ABOV SEMICONDUCTOR Co., Ltd.
8-BIT MICROCONTROLLERS

MC96F8316

User's Manual (Ver. 1.1)

REVISION HISTORY

VERSION 0.0 (November 10, 2011)

VERSION 1.0 (April 12, 2012)

Change '1.3/2.6mA (Typ/Max)' to "IDD2 @X-tal 12MHz" in DC Electrical characteristics.

Change '0.7/1.4mA (Typ/Max)' to "IDD2 @X-tal 10MHz" in DC Electrical characteristics.

Change '0.8/1.6mA (Typ/Max)' to "IDD2 @IRC 16MHz" in DC Electrical characteristics.

Change '60.0/90.0uA (Typ/Max)' to "IDD3" in DC Electrical characteristics.

Change '6.0/12.0uA (Typ/Max)' to "IDD4" in DC Electrical characteristics.

Change '±1.0%(T_A= 0°C ~ +50°C)/±2.0%(T_A= -20°C ~ +85°C)/±3.0%(T_A= -40°C ~ +85°C)' @2.0V – 5.5V to "IRC's Tolerance" in Internal RC Oscillator characteristics.

Change '±4 (Max)' to "ILE" in ADC electrical characteristics.

Change '50/150mV (Typ/Max)' to "LVR/LVI Hysteresis" in LVR/LVI electrical characteristics.

Change '8.0/12.0 uA (Typ/Max)' to "Current consumption(one of two)" in LVR/LVI characteristics.

Change '10.0/15.0 uA (Typ/Max)' to "Current consumption(both)" in LVR/LVI characteristics.

Add 'Instructions on how to use the input port' descriptions.

Add description about clock source(T1 A Match) of Timer 2.

Add 'Application circuit for ADC Key Input by resistor string'.

Retype a typo at 'EO Register description'.

Retype a typo on I2C Frequency formula.

Retype some typo errors.

VERSION 1.1 (April 20, 2012) This book

Change '30V/mS (Max)' to "VDD Voltage Rising Time" in Power-on Reset Electrical characteristics.

Version 1.1
Published by FAE Team

Table of Contents

List of Figures

List of Tables

MC96F8316

CMOS SINGLE-CHIP 8-BIT MICROCONTROLLER WITH 12-BIT A/D CONVERTER

1. Overview

1.1 Description

The MC96F8316 is advanced CMOS 8-bit microcontroller with 16k bytes of FLASH. This is powerful microcontroller which provides a highly flexible and cost effective solution to many embedded control applications. This provides the following features : 16k bytes of FLASH, 256 bytes of IRAM, 512 bytes of XRAM , general purpose I/O, basic interval timer, watchdog timer, 8/16-bit timer/counter, 16-bit PPG output, 8-bit PWM output, watch timer, buzzer driving port, SPI, UART, I2C, 12-bit A/D converter, on-chip POR, LVR, LVI, on-chip oscillator and clock circuitry. The MC96F8316 also supports power saving modes to reduce power consumption.

Device Name	FLASH	XRAM	IRAM	ADC	I/O PORT	Package
MC96F8316D	16k bytes	512 bytes	256 bytes	15 channel	30	32 SOP
MC96F8316M				12 channel	26	28 SOP
MC96F8316G				12 channel	26	28 SKDIP
MC96F8216U				11 channel	22	24 QFN
MC96F8216D				8 channel	18	20 SOP
MC96F8216B				8 channel	18	20 PDIP

1.2 Features

- **CPU**
  - 8 Bit CISC Core (8051 Compatible)
- **ROM (FLASH) Capacity**
  - 16k Bytes
  - Flash with self read/write capability
  - On chip debug and In-system programming (ISP)
  - Endurance : 100,000 times
- **256 Bytes IRAM**
- **512 Bytes XRAM**
- **General Purpose I/O (GPIO)**
  - Normal I/O : 30 Ports
    (P0[6:0], P1[7:0], P2[6:0], P3[7:0])
  - LED display drive capability pins : 14 Ports
    (P1[7:0], P2[5:0])
- **Basic Interval Timer (BIT)**
  - 8Bit × 1ch
  - **Watch Dog Timer (WDT)**
  - 8Bit × 1ch
  - 5kHz internal RC oscillator
- **Timer/ Counter**
  - 8Bit × 1ch (T0), 16Bit × 2ch (T1/T2)
- **Programmable Pulse Generation**
  - Pulse generation (by T1/T2)
  - 8Bit PWM (by T0)
- **Watch Timer (WT)**
  - 3.91mS/0.25S/0.5S/1S/1M interval at 32.768kHz
- **Buzzer**
  - 8Bit × 1ch
- **SPI**
  - 8Bit × 1ch
- **UART**
  - 8Bit × 1ch
- **I2C**
  - 8Bit × 1ch
- **12 Bit A/D Converter**
  - 15 Input channels
  - Power down wake-up function
- **Power On Reset**
  - Reset release level (1.4V)
- **Low Voltage Reset**
  - 14 level detect (1.60V/ 2.00V/ 2.10V/ 2.20V/ 2.32V/ 2.44V/ 2.59V/ 2.75V/ 2.93V/ 3.14V/ 3.38V/ 3.67V/ 4.00V/ 4.40V)
- **Low Voltage Indicator**
  - 13 level detect (2.00V/ 2.10V/ 2.20V/ 2.32V/ 2.44V/ 2.59V/ 2.75V/ 2.93V/ 3.14V/ 3.38V/ 3.67V/ 4.00V/ 4.40V)
- **Interrupt Sources**
  - External Interrupts
    (EINT0~4, EINT5, EINT6, EINT7~A, EINT10, EINT11, EINT12) (7)
  - Timer(0/1/2) (4)
  - WDT (1)
  - BIT (1)
  - WT (1)
  - SPI (1)
  - UART (2)
  - I2C (1)
  - ADC (1)
  - ADC Wake-up (1)
- **Internal RC Oscillator**
  - Inernal RC frequency:
    16MHz ±1.0% (T_A= 0 ~ +50°C)
- **Power Down Mode**
  - STOP, IDLE mode
- **Operating Voltage and Frequency**
  - 1.8V ~ 5.5V (@ 32 ~ 38kHz with X-tal)
  - 1.8V ~ 5.5V (@ 0.4 ~ 4.2MHz with X-tal)
  - 2.7V ~ 5.5V (@ 0.4 ~ 10.0MHz with X-tal)
  - 3.0V ~ 5.5V (@ 0.4 ~ 12.0MHz with X-tal)
  - 1.8V ~ 5.5V (@ 0.5 ~ 8.0MHz with Internal RC)
  - 2.0V ~ 5.5V (@ 0.5 ~ 16.0MHz with Internal RC)
  - Voltage dropout converter included for core
- **Minimum Instruction Execution Time**
  - 125nS (@ 16MHz main clock)
  - 61μS (@ 32.768kHz sub clock)
- **Operating Temperature:** – 40 ~ + 85℃
- **Oscillator Type**
  - 0.4-12MHz Crystal or Ceramic for main clock
  - 32.768kHz Crystal for sub clock
- **Package Type**
  - 32 SOP
  - 28 SOP/SKDIP
  - 24 QFN
  - 20 SOP/PDIP
  - Pb-free package

1.3 Ordering Information

Table 1-1 Ordering Information of MC96F8316

Device name	ROM size	IRAM size	XRAM size	Package
MC96F8316D	16k bytes FLASH	256 bytes	512 bytes	32 SOP
MC96F8316M				28 SOP
MC96F8316G				28 SKDIP
MC96F8216U				24 QFN
MC96F8216D				20 SOP
MC96F8216B				20 PDIP

1.4 Development Tools

1.4.1 Compiler

We do not provide the compiler. Please contact the third parties.

The core of MC96F8316 is Mentor 8051. And, device ROM size is smaller than 64k bytes. Developer can use all kinds of third party's standard 8051 compiler.

1.4.2 OCD emulator and debugger

The OCD (On Chip Debug) emulator supports ABOV Semiconductor's 8051 series MCU emulation.

The OCD interface uses two-wire interfacing between PC and MCU which is attached to user's system. The OCD can read or change the value of MCU internal memory and I/O peripherals. And the OCD also controls MCU internal debugging logic, it means OCD controls emulation, step run, monitoring, etc.

The OCD Debugger program works on Microsoft-Windows NT, 2000, XP, Vista (32bit) operating system.

If you want to see more details, please refer to OCD debugger manual. You can download debugger S/W and manual from our web-site.

Connection:

- DSCL (MC96F8316 P01 port)
- DSDA (MC96F8316 P00 port)

OCD connector diagram: Connect OCD with user system

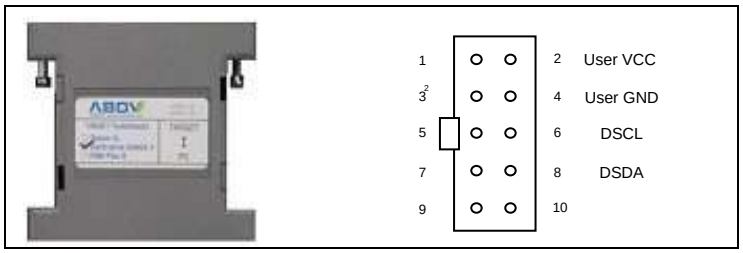


Figure 1.1 OCD Debugger and Pin Description

1.4.3 Programmer

Single programmer:

PGMplus USB: It programs MCU device directly.

Figure 1.2 PGMplusUSB (Single Writer)

StandAlone PGMplus: It programs MCU device directly.

Figure 1.3 StandAlone PGMplus (Single Writer)

OCD emulator: It can write code in MCU device too, because OCD debugging supports ISP (In System Programming).

It does not require additional H/W, except developer's target system.

Gang programmer:

It programs 8 MCU devices at once.

So, it is mainly used in mass production line.

Gang programmer is standalone type, it means it does not require host PC, after a program is downloaded from host PC to Gang programmer.

Figure 1.4 StandAlone Gang8 (for Mass Production)

2. Block Diagram

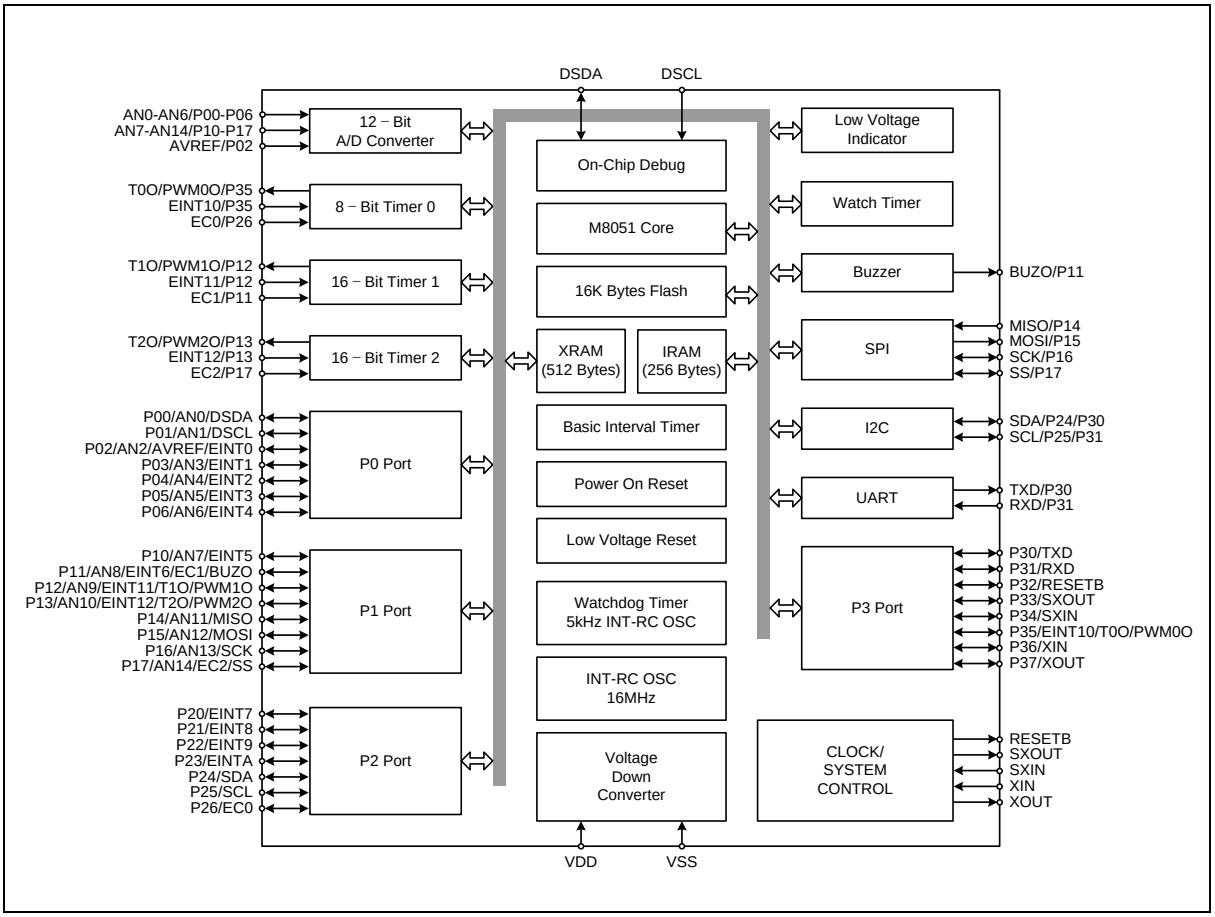


Figure 2.1 Block Diagram

NOTES) 1. The P04–P06, and P26 are not in the 28-pin package.
2. The P04–P06, P17, P20–P22, and P26 are not in the 24-pin package.
3. The P04–P06, P14–P17, P20, P23, P26, P33–P34 and are not in the 20-pin package.

3. Pin Assignment

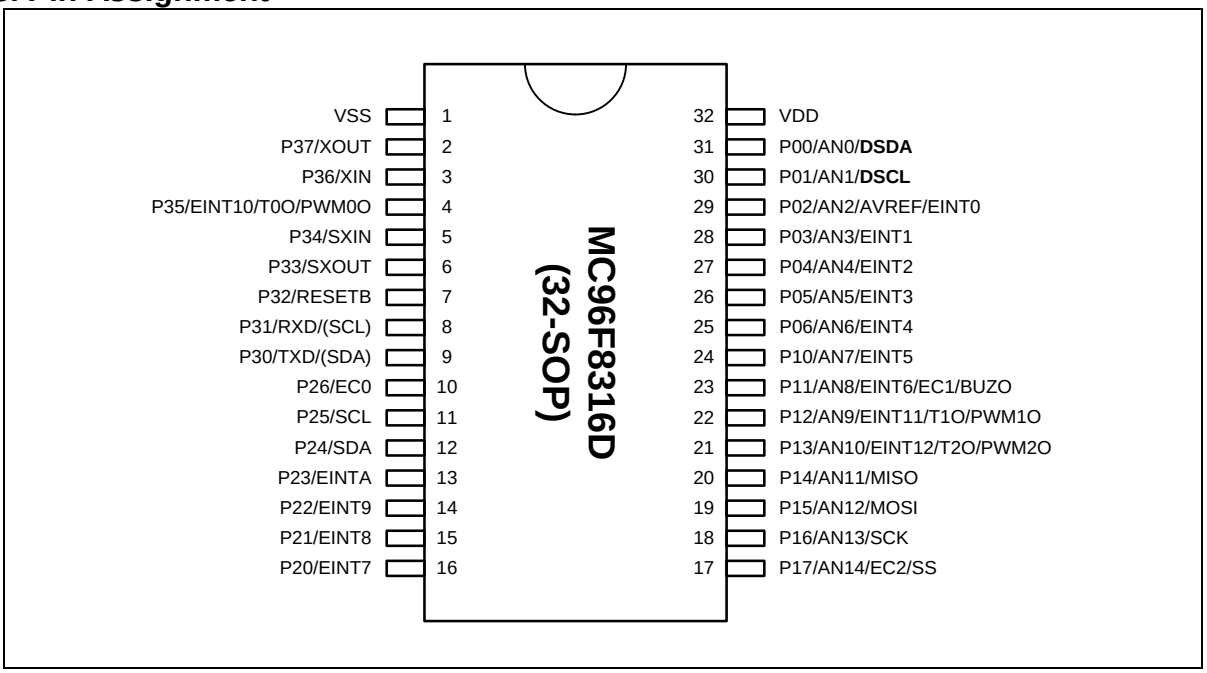


Figure 3.1 MC96F8316D 32SOP Pin Assignment

NOTES) 1. On On-Chip Debugging, ISP uses P0[1:0] pin as DSCL, DSDA.
2. The SDA/SCL lines for I2C can be configured on the P30/P31 pins by software control.

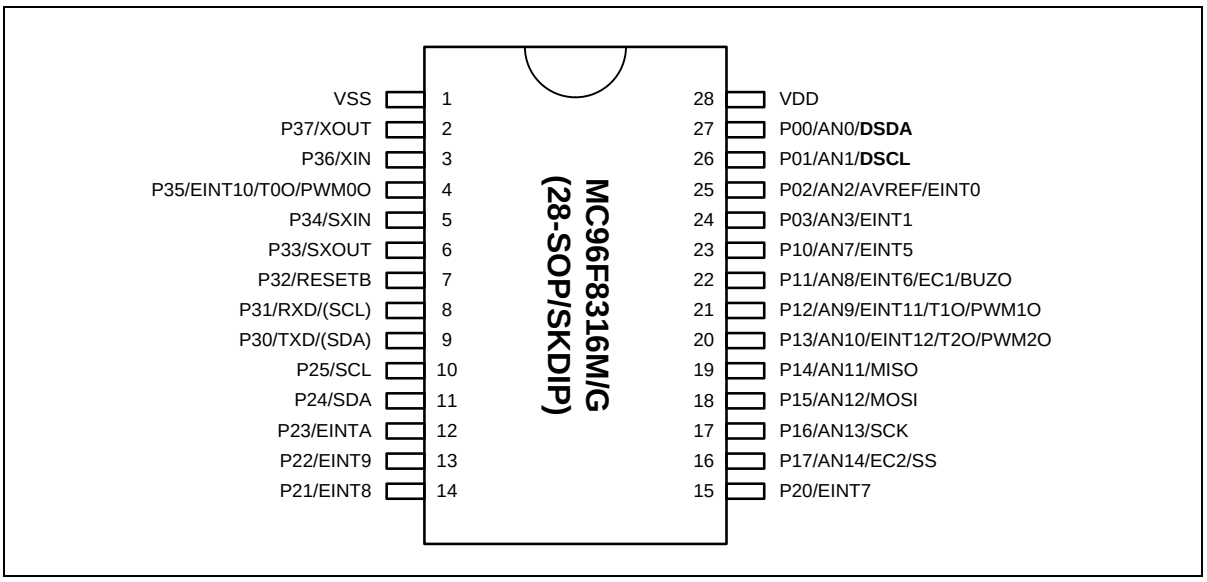


Figure 3.2 MC96F8316M/G 28SOP/28SKDIP Pin Assignment

NOTES) 1. On On-Chip Debugging, ISP uses P0[1:0] pin as DSCL, DSDA.
2. The P04-P06 and P26 pins should be selected as a push-pull output or an input with pull-up resistor by software control when the 28-pin package is used.
3. The SDA/SCL lines for I2C can be configured on the P30/P31 pins by software control.

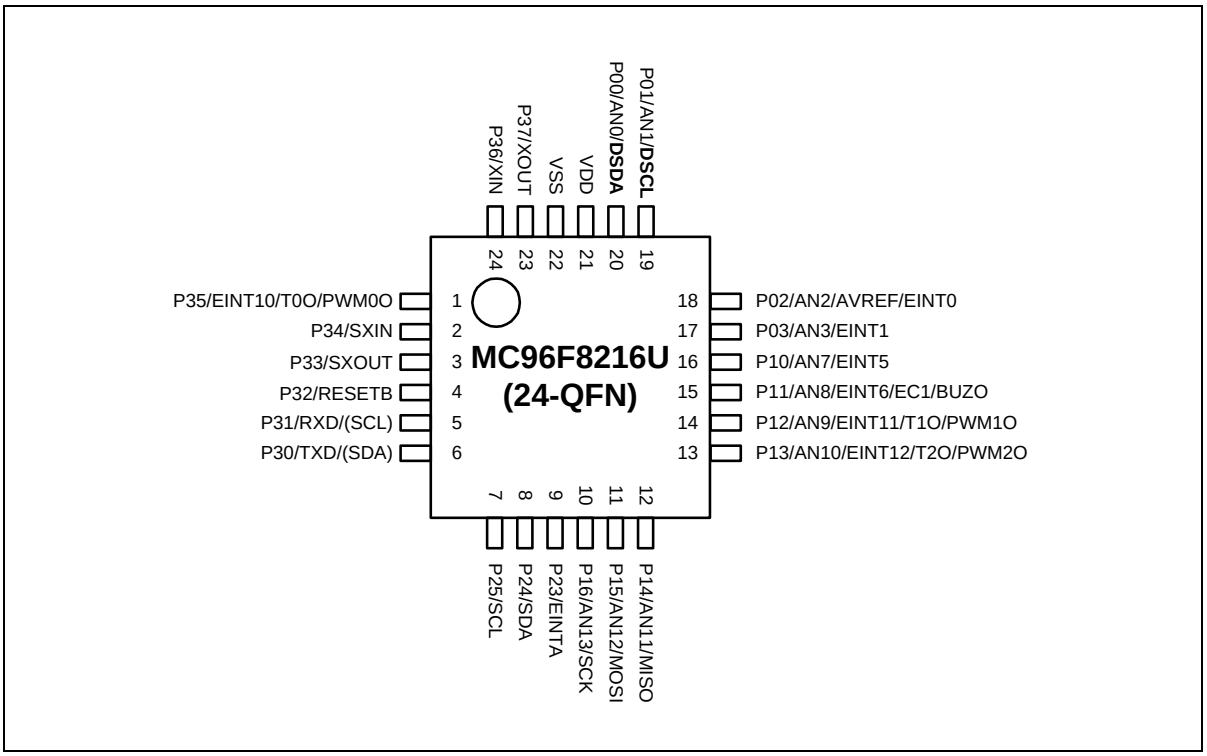


Figure 3.3 MC96F8216U 24QFN Pin Assignment

NOTES) 1. On On-Chip Debugging, ISP uses P0[1:0] pin as DSCL, DSDA.
2. The P04-P06, P17, P20-P22 and P26 pins should be selected as a push-pull output or an input with pull-up resistor by software control when the 24-pin package is used.
3. The SDA/SCL lines for I2C can be configured on the P30/P31 pins by software control.

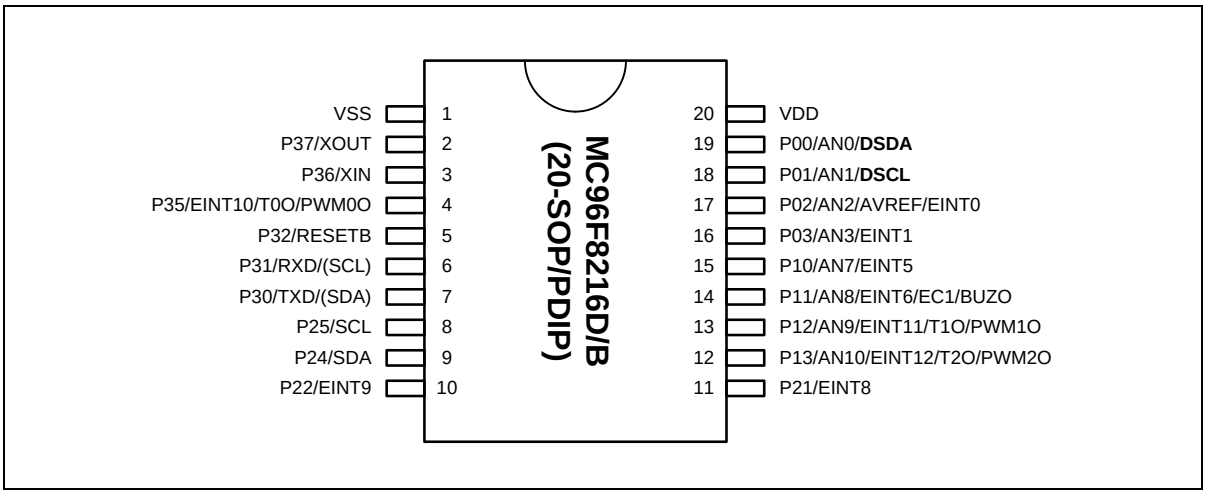


Figure 3.4 MC96F8216D/B 20SOP/20PDIP Pin Assignment

NOTES) 1. On On-Chip Debugging, ISP uses P0[1:0] pin as DSCL, DSDA.
2. The P04-P06, P14-P17, P20, P23, P26 and P33-P34 pins should be selected as a push-pull output or an input with pull-up resistor by software control when the 20-pin package is used.
3. The SDA/SCL lines for I2C can be configured on the P30/P31 pins by software control.

