 4V reference voltage	VDD = 5V	3.92	4	4.08	V
	Internal 3V reference voltage	VDD = 5V	2.94	3	3.06	V
	Internal 2V reference voltage	VDD = 5V	1.96	2	2.04	V
I_{AD}	ADC current consumption	VDD = 3V		0.65		mA
		VDD = 5V		0.90		mA
f_{ADCLK}	ADC clock	VDD = 3V			16	MHz
		VDD = 5V			32	MHz
f_{ADSMP}	ADC sampling rate	VDD = 3V			250	kHz
		VDD = 5V			500	kHz
t_{ADEN}	ADC function enable period	VDD = 5V	100			µs
DNL	Differential nonlinearity*	f_{ADSMP} = 62.5kHz		±2		LSB
		f_{ADSMP} = 250kHz		±2		LSB
		f_{ADSMP} = 500kHz		±5		LSB
INL	Integral Nonlinearity*	f_{ADSMP} = 62.5kHz		±2		LSB
		f_{ADSMP} = 250kHz		±2		LSB
		f_{ADSMP} = 500kHz		±5		LSB
NMC	No missing code*	f_{ADSMP} = 62.5kHz	10	11	12	Bit
		f_{ADSMP} = 250kHz		11		Bit
		f_{ADSMP} = 500kHz		9		Bit
V_{OFFSET}	Input offset voltage	Non-trimmed	-10	0	10	mV
		Trimmed	-2	0	2	mV

* Parameters with star mark: VDD = 5V, V_{REFH} = 2.4V, 25°C.

20.5 Flash Memory Characteristics

	Parameter	Test Condition	MIN	TYP	MAX	UNIT
V_{dd}	Supply voltage		1.8		5.5	V
T_{en}	Endurance time	25°C		*100K		cycle
I_{wrt}	Write current	25°C		3	4	mA
T_{wrt}	Write time	Write 1 page=32 bytes, 25°C		6	8	ms

* Parameters with star mark are non-verified design reference.

21 Instruction Set

This chapter categorizes the SN8F5702 microcontroller's comprehensive assembly instructions. It includes five categories—arithmetic operation, logic operation, data transfer operation, Boolean manipulation, and program branch—which are fully compatible with standard 8051.

Symbol description

Symbol	Description
Rn	Working register R0 - R7
direct	One of 128 internal RAM locations or any Special Function Register
@Ri	Indirect internal or external RAM location addressed by register R0 or R1
#data	8-bit constant (immediate operand)
#data16	16-bit constant (immediate operand)
bit	One of 128 software flags located in internal RAM, or any flag of bit-addressable Special Function Registers
addr16	Destination address for LCALL or LJMP, can be anywhere within the 64-Kbyte page of program memory address space
addr11	Destination address for ACALL or AJMP, within the same 2-Kbyte page of program memory as the first byte of the following instruction
rel	SJMP and all conditional jumps include an 8-bit offset byte. Its range is +127/-128 bytes relative to the first byte of the following instruction
A	Accumulator

Arithmetic operations

Mnemonic	Description
ADD A, Rn	Add register to accumulator
ADD A, direct	Add directly addressed data to accumulator
ADD A, @Ri	Add indirectly addressed data to accumulator
ADD A, #data	Add immediate data to accumulator
ADDC A, Rn	Add register to accumulator with carry
ADDC A, direct	Add directly addressed data to accumulator with carry
ADDC A, @Ri	Add indirectly addressed data to accumulator with carry
ADDC A, #data	Add immediate data to accumulator with carry
SUBB A, Rn	Subtract register from accumulator with borrow
SUBB A, direct	Subtract directly addressed data from accumulator with borrow
SUBB A, @Ri	Subtract indirectly addressed data from accumulator with borrow
SUBB A, #data	Subtract immediate data from accumulator with borrow
INC A	Increment accumulator
INC Rn	Increment register
INC direct	Increment directly addressed location
INC @Ri	Increment indirectly addressed location
INC DPTR	Increment data pointer
DEC A	Decrement accumulator
DEC Rn	Decrement register
DEC direct	Decrement directly addressed location
DEC @Ri	Decrement indirectly addressed location
MUL AB	Multiply A and B
DIV	Divide A by B
DA A	Decimally adjust accumulator