4. Package Diagram

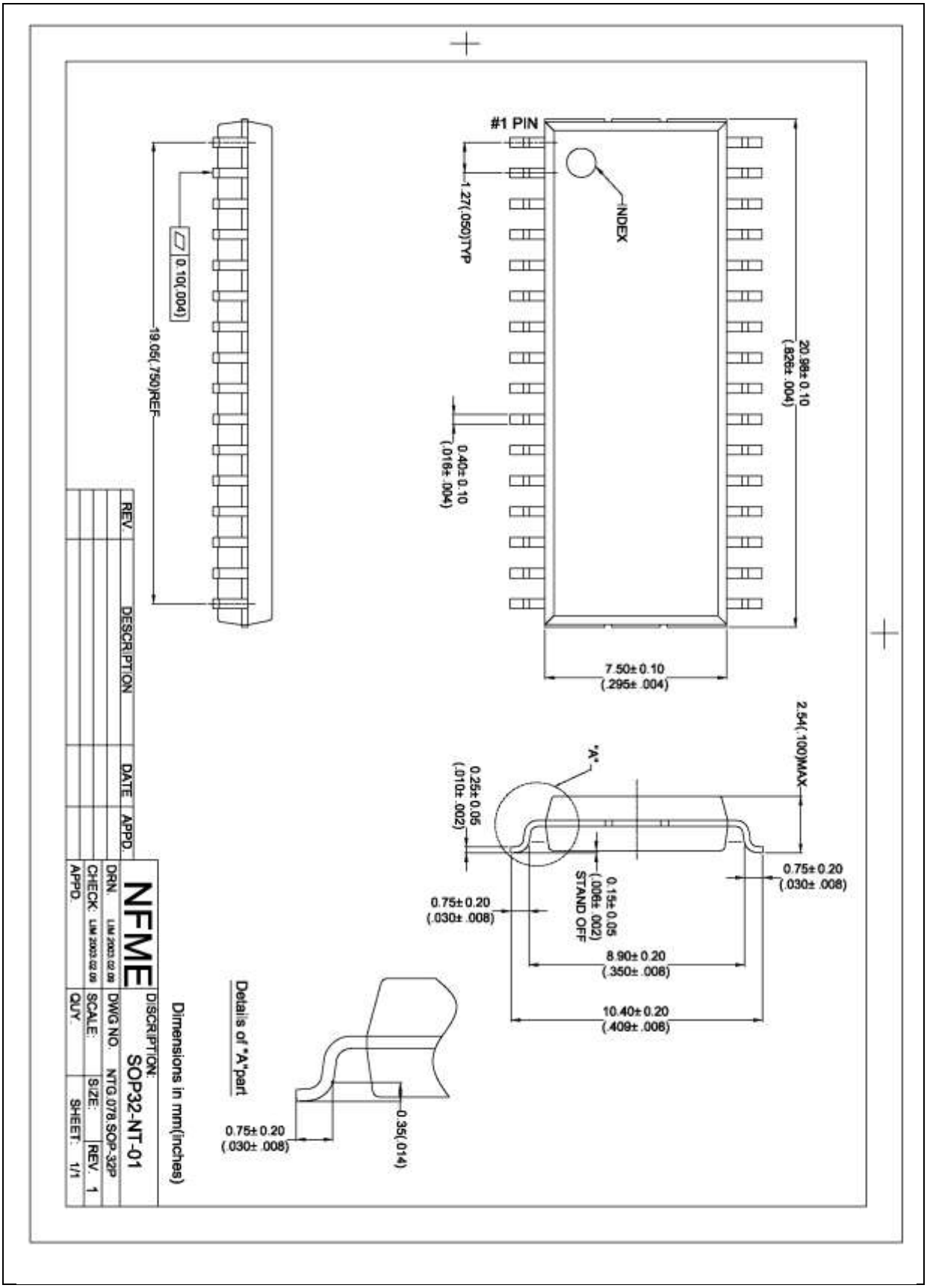


Figure 4.1 32-Pin SOP Package

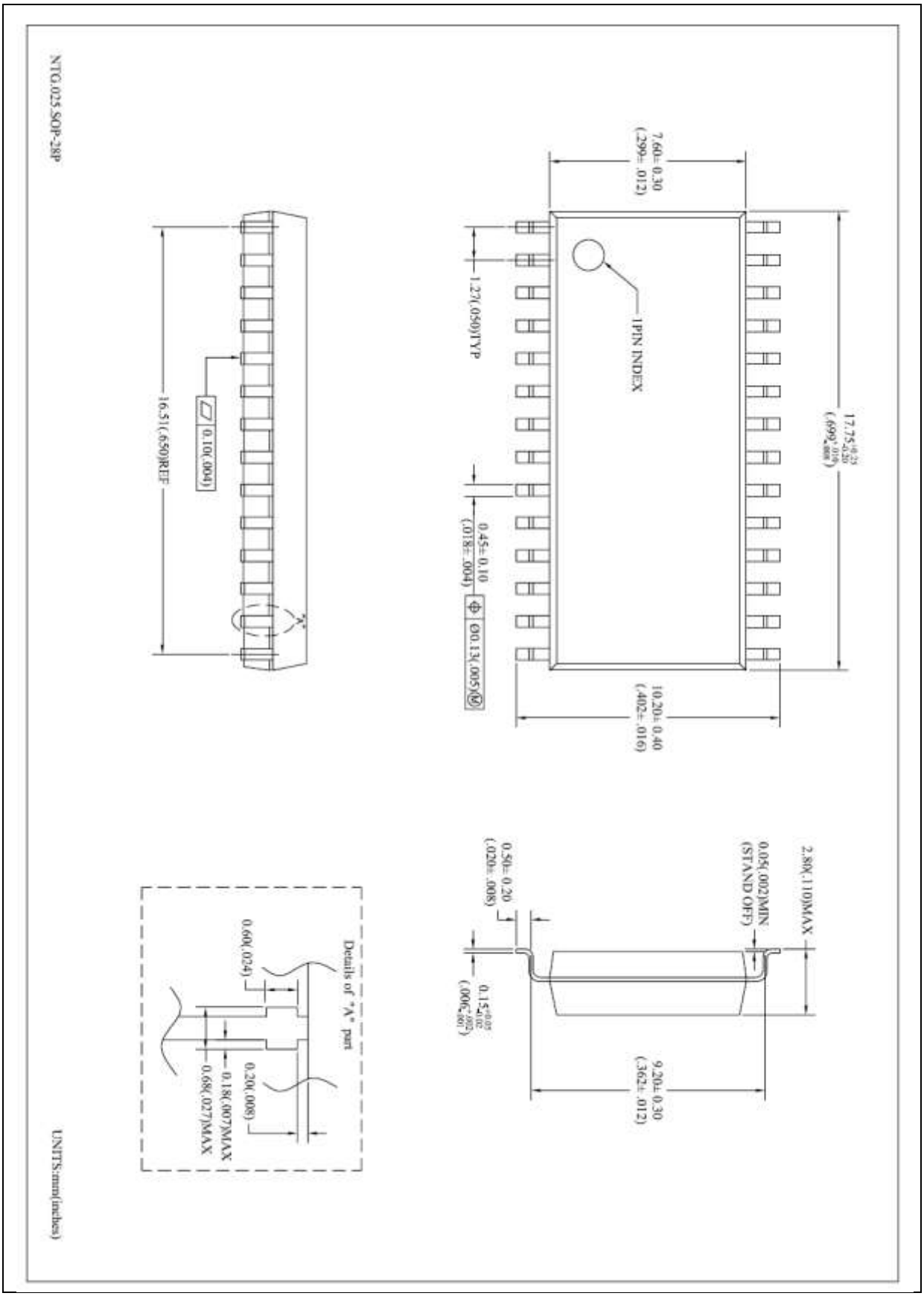


Figure 4.2 28-Pin SOP Package

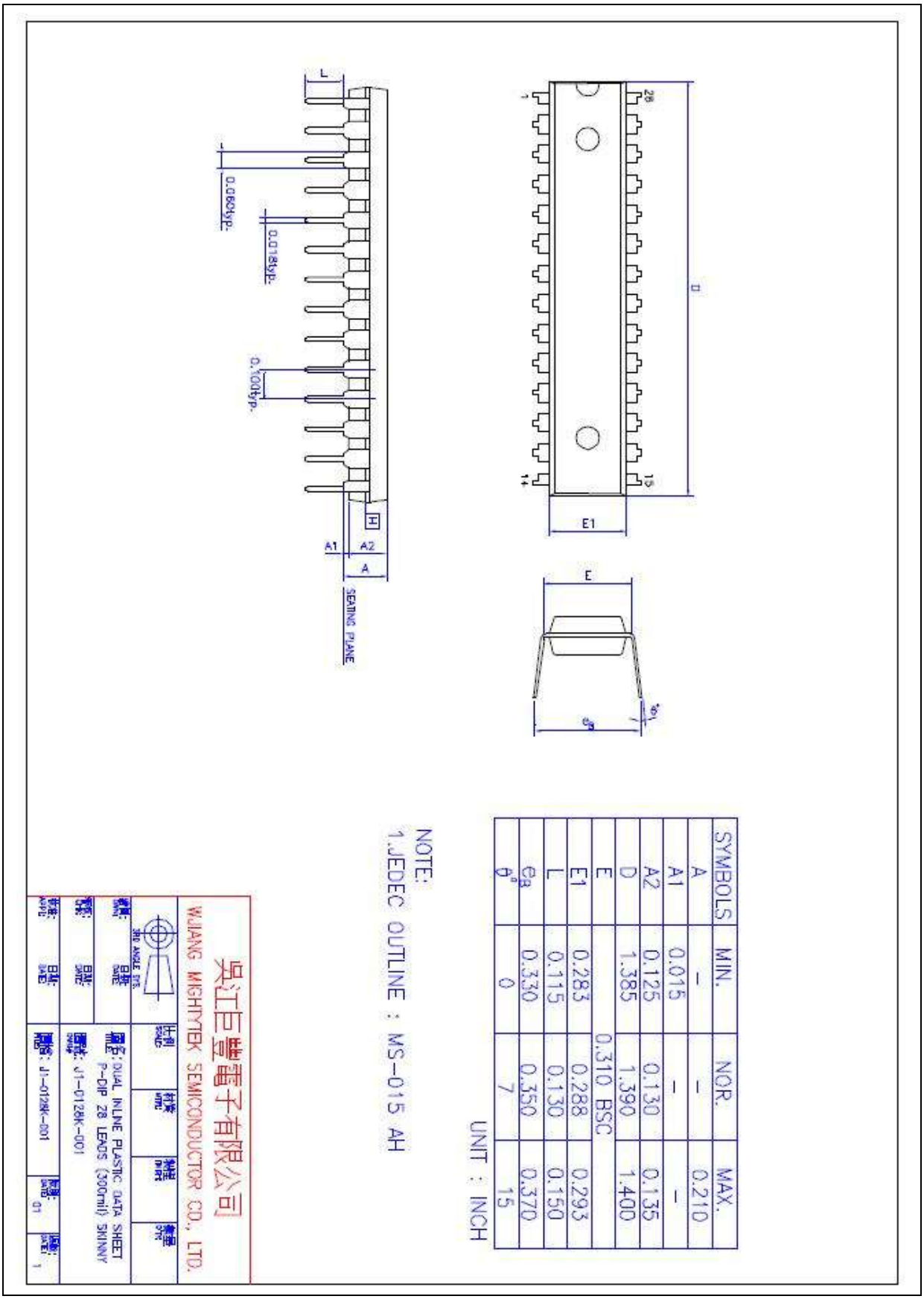
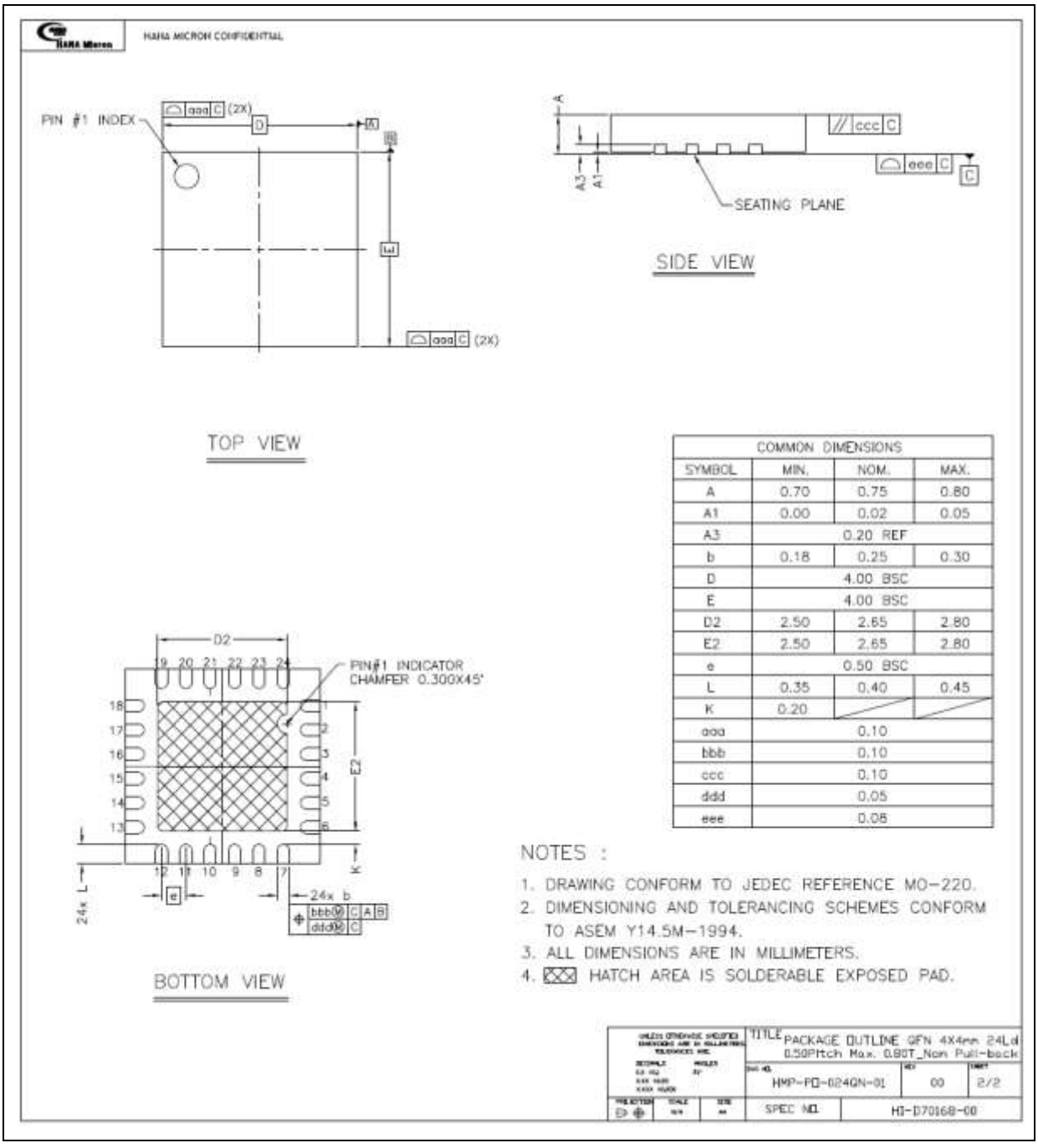


Figure 4.3 28-Pin SKDIP Package



COMMON DIMENSIONS			
SYMBOL	MIN.	NOM.	MAX.
A	0.70	0.75	0.80
A1	0.00	0.02	0.05
A3		0.20 REF	
b	0.18	0.25	0.30
D		4.00 BSC	
E		4.00 BSC	
D2	2.50	2.65	2.80
E2	2.50	2.65	2.80
e		0.50 BSC	
L	0.35	0.40	0.45
K	0.20		
aaa		0.10	
bbb		0.10	
ccc		0.10	
ddd		0.05	
eee		0.08	

Figure 4.4 24-Pin QFN Package

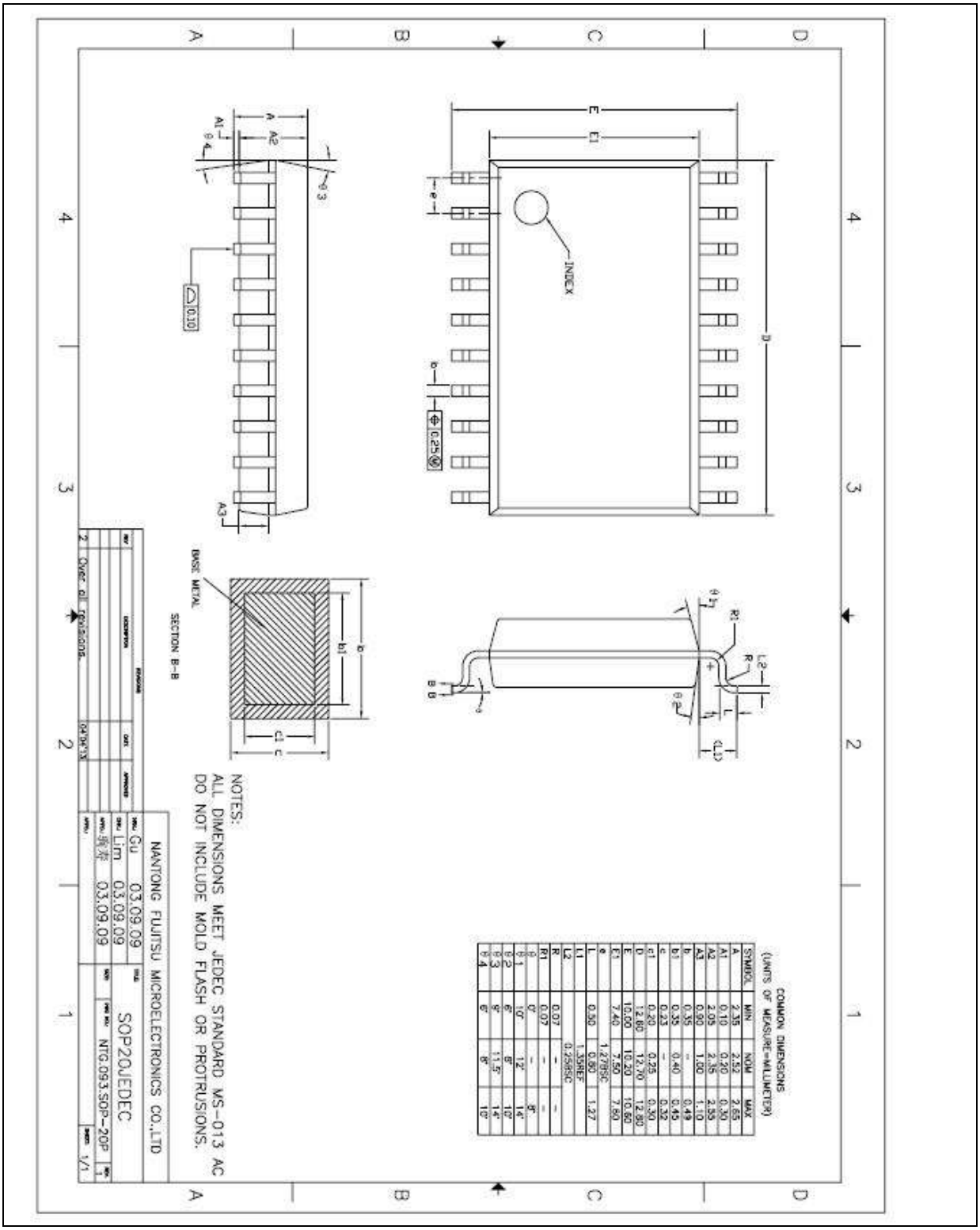


Figure 4.5 20-Pin SOP Package

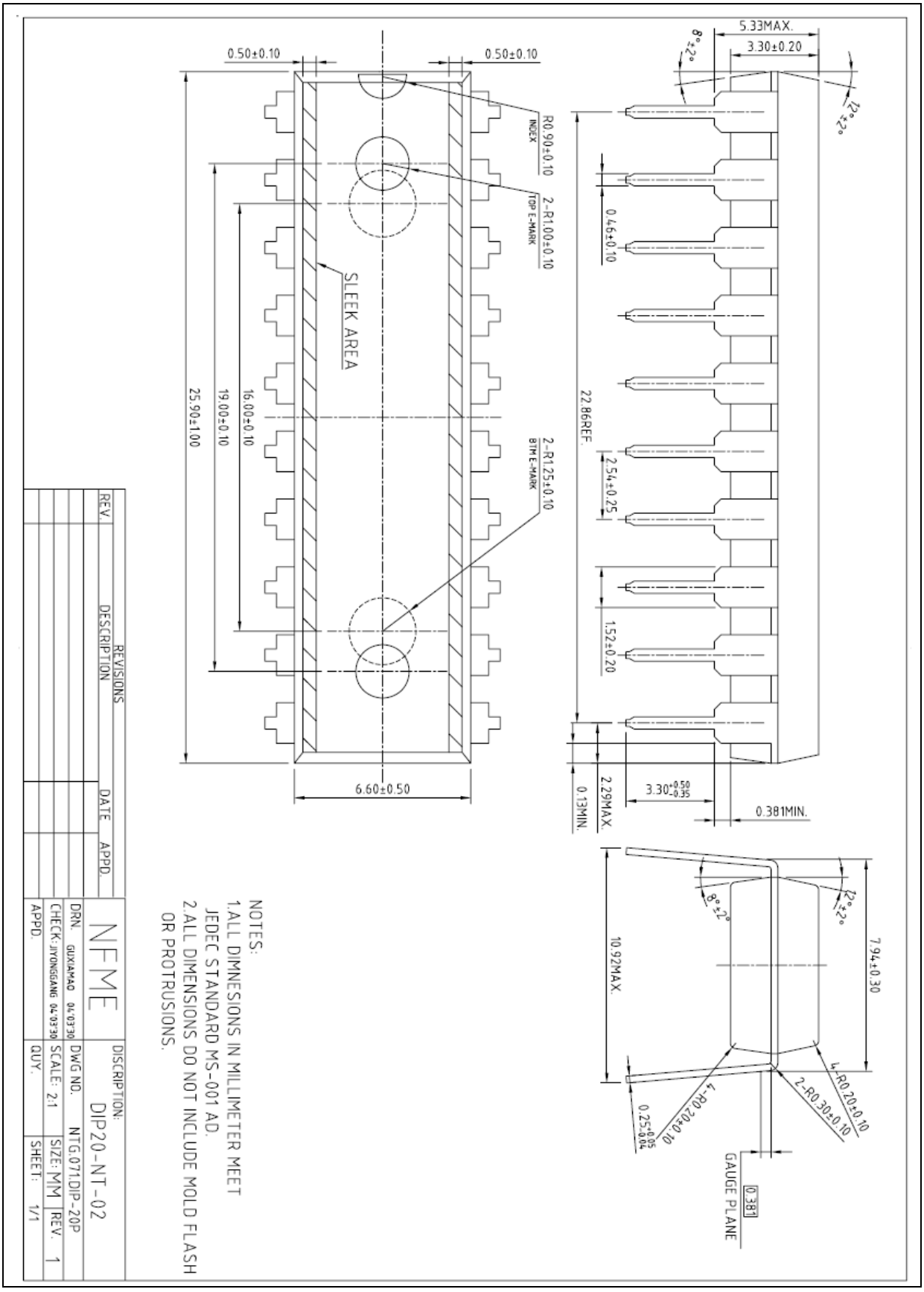


Figure 4.6 20-Pin PDIP Package

5. Pin Description

Table 5-1 Normal Pin Description

PIN Name	I/O	Function	@RESET	Shared with
P00	I/O	Port 0 is a bit-programmable I/O port which can be configured as a schmitt-trigger input, a push-pull output, or an open-drain output. A pull-up resistor can be specified in 1-bit unit. The P04 – P06 are only in the 32-Pin package.	Input	AN0/DSDA
P01				AN1/DSCL
P02				AN2/AVREF/EINT0
P03				AN3/EINT1
P04				AN4/EINT2
P05				AN5/EINT3
P06				AN6/EINT4
P10	I/O	Port 1 is a bit-programmable I/O port which can be configured as a schmitt-trigger input, a push-pull output, or an open-drain output. A pull-up resistor can be specified in 1-bit unit. The P17 is not in the 24-Pin package. The P14 – P17 are not in the 20-Pin package.	Input	AN7/EINT5
P11				AN8/EINT6/EC1/BUZO
P12				AN9/EINT11/T1O/PWM1O
P13				AN10/EINT12/T2O/PWM2O
P14				AN11/MISO
P15				AN12/MOSI
P16				AN13/SCK
P17				AN14/EC2/SS
P20	I/O	Port 2 is a bit-programmable I/O port which can be configured as a schmitt-trigger input, a push-pull output, or an open-drain output. A pull-up resistor can be specified in 1-bit unit. The P20 – P22 are not in the 24-Pin package. The P20 and P23 are not in the 20-Pin package. The P26 is only in the 32-Pin package.	Input	EINT7
P21				EINT8
P22				EINT9
P23				EINTA
P24				SDA
P25				SCL
P26				EC0
P30	I/O	Port 3 is a bit-programmable I/O port which can be configured as a schmitt-trigger input, a push-pull output, or an open-drain output. A pull-up resistor can be specified in 1-bit unit. The P33 – P34 are not in the 20-Pin package.	Input	TXD
P31				RXD
P32				RESETB
P33				SXOUT
P34				SXIN
P35				EINT10/T0O/PWM0O
P36				XIN
P37				XOUT

Table 5-1 Normal Pin Description (Continued)

PIN Name	I/O	Function	@RESET	Shared with
EINT0	I/O	External interrupt inputs	Input	P02/AN2/AVREF
EINT1				P03/AN3
EINT2				P04/AN4
EINT3				P05/AN5
EINT4				P06/AN6
EINT5				P10/AN7
EINT6				P11/AN8/EC1/BUZO
EINT7				P20
EINT8				P21
EINT9				P22
EINTA				P23
EINT10	I/O	External interrupt input and Timer 0 capture input	Input	P35/T0O/PWM0O
EINT11	I/O	External interrupt input and Timer 1 capture input	Input	P12/AN9/T1O/PWM1O
EINT12	I/O	External interrupt input and Timer 2 capture input	Input	P13/AN10/T2O/PWM2O
T0O	I/O	Timer 0 interval output	Input	P35/EINT10/PWM0O
T1O	I/O	Timer 1 interval output	Input	P12/AN9/EINT11/PWM1O
T2O	I/O	Timer 2 interval output	Input	P13/AN10/EINT12/PWM2O
PWM0O	I/O	Timer 0 PWM output	Input	P35/EINT10/T0O
PWM1O	I/O	Timer 1 PWM output	Input	P12/AN9/EINT11/T1O
PWM2O	I/O	Timer 2 PWM output	Input	P13/AN10/EINT12/T2O
EC0	I/O	Timer 0 event count input	Input	P26
EC1	I/O	Timer 1 event count input	Input	P11/AN8/EINT6/BUZO
EC2	I/O	Timer 2 event count input	Input	P17/AN14/SS
BUZO	I/O	Buzzer signal output	Input	P11/AN8/EINT6/EC1
SCK	I/O	Serial clock input/output	Input	P16/AN13
MISO	I/O	Serial data input/output	Input	P14/AN11
MOSI	I/O	Serial data input/output	Input	P15/AN12
SS	I/O	Slave select input	Input	P17/AN14/EC2
TXD	I/O	UART data output	Input	P30
RXD	I/O	UART data input	Input	P31
SCL	I/O	I2C clock input/output	Input	P25
SDA	I/O	I2C data input/output	Input	P24

Table 5-1 Normal Pin Description (Continued)

PIN Name	I/O	Function	@RESET	Shared with
AVREF	I/O	A/D converter reference voltage	Input	P02/AN2/EINT0
AN0	I/O	A/D converter analog input channels	Input	P00/DSDA
AN1				P01/DSCL
AN2				P02/AVREF/EINT0
AN3				P03/EINT1
AN4				P04/EINT2
AN5				P05/EINT3
AN6				P06/EINT4
AN7				P10/EINT5
AN8				P11/EINT6/EC1/BUZO
AN9				P12/EINT11/T1O/PWM1O
AN10				P13/EINT12/T2O/PWM2O
AN11				P14/MISO
AN12				P15/MOSI
AN13				P16/SCK
AN14				P17/EC2/SS
RESETB	I/O	System reset pin with a pull-up resistor when it is selected as the RESETB by CONFIGURE OPTION	Input	P32
DSDA	I/O	On chip debugger data input/output (NOTE5,6)	Input	P00
DSCL	I/O	On chip debugger clock input (NOTE5,6)	Input	P01
XIN	I/O	Main oscillator pins	Input	P36
XOUT				P37
SXIN	I/O	Sub oscillator pins	Input	P34
SXOUT				P33
VDD, VSS	–	Power input pins	–	–

NOTES) 1. The P04-P06 and P26 are not in the 28-Pin package.
2. The P04-P06, P17, P20-P22, and P26 are not in the 24-Pin package.
3. The P04-P06, P14-P17, P20, P23, P26 and P33-P34 are not in the 20-Pin package.
4. The P32/RESETB pin is configured as one of the P32 and the RESETB pin by the "CONFIGURE OPTION".
5. If the P00/DSDA and P01/DSCL pins are connected to an emulator during power-on reset, the pins are automatically configured as the debugger pins.
6. The P00/DSDA and P01/DSCL pins are configured as inputs with internal pull-up resistor only during the reset or power-on reset.
7. The P37/XOUT, P36/XIN, P34/SXIN, and P33/SXOUT pins are configured as a function pin by software control.

6. Port Structures

6.1 General Purpose I/O Port

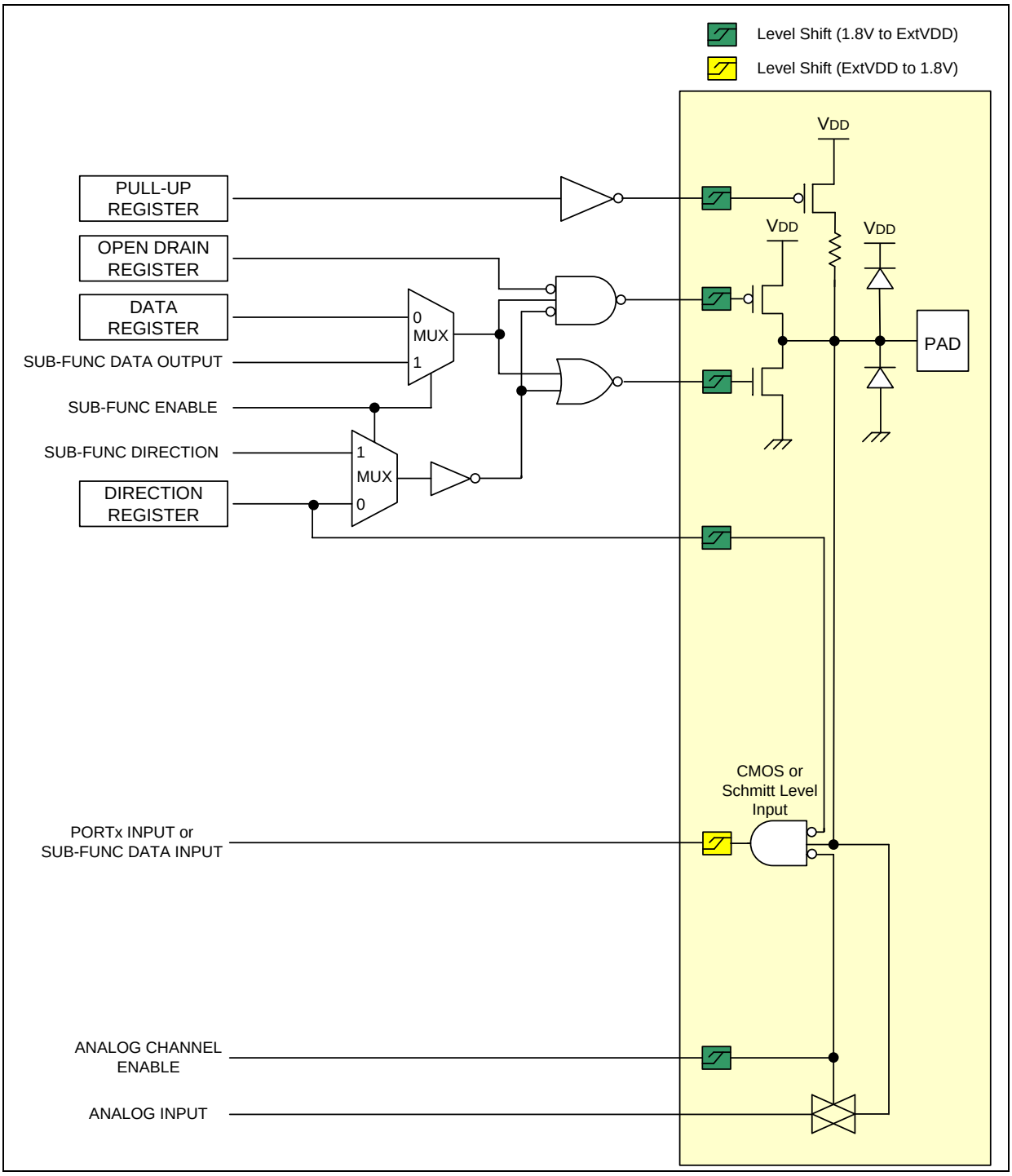


Figure 6.1 General Purpose I/O Port

6.2 External Interrupt I/O Port

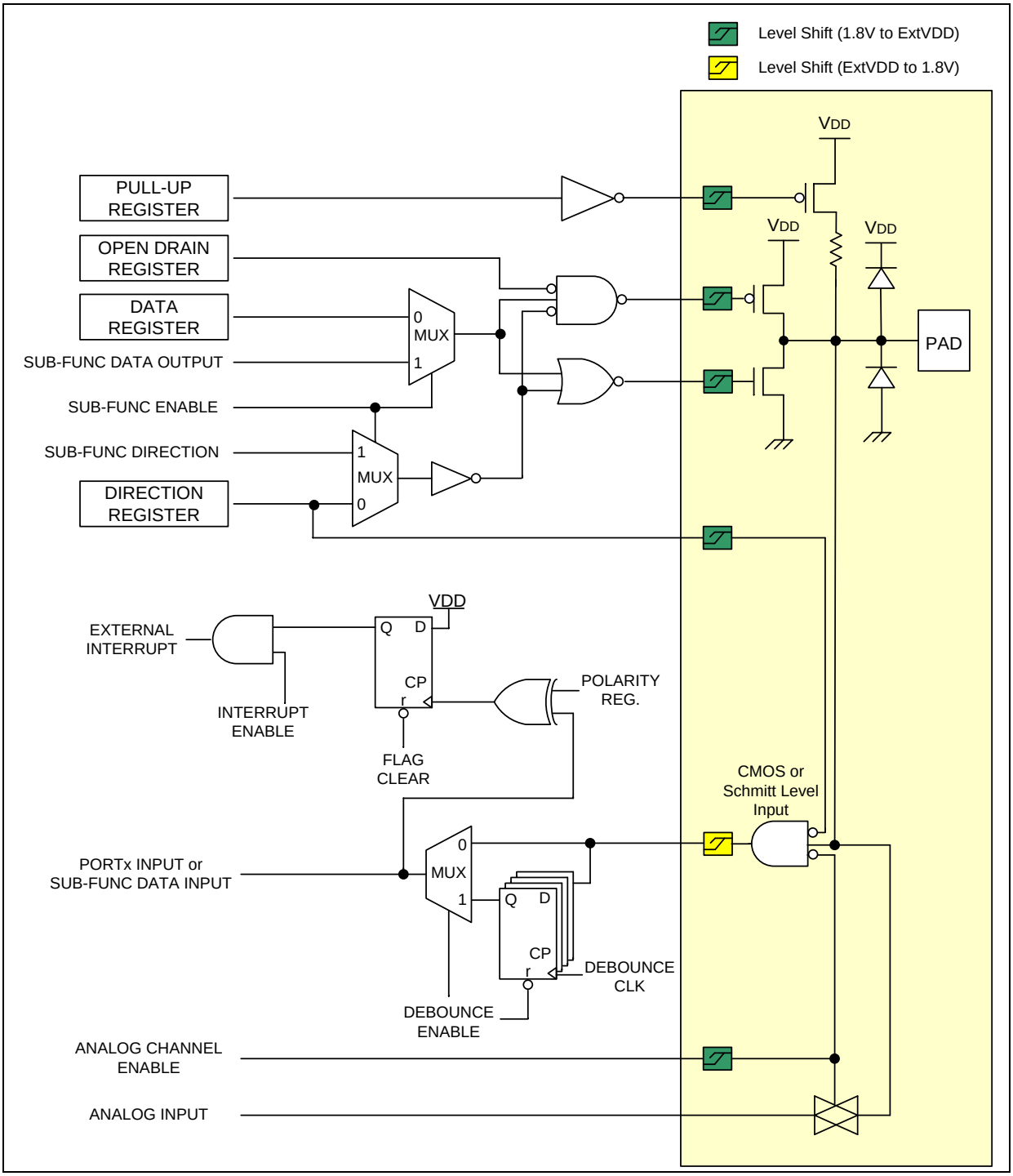


Figure 6.2 External Interrupt I/O Port

7. Electrical Characteristics

7.1 Absolute Maximum Ratings

Table 7-1 Absolute Maximum Ratings

Parameter	Symbol	Rating	Unit	Note
Supply Voltage	VDD	-0.3 ~ +6.5	V	–
Normal Voltage Pin	V_I	-0.3 ~ VDD+0.3	V	Voltage on any pin with respect to VSS
	V_O	-0.3 ~ VDD+0.3	V	
	I_{OH}	-25	mA	Maximum current output sourced by (I_{OH} per I/O pin)
	$\sum I_{OH}$	-200	mA	Maximum current ($\sum I_{OH}$)
	I_{OL}	180	mA	Maximum current sunk by (I_{OL} per I/O pin)
	$\sum I_{OL}$	200	mA	Maximum current ($\sum I_{OL}$)
Total Power Dissipation	P_T	600	mW	–
Storage Temperature	T_{STG}	-65 ~ +150	°C	–

NOTE) Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. This is a stress rating only and functional operation of the device at any other conditions beyond those indicated in the operational sections of this specification is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

7.2 Recommended Operating Conditions

Table 7-2 Recommended Operating Conditions

(T_A= -40°C ~ +85°C)

Parameter	Symbol	Conditions		MIN	TYP	MAX	Unit
Operating Voltage	VDD	f_X= 32 ~ 38kHz	SX-tal	1.8	–	5.5	V
		f_X= 0.4 ~ 4.2MHz	X-tal	1.8	–	5.5	
		f_X= 0.4 ~ 10.0MHz		2.7	–	5.5	
		f_X= 0.4 ~ 12.0MHz		3.0	–	5.5	
		f_X= 0.5 ~ 8.0MHz	Internal RC	1.8	–	5.5	
		f_X= 0.5 ~ 16.0MHz		2.0	–	5.5	
Operating Temperature	T_{OPR}	VDD= 1.8 ~ 5.5V		-40	–	85	°C

7.3 A/D Converter Characteristics

Table 7-3 A/D Converter Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, VSS= 0V)

Parameter	Symbol	Conditions		MIN	TYP	MAX	Unit
Resolution	–	–		–-	12	–	bit
Integral Linear Error	ILE	AVREF= 2.7V – 5.5V fx= 8MHz		–	–	±4	LSB
Differential Linearity Error	DLE			–	–	±1	
Zero Offset Error	ZOE			–	–	±3	
Full Scale Error	FSE			–	–	±3	
Conversion Time	t_{CON}	12bit resolution, 8MHz		20	–	–	µS
Analog Input Voltage	V_{AN}	–		VSS	–	AVREF	V
Analog Reference Voltage	AVREF	–		1.8	–	VDD	
VDD18	–	–		–	1.8	–	V
Analog Input Leakage Current	I_{AN}	AVREF= 5.12V		–	–	2	µA
ADC Operating Current	I_{ADC}	Enable	VDD= 5.12V	–	1	2	mA
		Disable		–	–	0.1	µA

NOTES) 1. Zero offset error is the difference between 000000000000 and the converted output for zero input voltage (VSS).

2. Full scale error is the difference between 111111111111 and the converted output for full-scale input voltage (AVREF).

7.4 Power-On Reset Characteristics

Table 7-4 Power-on Reset Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, VSS= 0V)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
RESET Release Level	V_{POR}	–	–	1.4	–	V
VDD Voltage Rising Time	t_R	–	0.05	–	30.0	V/mS
POR Current	I_{POR}	–	–	0.2	–	µA

7.5 Low Voltage Reset and Low Voltage Indicator Characteristics

Table 7-5 LVR and LVI Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, VSS= 0V)

Parameter	Symbol	Conditions		MIN	TYP	MAX	Unit
Detection Level	V_{LVR} V_{LVI}	The LVR can select all levels but LVI can select other levels except 1.60V.		–	1.60	1.75	V
				1.85	2.00	2.15	
				1.95	2.10	2.25	
				2.05	2.20	2.35	
				2.17	2.32	2.47	
				2.29	2.44	2.59	
				2.39	2.59	2.79	
				2.55	2.75	2.95	
				2.73	2.93	3.13	
				2.94	3.14	3.34	
				3.18	3.38	3.58	
				3.37	3.67	3.97	
				3.70	4.00	4.30	
				4.10	4.40	4.70	
Hysteresis	△V	–		–	50	150	mV
Minimum Pulse Width	t_{LW}	–		100	–	–	μS
LVR and LVI Current	I_{BL}	Enable (Both)	VDD= 3V	–	10.0	15.0	μA
		Enable (One of two)		–	8.0	12.0	
		Disable (Both)		–	–	0.1	

7.6 Internal RC Oscillator Characteristics

Table 7-6 High Internal RC Oscillator Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, VSS= 0V)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Frequency	f_{IRC}	V_{DD} = 2.0 – 5.5 V	–	16	–	MHz
Tolerance	–	T_A = 0°C to +50 °C	–	–	±1	%
		T_A = -20°C to +85 °C			±2	
		T_A = -40°C to +85 °C			±3	
Clock Duty Ratio	TOD	–	40	50	60	%
Stabilization Time	T_{HFS}	–	–	–	100	μS
IRC Current	I_{IRC}	Enable	–	0.2	–	mA
		Disable	–	–	0.1	μA

7.7 Internal Watch-Dog Timer RC Oscillator Characteristics

Table 7-7 Internal WDTRC Oscillator Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, VSS= 0V)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Frequency	f_{WDTRC}	–	2	5	10	kHz
Stabilization Time	t_{WDTS}	–	–	–	1	mS
WDTRC Current	I_{WDTRC}	Enable	–	1	–	μA
		Disable	–	–	0.1	

7.8 DC Characteristics

Table 7-8 DC Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, VSS= 0V, f_{XIN}= 12MHz)

Parameter	Symbol	Conditions		MIN	TYP	MAX	Unit
Input High Voltage	V_{IH}	All input pins, RESETB		0.8VDD	–	VDD	V
Input Low Voltage	V_{IL}	All input pins, RESETB		–	–	0.2VDD	V
Output High Voltage	V_{OH1}	VDD= 4.5V, I_{OH}= -2mA, All output ports except V_{OH2}, V_{OH3}		VDD-1.0	–	–	V
	V_{OH2}	VDD= 4.5V, I_{OH}= -10mA; P20-P25		VDD-2.0	–	–	
	V_{OH3}	VDD= 4.5V, I_{OH}= -20mA; P1		VDD-2.0	–	–	
Output Low Voltage	V_{OL1}	VDD=4.5V, I_{OL}= 15mA; All output ports except V_{OL2}		–	–	1.0	
	V_{OL2}	VDD= 4.5V, I_{OL}= 160mA; P20-P25		–	1.5	3.0	V
Input High Leakage Current	I_{IH}	All input ports		–	–	1	µA
Input Low Leakage Current	I_{IL}	All input ports		-1	–	–	µA
Pull-Up Resistor	R_{PU1}	VI=0V, T_A= 25°C All Input ports	VDD=5.0V	25	50	100	kΩ
			VDD=3.0V	50	100	200	
	R_{PU2}	VI=0V, T_A= 25°C RESETB	VDD=5.0V	150	250	400	kΩ
			VDD=3.0V	300	500	700	
ADC wake-up pull-up resistor	R_{AWPU1}	T_A= 25°C		100	150	200	kΩ
	R_{AWPU2}			200	300	400	
OSC feedback resistor	R_{X1}	XIN= VDD, XOUT= VSS T_A= 25°C, VDD= 5V		600	1200	2000	kΩ
	R_{X2}	SXIN=VDD, SXOUT=VSS T_A= 25 °C ,VDD=5V		2500	5000	10000	

Table 7-9 DC Characteristics (Continued)

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, VSS= 0V, f_{XIN}= 12MHz)

Parameter	Symbol	Condition		MIN	TYP	MAX	Unit
Supply Current	I_{DD1} (RUN)	f_{XIN}= 12MHz, VDD= 5V±10%		–	3.0	6.0	mA
		f_{XIN}= 10MHz, VDD= 3V±10%		–	2.2	4.4	
		f_{IRC}= 16MHz, VDD= 5V±10%		–	3.0	6.0	
	I_{DD2} (IDLE)	f_{XIN}= 12MHz, VDD= 5V±10%		–	1.3	2.6	mA
		f_{XIN}= 10MHz, VDD= 3V±10%		–	0.7	1.4	
		f_{IRC}= 16MHz, VDD= 5V±10%		–	0.8	1.6	
	I_{DD3}	f_{XIN}= 32.768kHz VDD= 3V±10% T_A= 25°C	Sub RUN	–	60.0	90.0	µA
	I_{DD4}		Sub IDLE	–	6.0	12.0	µA
	I_{DD5}	STOP, VDD= 5V±10%, T_A= 25°C		–	0.5	3.0	µA

NOTES) 1. Where the f_{XIN} is an external main oscillator, f_{SUB} is an external sub oscillator, the f_{IRC} is an internal RC oscillator, and the fx is the selected system clock.

2. All supply current items don't include the current of an internal Watch-dog timer RC (WDTRC) oscillator and a peripheral block.

3. All supply current items include the current of the power-on reset (POR) block.

7.9 AC Characteristics

Table 7-9 AC Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
RESETB input low width	t_{RST}	Input, VDD= 5V	10	–	–	μS
Interrupt input high, low width	t_{IWH}, t_{IWL}	All interrupt, VDD= 5V	200	–	–	nS
External Counter Input High, Low Pulse Width	t_{ECWH}, t_{ECWL}	ECn, VDD = 5 V (n= 0, 1, 2)	200	–	–	
External Counter Transition Time	t_{REC}, t_{FEC}	ECn, VDD = 5 V (n= 0, 1, 2)	20	–	–	

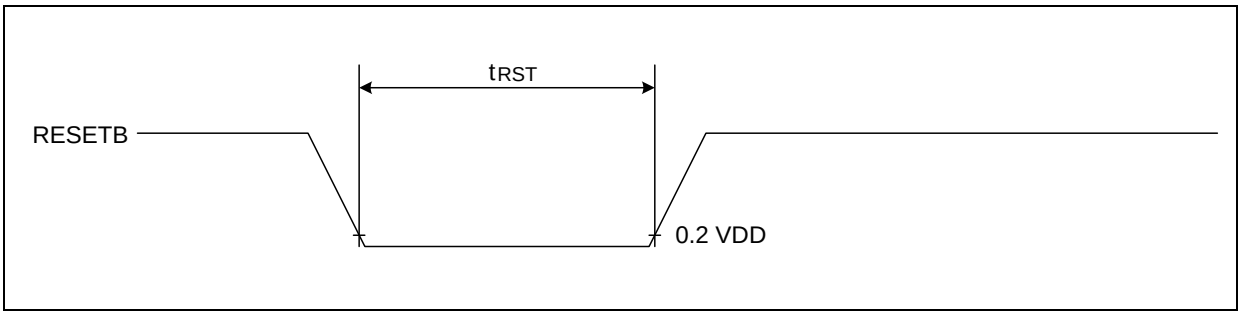


Figure 7.1 Input Timing for RESETB

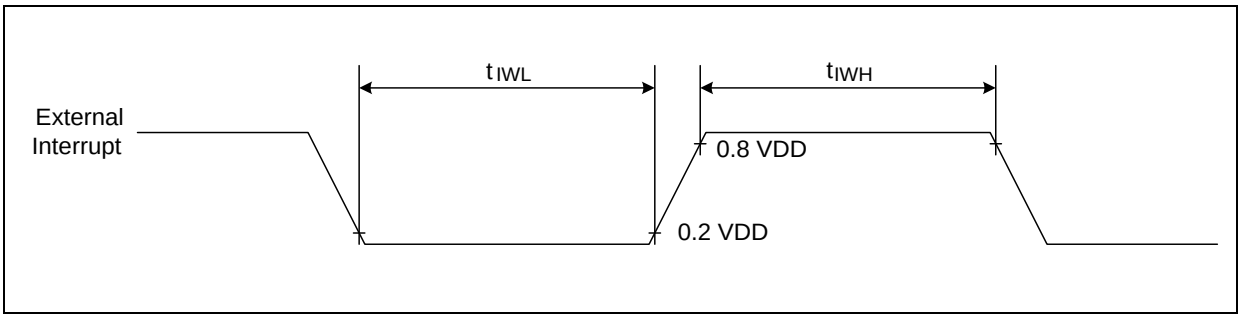


Figure 7.2 Input Timing for External Interrupts

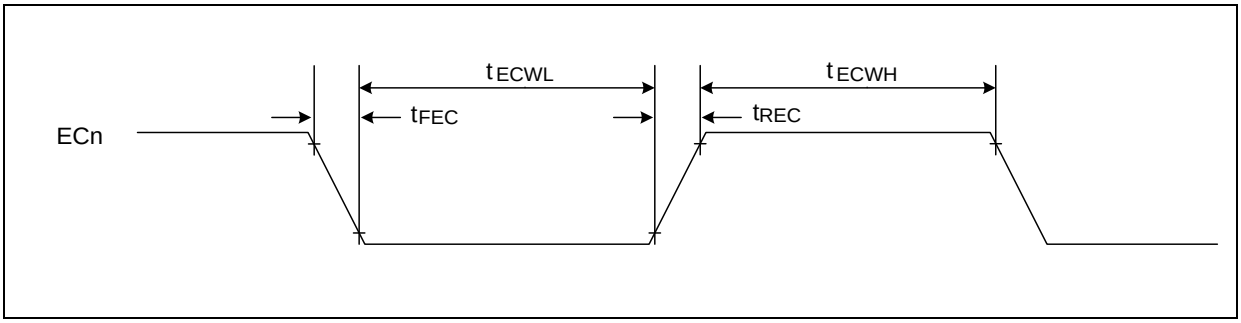


Figure 7.3 Input Timing for EC0, EC1, EC2

7.10 SPI Characteristics

Table 7-10 SPI Characteristics

(T_A= -40°C – +85°C, VDD= 1.8V – 5.5V)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Output Clock Pulse Period	t_{SCK}	Internal SCK source	200	–	–	nS
Input Clock Pulse Period		External SCK source	200	–	–	
Output Clock High, Low Pulse Width	t_{SCKH}, t_{SCKL}	Internal SCK source	70	–	–	
Input Clock High, Low Pulse Width		External SCK source	70	–	–	
First Output Clock Delay Time	t_{FOD}	Internal/External SCK source	100	–	–	
Output Clock Delay Time	t_{DS}	–	–	–	50	
Input Setup Time	t_{DIS}	–	100	–	–	
Input Hold Time	t_{DIH}	–	150	–	–	

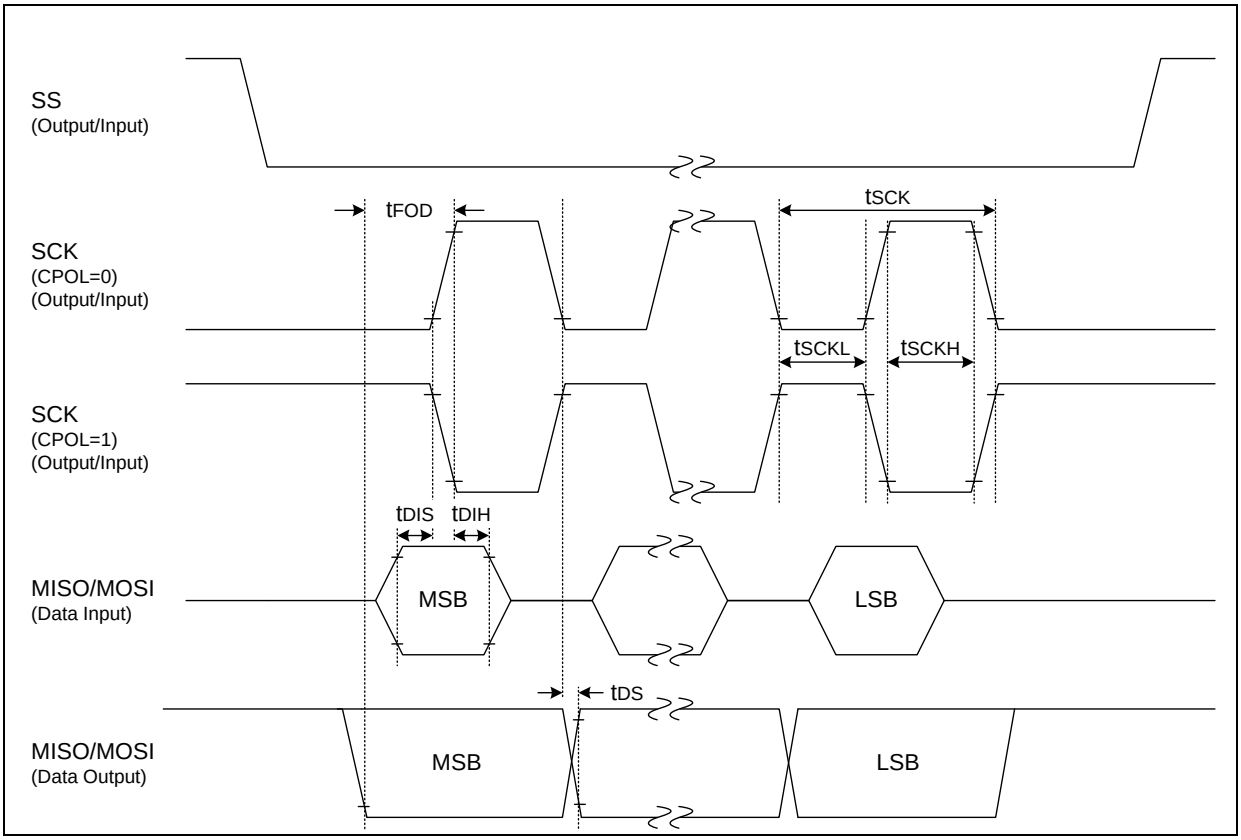


Figure 7.4 SPI Timing

7.11 UART Characteristics

Table 7-11 UART Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, f_{XIN}=11.1MHz)

Parameter	Symbol	MIN	TYP	MAX	Unit
Serial port clock cycle time	t_{SCK}	1250	t_{CPU} x 16	1650	nS
Output data setup to clock rising edge	t_{S1}	590	t_{CPU} x 13	–	nS
Clock rising edge to input data valid	t_{S2}	–	–	590	nS
Output data hold after clock rising edge	t_{H1}	t_{CPU} - 50	t_{CPU}	–	nS
Input data hold after clock rising edge	t_{H2}	0	–	–	nS
Serial port clock High, Low level width	t_{HIGH}, t_{LOW}	470	t_{CPU} x 8	970	nS

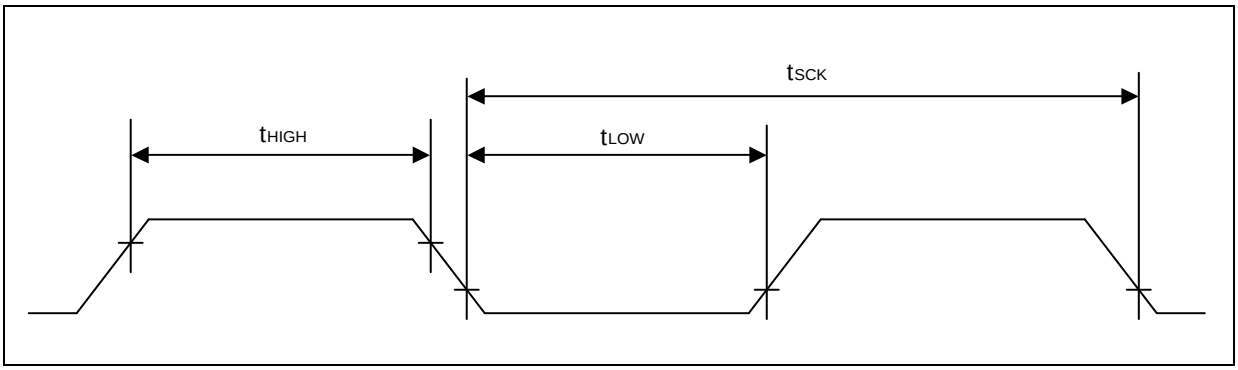


Figure 7.5 Waveform for UART Timing Characteristics

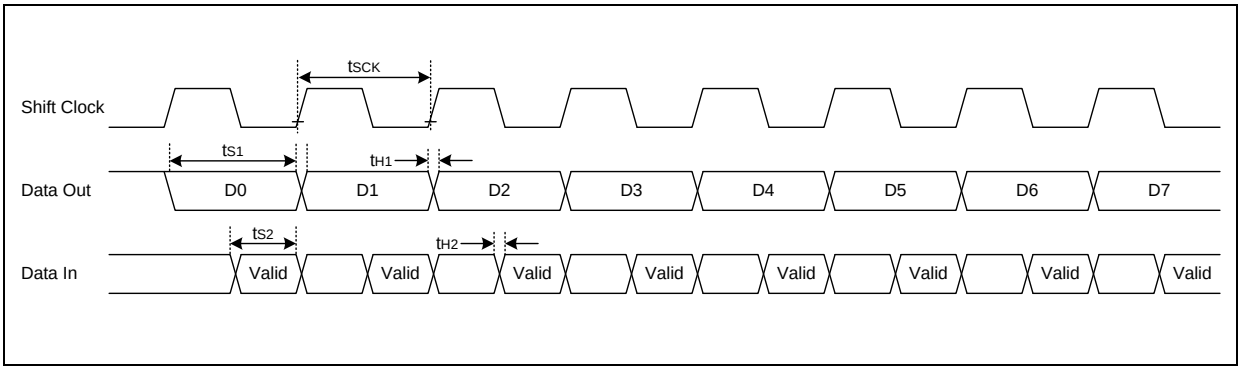


Figure 7.6 Timing Waveform for the UART Module

7.12 I2C Characteristics

Table 7-12 I2C Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V)

Parameter	Symbol	Standard Mode		High-Speed Mode		Unit
		MIN	MAX	MIN	MAX	
Clock frequency	t_{SCL}	0	100	0	400	kHz
Clock High Pulse Width	t_{SCLH}	4.0	–	0.6	–	μS
Clock Low Pulse Width	t_{SCLL}	4.7	–	1.3	–	
Bus Free Time	t_{BF}	4.7	–	1.3	–	
Start Condition Setup Time	t_{STSU}	4.7	–	0.6	–	
Start Condition Hold Time	t_{STHD}	4.0	–	0.6	–	
Stop Condition Setup Time	t_{SPSU}	4.0	–	0.6	–	
Stop Condition Hold Time	t_{SPHD}	4.0	–	0.6	–	
Output Valid from Clock	t_{VD}	0	–	0	–	
Data Input Hold Time	t_{DIH}	0	–	0	1.0	
Data Input Setup Time	t_{DIS}	250	–	100	–	nS

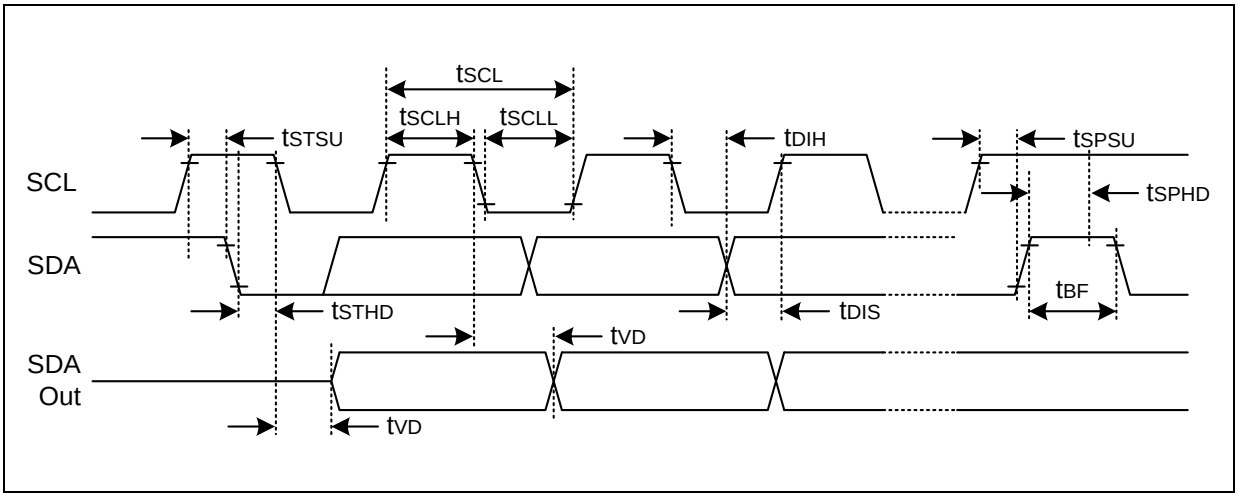


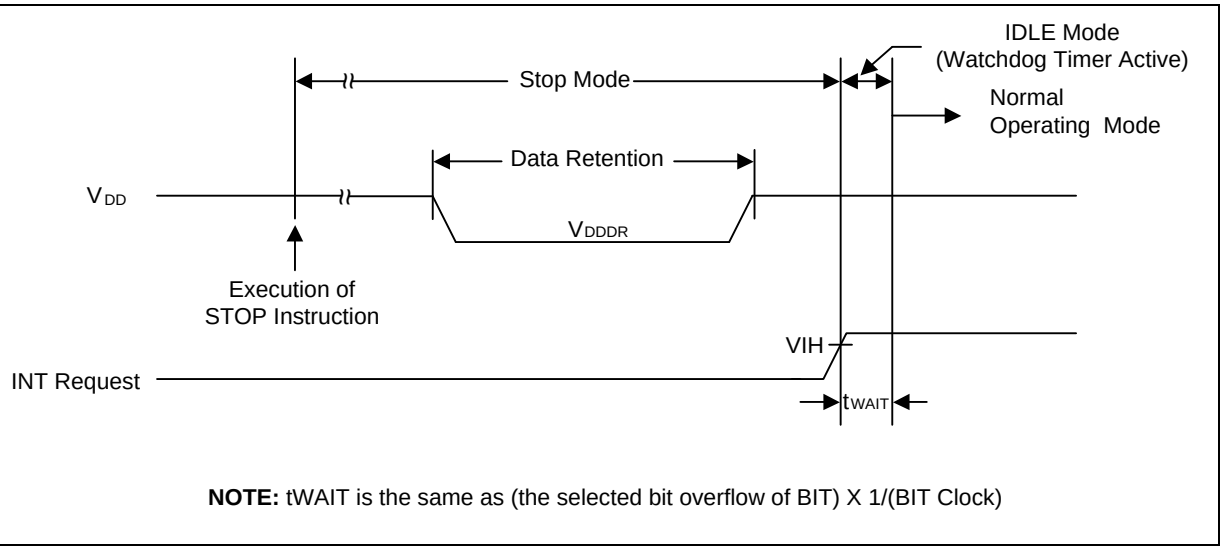
Figure 7.7 I2C Timing

7.13 Data Retention Voltage in Stop Mode

Table 7-13 Data Retention Voltage in Stop Mode

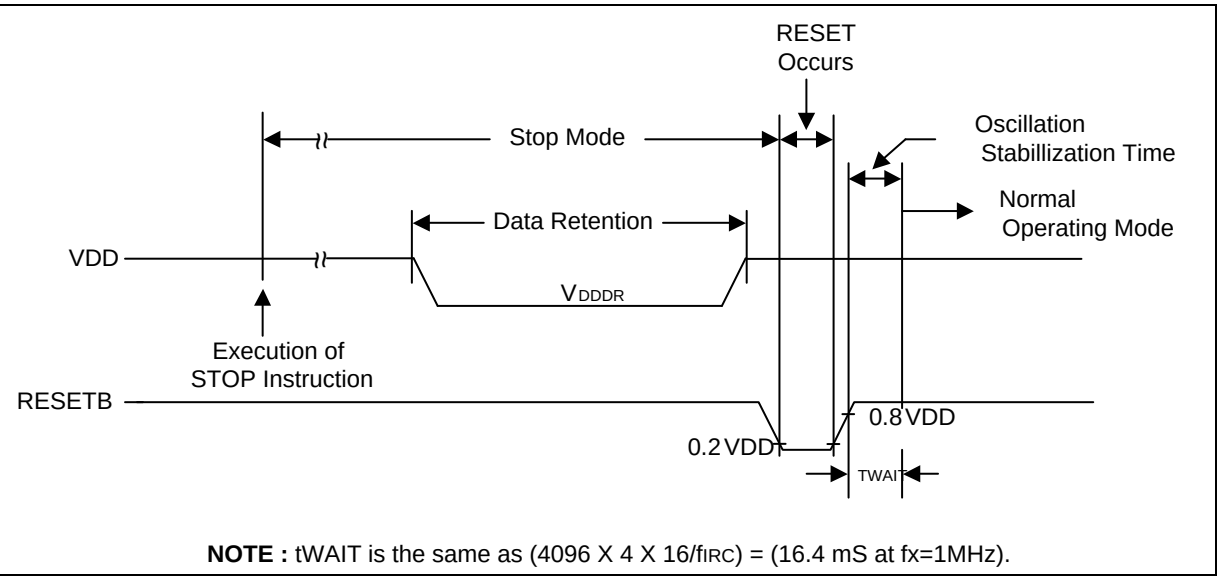
(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
Data retention supply voltage	V_{DDDR}	–	1.8	–	5.5	V
Data retention supply current	I_{DDDR}	VDDR= 1.8V, (T_A= 25°C), Stop mode	–	–	1	μA



NOTE: tWAIT is the same as (the selected bit overflow of BIT) X 1/(BIT Clock)

Figure 7.8 Stop Mode Release Timing when Initiated by an Interrupt



NOTE : tWAIT is the same as (4096 X 4 X 16/f_{IRC}) = (16.4 mS at fx=1MHz).