Logic operations

Mnemonic	Description
ANL A, Rn	AND register to accumulator
ANL A, direct	AND directly addressed data to accumulator
ANL A, @Ri	AND indirectly addressed data to accumulator
ANL A, #data	AND immediate data to accumulator
ANL direct, A	AND accumulator to directly addressed location
ANL direct, #data	AND immediate data to directly addressed location
ORL A, Rn	OR register to accumulator

ORL A, direct	OR directly addressed data to accumulator
ORL A, @Ri	OR indirectly addressed data to accumulator
ORL A, #data	OR immediate data to accumulator
ORL direct, A	OR accumulator to directly addressed location
ORL direct, #data	OR immediate data to directly addressed location
XRL A, Rn	Exclusive OR (XOR) register to accumulator
XRL A, direct	XOR directly addressed data to accumulator
XRL A, @Ri	XOR indirectly addressed data to accumulator
XRL A, #data	XOR immediate data to accumulator
XRL direct, A	XOR accumulator to directly addressed location
XRL direct, #data	XOR immediate data to directly addressed location
CLR A	Clear accumulator
CPL A	Complement accumulator
RL A	Rotate accumulator left
RLC A	Rotate accumulator left through carry
RR A	Rotate accumulator right
RRC A	Rotate accumulator right through carry
SWAP A	Swap nibbles within the accumulator

Data transfer operations

Mnemonic	Description
MOV A, Rn	Move register to accumulator
MOV A, direct	Move directly addressed data to accumulator
MOV A, @Ri	Move indirectly addressed data to accumulator
MOV A, #data	Move immediate data to accumulator
MOV Rn, A	Move accumulator to register
MOV Rn, direct	Move directly addressed data to register
MOV Rn, #data	Move immediate data to register
MOV direct, A	Move accumulator to direct
MOV direct, Rn	Move register to direct
MOV direct1, direct2	Move directly addressed data to directly addressed location
MOV direct, @Ri	Move indirectly addressed data to directly addressed location
MOV direct, #data	Move immediate data to directly addressed location
MOV @Ri, A	Move accumulator to indirectly addressed location
MOV @Ri, direct	Move directly addressed data to indirectly addressed location
MOV @Ri, #data	Move immediate data to in directly addressed location

MOV DPTR, #data16	Load data pointer with a 16-bit immediate
MOVC A, @A+DPTR	Load accumulator with a code byte relative to DPTR
MOVC A, @A+PC	Load accumulator with a code byte relative to PC
MOVX A, @Ri	Move external RAM (8-bit address) to accumulator
MOVX A, @DPTR	Move external RAM (16-bit address) to accumulator
MOVX @Ri, A	Move accumulator to external RAM (8-bit address)
MOVX @DPTR, A	Move accumulator to external RAM (16-bit address)
PUSH direct	Push directly addressed data onto stack
POP direct	Pop directly addressed location from stack
XCH A, Rn	Exchange register with accumulator
XCH A, direct	Exchange directly addressed location with accumulator
XCH A, @Ri	Exchange indirect RAM with accumulator
XCHD A, @Ri	Exchange low-order nibbles of indirect and accumulator

Boolean manipulation

Mnemonic	Description
CLR C	Clear carry flag
CLR bit	Clear directly addressed bit
SETB C	Set carry flag
SETB bit	Set directly addressed bit
CPL C	Complement carry flag
CPL bit	Complement directly addressed bit
ANL C, bit	AND directly addressed bit to carry flag
ANL C, /bit	AND complement of directly addressed bit to carry
ORL C, bit	OR directly addressed bit to carry flag
ORL C, /bit	OR complement of directly addressed bit to carry
MOV C, bit	Move directly addressed bit to carry flag
MOV bit, C	Move carry flag to directly addressed bit

Program branches

Mnemonic	Description
ACALL addr11	Absolute subroutine call
LCALL addr16	Long subroutine call
RET	Return from subroutine
RETI	Return from interrupt
AJMP addr11	Absolute jump
LJMP addr16	Long jump
SJMP rel	Short jump (relative address)
JMP @A+DPTR	Jump indirect relative to the DPTR
JZ rel	Jump if accumulator is zero
JNZ rel	Jump if accumulator is not zero
JC rel	Jump if carry flag is set
JNC rel	Jump if carry flag is not set
JB bit, rel	Jump if directly addressed bit is set
JNB bit, rel	Jump if directly addressed bit is not set
JBC bit, rel	Jump if directly addressed bit is set and clear bit
CJNE A, direct, rel	Compare directly addressed data to accumulator and jump if not equal
CJNE A, #data, rel	Compare immediate data to accumulator and jump if not equal
CJNE Rn, #data, rel	Compare immediate data to register and jump if not equal
CJNE @Ri, #data, rel	Compare immediate to indirect and jump if not equal
DJNZ Rn, rel	Decrement register and jump if not zero
DJNZ direct, rel	Decrement directly addressed location and jump if not zero
NOP	No operation for one cycle