Figure 7.9 Stop Mode Release Timing when Initiated by RESETB

7.14 Internal Flash Rom Characteristics

Table 7-14 Internal Flash Rom Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V, VSS= 0V)

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
Sector Write Time	t_{FSW}	–	–	2.5	2.7	mS
Sector Erase Time	t_{FSE}	–	–	2.5	2.7	
Hard-Lock Time	t_{FHL}	–	–	2.5	2.7	
Page Buffer Reset Time	t_{FBR}	–	–	–	5	µS
Flash Programming Frequency	f_{PGM}	–	0.4	–	–	MHz
Endurance of Write/Erase	NF_{WE}	–	–	–	100,000	Times

NOTE) During a flash operation, SCLK[1:0] of SCCR must be set to “00” or “01” (INT-RC OSC or Main X-TAL for system clock).

7.15 Input/Output Capacitance

Table 7-15 Input/Output Capacitance

(T_A= -40°C ~ +85°C, VDD= 0V)

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
Input Capacitance	C_{IN}	fx= 1MHz Unmeasured pins are connected to VSS	–	–	10	pF
Output Capacitance	C_{OUT}					
I/O Capacitance	C_{IO}					

7.16 Main Clock Oscillator Characteristics

Table 7-16 Main Clock Oscillator Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V)

Oscillator	Parameter	Condition	MIN	TYP	MAX	Unit
Crystal	Main oscillation frequency	1.8V – 5.5V	0.4	–	4.2	MHz
		2.7V – 5.5V	0.4	–	10.0	
		3.0V – 5.5V	0.4	–	12.0	
Ceramic Oscillator	Main oscillation frequency	1.8V – 5.5V	0.4	–	4.2	MHz
		2.7V – 5.5V	0.4	–	10.0	
		3.0V – 5.5V	0.4	–	12.0	
External Clock	XIN input frequency	1.8V – 5.5V	0.4	–	4.2	MHz
		2.7V – 5.5V	0.4	–	10.0	
		3.0V – 5.5V	0.4	–	12.0	

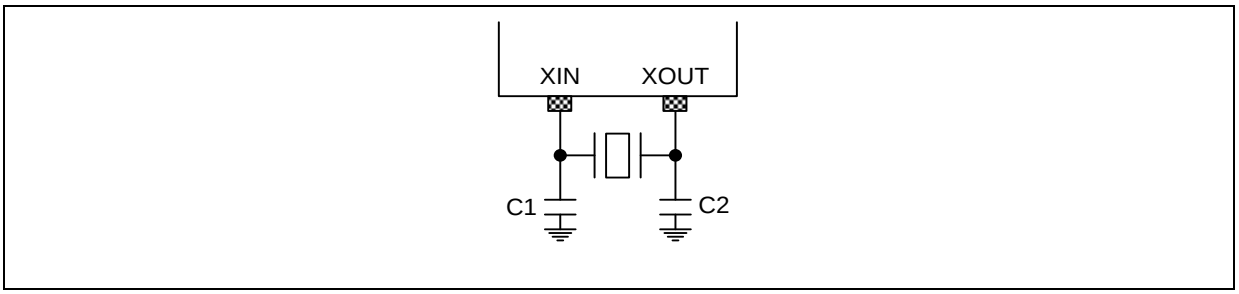


Figure 7.10 Crystal/Ceramic Oscillator

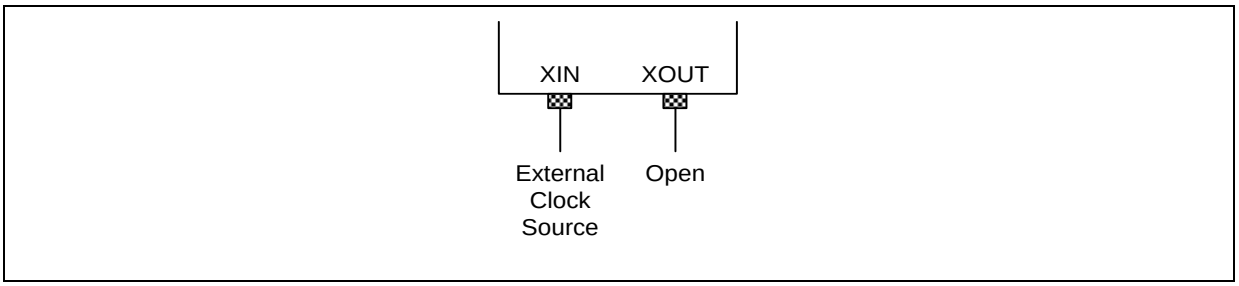


Figure 7.11 External Clock

7.17 Sub Clock Oscillator Characteristics

Table 7-17 Sub Clock Oscillator Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V)

Oscillator	Parameter	Condition	MIN	TYP	MAX	Unit
Crystal	Sub oscillation frequency	1.8V – 5.5V	32	32.768	38	kHz
External Clock	SXIN input frequency		32	–	100	kHz

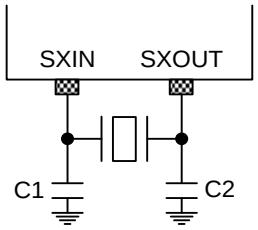


Figure 7.12 Crystal Oscillator

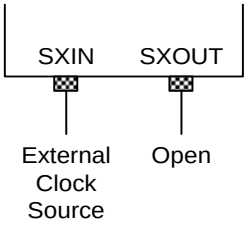


Figure 7.13 External Clock

7.18 Main Oscillation Stabilization Characteristics

Table 7-18 Main Oscillation Stabilization Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V)

Oscillator	Parameter	MIN	TYP	MAX	Unit
Crystal	fx > 1MHz Oscillation stabilization occurs when VDD is equal to the minimum oscillator voltage range.	–	–	60	mS
Ceramic		–	–	10	mS
External Clock	f_{XIN} = 0.4 to 12MHz XIN input high and low width (t_{XH}, t_{XL})	42	–	1250	nS

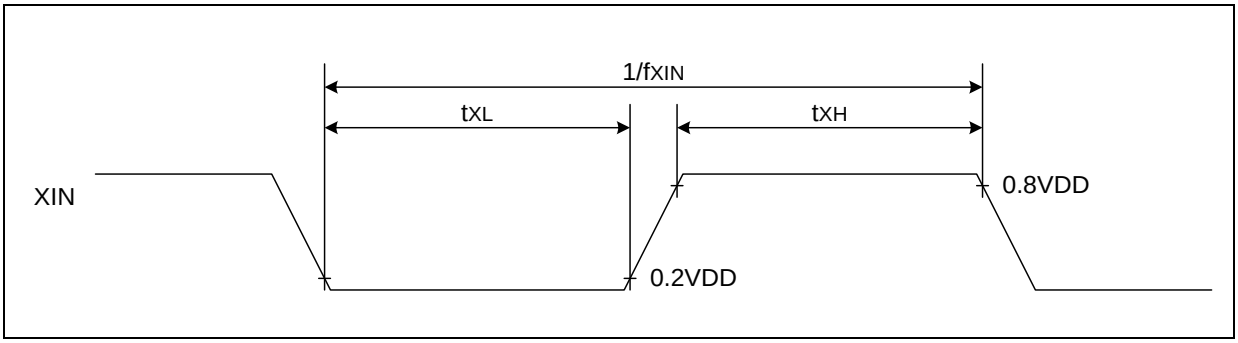


Figure 7.14 Clock Timing Measurement at XIN

7.19 Sub Oscillation Characteristics

Table 7-19 Sub Oscillation Stabilization Characteristics

(T_A= -40°C ~ +85°C, VDD= 1.8V ~ 5.5V)

Oscillator	Parameter	MIN	TYP	MAX	Unit
Crystal	–	–	–	10	S
External Clock	SXIN input high and low width (t_{XH}, t_{XL})	5	–	15	µS

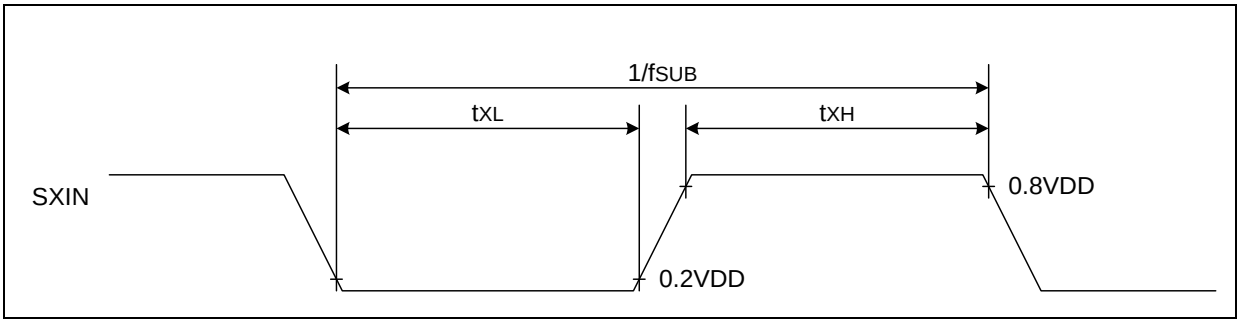


Figure 7.15 Clock Timing Measurement at SXIN

7.20 Operating Voltage Range

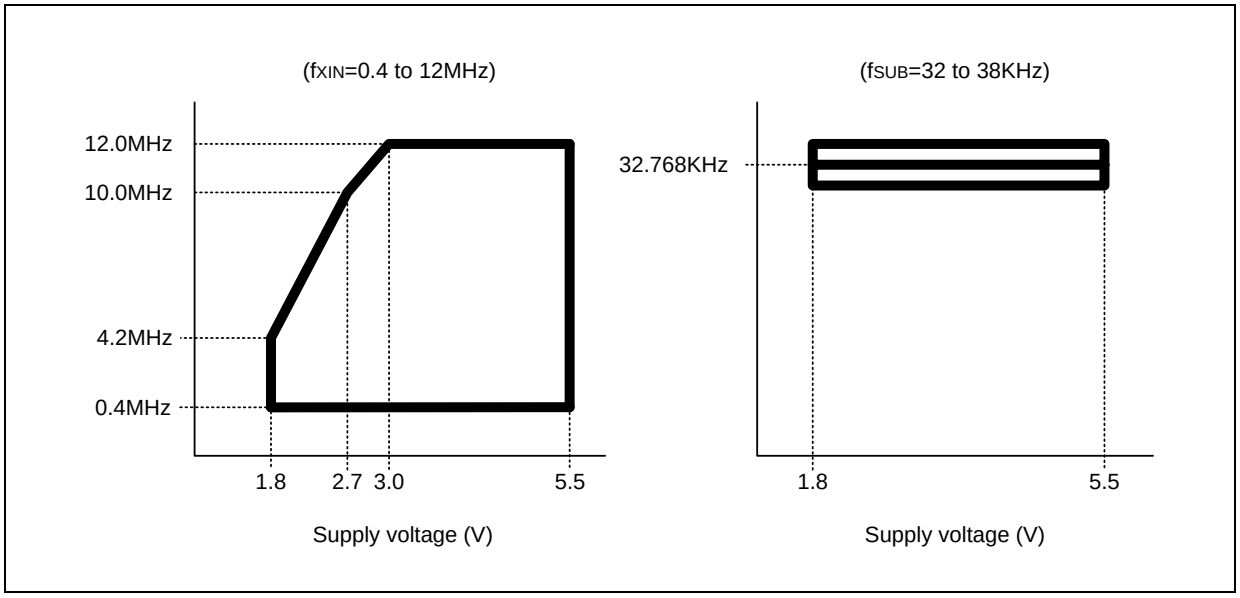


Figure 7.16 Operating Voltage Range

7.21 Recommended Circuit and Layout

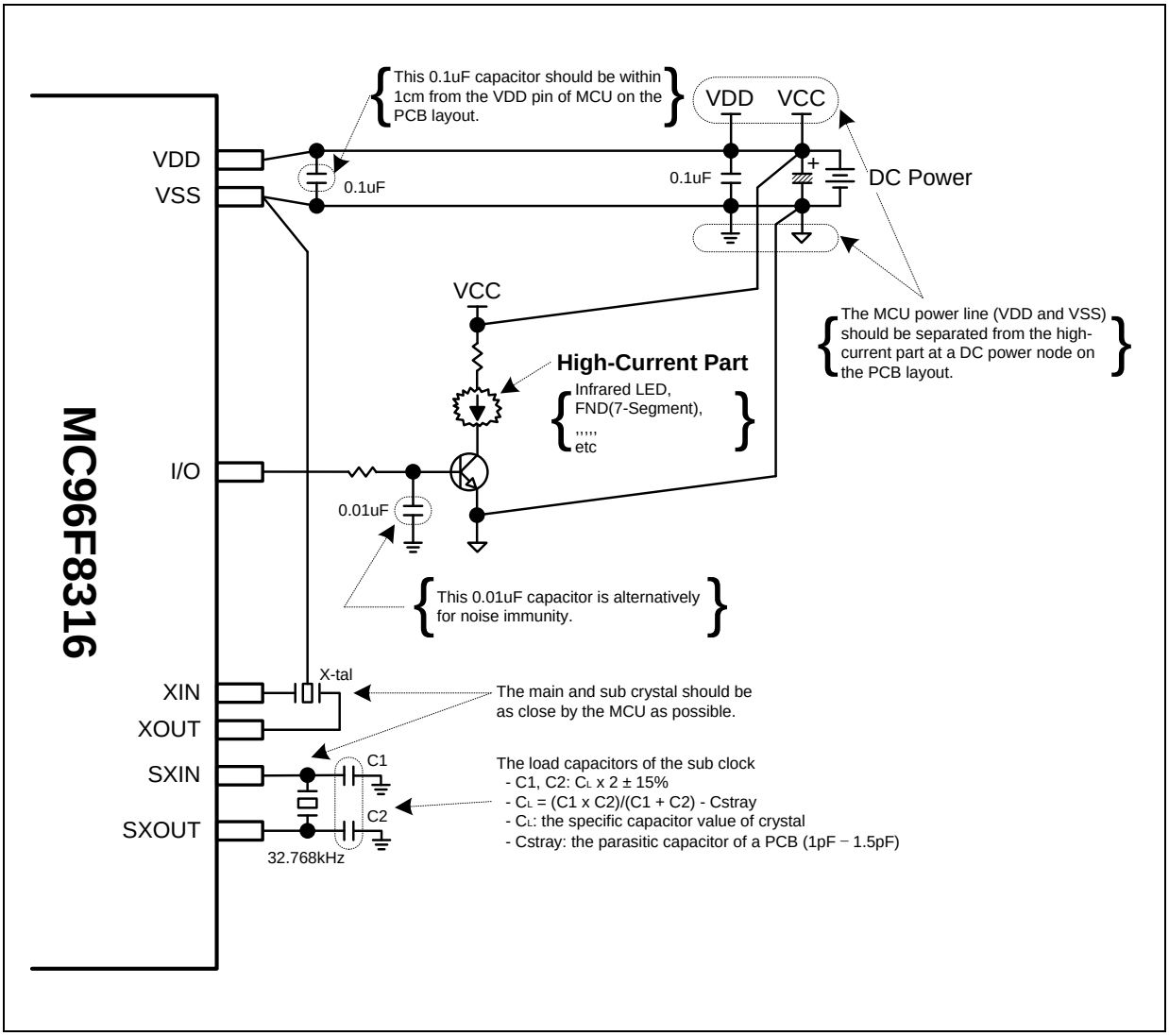


Figure 7.17 Recommended Circuit and Layout

7.22 Typical Characteristics

These graphs and tables provided in this section are only for design guidance and are not tested or guaranteed. In graphs or tables some data are out of specified operating range (e.g. out of specified VDD range). This is only for information and devices are guaranteed to operate properly only within the specified range.

The data presented in this section is a statistical summary of data collected on units from different lots over a period of time. “Typical” represents the mean of the distribution while “max” or “min” represents (mean + 3σ) and (mean - 3σ) respectively where σ is standard deviation.

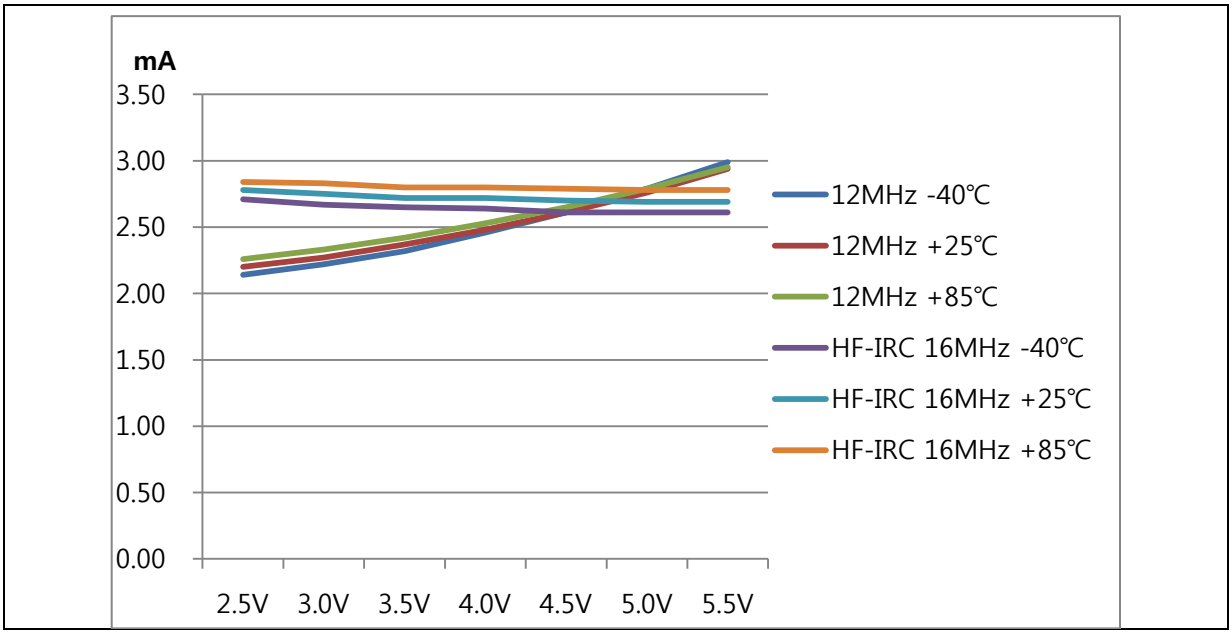


Figure 7.18 RUN (IDD1) Current

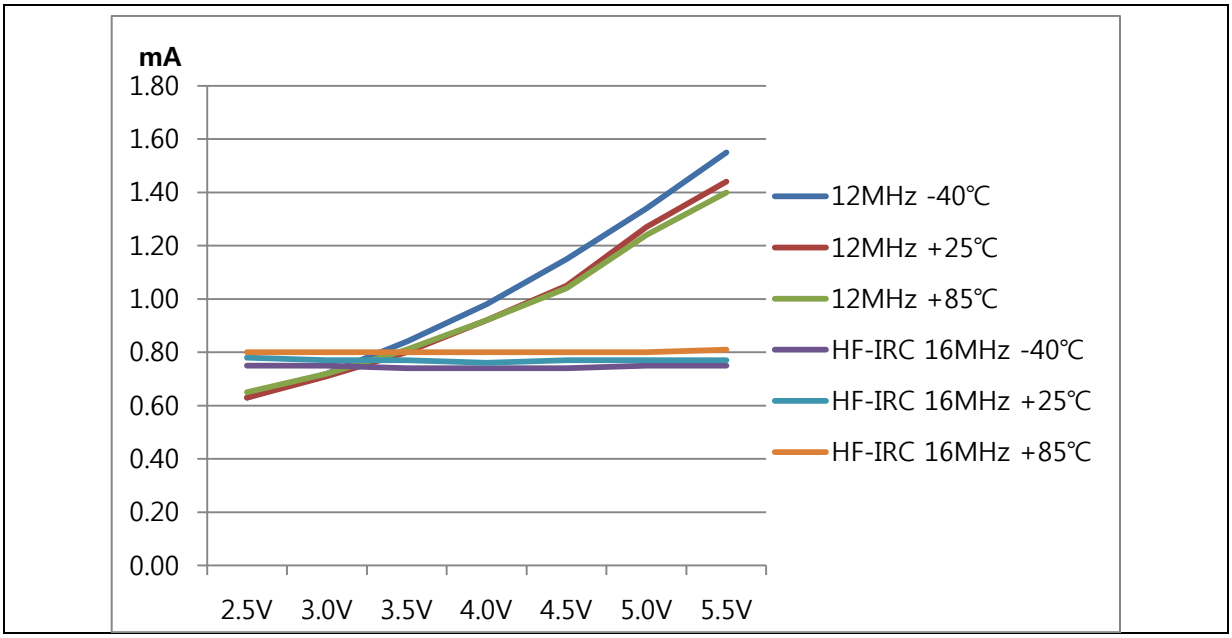


Figure 7.19 IDLE (IDD2) Current

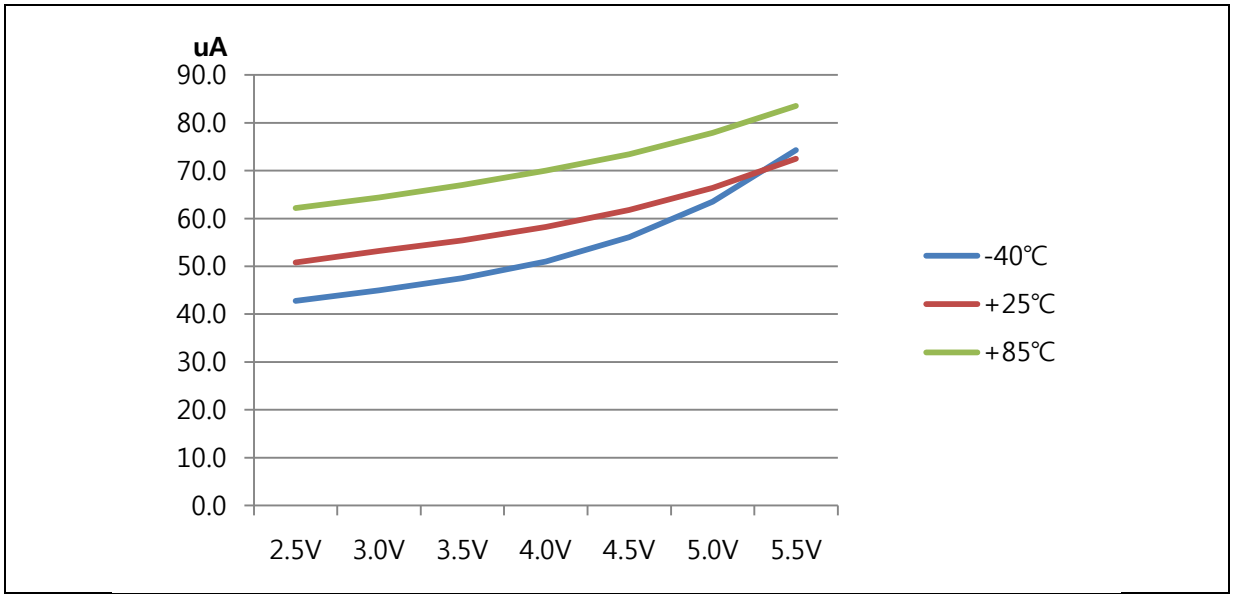


Figure 7.20 SUB RUN (IDD3) Current

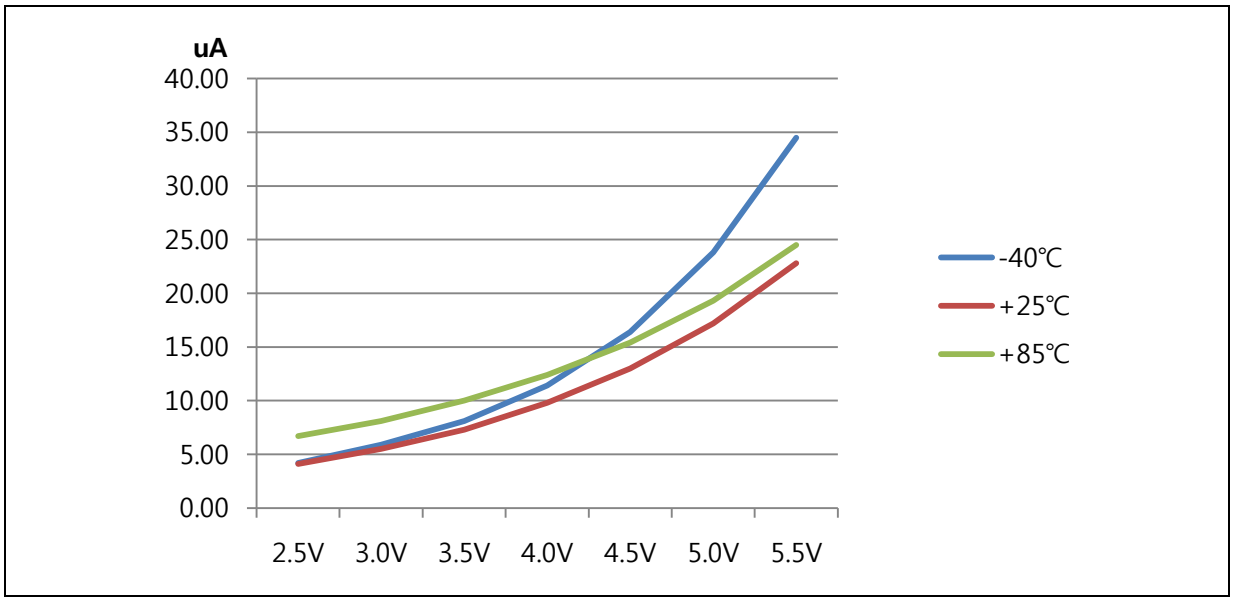


Figure 7.21 SUB IDLE (IDD4) Current

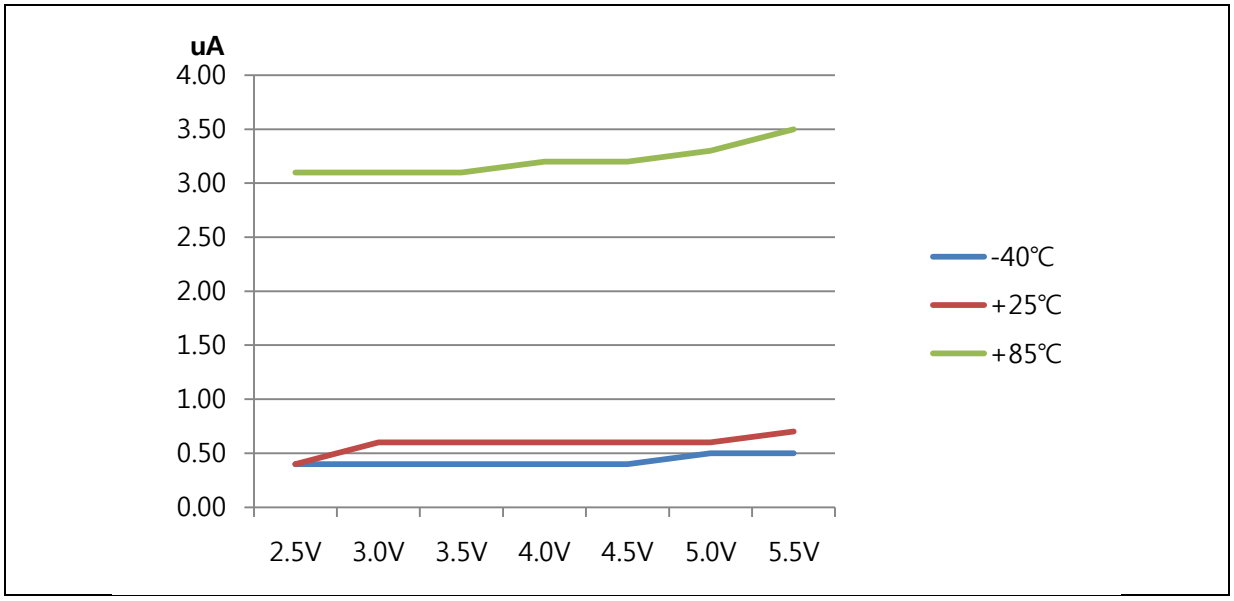


Figure 7.22 STOP (IDD5) Current

8. Memory

The MC96F8316 addresses two separate address memory stores: Program memory and Data memory. The logical separation of Program and Data memory allows Data memory to be accessed by 8-bit addresses, which makes the 8-bit CPU access the data memory more rapidly. Nevertheless, 16-bit Data memory addresses can also be generated through the DPTR register.

MC96F8316 provides on-chip 16k bytes of the ISP type flash program memory, which can be read and written to. Internal data memory (IRAM) is 256 bytes and it includes the stack area. External data memory (XRAM) is 512 bytes.

8.1 Program Memory

A 16-bit program counter is capable of addressing up to 64k bytes, but this device has just 16k bytes program memory space.

Figure 8-1 shows the map of the lower part of the program memory. After reset, the CPU begins execution from location 0000H. Each interrupt is assigned a fixed location in program memory. The interrupt causes the CPU to jump to that location, where it commences execution of the service routine. External interrupt 11, for example, is assigned to location 000BH. If external interrupt 11 is going to be used, its service routine must begin at location 000BH. If the interrupt is not going to be used, its service location is available as general purpose program memory. If an interrupt service routine is short enough (as is often the case in control applications), it can reside entirely within that 8 byte interval. Longer service routines can use a jump instruction to skip over subsequent interrupt locations, if other interrupts are in use.

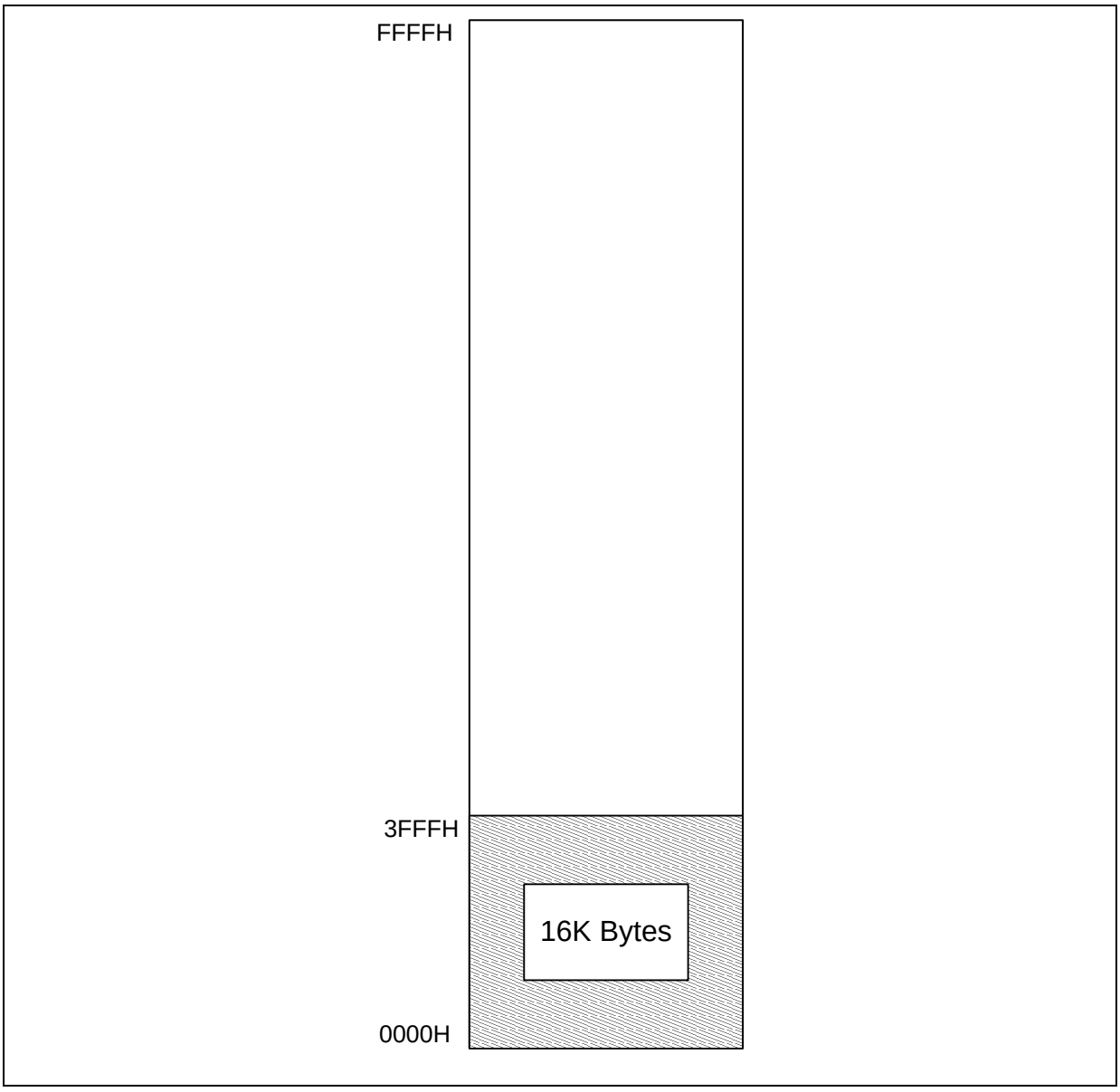


Figure 8.1 Program Memory

- 16k Bytes Including Interrupt Vector Region

8.2 Data Memory

Figure 8-2 shows the internal data memory space available.

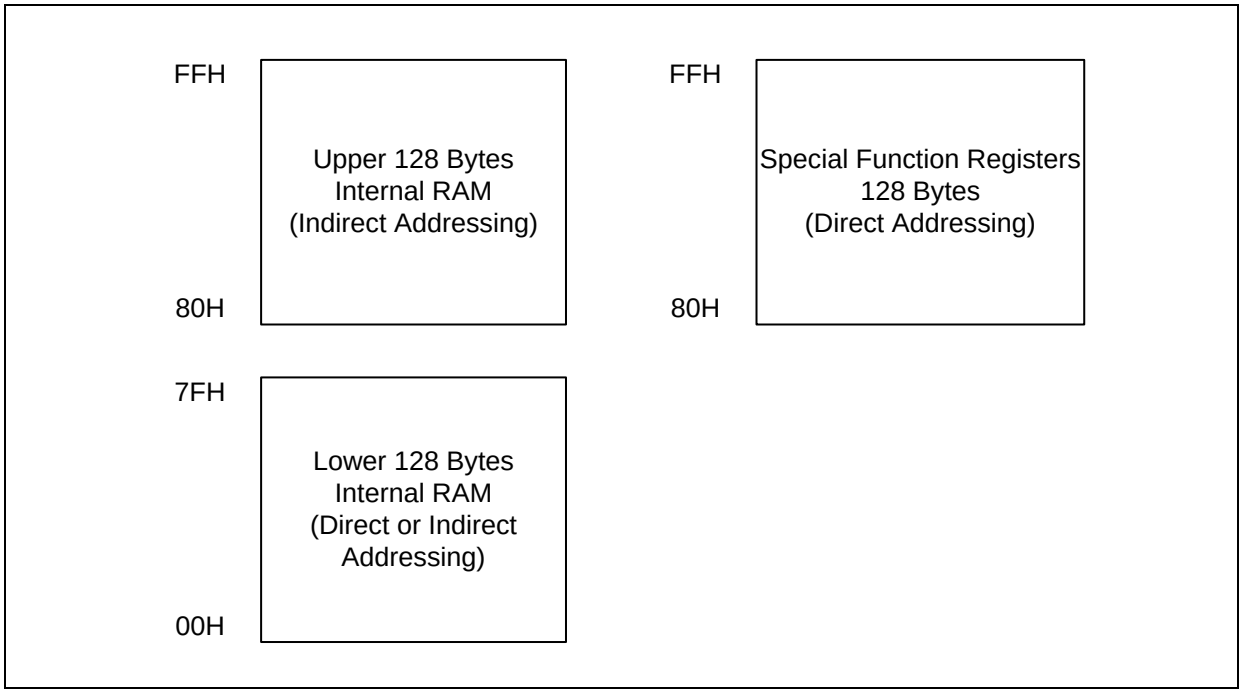


Figure 8.2 Data Memory Map

The internal data memory space is divided into three blocks, which are generally referred to as the lower 128 bytes, upper 128 bytes, and SFR space.

Internal data memory addresses are always one byte wide, which implies an address space of only 256 bytes. However, in fact the addressing modes for internal RAM can accommodate up to 384 bytes by using a simple trick. Direct addresses higher than 7FH access one memory space and indirect addresses higher than 7FH access a different memory space. Thus Figure 8-2 shows the upper 128 bytes and SFR space occupying the same block of addresses, 80H through FFH, although they are physically separate entities.

The lower 128 bytes of RAM are present in all 8051 devices as mapped in Figure 8-3. The lowest 32 bytes are grouped into 4 banks of 8 registers. Program instructions call out these registers as R0 through R7. Two bits in the Program Status Word select which register bank is in use. This allows more efficient use of code space, since register instructions are shorter than instructions that use direct addressing.

The next 16 bytes above the register banks form a block of bit-addressable memory space. The 8051 instruction set includes a wide selection of single-bit instructions, and the 128 bits in this area can be directly addressed by these instructions. The bit addresses in this area are 00H through 7FH.

All of the bytes in the lower 128 bytes can be accessed by either direct or indirect addressing. The upper 128 bytes RAM can only be accessed by indirect addressing. These spaces are used for data RAM and stack.

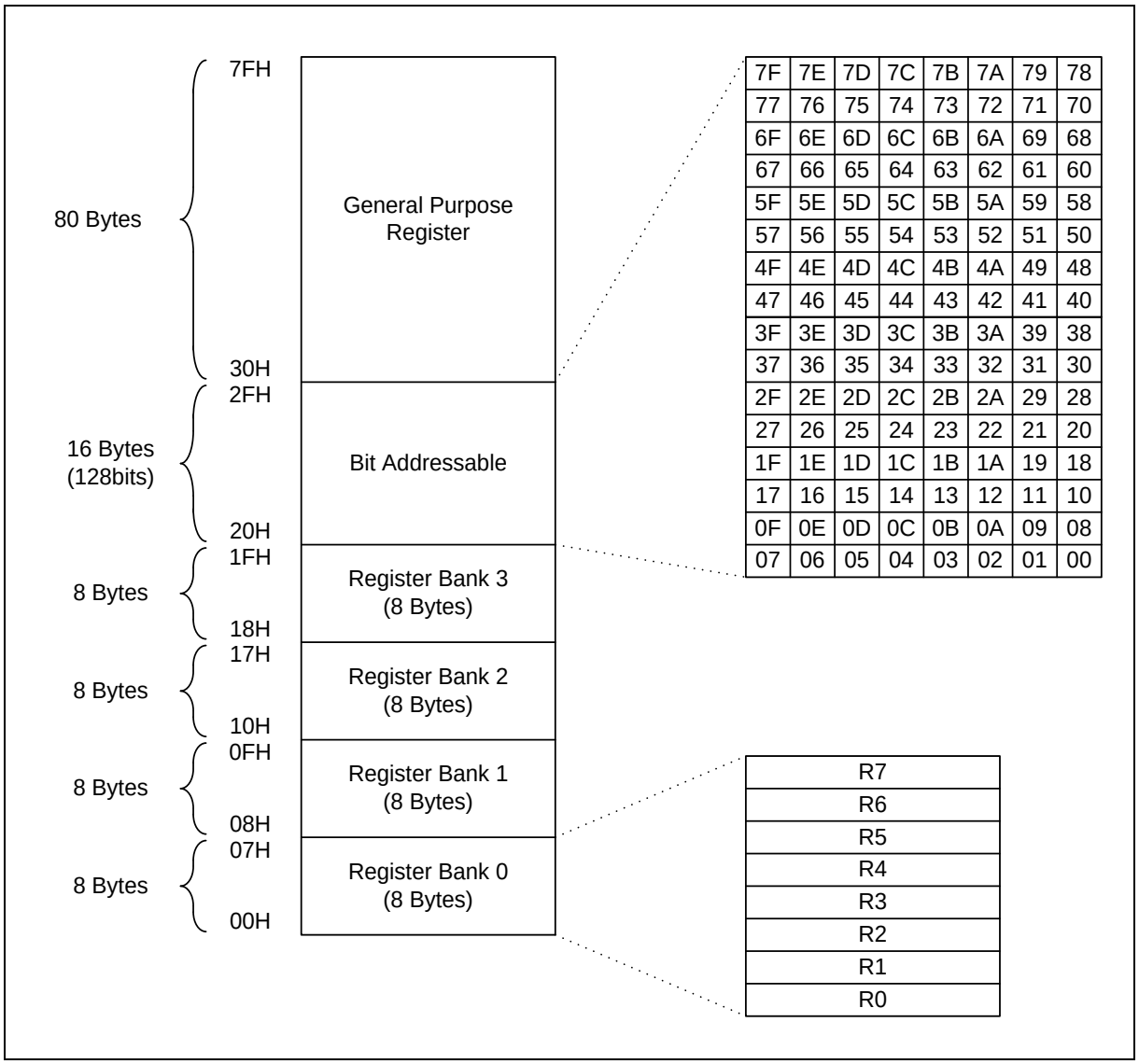


Figure 8.3 Lower 128 Bytes RAM

8.3 XRAM Memory

MC96F8316 has 512 bytes XRAM. This area has no relation with RAM/FLASH. It can be read and written to through SFR with 8-bit unit.

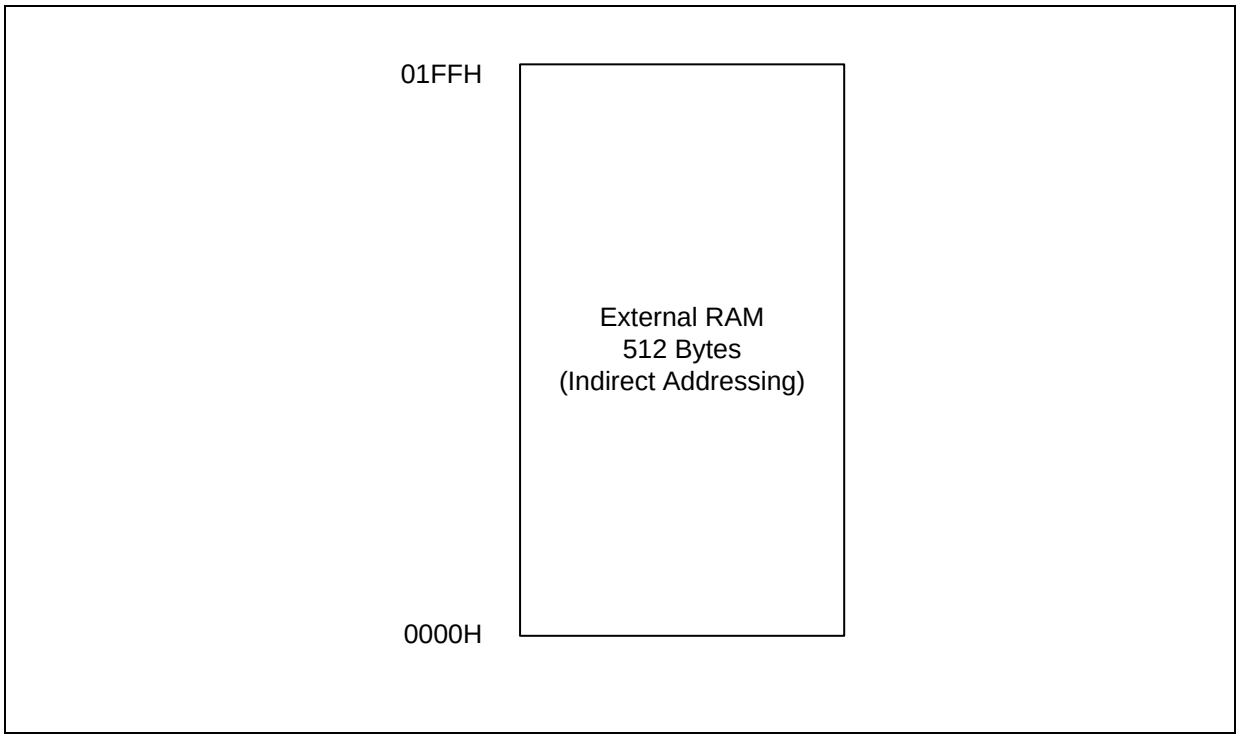


Figure 8.4 XDATA Memory Area

8.4 SFR Map

8.4.1 SFR Map Summary

Table 8-1 SFR Map Summary

– Reserved

M8051 compatible

	00H/8H[1]	01H/9H	02H/0AH	03H/0BH	04H/0CH	05H/0DH	06H/0EH	07H/0FH
0F8H	IP1	–	FSADRH	FSADRM	FSADRL	FIDR	FMCR	–
0F0H	B	I2CSAR1	ADWRCR0	ADWRCR1	ADWRCR2	ADWRCR3	ADWCRL	ADWCRH
0E8H	RSTFR	I2CCR	I2CSR	I2CSAR0	I2CDR	I2CSDHR	I2CSCLR	I2CSCHR
0E0H	ACC	–	UARTCR1	UARTCR2	UARTCR3	UARTST	UARTBD	UARTDR
0D8H	LVRCR	–	–	–	ADWIFRL	ADWIFRH	P03DB	P12DB
0D0H	PSW	–	–	P0FSR	P1FSRL	P1FSRH	P2FSR	P3FSR
0C8H	OSCCR	–	–	–	–	–	–	–
0C0H	EIFLAG0	P3IO	T2CRL	T2CRH	T2ADRL	T2ADRH	T2BDRL	T2BDRH
0B8H	IP	P2IO	T1CRL	T1CRH	T1ADRL	T1ADRH	T1BDRL	T1BDRH
0B0H	EIFLAG1	P1IO	T0CR	T0CNT	T0DR/ T0CDR	SPICR	SPIDR	SPISR
0A8H	IE	IE1	IE2	IE3	P0PU	P1PU	P2PU	P3PU
0A0H	IIFLAG	P0IO	EO	–	EIPOL0L	EIPOL0H	EIPOL1	EIPOL2
98H	P3	–	–	–	ADCCRL	ADCCRH	ADCDRL	ADCDRH
90H	P2	P0OD	P1OD	P2OD	P3OD	–	WTCR	BUZCR
88H	P1	WTDR/ WTCNT	SCCR	BITCR	BITCNT	WDTCR	WDTDR/ WDTCNT	BUZDR
80H	P0	SP	DPL	DPH	DPL1	DPH1	LVICR	PCON

NOTE) These registers are bit-addressable.

8.4.2 SFR Map

Table 8-2 SFR Map

Address	Function	Symbol	R/W	@Reset							
				7	6	5	4	3	2	1	0
80H	P0 Data Register	P0	R/W	–	0	0	0	0	0	0	0
81H	Stack Pointer	SP	R/W	0	0	0	0	0	1	1	1
82H	Data Pointer Register Low	DPL	R/W	0	0	0	0	0	0	0	0
83H	Data Pointer Register High	DPH	R/W	0	0	0	0	0	0	0	0
84H	Data Pointer Register Low 1	DPL1	R/W	0	0	0	0	0	0	0	0
85H	Data Pointer Register High 1	DPH1	R/W	0	0	0	0	0	0	0	0
86H	Low Voltage Indicator Control Register	LVICR	R/W	–	–	0	0	0	0	0	0
87H	Power Control Register	PCON	R/W	0	–	–	–	0	0	0	0
88H	P1 Data Register	P1	R/W	0	0	0	0	0	0	0	0
89H	Watch Timer Data Register	WTDR	W	0	1	1	1	1	1	1	1
	Watch Timer Counter Register	WTCNT	R	–	0	0	0	0	0	0	0
8AH	System and Clock Control Register	SCCR	R/W	–	–	–	–	–	–	0	0
8BH	Basic Interval Timer Control Register	BITCR	R/W	0	0	0	–	0	0	0	1
8CH	Basic Interval Timer Counter Register	BITCNT	R	0	0	0	0	0	0	0	0
8DH	Watch Dog Timer Control Register	WDTCR	R/W	0	0	0	–	–	–	0	0
8EH	Watch Dog Timer Data Register	WDTDR	W	1	1	1	1	1	1	1	1
	Watch Dog Timer Counter Register	WDTCNT	R	0	0	0	0	0	0	0	0
8FH	BUZZER Data Register	BUZDR	R/W	1	1	1	1	1	1	1	1
90H	P2 Data Register	P2	R/W	–	0	0	0	0	0	0	0
91H	P0 Open-drain Selection Register	P0OD	R/W	–	0	0	0	0	0	0	0
92H	P1 Open-drain Selection Register	P1OD	R/W	0	0	0	0	0	0	0	0
93H	P2 Open-drain Selection Register	P2OD	R/W	–	0	0	0	0	0	0	0
94H	P3 Open-drain Selection Register	P3OD	R/W	0	0	0	0	0	0	0	0
95H	Reserved	–	–	–							
96H	Watch Timer Control Register	WTCR	R/W	0	–	–	0	0	0	0	0
97H	BUZZER Control Register	BUZCR	R/W	–	–	–	–	0	0	0	0
98H	P3 Data Register	P3	R/W	0	0	0	0	0	0	0	0
99H	Reserved	–	–	–							
9AH	Reserved	–	–	–							
9BH	Reserved	–	–	–							
9CH	A/D Converter Control Low Register	ADCCRL	R/W	0	0	0	0	0	0	0	0
9DH	A/D Converter Control High Register	ADCCRH	R/W	0	–	–	0	0	0	0	0
9EH	A/D Converter Data Low Register	ADCDRL	R	x	x	x	x	x	x	x	x
9FH	A/D Converter Data High Register	ADCDRH	R	x	x	x	x	x	x	x	x

Table 8-2 SFR Map (Continued)

Address	Function	Symbol	R/W	@Reset							
				7	6	5	4	3	2	1	0
A0H	Internal Interrupt Flag Register	IIFLAG	R/W	–	–	–	–	–	0	0	0
A1H	P0 Direction Register	P0IO	R/W	–	0	0	0	0	0	0	0
A2H	Extended Operation Register	EO	R/W	–	–	–	0	–	0	0	0
A3H	Reserved	–	–	–							
A4H	External Interrupt Polarity 0 Low Register	EIPOL0L	R/W	0	0	0	0	0	0	0	0
A5H	External Interrupt Polarity 0 High Register	EIPOL0H	R/W	–	–	0	0	0	0	0	0
A6H	External Interrupt Polarity 1 Register	EIPOL1	R/W	–	–	0	0	0	0	0	0
A7H	External Interrupt Polarity 2 Register	EIPOL2	R/W	0	0	0	0	0	0	0	0
A8H	Interrupt Enable Register	IE	R/W	0	–	0	–	–	0	0	0
A9H	Interrupt Enable Register 1	IE1	R/W	–	–	0	0	0	0	0	0
AAH	Interrupt Enable Register 2	IE2	R/W	–	–	0	–	0	0	0	0
ABH	Interrupt Enable Register 3	IE3	R/W	–	–	–	0	0	0	0	0
ACH	P0 Pull-up Resistor Selection Register	P0PU	R/W	–	0	0	0	0	0	0	0
ADH	P1 Pull-up Resistor Selection Register	P1PU	R/W	0	0	0	0	0	0	0	0
AEH	P2 Pull-up Resistor Selection Register	P2PU	R/W	–	0	0	0	0	0	0	0
AFH	P3 Pull-up Resistor Selection Register	P3PU	R/W	0	0	0	0	0	0	0	0
B0H	External Interrupt Flag 1 Register	EIFLAG1	R/W	–	0	0	0	0	0	0	0
B1H	P1 Direction Register	P1IO	R/W	0	0	0	0	0	0	0	0
B2H	Timer 0 Control Register	T0CR	R/W	0	–	0	0	0	0	0	0
B3H	Timer 0 Counter Register	T0CNT	R	0	0	0	0	0	0	0	0
B4H	Timer 0 Data Register	T0DR	R/W	1	1	1	1	1	1	1	1
	Timer 0 Capture Data Register	T0CDR	R	0	0	0	0	0	0	0	0
B5H	SPI Control Register	SPICR	R/W	0	0	0	0	0	0	0	0
B6H	SPI Data Register	SPIDR	R/W	0	0	0	0	0	0	0	0
B7H	SPI Status Register	SPISR	R/W	0	0	0	–	0	0	–	–
B8H	Interrupt Priority Register	IP	R/W	–	–	0	0	0	0	0	0
B9H	P2 Direction Register	P2IO	R/W	–	0	0	0	0	0	0	0
BAH	Timer 1 Control Low Register	T1CRL	R/W	0	0	0	0	–	0	0	0
BBH	Timer 1 Control High Register	T1CRH	R/W	0	–	0	0	–	–	–	0
BCH	Timer 1 A Data Low Register	T1ADRL	R/W	1	1	1	1	1	1	1	1
BDH	Timer 1 A Data High Register	T1ADRH	R/W	1	1	1	1	1	1	1	1
BEH	Timer 1 B Data Low Register	T1BDRL	R/W	1	1	1	1	1	1	1	1
BFH	Timer 1 B Data High Register	T1BDRH	R/W	1	1	1	1	1	1	1	1

Table 8-2 SFR Map (Continued)

Address	Function	Symbol	R/W	@Reset							
				7	6	5	4	3	2	1	0
C0H	External Interrupt Flag 0 Register	EIFLAG0	R/W	–	0	0	0	0	0	0	0
C1H	P3 Direction Register	P3IO	R/W	0	0	0	0	0	0	0	0
C2H	Timer 2 Control Low Register	T2CRL	R/W	0	0	0	0	0	0	0	0
C3H	Timer 2 Control High Register	T2CRH	R/W	0	–	0	0	–	–	–	0
C4H	Timer 2 A Data Low Register	T2ADRL	R/W	1	1	1	1	1	1	1	1
C5H	Timer 2 A Data High Register	T2ADRH	R/W	1	1	1	1	1	1	1	1
C6H	Timer 2 B Data Low Register	T2BDRL	R/W	1	1	1	1	1	1	1	1
C7H	Timer 2 B Data High Register	T2BDRH	R/W	1	1	1	1	1	1	1	1
C8H	Oscillator Control Register	OSCCR	R/W	–	–	0	0	1	0	0	0
C9H	Reserved	–	–	–							
CAH	Reserved	–	–	–							
CBH	Reserved	–	–	–							
CCH	Reserved	–	–	–							
CDH	Reserved	–	–	–							
CEH	Reserved	–	–	–							
CFH	Reserved	–	–	–							
D0H	Program Status Word Register	PSW	R/W	0	0	0	0	0	0	0	0
D1H	Reserved	–	–	–							
D2H	Reserved	–	–	–							
D3H	P0 Function Selection Register	P0FSR	R/W	0	0	0	0	0	0	0	0
D4H	P1 Function Selection Low Register	P1FSRL	R/W	–	0	0	0	0	0	0	0
D5H	P1 Function Selection High Register	P1FSRH	R/W	–	0	0	0	0	0	0	0
D6H	P2 Function Selection Register	P2FSR	R/W	–	–	–	–	–	–	0	0
D7H	P3 Function Selection Register	P3FSR	R/W	0	0	0	0	0	0	0	0
D8H	Low Voltage Reset Control Register	LVRCR	R/W	0	–	–	0	0	0	0	0
D9H	Reserved	–	–	–							
DAH	Reserved	–	–	–							
DBH	Reserved	–	–	–							
DCH	ADC Wake-up Interrupt Flag Low Register	ADWIFRL	R/W	0	0	0	0	0	0	0	0
DDH	ADC Wake-up Interrupt Flag High Register	ADWIFRH	R/W	–	0	0	0	0	0	0	0
DEH	P03 Debounce Enable Register	P03DB	R/W	0	0	0	0	0	0	0	0
DFH	P12 Debounce Enable Register	P12DB	R/W	0	0	0	0	0	0	0	0

Table 8-2 SFR Map (Continued)

Address	Function	Symbol	R/W	@Reset							
				7	6	5	4	3	2	1	0
E0H	Accumulator A Register	ACC	R/W	0	0	0	0	0	0	0	0
E1H	Reserved	–	–	–							
E2H	UART Control Register 1	UARTCR1	R/W	–	–	0	0	0	0	0	–
E3H	UART Control Register 2	UARTCR2	R/W	0	0	0	0	0	0	0	0
E4H	UART Control Register 3	UARTCR3	R/W	–	0	–	–	–	0	0	0
E5H	UART Status Register	UARTST	R/W	1	0	0	0	0	0	0	0
E6H	UART Baud Rate Generation Register	UARTBD	R/W	1	1	1	1	1	1	1	1
E7H	UART Data Register	UARTDR	R/W	0	0	0	0	0	0	0	0
E8H	Reset Flag Register	RSTFR	R/W	1	x	0	0	x	–	–	–
E9H	I2C Control Register	I2CCR	R/W	0	0	0	0	0	0	0	0
EAH	I2C Status Register	I2CSR	R/W	0	0	0	0	0	0	0	0
EBH	I2C Slave Address 0 Register	I2CSAR0	R/W	0	0	0	0	0	0	0	0
ECH	I2C Data Register	I2CDR	R/W	0	0	0	0	0	0	0	0
EDH	I2C SDA Hold Time Register	I2CSDHR	R/W	0	0	0	0	0	0	0	1
EEH	I2C SCL Low Period Register	I2CSCLR	R/W	0	0	1	1	1	1	1	1
EFH	I2C SCL High Period Register	I2CSCHR	R/W	0	0	1	1	1	1	1	1
F0H	B Register	B	R/W	0	0	0	0	0	0	0	0
F1H	I2C Slave Address 1 Register	I2CSAR1	R/W	0	0	0	0	0	0	0	0
F2H	ADC Wake-up Resistor Control Register0	ADWRCR0	R/W	0	0	0	0	0	0	0	0
F3H	ADC Wake-up Resistor Control Register1	ADWRCR1	R/W	0	0	0	0	0	0	0	0
F4H	ADC Wake-up Resistor Control Register2	ADWRCR2	R/W	0	0	0	0	0	0	0	0
F5H	ADC Wake-up Resistor Control Register3	ADWRCR3	R/W	–	–	0	0	0	0	0	0
F6H	ADC Wake-up Control Low Register	ADWCRL	R/W	0	0	0	0	0	0	0	0
F7H	ADC Wake-up Control High Register	ADWCRH	R/W	–	0	0	0	0	0	0	0
F8H	Interrupt Priority Register 1	IP1	R/W	–	–	0	0	0	0	0	0
F9H	Reserved	–	–	–							
FAH	Flash Sector Address High Register	FSADRH	R/W	–	–	–	–	0	0	0	0
FBH	Flash Sector Address Middle Register	FSADRM	R/W	0	0	0	0	0	0	0	0
FCH	Flash Sector Address Low Register	FSADRL	R/W	0	0	0	0	0	0	0	0
FDH	Flash Identification Register	FIDR	R/W	0	0	0	0	0	0	0	0
FEH	Flash Mode Control Register	FMCR	R/W	0	–	–	–	–	0	0	0
FFH	Reserved	–	–	–							

8.4.3 Compiler Compatible SFR

ACC (Accumulator Register) : E0H

7	6	5	4	3	2	1	0
ACC							
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

ACC	Accumulator

B (B Register) : F0H

7	6	5	4	3	2	1	0
B							
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

B	B Register

SP (Stack Pointer) : 81H

7	6	5	4	3	2	1	0
SP							
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 07H

SP	Stack Pointer

DPL (Data Pointer Register Low) : 82H

7	6	5	4	3	2	1	0
DPL							
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

DPL	Data Pointer Low

DPH (Data Pointer Register High) : 83H

7	6	5	4	3	2	1	0
DPH							
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

DPH	Data Pointer High

DPL1 (Data Pointer Register Low 1) : 84H

7	6	5	4	3	2	1	0
DPL1							
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

DPL1 Data Pointer Low 1

DPH1 (Data Pointer Register High 1) : 85H

7	6	5	4	3	2	1	0
DPH1							
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

DPH1 Data Pointer High 1

PSW (Program Status Word Register) : D0H

7	6	5	4	3	2	1	0
CY	AC	F0	RS1	RS0	OV	F1	P
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

CY	Carry Flag
AC	Auxiliary Carry Flag
F0	General Purpose User-Definable Flag
RS1	Register Bank Select bit 1
RS0	Register Bank Select bit 0
OV	Overflow Flag
F1	User-Definable Flag
P	Parity Flag. Set/Cleared by hardware each instruction cycle to indicate an odd/even number of ‘1’ bits in the accumulator

EO (Extended Operation Register) : A2H

7	6	5	4	3	2	1	0
–	–	–	TRAP_EN	–	DPSEL2	DPSEL1	DPSEL0
–	–	–	R/W	–	R/W	R/W	R/W

Initial value : 00H

TRAP_EN Select the Instruction **(Keep always ‘0’)**.