22 Debug Interface

The debug interface, aka SWAT, shares one pin with GPIO P1.1 which can update full range of the on-chip program memory (IROM), and cooperate with development environment. The shared pin is automatically reserved for debug interface if a SN-Link is connected before microcontroller's power-on, whereas the pin remains other function(s) if it does not detect any handshake signal during microcontroller's power-on sequence.

22.1 Minimum Requirement

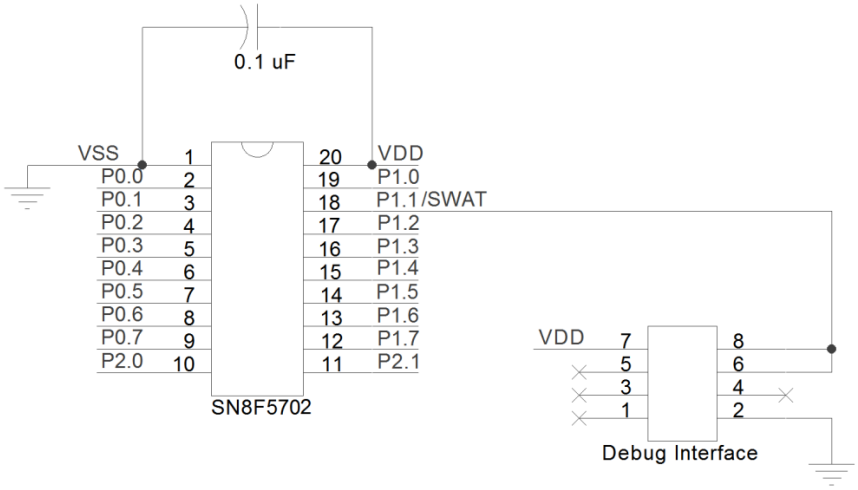
The following items are essential to build up an appropriate development environment. The compatibility is verified on listed versions, and is expected to execute perfectly on later version. SN-Link related information is available to download on SONiX website (www.sonix.com.tw);
Keil C51 is downloadable on www.keil.com/c51.

- **SN-Link Adapter II** with updated firmware version 3.1
- **SN-Link Driver for Keil C51** version 1.00.32
- **Keil C51** version 9.50a and 9.54a

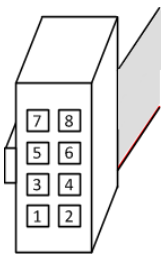
22.2 Debug Interface Hardware

The circuit below demonstrates the appropriate method to connect microcontroller's SWAT pin and SN-Link Adapter II.

Before starting debug, microcontroller's power (VDD) must be switched off. Connect the SWAT to both 5th and 7th pins of SN-Link, and respectively link VDD and VSS to 8th pin and 1st pin. A handshake procedure would be automatically started by turn on the microcontroller, and SN-Link's red LED (Run) indicates the success of connection (refer *SN8F5000 Debug Tool Manual* for further detail).



example circuit



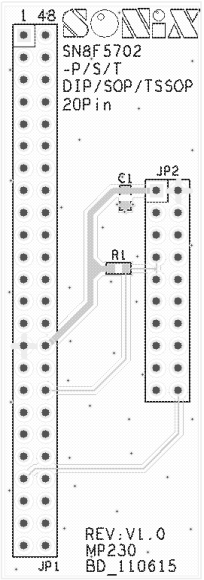
SN-Link header

23 ROM Programming Pin

SN8F5702 Series Flash ROM erase/program/verify support SN-LINK and MP5 Writer

- SN-LINK: Debug interface.
- MP5 Writer: For SN8F5702 series version.