0 Select MOVC @(DPTR++), A

1 Select Software TRAP Instruction

DPSEL[2:0] Select Banked Data Pointer Register

DPSEL2	DPSEL1	SPSEL0	Description
0	0	0	DPTR0
0	0	1	DPTR1
Reserved			

9. I/O Ports

9.1 I/O Ports

The MC96F8316 has four groups of I/O ports (P0 ~ P3). Each port can be easily configured by software as I/O pin, internal pull up and open-drain pin to meet various system configurations and design requirements. Also P0, P1, P2, and P3 include function that can generate interrupt according to change of state of the pin.

9.2 Port Register

9.2.1 Data Register (Px)

Data Register is a bidirectional I/O port. If ports are configured as output ports, data can be written to the corresponding bit of the Px. If ports are configured as input ports, the data can be read from the corresponding bit of the Px.

9.2.2 Direction Register (PxIO)

Each I/O pin can be independently used as an input or an output through the PxIO register. Bits cleared in this register will make the corresponding pin of Px to input mode. Set bits of this register will make the pin to output mode. Almost bits are cleared by a system reset, but some bits are set by a system reset.

9.2.3 Pull-up Resistor Selection Register (PxPU)

The on-chip pull-up resistor can be connected to I/O ports individually with a pull-up resistor selection register (PxPU). The pull-up register selection controls the pull-up resister enable/disable of each port. When the corresponding bit is 1, the pull-up resister of the pin is enabled. When 0, the pull-up resister is disabled. All bits are cleared by a system reset.

9.2.4 Open-drain Selection Register (PxOD)

There are internally open-drain selection registers (PxOD) for P0 ~ P3. The open-drain selection register controls the open-drain enable/disable of each port. Almost ports become push-pull by a system reset, but some ports become open-drain by a system reset.

9.2.5 Debounce Enable Register (PxDB)

P0[6:2], P1[3:0], P2[3:0] and P35 support debounce function. Debounce clocks of each ports are fx/1, fx/4, and fx/4096.

9.2.6 Port Function Selection Register (PxFSR)

These registers define alternative functions of ports. Please remember that these registers should be set properly for alternative port function. A reset clears the PxFSR register to ‘00H’, which makes all pins to normal I/O ports.

9.2.7 Register Map

Table 9-1 Port Register Map

Name	Address	Dir	Default	Description
P0	80H	R/W	00H	P0 Data Register
P0IO	A1H	R/W	00H	P0 Direction Register
P0OD	91H	R/W	00H	P0 Open-drain Selection Register
P0PU	ACH	R/W	00H	P0 Pull-up Resistor Selection Register
P03DB	DEH	R/W	00H	P0/P3 Debounce Enable Register
P0FSR	D3H	R/W	00H	P0 Function Selection Register
P1	88H	R/W	00H	P1 Data Register
P1IO	B1H	R/W	00H	P1 Direction Register
P1OD	92H	R/W	00H	P1 Open-drain Selection Register
P1PU	ADH	R/W	00H	P1 Pull-up Resistor Selection Register
P12DB	DFH	R/W	00H	P1/P2 Debounce Enable Register
P1FSRH	D5H	R/W	00H	P1 Function Selection High Register
P1FSRL	D4H	R/W	00H	P1 Function Selection Low Register
P2	90H	R/W	00H	P2 Data Register
P2IO	B9H	R/W	00H	P2 Direction Register
P2OD	93H	R/W	00H	P2 Open-drain Selection Register
P2PU	AEH	R/W	00H	P2 Pull-up Resistor Selection Register
P2FSR	D6H	R/W	00H	P2 Function Selection Register
P3	98H	R/W	00H	P3 Data Register
P3IO	C1H	R/W	00H	P3 Direction Register
P3OD	94H	R/W	00H	P3 Open-drain Selection Register
P3PU	AFH	R/W	00H	P3 Pull-up Resistor Selection Register
P3FSR	D7H	R/W	00H	P3 Function Selection Register

9.3 P0 Port

9.3.1 P0 Port Description

P0 is 7-bit I/O port. P0 control registers consist of P0 data register (P0), P0 direction register (P0IO), debounce enable register (P03DB), P0 pull-up resistor selection register (P0PU), and P0 open-drain selection register (P0OD). Refer to the port function selection registers for the P0 function selection.

9.3.2 Register description for P0

P0 (P0 Data Register) : 80H

7	6	5	4	3	2	1	0
–	P06	P05	P04	P03	P02	P01	P00
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P0[6:0] I/O Data

P0IO (P0 Direction Register) : A1H

7	6	5	4	3	2	1	0
–	P06IO	P05IO	P04IO	P03IO	P02IO	P01IO	P00IO
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P0IO[6:0] P0 Data I/O Direction.

0 Input

1 Output

NOTE: EINT0 ~ EINT4 function possible when input

P0PU (P0 Pull-up Resistor Selection Register) : ACH

7	6	5	4	3	2	1	0
–	P06PU	P05PU	P04PU	P03PU	P02PU	P01PU	P00PU
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P0PU[6:0] Configure Pull-up Resistor of P0 Port

0 Disable

1 Enable

P0OD (P0 Open-drain Selection Register) : 91H

7	6	5	4	3	2	1	0
–	P06OD	P05OD	P04OD	P03OD	P02OD	P01OD	P00OD
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P0OD[6:0] Configure Open-drain of P0 Port

0 Push-pull output

1 Open-drain output

P03DB (P0/P3 Debounce Enable Register) : DEH

7	6	5	4	3	2	1	0
DBCLK1	DBCLK0	P35DB	P06DB	P05DB	P04DB	P03DB	P02DB
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

DBCLK[1:0] Configure Debounce Clock of Port

DBCLK1	DBCLK0	Description
0	0	fx/1
0	1	fx/4
1	0	fx/4096
1	1	Reserved

P35DB Configure Debounce of P35 Port

0	Disable
1	Enable

P06DB Configure Debounce of P06 Port

0	Disable
1	Enable

P05DB Configure Debounce of P05 Port

0	Disable
1	Enable

P04DB Configure Debounce of P04 Port

0	Disable
1	Enable

P03DB Configure Debounce of P03Port

0	Disable
1	Enable

P02DB Configure Debounce of P02 Port

0	Disable
1	Enable

NOTES) 1. If the same level is not detected on enabled pin three or four times in a row at the sampling clock, the signal is eliminated as noise.

2. A pulse level should be input for the duration of 3 clock or more to be actually detected as a valid edge.

3. The port debounce is automatically disabled at stop mode and recovered after stop mode release.

9.4 P1 Port

9.4.1 P1 Port Description

P1 is 8-bit I/O port. P1 control registers consist of P1 data register (P1), P1 direction register (P1IO), debounce enable register (P12DB), P1 pull-up resistor selection register (P1PU), and P1 open-drain selection register (P1OD) . Refer to the port function selection registers for the P1 function selection.

9.4.2 Register description for P1

P1 (P1 Data Register) : 88H

7	6	5	4	3	2	1	0
P17	P16	P15	P14	P13	P12	P11	P10
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P1[7:0] I/O Data

P1IO (P1 Direction Register) : B1H

7	6	5	4	3	2	1	0
P17IO	P16IO	P15IO	P14IO	P13IO	P12IO	P11IO	P10IO
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P1IO[7:0] P1 Data I/O Direction

0 Input

1 Output

NOTE: EINT5/ENINT6/EINT11/EINT12/EC1/EC2/SS function possible when input

P1PU (P1 Pull-up Resistor Selection Register) : ADH

7	6	5	4	3	2	1	0
P17PU	P16PU	P15PU	P14PU	P13PU	P12PU	P11PU	P10PU
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P1PU[7:0] Configure Pull-up Resistor of P1 Port

0 Disable

1 Enable

P1OD (P1 Open-drain Selection Register) : 92H

7	6	5	4	3	2	1	0
P17OD	P16OD	P15OD	P14OD	P13OD	P12OD	P11OD	P10OD
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P1OD[7:0] Configure Open-drain of P1 Port

0 Push-pull output

1 Open-drain output

P12DB (P1/P2 Debounce Enable Register) : DFH

7	6	5	4	3	2	1	0
P23DB	P22DB	P21DB	P20DB	P13DB	P12DB	P11DB	P10DB
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P23DB	Configure Debounce of P23 Port	
	0	Disable
	1	Enable
P22DB	Configure Debounce of P22 Port	
	0	Disable
	1	Enable
P21DB	Configure Debounce of P21 Port	
	0	Disable
	1	Enable
P20DB	Configure Debounce of P20 Port	
	0	Disable
	1	Enable
P13DB	Configure Debounce of P13 Port	
	0	Disable
	1	Enable
P12DB	Configure Debounce of P12 Port	
	0	Disable
	1	Enable
P11DB	Configure Debounce of P11 Port	
	0	Disable
	1	Enable
P10DB	Configure Debounce of P10 Port	
	0	Disable
	1	Enable

NOTES) 1. If the same level is not detected on enabled pin three or four times in a row at the sampling clock, the signal is eliminated as noise.

2. A pulse level should be input for the duration of 3 clock or more to be actually detected as a valid edge.

3. The port debounce is automatically disabled at stop mode and recovered after stop mode release.

4. Refer to the port 0/3 debounce enable register (P03DB) for the debounce clock of port 1 and port 2.

9.5 P2 Port

9.5.1 P2 Port Description

P2 is 7-bit I/O port. P2 control registers consist of P2 data register (P2), P2 direction register (P2IO), P2 pull-up resistor selection register (P2PU) and P2 open-drain selection register (P2OD). Refer to the port function selection registers for the P2 function selection.

9.5.2 Register description for P2

P2 (P2 Data Register) : 90H

7	6	5	4	3	2	1	0
–	P26	P25	P24	P23	P22	P21	P20
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P2[6:0] I/O Data

P2IO (P2 Direction Register) : B9H

7	6	5	4	3	2	1	0
–	P26IO	P25IO	P24IO	P23IO	P22IO	P21IO	P20IO
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P2IO[6:0] P2 Data I/O Direction

0 Input

1 Output

NOTE: EINT7 – EINTA, EC0 function possible when input

P2PU (P2 Pull-up Resistor Selection Register) : AEH

7	6	5	4	3	2	1	0
–	P26PU	P25PU	P24PU	P23PU	P22PU	P21PU	P20PU
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P2PU[6:0] Configure Pull-up Resistor of P2 Port

0 Disable

1 Enable

P2OD (P2 Open-drain Selection Register) : 93H

7	6	5	4	3	2	1	0
–	P26OD	P25OD	P24OD	P23OD	P22OD	P21OD	P20OD
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P2OD[6:0] Configure Open-drain of P2 Port

0 Push-pull output

1 Open-drain output

9.6 P3 Port

9.6.1 P3 Port Description

P3 is 8-bit I/O port. P3 control registers consist of P3 data register (P3), P3 direction register (P3IO), P3 pull-up resistor selection register (P3PU) and P3 open-drain selection register (P3OD). Refer to the port function selection registers for the P3 function selection.

9.6.2 Register description for P3

P3 (P3 Data Register) : 98H

7	6	5	4	3	2	1	0
P37	P36	P35	P34	P33	P32	P31	P30
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P3[7:0] I/O Data

P3IO (P3 Direction Register) : C1H

7	6	5	4	3	2	1	0
P37IO	P36IO	P35IO	P34IO	P33IO	P32IO	P31IO	P30IO
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P3IO[7:0] P3 Data I/O Direction

0 Input

1 Output

NOTE: RXD, EINT10 function possible when input

P3PU (P3 Pull-up Resistor Selection Register) : AFH

7	6	5	4	3	2	1	0
P37PU	P36PU	P35PU	P34PU	P33PU	P32PU	P31PU	P30PU
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P3PU[7:0] Configure Pull-up Resistor of P3 Port

0 Disable

1 Enable

P3OD (P3 Open-drain Selection Register) : 94H

7	6	5	4	3	2	1	0
P37OD	P36OD	P35OD	P34OD	P33OD	P32OD	P31OD	P30OD
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P3OD[7:0] Configure Open-drain of P3 Port

0 Push-pull output

1 Open-drain output

9.7 Port Function

9.7.1 Port Function Description

Port function control registers consist of Port function selection register 0 ~ 3. (P0FSR ~ P3FSR).

9.7.2 Register description for P0FSR ~ P3FSR

P0FSR (Port 0 Function Selection Register) : D3H

7	6	5	4	3	2	1	0
P0FSR7	P0FSR6	P0FSR5	P0FSR4	P0FSR3	P0FSR2	P0FSR1	P0FSR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P0FSR7 P06 Function select
- 0 I/O Port (EINT4 function possible when input)
- 1 AN6 Function

P0FSR6 P05 Function select
- 0 I/O Port (EINT3 function possible when input)
- 1 AN5 Function

P0FSR5 P04 Function select
- 0 I/O Port (EINT2 function possible when input)
- 1 AN4 Function

P0FSR4 P03 Function select
- 0 I/O Port (EINT1 function possible when input)
- 1 AN3 Function

P0FSR[3:2] P02 Function Select

P0FSR3	P0FSR2	Description
0	0	I/O Port (EINT0 function possible when input)
0	1	AVREF Function
1	0	AN2 Function
1	1	Not used

P0FSR1 P01 Function select
- 0 I/O Port
- 1 AN1 Function

P0FSR0 P00 Function select
- 0 I/O Port
- 1 AN0 Function

P1FSRH (Port 1 Function Selection High Register) : D5H

7	6	5	4	3	2	1	0
–	P1FSRH6	P1FSRH5	P1FSRH4	P1FSRH3	P1FSRH2	P1FSRH1	P1FSRH0
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P1FSRH6 P17 Function Select

0	I/O Port (EC2/SS function possible when input)
1	AN14 Function

P1FSRH[5:4] P16 Function Select

P1FSRH5	P1FSRH4	Description
0	0	I/O Port
0	1	SCK Function
1	0	AN13 Function
1	1	Not used

P1FSRH[3:2] P15 Function Select

P1FSRH3	P1FSRH2	Description
0	0	I/O Port
0	1	MOSI Function
1	0	AN12 Function
1	1	Not used

P1FSRH[1:0] P14 Function Select

P1FSRH1	P0FSRH0	Description
0	0	I/O Port
0	1	MISO Function
1	0	AN11 Function
1	1	Not used

P1FSRL (Port 1 Function Selection Low Register) : D4H

7	6	5	4	3	2	1	0
–	P1FSRL6	P1FSRL5	P1FSRL4	P1FSRL3	P1FSRL2	P1FSRL1	P1FSRL0
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P1FSRL[6:5] P13 Function Select

P1FSRL6	P1FSRL5	Description
0	0	I/O Port (EINT12 function possible when input)
0	1	T2O/PWM2O Function
1	0	AN10 Function
1	1	Not used

P1FSRL[4:3] P12 Function Select

P1FSRL4	P1FSRL3	Description
0	0	I/O Port (EINT11 function possible when input)
0	1	T1O/PWM1O Function
1	0	AN9 Function
1	1	Not used

P1FSRL[2:1] P11 Function Select

P1FSRL2	P1FSRL1	Description
0	0	I/O Port (EINT6/EC1 function possible when input)
0	1	BUZO Function
1	0	AN8 Function
1	1	Not used

P1FSRL0 P10 Function Select

0	I/O Port (EINT5 function possible when input)
1	AN7 Function

P2FSR (Port 2 Function Selection Register) : D6H

7	6	5	4	3	2	1	0
–	–	–	–	–	–	P2FSR1	P2FSR0
–	–	–	–	–	–	R/W	R/W

Initial value : 00H

P2FSR1	P25 Function select	
	0	I/O Port
	1	SCL Function
P2FSR0	P24 Function Select	
	0	I/O Port
	1	SDA Function

P3FSR (Port 3 Function Selection Register) : D7H

7	6	5	4	3	2	1	0
P3FSR7	P3FSR6	P3FSR5	P3FSR4	P3FSR3	P3FSR2	P3FSR1	P3FSR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

P3FSR7 P37 Function select
- 0 I/O Port
- 1 XOUT Function

P3FSR6 P36 Function Select
- 0 I/O Port
- 1 XIN Function

P3FSR5 P35 Function select
- 0 I/O Port
- 1 T0O/PWM0O Function

P3FSR4 P34 Function Select
- 0 I/O Port
- 1 SXIN Function

P3FSR3 P33 Function select
- 0 I/O Port
- 1 SXOUT Function

P3FSR2 P31 Function Select
- 0 I/O Port (RXD function possible when input)
- 1 SCL Function

P3FSR[1:0] P30 Function select

P3FSR1	P3FSR0	Description
0	0	I/O Port
0	1	TXD Function
1	0	SDA Function
1	1	Not used

NOTE) Refer to the configure option for the P32/RESETB

10. Interrupt Controller

10.1 Overview

The MC96F8316 supports up to 20 interrupt sources. The interrupts have separate enable register bits associated with them, allowing software control. They can also have four levels of priority assigned to them. The non-maskable interrupt source is always enabled with a higher priority than any other interrupt source, and is not controllable by software. The interrupt controller has following features:

- Receive the request from 20 interrupt source
- 6 group priority
- 4 priority levels
- Multi Interrupt possibility
- If the requests of different priority levels are received simultaneously, the request of higher priority level is served first.
- Each interrupt source can be controlled by EA bit and each IEx bit
- Interrupt latency: 3~9 machine cycles in single interrupt system

The non-maskable interrupt is always enabled. The maskable interrupts are enabled through four pair of interrupt enable registers (IE, IE1, IE2, IE3). Each bit of IE, IE1, IE2, IE3 register individually enables/disables the corresponding interrupt source. Overall control is provided by bit 7 of IE (EA). When EA is set to '0', all interrupts are disabled: when EA is set to '1', interrupts are individually enabled or disabled through the other bits of the interrupt enable registers. The EA bit is always cleared to '0' jumping to an interrupt service vector and set to '1' executing the [RETI] instruction. The MC96F8316 supports a four-level priority scheme. Each maskable interrupt is individually assigned to one of four priority levels according to IP and IP1.

Default interrupt mode is level-trigger mode basically, but if needed, it is possible to change to edge-trigger mode. Table 10-1 shows the Interrupt Group Priority Level that is available for sharing interrupt priority. Priority of a group is set by two bits of interrupt priority registers (one bit from IP, another one from IP1). Interrupt service routine serves higher priority interrupt first. If two requests of different priority levels are received simultaneously, the request of higher priority level is served prior to the lower one.

Table 10-1 Interrupt Group Priority Level

Interrupt Group	Highest → Lowest			
0 (Bit0)	Interrupt 0	Interrupt 6	Interrupt 12	Interrupt 18
1 (Bit1)	Interrupt 1	Interrupt 7	Interrupt 13	Interrupt 19
2 (Bit2)	Interrupt 2	Interrupt 8	Interrupt 14	Interrupt 20
3 (Bit3)	Interrupt 3	Interrupt 9	Interrupt 15	Interrupt 21
4 (Bit4)	Interrupt 4	Interrupt 10	Interrupt 16	Interrupt 22
5 (Bit5)	Interrupt 5	Interrupt 11	Interrupt 17	Interrupt 23

Highest

Lowest

10.2 External Interrupt

The external interrupt on INT0, INT1, INT2, INT3, INT4, INT5, INT6, INT7, INT8, INT9, INTA, INT10, INT11 and INT12 pins receive various interrupt request depending on the external interrupt polarity 0 high/low register (EIPOL0H/L), external interrupt polarity 1 register (EIPOL1) and external interrupt polarity 2 register (EIPOL2) as shown in Figure 10.1. Also each external interrupt source has enable/disable bits. The external interrupt flag 0 register (EIFLAG0) and external interrupt flag 1 register (EIFLAG1) provides the status of external interrupts.

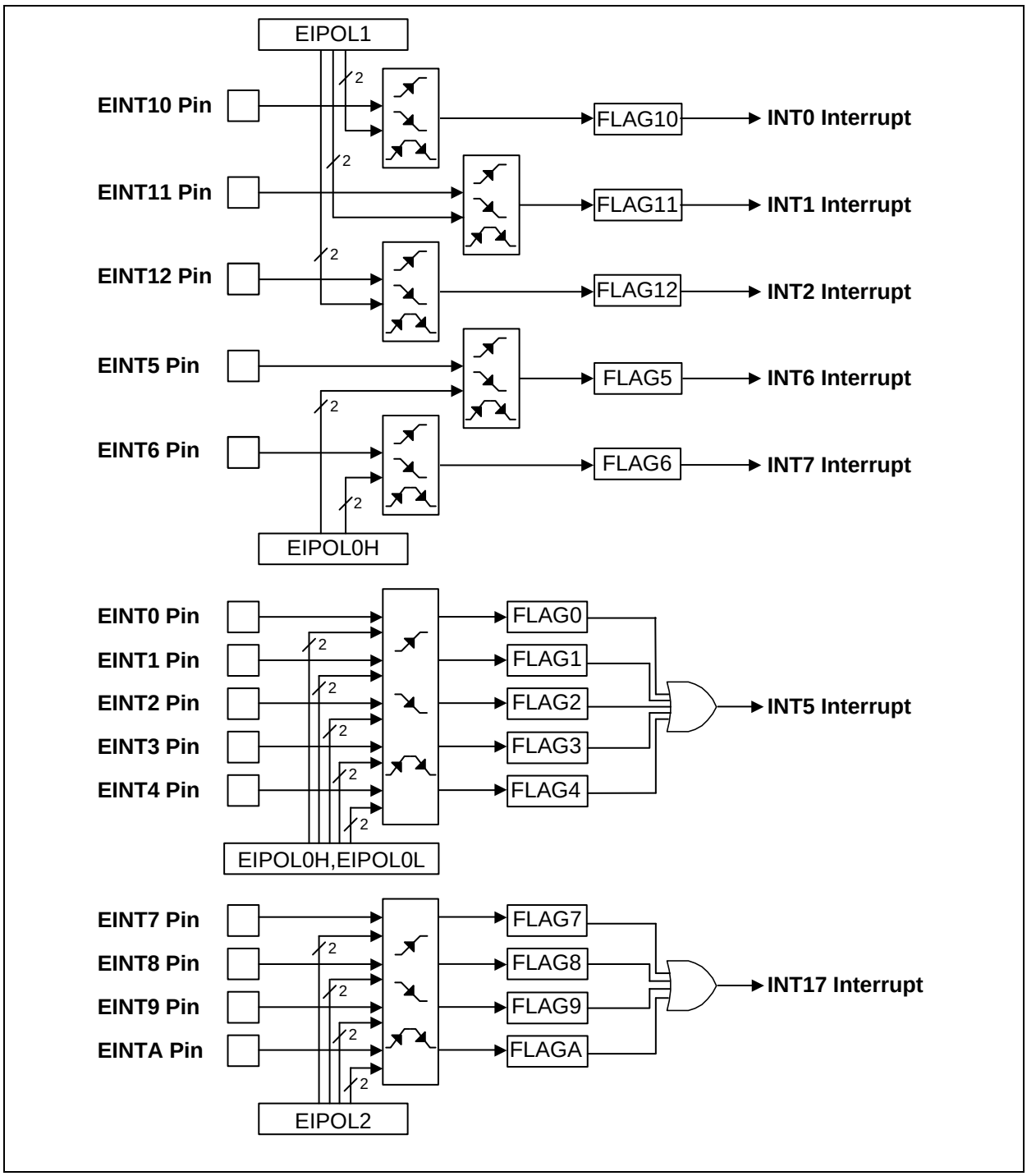


Figure 10.1 External Interrupt Description

10.3 Block Diagram

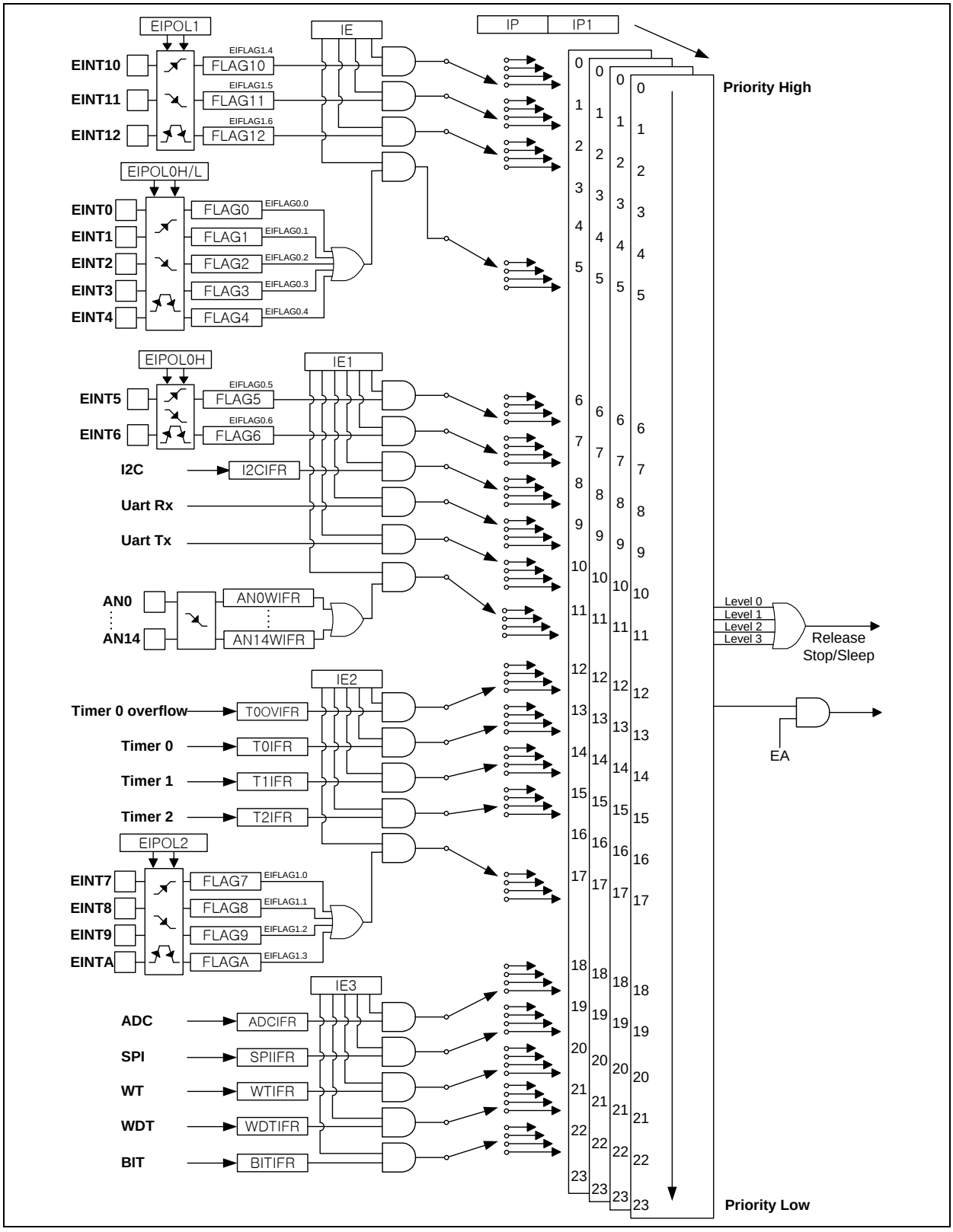


Figure 10.2 Block Diagram of Interrupt

NOTES) 1. The release signal for stop/idle mode may be generated by all interrupt sources which are enabled without reference to the priority level.

2. An interrupt request is delayed while data are written to IE, IE1, IE2, IE3, IP, IP1, and PCON register.

10.4 Interrupt Vector Table

The interrupt controller supports 24 interrupt sources as shown in the Table 10-2. When interrupt is served, long call instruction (LCALL) is executed and program counter jumps to the vector address. All interrupt requests have their own priority order.

Table 10-2 Interrupt Vector Address Table

Interrupt Source	Symbol	Interrupt Enable Bit	Polarity	Mask	Vector Address
Hardware Reset	RESETB	0 0	0	Non-Maskable	0000H
External Interrupt 10	INT0	IE.0	1	Maskable	0003H
External Interrupt 11	INT1	IE.1	2	Maskable	000BH
External Interrupt 12	INT2	IE.2	3	Maskable	0013H
-	INT3	IE.3	4	Maskable	001BH
-	INT4	IE.4	5	Maskable	0023H
External Interrupt 0 – 4	INT5	IE.5	6	Maskable	002BH
External Interrupt 5	INT6	IE1.0	7	Maskable	0033H
External Interrupt 6	INT7	IE1.1	8	Maskable	003BH
I2C Interrupt	INT8	IE1.2	9	Maskable	0043H
UART Rx Interrupt	INT9	IE1.3	10	Maskable	004BH
UART Tx Interrupt	INT10	IE1.4	11	Maskable	0053H
ADC Wake-up Interrupt	INT11	IE1.5	12	Maskable	005BH
T0 Overflow Interrupt	INT12	IE2.0	13	Maskable	0063H
T0 Match Interrupt	INT13	IE2.1	14	Maskable	006BH
T1 Match Interrupt	INT14	IE2.2	15	Maskable	0073H
T2 Match Interrupt	INT15	IE2.3	16	Maskable	007BH
-	INT16	IE2.4	17	Maskable	0083H
External Interrupt 7 – A	INT17	IE2.5	18	Maskable	008BH
ADC Interrupt	INT18	IE3.0	19	Maskable	0093H
SPI Interrupt	INT19	IE3.1	20	Maskable	009BH
WT Interrupt	INT20	IE3.2	21	Maskable	00A3H
WDT Interrupt	INT21	IE3.3	22	Maskable	00ABH
BIT Interrupt	INT22	IE3.4	23	Maskable	00B3H
-	INT23	IE3.5	24	Maskable	00BBH

For maskable interrupt execution, EA bit must set ‘1’ and specific interrupt must be enabled by writing ‘1’ to associated bit in the IEx. If an interrupt request is received, the specific interrupt request flag is set to ‘1’. And it remains ‘1’ until CPU accepts interrupt. If the interrupt is served, the interrupt request flag will be cleared automatically.

10.5 Interrupt Sequence

An interrupt request is held until the interrupt is accepted or the interrupt latch is cleared to ‘0’ by a reset or an instruction. Interrupt acceptance always generates at last cycle of the instruction. So instead of fetching the current instruction, CPU executes internally LCALL instruction and saves the PC at stack. For the interrupt service routine, the interrupt controller gives the address of LJMP instruction to CPU. Since the end of the execution of current instruction, it needs 3~9 machine cycles to go to the interrupt service routine. The interrupt service task is terminated by the interrupt return instruction [RETI]. Once an interrupt request is generated, the following process is performed.

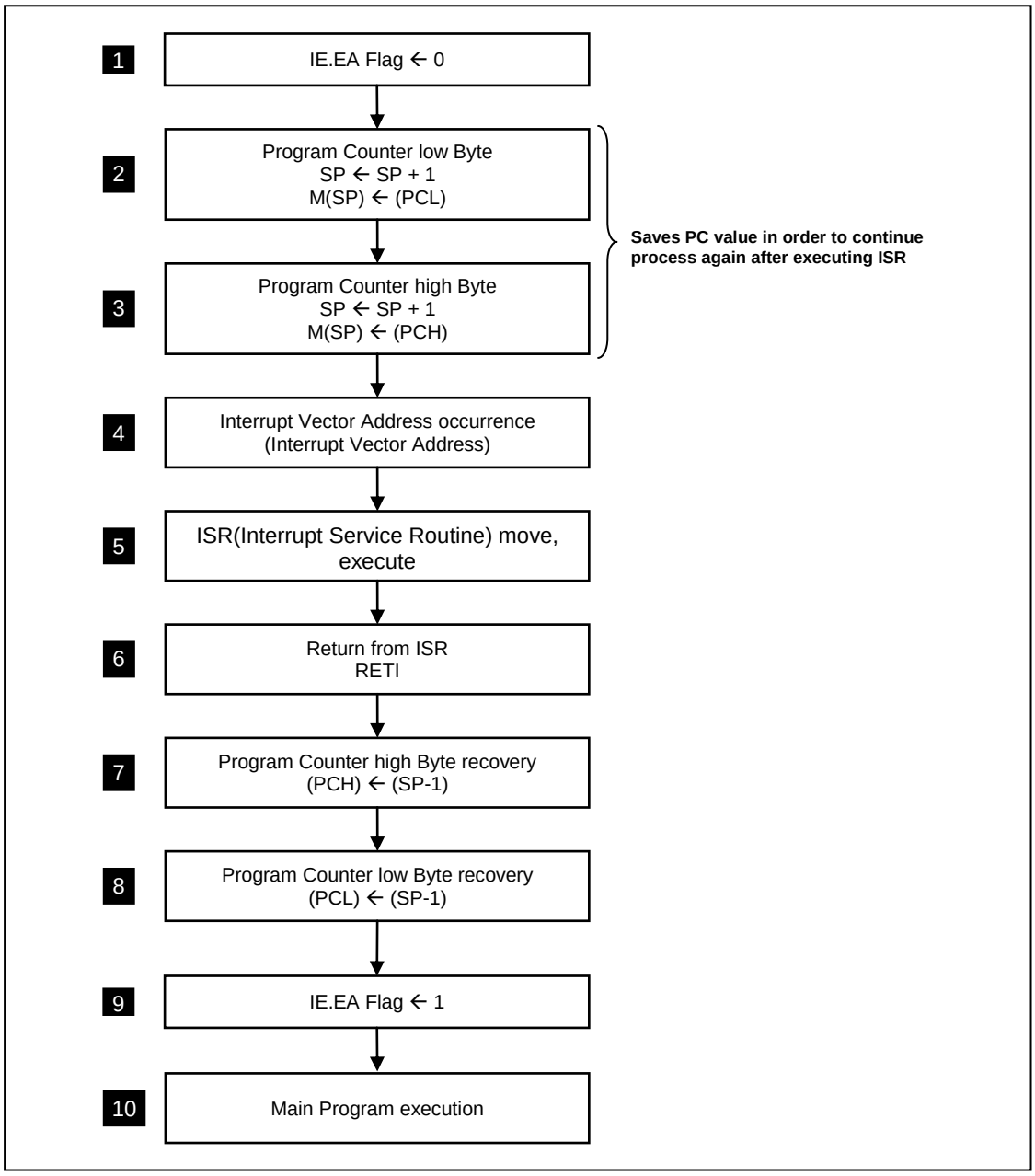


Figure 10.3 Interrupt Vector Address Table

10.6 Effective Timing after Controlling Interrupt Bit

Case a) Control Interrupt Enable Register (IE, IE1, IE2, IE3)

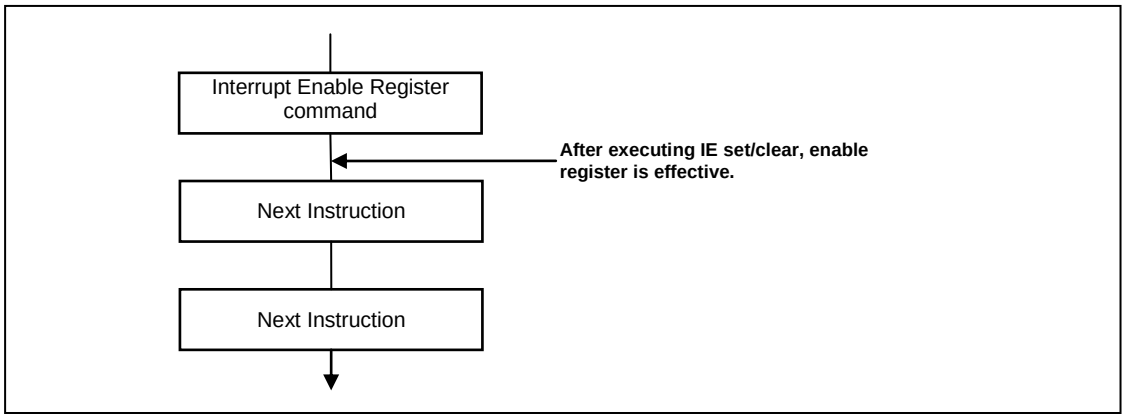


Figure 10.4 Effective Timing of Interrupt Enable Register

Case b) Interrupt flag Register

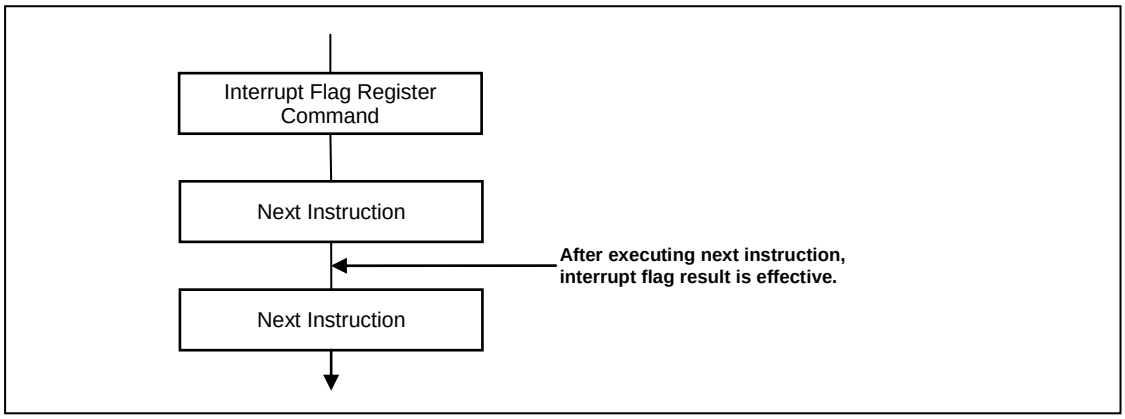


Figure 10.5 Effective Timing of Interrupt Flag Register

10.7 Multi Interrupt

If two requests of different priority levels are received simultaneously, the request of higher priority level is served first. If more than one interrupt request are received, the interrupt polling sequence determines which request is served first by hardware. However, for special features, multi-interrupt processing can be executed by software.

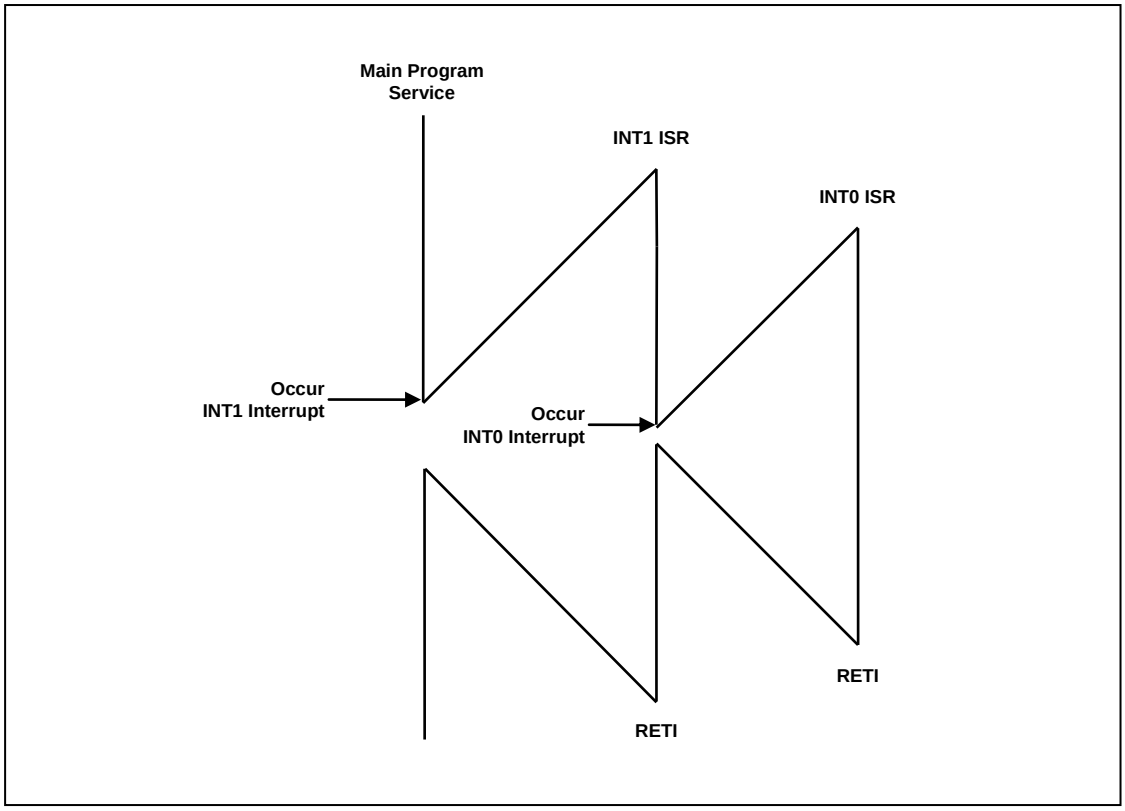


Figure 10.6 Effective Timing of Interrupt

Figure 10.6 shows an example of multi-interrupt processing. While INT1 is served, INT0 which has higher priority than INT1 is occurred. Then INT0 is served immediately and then the remain part of INT1 service routine is executed. If the priority level of INT0 is same or lower than INT1, INT0 will be served after the INT1 service has completed.

An interrupt service routine may be only interrupted by an interrupt of higher priority and, if two interrupts of different priority occur at the same time, the higher level interrupt will be served first. An interrupt cannot be interrupted by another interrupt of the same or a lower priority level. If two interrupts of the same priority level occur simultaneously, the service order for those interrupts is determined by the scan order.

10.8 Interrupt Enable Accept Timing

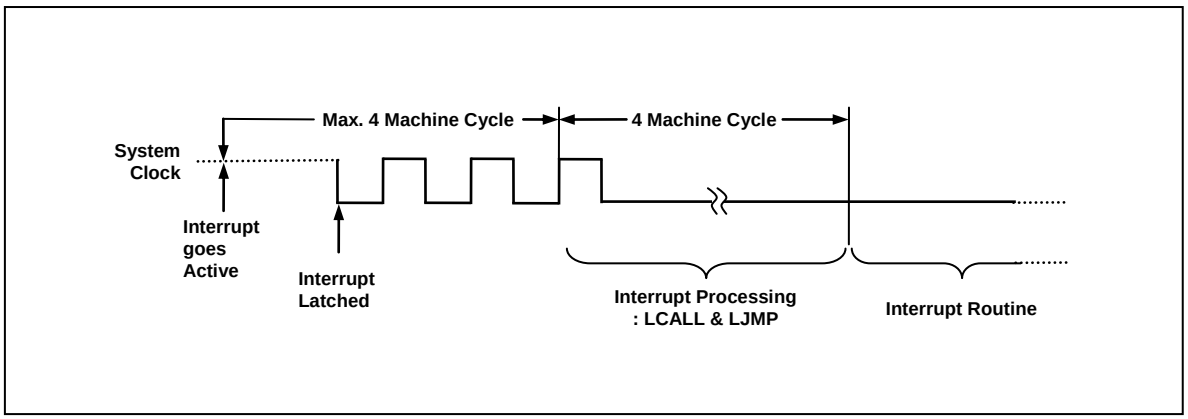


Figure 10.7 Interrupt Response Timing Diagram

10.9 Interrupt Service Routine Address

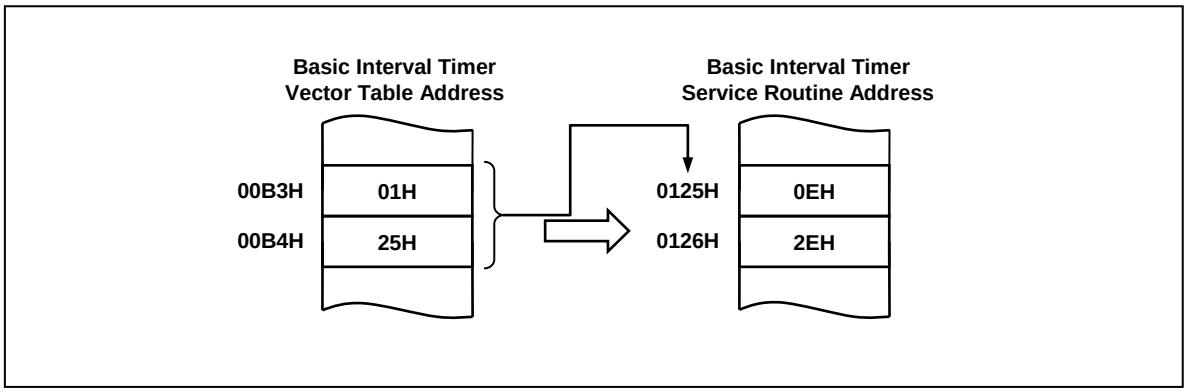


Figure 10.8 Correspondence between Vector Table Address and the Entry Address of ISP

10.10 Saving/Restore General-Purpose Registers

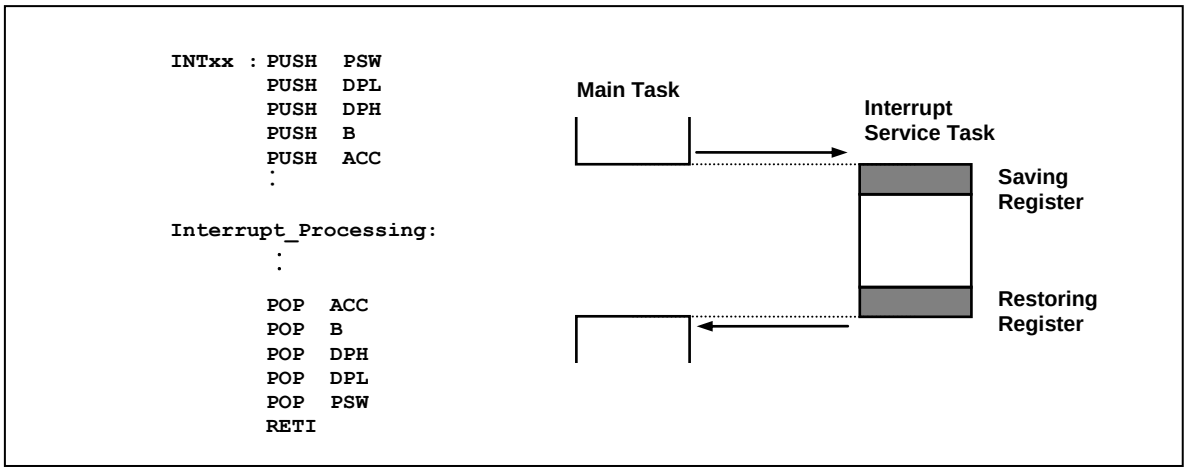


Figure 10.9 Saving/Restore Process Diagram and Sample Source

10.11 Interrupt Timing

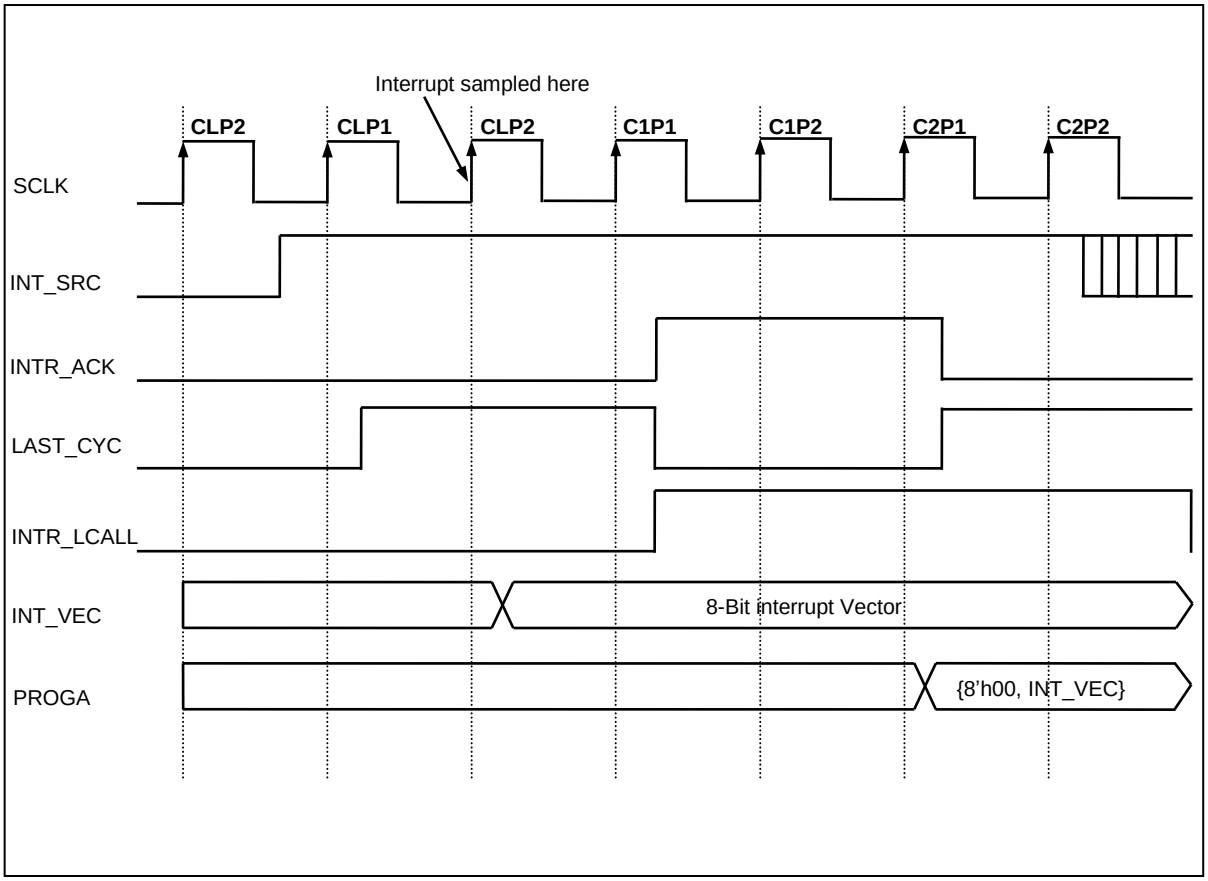


Figure 10.10 Timing Chart of Interrupt Acceptance and Interrupt Return Instruction

Interrupt sources are sampled at the last cycle of a command. If an interrupt source is detected the lower 8-bit of interrupt vector (INT_VEC) is decided. M8051W core makes interrupt acknowledge at the first cycle of a command, and executes long call to jump to interrupt service routine.

NOTE) command cycle CLPx: L=Last cycle, 1=1st cycle or 1st phase, 2=2nd cycle or 2nd phase

10.12 Interrupt Register Overview

10.12.1 Interrupt Enable Register (IE, IE1, IE2, IE3)

Interrupt enable register consists of global interrupt control bit (EA) and peripheral interrupt control bits. Total 24 peripherals are able to control interrupt.

10.12.2 Interrupt Priority Register (IP, IP1)

The 24 interrupts are divided into 6 groups which have each 4 interrupt sources. A group can be assigned 4 levels interrupt priority using interrupt priority register. Level 3 is the highest priority, while level 0 is the lowest priority. After a reset IP and IP1 are cleared to '00H'. If interrupts have the same priority level, lower number interrupt is served first.

10.12.3 External Interrupt Flag Register (EIFLAG0, EIFLAG1)

The external interrupt flag 0 register (EIFLAG0) and external interrupt flag 1 register (EIFLAG1) are set to '1' when the external interrupt generating condition is satisfied. The flag is cleared when the interrupt service routine is executed. Alternatively, the flag can be cleared by writing '0' to it.

10.12.4 External Interrupt Polarity Register (EIPOL0H, EIPOL0L, EIPOL1, EIPOL2)

The external interrupt polarity 0 high/low register (EIPOL0H/L), external interrupt polarity 1 register (EIPOL1) and external interrupt polarity 2 register (EIPOL2) determines which type of rising/falling/both edge interrupt. Initially, default value is no interrupt at any edge.

10.12.5 Register Map

Table 10-3 Interrupt Register Map

Name	Address	Dir	Default	Description
IE	A8H	R/W	00H	Interrupt Enable Register
IE1	A9H	R/W	00H	Interrupt Enable Register 1
IE2	AAH	R/W	00H	Interrupt Enable Register 2
IE3	ABH	R/W	00H	Interrupt Enable Register 3
IP	B8H	R/W	00H	Interrupt Priority Register
IP1	F8H	R/W	00H	Interrupt Priority Register 1
IIFLAG	A0H	R/W	00H	Internal Interrupt Flag Register
EIFLAG0	C0H	R/W	00H	External Interrupt Flag 0 Register
EIPOL0L	A4H	R/W	00H	External Interrupt Polarity 0 Low Register
EIPOL0H	A5H	R/W	00H	External Interrupt Polarity 0 High Register
EIFLAG1	B0H	R/W	00H	External Interrupt Flag 1 Register
EIPOL1	A6H	R/W	00H	External Interrupt Polarity 1 Register
EIPOL2	A7H	R/W	00H	External Interrupt Polarity 2 Register

10.13 Interrupt Register Description

The interrupt register is used for controlling interrupt functions. Also it has external interrupt control registers. The interrupt register consists of interrupt enable register (IE), interrupt enable register 1 (IE1), interrupt enable register 2 (IE2) and interrupt enable register 3 (IE3). For external interrupt, it consists of external interrupt flag 0 register (EIFLAG0), external interrupt polarity 0 high/low register (EIPOL0H/L), external interrupt flag 1 register (EIFLAG1), external interrupt polarity 1 register (EIPOL1) and external interrupt polarity 2 register (EIPOL2).

10.13.1 Register Description for Interrupt

IE (Interrupt Enable Register) : A8H

7	6	5	4	3	2	1	0
EA	–	INT5E	–	–	INT2E	INT1E	INT0E
R/W	–	R/W	–	–	R/W	R/W	R/W

Initial value : 00H

EA	Enable or Disable All Interrupt bits	
	0	All Interrupt disable
	1	All Interrupt enable
INT5E	Enable or Disable External Interrupt 0 ~ 4 (EINT0 ~ EINT4)	
	0	Disable
	1	Enable
INT2E	Enable or Disable External Interrupt 12(EINT12)	
	0	Disable
	1	Enable
INT1E	Enable or Disable External Interrupt 11(EINT11)	
	0	Disable
	1	Enable
INT0E	Enable or Disable External Interrupt 10 (EINT10)	
	0	Disable
	1	Enable

IE1 (Interrupt Enable Register 1): A9H

7	6	5	4	3	2	1	0
–	–	INT11E	INT10E	INT9E	INT8E	INT7E	INT6E
–	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

INT11E Enable or Disable ADC Wake-up Interrupt
- 0 Disable
- 1 Enable

INT10E Enable or Disable UART Tx Interrupt
- 0 Disable
- 1 Enable

INT9E Enable or Disable UART Rx Interrupt
- 0 Disable
- 1 Enable

INT8E Enable or Disable I2C Interrupt
- 0 Disable
- 1 Enable

INT7E Enable or Disable External Interrupt 6 (EINT6)
- 0 Disable
- 1 Enable

INT6E Enable or Disable External Interrupt 5 (EINT5)
- 0 Disable
- 1 Enable

IE2 (Interrupt Enable Register 2) : AAH

7	6	5	4	3	2	1	0
–	–	INT17E	–	INT15E	INT14E	INT13E	INT12E
–	–	R/W	–	R/W	R/W	R/W	R/W

Initial value : 00H

INT17E Enable or Disable External Interrupt 7 ~ A (EINT7 ~ EINTA)
- 0 Disable
- 1 Enable

INT15E Enable or Disable Timer 2 Match Interrupt
- 0 Disable
- 1 Enable

INT14E Enable or Disable Timer 1 Match Interrupt
- 0 Disable
- 1 Enable

INT13E Enable or Disable Timer 0 Match nterrupt
- 0 Disable
- 1 Enable

INT12E Enable or Disable Timer 0 Overflow Interrupt
- 0 Disable
- 1 Enable

IE3 (Interrupt Enable Register 3) : ABH

7	6	5	4	3	2	1	0
–	–	–	INT22E	INT21E	INT20E	INT19E	INT18E
–	–	–	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

INT22E	Enable or Disable BIT Interrupt	
	0	Disable
	1	Enable
INT21E	Enable or Disable WDT Interrupt	
	0	Disable
	1	Enable
INT20E	Enable or Disable WT Interrupt	
	0	Disable
	1	Enable
INT19E	Enable or Disable SPI Interrupt	
	0	Disable
	1	Enable
INT18E	Enable or Disable ADC Interrupt	
	0	Disable
	1	Enable

IP (Interrupt Priority Register) : B8H

7	6	5	4	3	2	1	0
–	–	IP5	IP4	IP3	IP2	IP1	IP0
–	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

IP1 (Interrupt Priority Register 1) : F8H

7	6	5	4	3	2	1	0
–	–	IP15	IP14	IP13	IP12	IP11	IP10
–	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

IP[5:0], IP1[5:0] Select Interrupt Group Priority

IP1x	IPx	Description
0	0	level 0 (lowest)
0	1	level 1
1	0	level 2
1	1	level 3 (highest)

IIFLAG (Internal Interrupt Flag Register) : A0H

7	6	5	4	3	2	1	0
–	–	–	–	–	IICIFR	T0OVIFR	T0IFR
–	–	–	–	–	R	R/W	R/W

Initial value : 00H

IICIFR This is an interrupt flag bit. When an interrupt occurs, this bit becomes ‘1’. This bit is cleared when write any values in the I2CSR register.

0 I2C interrupt no generation

1 I2C interrupt generation

T0OVIFR When T0 overflow interrupt occurs, this bit becomes ‘1’. For clearing bit, write ‘0’ to this bit or auto clear by INT_ACK signal.