23.1 MP5 Writer Transition Board Socket Pin Assignment



JP7 (Mapping to 48-pin text tool):

DIP1	1	48	DIP48
DIP2	2	47	DIP47
DIP3	3	46	DIP46
DIP4	4	45	DIP45
DIP5	5	44	DIP44
DIP6	6	43	DIP43
DIP7	7	42	DIP42
DIP8	8	41	DIP41
DIP9	9	40	DIP40
DIP10	10	39	DIP39
DIP11	11	38	DIP38
DIP12	12	37	DIP37
DIP13	13	36	DIP36
DIP14	14	35	DIP35
DIP15	15	34	DIP34
DIP16	16	33	DIP33
DIP17	17	32	DIP32
DIP18	18	31	DIP31
DIP19	19	30	DIP30
DIP20	20	29	DIP29
DIP21	21	28	DIP28
DIP22	22	27	DIP27
DIP23	23	26	DIP26
DIP24	24	25	DIP25

Writer JP5/JP6:

VDD	1	2	GND
-	3	4	-
-	5	6	-
SWAT	7	8	-
SWAT	9	10	-
-	11	12	-
-	13	14	-
-	15	16	-
-	17	18	-
-	19	20	PDB

JP5 for Writer transition board

JP6 for MCU <48 pin package

23.2 MP5 Writer Programming Pin Mapping

SN8F5702P/S/T (DIP20/SOP20/TSSOP20):

Writer Connector		MCU and JP7 48-pin text tool pin assignment		
JP5/JP6 Pin Number	JP5/JP6 Pin Name	MCU Pin Number	MCU Pin Name	JP7 Pin Number
1	VDD	20	VDD	34
2	GND	1	VSS	15
7	SWAT	18	P1.1	32
9	SWAT	18	P1.1	32
20	PDB	7	P0.5	21

SN8F5702J (QFN20):

Writer Connector		MCU and JP7 48-pin text tool pin assignment		
JP5/JP6 Pin Number	JP5/JP6 Pin Name	MCU Pin Number	MCU Pin Name	JP7 Pin Number
1	VDD	18	VDD	32
2	GND	19	VSS	33
7	SWAT	16	P1.1	30
9	SWAT	16	P1.1	30
20	PDB	5	P0.5	19

SN8F570200A (MSOP10):

Writer Connector		MCU and JP7 48-pin text tool pin assignment		
JP5/JP6 Pin Number	JP5/JP6 Pin Name	MCU Pin Number	MCU Pin Name	JP7 Pin Number
1	VDD	1	VDD	20
2	GND	2	VSS	21
7	SWAT	9	P1.1	28
9	SWAT	9	P1.1	28
20	PDB	5	P0.5	24

SN8F570202S (SOP8):

Writer Connector		MCU and JP7 48-pin text tool pin assignment		
JP5/JP6 Pin Number	JP5/JP6 Pin Name	MCU Pin Number	MCU Pin Name	JP7 Pin Number
1	VDD	1	VDD	21
2	GND	8	VSS	28
7	SWAT	5	P1.1	25
9	SWAT	5	P1.1	25
20	PDB	3	P0.5	23

SN8F570210S (SOP14):

Writer Connector		MCU and JP7 48-pin text tool pin assignment		
JP5/JP6 Pin Number	JP5/JP6 Pin Name	MCU Pin Number	MCU Pin Name	JP7 Pin Number
1	VDD	14	VDD	31
2	GND	1	VSS	18
7	SWAT	12	P1.1	29
9	SWAT	12	P1.1	29
20	PDB	5	P0.5	22

SN8F570211S (SOP14):

Writer Connector		MCU and JP7 48-pin text tool pin assignment		
JP5/JP6 Pin Number	JP5/JP6 Pin Name	MCU Pin Number	MCU Pin Name	JP7 Pin Number
1	VDD	14	VDD	31
2	GND	1	VSS	18
7	SWAT	12	P1.1	29
9	SWAT	12	P1.1	29
20	PDB	6	P0.5	23

SN8F570212S/T (SOP16/TSSOP16):

Writer Connector		MCU and JP7 48-pin text tool pin assignment		
JP5/JP6 Pin Number	JP5/JP6 Pin Name	MCU Pin Number	MCU Pin Name	JP7 Pin Number
1	VDD	16	VDD	32
2	GND	1	VSS	17
7	SWAT	14	P1.1	30
9	SWAT	14	P1.1	30
20	PDB	6	P0.5	22

SN8F570213S (SOP14):

Writer Connector		MCU and JP7 48-pin text tool pin assignment		
JP5/JP6 Pin Number	JP5/JP6 Pin Name	MCU Pin Number	MCU Pin Name	JP7 Pin Number
1	VDD	1	VDD	18
2	GND	14	VSS	31
7	SWAT	12	P1.1	29
9	SWAT	12	P1.1	29
20	PDB	5	P0.5	22

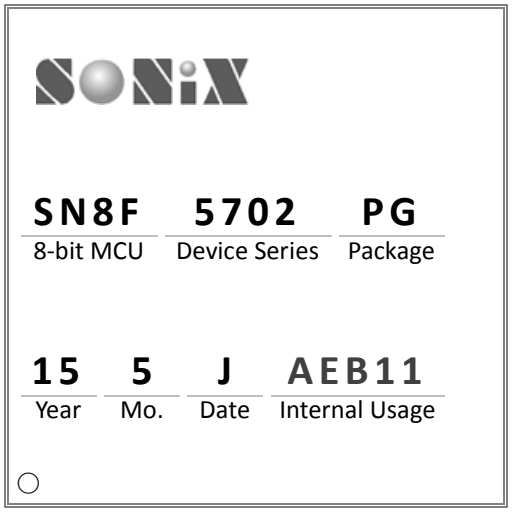
24 Ordering Information

A typical surface of SONiX microcontroller is printed with three columns: logo, device's full name, and date code.

SONiX Logo

Full Name

Date Code



24.1 Device Nomenclature

Full Name	Packing Type
S8F5702W	Wafer
SN8F5702H	Dice
SN8F5702PG	PDIP, 20 pins, Green package
SN8F5702SG	SOP, 20 pins, Green package
SN8F5702TG	TSSOP, 20 pins, Green package
SN8F5702JG	QFN, 20 pins, Green package
SN8F570212SG	SOP, 16 pins, Green package
SN8F570212TG	TSSOP, 16 pins, Green package
SN8F570210SG	SOP, 14 pins, Green package
SN8F570211SG	SOP, 14 pins, Green package
SN8F570213SG	SOP, 14 pins, Green package
SN8F570200AG	MSOP, 10 pins, Green package
SN8F570202SG	SOP, 8 pins, Green package

24.2 Date Code

The date code includes two parts: date of manufacture and production serial code. The first part is public information which is encoded by following principles.

Year	15: 2015 16: 2016 17: 2017 et cetera
Month	1: January 2: February 3: March A: October B: November C: December et cetera
Date	1: 01 2: 02 3: 03 A: 10 B: 11 et cetera

25 Appendix: Reference Document

Sonix provides reference document for users to help them quickly familiar SN8F5000 family (downloadable on cooperative website: www.sonix.com.tw).

Document Name	Description
SN8F5000 Starter-Kit User Manual	This documentation introduces SN8F5000 family all Starter-Kit, providing the user selects an appropriate starter-kit for development.
SN8F5000 Family Instruction Set	The document details the 8051 instruction set, and a simple example illustrates operation.
SN8F5000 Family Instruction Mapping Table	This document supplies the information about mapping assembly instructions from 8-Bit Flash/ OTP Type to 8051 Flash Type.
SN8F5000 Packaging Information	This documentation introduces SN8F5000 family microcontrollers' mechanical data, such as height, width and pitch information.
SN8F5000 Debug Tool Manual	This document teaches the user to install software Keil C51, and helped create a new project to be developed.

SN8F5702 Series Datasheet

8051-based Microcontroller

Corporate Headquarters
10F-1, No. 36, Taiyuan St.
Chupei City, Hsinchu, Taiwan
TEL: +886-3-5600888
FAX: +886-3-5600889

Taipei Sales Office
15F-2, No. 171, Songde Rd.
Taipei City, Taiwan
TEL: +886-2-27591980
FAX: +886-2-27598180
mkt@sonix.com.tw
sales@sonix.com.tw

Hong Kong Sales Office
Unit 2603, No. 11, Wo Shing St.
Fo Tan, Hong Kong
TEL: +852-2723-8086
FAX: +852-2723-9179
hk@sonix.com.tw

Shenzhen Contact Office
High Tech Industrial Park,
Shenzhen, China
TEL: +86-755-2671-9666
FAX: +86-755-2671-9786
mkt@sonix.com.tw
sales@sonix.com.tw

USA Office
TEL: +1-714-3309877
TEL: +1-949-4686539
tlightbody@earthlink.net

Japan Office
2F, 4 Chome-8-27 Kudanminami
Chiyoda-ku, Tokyo, Japan
TEL: +81-3-6272-6070
FAX: +81-3-6272-6165
jpsales@sonix.com.tw

FAE Support via email
8-bit Microcontroller Products:
sa1fae@sonix.com.tw
All Products: fae@sonix.com.tw