0 T0 overflow interrupt no generation

1 T0 overflow interrupt generation

T0IFR When T0 interrupt occurs, this bit becomes ‘1’. For clearing bit, write ‘0’ to this bit or auto clear by INT_ACK signal.

0 T0 interrupt no generation

1 T0 interrupt generation

EIFLAG0 (External Interrupt Flag 0 Register) : C0H

7	6	5	4	3	2	1	0
–	FLAG6	FLAG5	FLAG4	FLAG3	FLAG2	FLAG1	FLAG0
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

EIFLAG0[6:5] When an External Interrupt 5 ~ 6 is occurred, the flag becomes '1'. The flag is cleared by writing '0' to the bit or automatically cleared by INT_ACK signal.

0 External Interrupt 5 ~ 6 not occurred

1 External Interrupt 5 ~ 6 occurred

EIFLAG0[4:0] When an External Interrupt 0 ~ 4 is occurred, the flag becomes '1'. The flag is cleared only by writing '0' to the bit. So, the flag should be cleared by software.

0 External Interrupt 0 ~ 4 not occurred

1 External Interrupt 0 ~ 4 occurred

EIPOL0H (External Interrupt Polarity 0 High Register): A5H

7	6	5	4	3	2	1	0
–	–	POL6		POL5		POL4	
–	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

EIPOL0H[5:0] External interrupt (EINT6, EINT5, EINT4) polarity selection

POLn[1:0]		Description
0	0	No interrupt at any edge
0	1	Interrupt on rising edge
1	0	Interrupt on falling edge
1	1	Interrupt on both of rising and falling edge

Where n =4, 5 and 6

EIPOL0L (External Interrupt Polarity 0 Low Register): A4H

7	6	5	4	3	2	1	0
POL3		POL2		POL1		POL0	
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

EIPOL0L[7:0] External interrupt (EINT3, EINT2, EINT1, EINT0) polarity selection

POLn[1:0]		Description
0	0	No interrupt at any edge
0	1	Interrupt on rising edge
1	0	Interrupt on falling edge
1	1	Interrupt on both of rising and falling edge

Where n =0, 1, 2 and 3

EIFLAG1 (External Interrupt Flag 1 Register) : B0H

7	6	5	4	3	2	1	0
–	FLAG12	FLAG11	FLAG10	FLAGA	FLAG9	FLAG8	FLAG7
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

EIFLAG1[6:4] When an External Interrupt 10 ~ 12 is occurred, the flag becomes '1'. The flag is cleared by writing '0' to the bit or automatically cleared by INT_ACK signal.

0 External Interrupt 10 ~ 12 not occurred

1 External Interrupt 10 ~ 12 occurred

EIFLAG1[3:0] When an External Interrupt 7 ~ A is occurred, the flag becomes '1'. The flag is cleared only by writing '0' to the bit. So, the flag should be cleared by software.

0 External Interrupt 7 ~ A not occurred

1 External Interrupt 7 ~ A occurred

EIPOL1 (External Interrupt Polarity 1 Register): A6H

7	6	5	4	3	2	1	0
–	–	POL12		POL11		POL10	
–	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

EIPOL1[5:0] External interrupt (EINT12, EINT11, EINT10) polarity selection

POLn[1:0]		Description
0	0	No interrupt at any edge
0	1	Interrupt on rising edge
1	0	Interrupt on falling edge
1	1	Interrupt on both of rising and falling edge

Where n =10, 11 and 12

EIPOL2 (External Interrupt Polarity 2 Register): A7H

7	6	5	4	3	2	1	0
POLA		POL9		POL8		POL7	
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

EIPOL2[7:0] External interrupt (EINTA, EINT9, EINT8, EINT7) polarity selection

POLn[1:0]		Description
0	0	No interrupt at any edge
0	1	Interrupt on rising edge
1	0	Interrupt on falling edge
1	1	Interrupt on both of rising and falling edge

Where n = 7, 8, 9 and A

11. Peripheral Hardware

11.1 Clock Generator

11.1.1 Overview

As shown in Figure 11.1, the clock generator produces the basic clock pulses which provide the system clock to be supplied to the CPU and the peripheral hardware. It contains main/sub-frequency clock oscillator. The main/sub clock operation can be easily obtained by attaching a crystal between the XIN/SXIN and XOUT/SXOUT pin, respectively. The main/sub clock can be also obtained from the external oscillator. In this case, it is necessary to put the external clock signal into the XIN/SXIN pin and open the XOUT/SXOUT pin. The default system clock is 1MHz INT-RC Oscillator and the default division rate is sixteen. In order to stabilize system internally, it is used 1MHz INT-RC oscillator on POR.

- Calibrated Internal RC Oscillator (16 MHz)
  - . INT-RC OSC/1 (16 MHz)
  - . INT-RC OSC/2 (8 MHz)
  - . INT-RC OSC/4 (4 MHz)
  - . INT-RC OSC/8 (2 MHz)
  - . INT-RC OSC/16 (1 MHz, Default system clock)
  - . INT-RC OSC/32 (0.5 MHz)
- Main Crystal Oscillator (0.4~12 MHz)
- Sub Crystal Oscillator (32.768 kHz)
- Internal WDTRC Oscillator (5 kHz)

11.1.2 Block Diagram

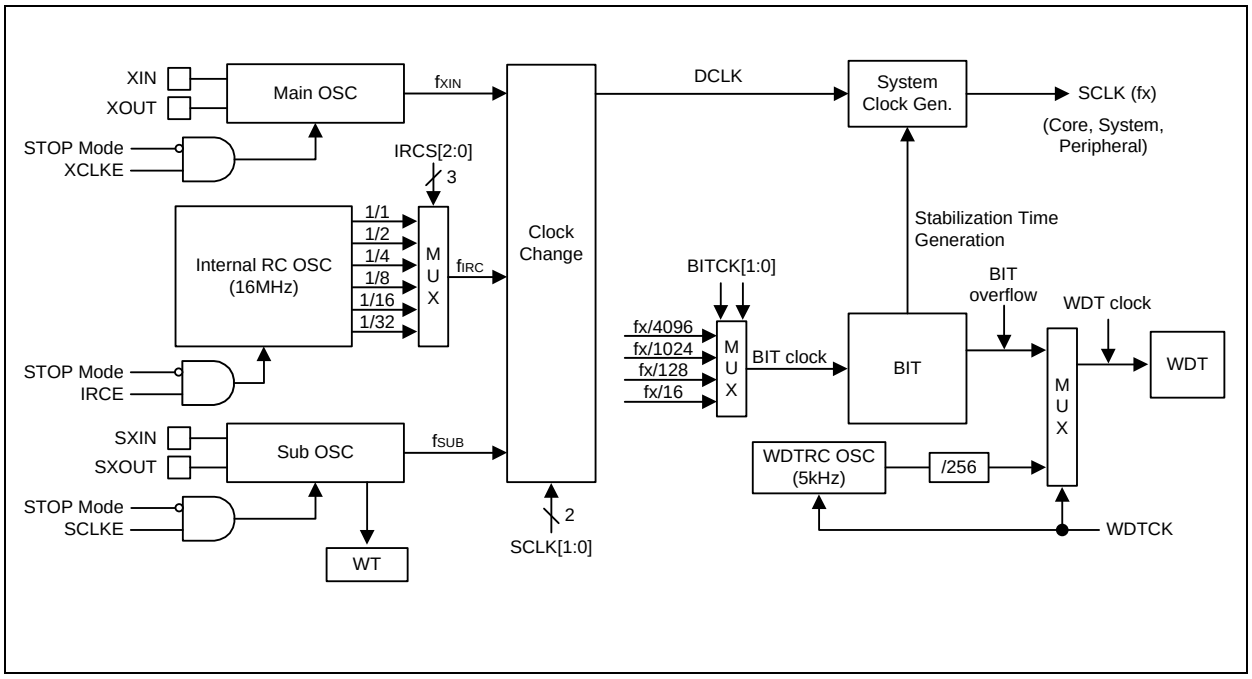


Figure 11.1 Clock Generator Block Diagram

11.1.3 Register Map

Table 11-1 Clock Generator Register Map

Name	Address	Dir	Default	Description
SCCR	8AH	R/W	00H	System and Clock Control Register
OSCCR	C8H	R/W	08H	Oscillator Control Register

11.1.4 Clock Generator Register Description

The clock generator register uses clock control for system operation. The clock generation consists of System and clock control register and oscillator control register.

11.1.5 Register Description for Clock Generator

SCCR (System and Clock Control Register) : 8AH

7	6	5	4	3	2	1	0
–	–	–	–	–	–	SCLK1	SCLK0
–	–	–	–	–	–	R/W	R/W

Initial value : 00H

SCLK [1:0] System Clock Selection Bit

SCLK1	SCLK0	Description
0	0	INT RC OSC (f_{IRC}) for system clock
0	1	External Main OSC (f_{XIN}) for system clock
1	0	External Sub OSC (f_{SUB}) for system clock
1	1	Not used

OSCCR (Oscillator Control Register) : C8H

7	6	5	4	3	2	1	0
–	–	IRCS2	IRCS1	IRCS0	IRCE	XCLKE	SCLKE
–	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 08H

IRCS[2:0] Internal RC Oscillator Post-divider Selection

IRCS2	IRCS1	IRCS0	Description
0	0	0	INT-RC/32 (0.5MHz)
0	0	1	INT-RC/16 (1MHz)
0	1	0	INT-RC/8 (2MHz)
0	1	1	INT-RC/4 (4MHz)
1	0	0	INT-RC/2 (8MHz)
1	0	1	INT-RC/1 (16MHz)
Other values			Not used

IRCE Control the Operation of the Internal RC Oscillator

0	Enable operation of INT-RC OSC
1	Disable operation of INT-RC OSC

XCLKE Control the Operation of the External Main Oscillator

0	Disable operation of X-TAL
1	Enable operation of X-TAL

SCLKE Control the Operation of the External Sub Oscillator

0	Disable operation of SX-TAL
1	Enable operation of SX-TAL

11.2 Basic Interval Timer

11.2.1 Overview

The MC96F8316 has one 8-bit basic interval timer that is free-run and can't stop. Block diagram is shown in Figure 11.2. In addition, the basic interval timer generates the time base for watchdog timer counting. It also provides a basic interval timer interrupt (BITIFR).

The MC96F8316 has these basic interval timer (BIT) features:

- During Power On, BIT gives a stable clock generation time
- On exiting Stop mode, BIT gives a stable clock generation time
- As timer function, timer interrupt occurrence

11.2.2 Block Diagram

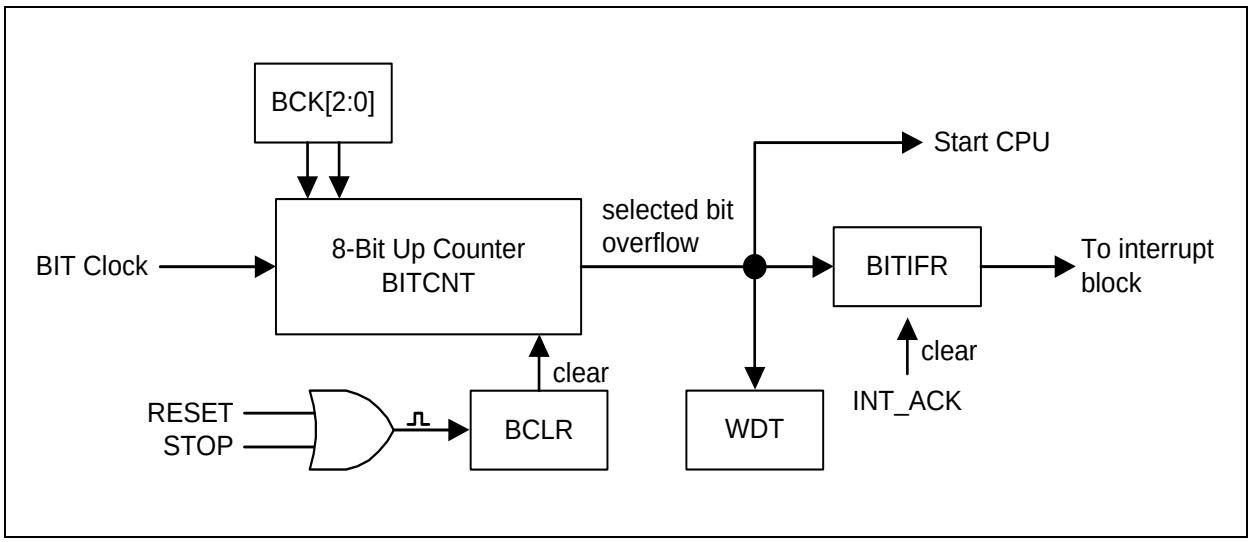


Figure 11.2 Basic Interval Timer Block Diagram

11.2.3 Register Map

Table 11-2 Basic Interval Timer Register Map

Name	Address	Dir	Default	Description
BITCNT	8CH	R	00H	Basic Interval Timer Counter Register
BITCR	8BH	R/W	01H	Basic Interval Timer Control Register

11.2.4 Basic Interval Timer Register Description

The basic interval timer register consists of basic interval timer counter register (BITCNT) and basic interval timer control register (BITCR). If BCLR bit is set to '1', BITCNT becomes '0' and then counts up. After 1 machine cycle, BCLR bit is cleared to '0' automatically.

11.2.5 Register Description for Basic Interval Timer

BITCNT (Basic Interval Timer Counter Register) : 8CH

7	6	5	4	3	2	1	0
BITCNT7	BITCNT6	BITCNT5	BITCNT4	BITCNT3	BITCNT2	BITCNT1	BITCNT0
R	R	R	R	R	R	R	R

Initial value : 00H

BITCNT[7:0] BIT Counter

BITCR (Basic Interval Timer Control Register) : 8BH

7	6	5	4	3	2	1	0
BITIFR	BITCK1	BITCK0	–	BCLR	BCK2	BCK1	BCK0
R/W	R/W	R/W	–	R/W	R/W	R/W	R/W

Initial value : 01H

BITIFR — When BIT Interrupt occurs, this bit becomes '1'. For clearing bit, write '0' to this bit or auto clear by INT_ACK signal.

0	BIT interrupt no generation
1	BIT interrupt generation

BITCK[1:0] — Select BIT clock source

BITCK1	BITCK0	Description
0	0	fx/4096
0	1	fx/1024
1	0	fx/128
1	1	fx/16

BCLR — If this bit is written to '1', BIT Counter is cleared to '0'

0	Free Running
1	Clear Counter

BCK[2:0] — Select BIT overflow period

BCK2	BCK1	BCK0	Description
0	0	0	Bit 0 overflow (BIT Clock * 2)
0	0	1	Bit 1 overflow (BIT Clock * 4) (default)
0	1	0	Bit 2 overflow (BIT Clock * 8)
0	1	1	Bit 3 overflow (BIT Clock * 16)
1	0	0	Bit 4 overflow (BIT Clock * 32)
1	0	1	Bit 5 overflow (BIT Clock * 64)
1	1	0	Bit 6 overflow (BIT Clock * 128)
1	1	1	Bit 7 overflow (BIT Clock * 256)

11.3 Watch Dog Timer

11.3.1 Overview

The watchdog timer rapidly detects the CPU malfunction such as endless looping caused by noise or something like that, and resumes the CPU to the normal state. The watchdog timer signal for malfunction detection can be used as either a CPU reset or an interrupt request. When the watchdog timer is not being used for malfunction detection, it can be used as a timer to generate an interrupt at fixed intervals. It is possible to use free running 8-bit timer mode (WDTRSON='0') or watch dog timer mode (WDTRSON='1') as setting WDTCR[6] bit. If WDTCR[5] is written to '1', WDT counter value is cleared and counts up. After 1 machine cycle, this bit is cleared to '0' automatically. The watchdog timer consists of 8-bit binary counter and the watchdog timer data register. When the value of 8-bit binary counter is equal to the 8 bits of WDTCNT, the interrupt request flag is generated. This can be used as Watchdog timer interrupt or reset of CPU in accordance with the bit WDTRSON.

The input clock source of watch dog timer is the BIT overflow. The interval of watchdog timer interrupt is decided by BIT overflow period and WDTDR set value. The equation can be described as

WDT Interrupt Interval = (BIT Interrupt Interval) X (WDTDR Value+1)

11.3.2 WDT Interrupt Timing Waveform

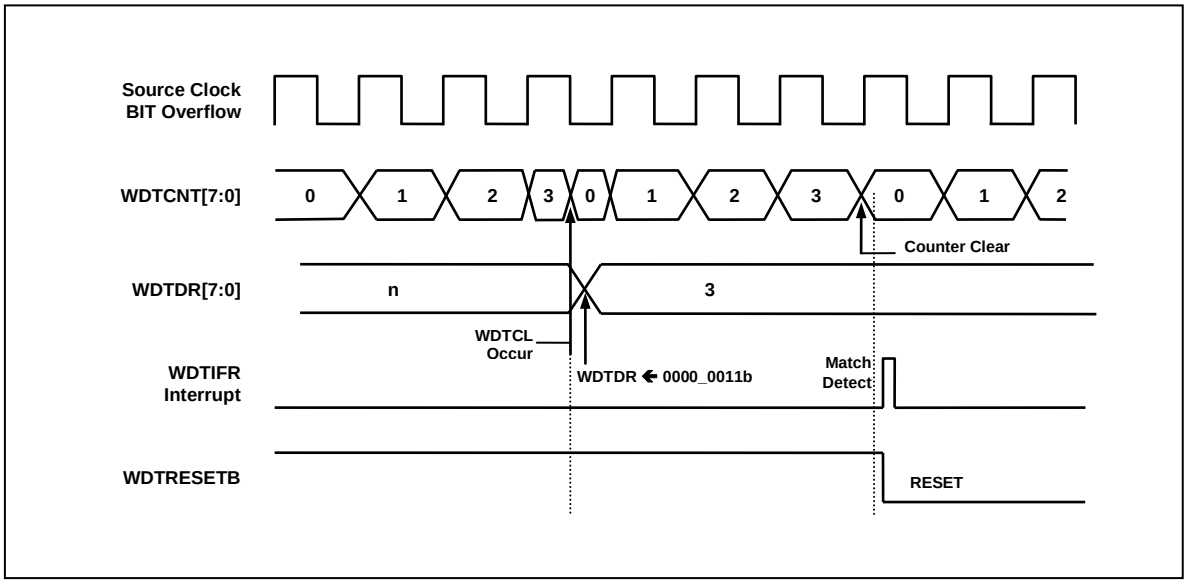


Figure 11.3 Watch Dog Timer Interrupt Timing Waveform

11.3.3 Block Diagram

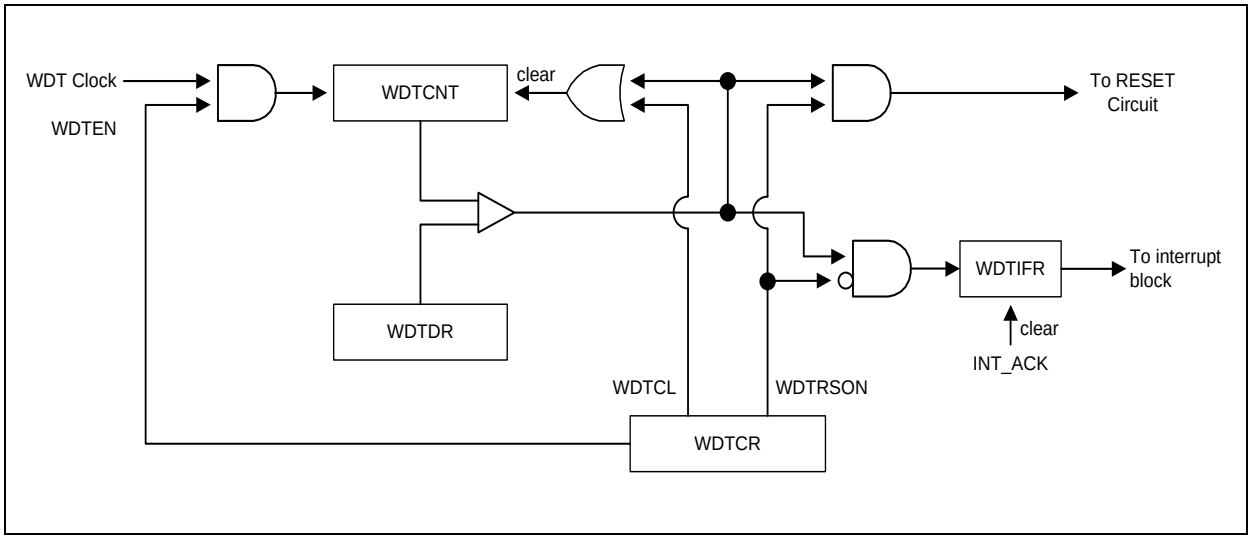


Figure 11.4 Watch Dog Timer Block Diagram

11.3.4 Register Map

Table 11-3 Watch Dog Timer Register Map

Name	Address	Dir	Default	Description
WDTCNT	8EH	R	00H	Watch Dog Timer Counter Register
WDTDR	8EH	W	FFH	Watch Dog Timer Data Register
WDTCR	8DH	R/W	00H	Watch Dog Timer Control Register

11.3.5 Watch Dog Timer Register Description

The watch dog timer register consists of watch dog timer counter register (WDTCNT), watch dog timer data register (WDTDR) and watch dog timer control register (WDTCR).

11.3.6 Register Description for Watch Dog Timer

WDTCNT (Watch Dog Timer Counter Register: Read Case) : 8EH

7	6	5	4	3	2	1	0
WDTCNT7	WDTCNT6	WDTCNT5	WDTCNT4	WDTCNT3	WDTCNT2	WDTCNT1	WDTCNT0
R	R	R	R	R	R	R	R

Initial value : 00H

WDTCNT[7:0] WDT Counter

WDTDR (Watch Dog Timer Data Register: Write Case) : 8EH

7	6	5	4	3	2	1	0
WDTDR7	WDTDR6	WDTDR5	WDTDR4	WDTDR3	WDTDR2	WDTDR1	WDTDR0
W	W	W	W	W	W	W	W

Initial value : FFH

WDTDR[7:0] Set a period
WDT Interrupt Interval=(BIT Interrupt Interval) x(WDTDR Value+1)
NOTE) Do not write “0” in the WDTDR register.

WDTCR (Watch Dog Timer Control Register) : 8DH

7	6	5	4	3	2	1	0
WDTEN	WDTRSON	WDTCL	–	–	–	WDTCK	WDTIFR
R/W	R/W	R/W	–	–	–	R/W	R/W

Initial value : 00H

WDTEN Control WDT Operation
0 Disable
1 Enable

WDTRSON Control WDT RESET Operation
0 Free Running 8-bit timer
1 Watch Dog Timer RESET ON

WDTCL Clear WDT Counter
0 Free Run
1 Clear WDT Counter (auto clear after 1 Cycle)

WDTCK Control WDT Clock Selection Bit
0 BIT overflow for WDT clock (WDTRC disable)
1 WDTRC for WDT clock (WDTRC enable)

WDTIFR When WDT Interrupt occurs, this bit becomes ‘1’. For clearing bit, write ‘0’ to this bit or auto clear by INT_ACK signal.
0 WDT Interrupt no generation
1 WDT Interrupt generation

11.4 Watch Timer

11.4.1 Overview

The watch timer has the function for RTC (Real Time Clock) operation. It is generally used for RTC design. The internal structure of the watch timer consists of the clock source select circuit, timer counter circuit, output select circuit, and watch timer control register. To operate the watch timer, determine the input clock source, output interval, and set WTEN to '1' in watch timer control register (WTCR). It is able to execute simultaneously or individually. To stop or reset WT, clear the WTEN bit in WTCR register. Even if CPU is STOP mode, sub clock is able to be so alive that WT can continue the operation. The watch timer counter circuits may be composed of 21-bit counter which contains low 14-bit with binary counter and high 7-bit counter in order to raise resolution. In WTDR, it can control WT clear and set interval value at write time, and it can read 7-bit WT counter value at read time.

11.4.2 Block Diagram

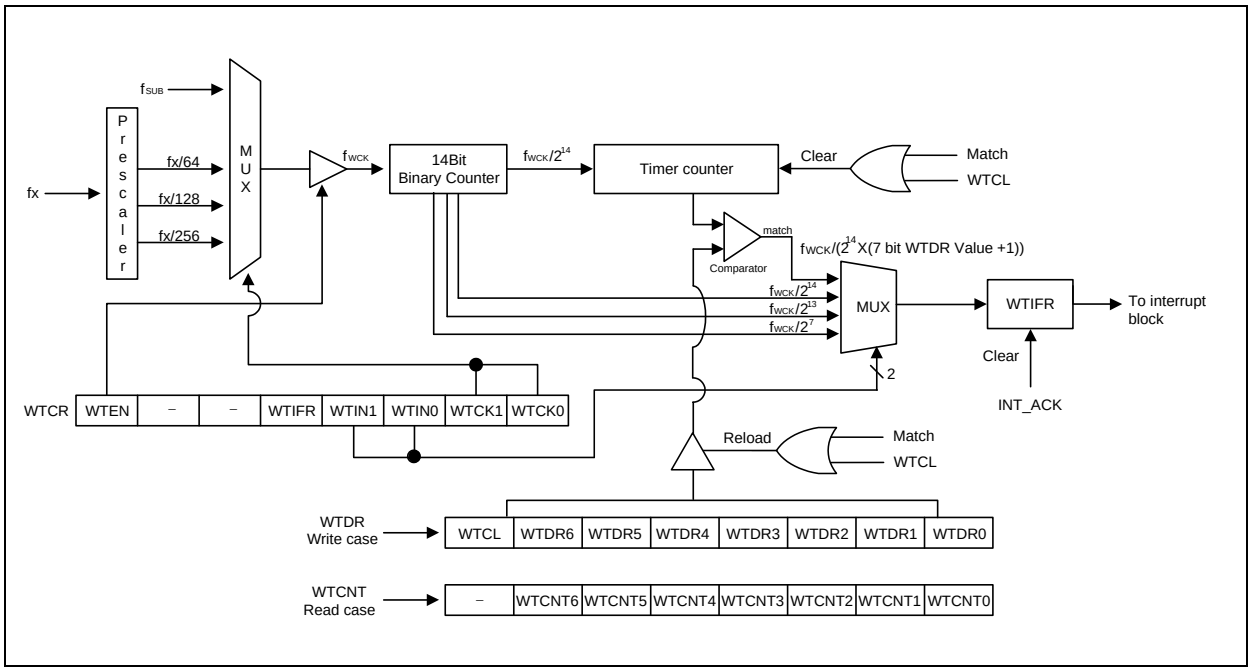


Figure 11.5 Watch Timer Block Diagram

11.4.3 Register Map

Table 11-4 Watch Timer Register Map

Name	Address	Dir	Default	Description
WTCNT	89H	R	00H	Watch Timer Counter Register
WTDR	89H	W	7FH	Watch Timer Data Register
WTCR	96H	R/W	00H	Watch Timer Control Register

11.4.4 Watch Timer Register Description

The watch timer register consists of watch timer counter register (WTCNT), watch timer data register (WTDR), and watch timer control register (WTCR). As WTCR is 6-bit writable/readable register, WTCR can control the clock source (WTCK[1:0]), interrupt interval (WTIN[1:0]), and function enable/disable (WTEN). Also there is WT interrupt flag bit (WTIFR).

11.4.5 Register Description for Watch Timer

WTCNT (Watch Timer Counter Register: Read Case) : 89H

7	6	5	4	3	2	1	0
–	WTCNT6	WTCNT5	WTCNT4	WTCNT3	WTCNT2	WTCNT1	WTCNT0
–	R	R	R	R	R	R	R

Initial value : 00H

WTCNT[6:0] WT Counter

WTDR (Watch Timer Data Register: Write Case) : 89H

7	6	5	4	3	2	1	0
WTCL	WTDR6	WTDR5	WTDR4	WTDR3	WTDR2	WTDR1	WTDR0
R/W	W	W	W	W	W	W	W

Initial value : 7FH

WTCL Clear WT Counter
0 Free Run
1 Clear WT Counter (auto clear after 1 Cycle)

WTDR[6:0] Set WT period
WT Interrupt Interval=fwck/(2^14 x(7bit WTDR Value+1))
NOTE) Do not write “0” in the WTDR register.

WTCR (Watch Timer Control Register) : 96H

7	6	5	4	3	2	1	0
WTEN	–	–	WTIFR	WTIN1	WTIN0	WTCK1	WTCK0
R/W	–	–	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

WTEN Control Watch Timer

0	Disable
1	Enable

WTIFR When WT Interrupt occurs, this bit becomes '1'. For clearing bit, write '0' to this bit or automatically clear by INT_ACK signal.

0	WT Interrupt no generation
1	WT Interrupt generation

WTIN[1:0] Determine interrupt interval

WTIN1	WTIN0	Description
0	0	f_{WCK}/2^7
0	1	f_{WCK}/2^13
1	0	f_{WCK}/2^14
1	1	f_{WCK}/(2^14 x (7bit WTDR Value+1))

WTCK[1:0] Determine Source Clock

WTCK1	WTCK0	Description
0	0	f_{SUB}
0	1	f_X/256
1	0	f_X/128
1	1	f_X/64

NOTE) f_X – System clock frequency (Where fx= 4.19MHz)

f_{SUB} – Sub clock oscillator frequency (32.768kHz)

f_{WCK} – Selected Watch timer clock

11.5 Timer 0

11.5.1 Overview

The 8-bit timer 0 consists of multiplexer, timer 0 counter register, timer 0 data register, timer 0 capture data register and timer 0 control register (T0CNT, T0DR, T0CDR, T0CR).

It has three operating modes:

- 8-bit timer/counter mode
- 8-bit PWM output mode
- 8-bit capture mode

The timer/counter 0 can be clocked by an internal or an external clock source (EC0). The clock source is selected by clock selection logic which is controlled by the clock selection bits (T0CK[2:0]).

- TIMER 0 clock source: f_X/2, 4, 8, 32, 128, 512, 2048 and EC0

In the capture mode, by EINT10, the data is captured into input capture data register (T0CDR). In timer/counter mode, whenever counter value is equal to T0DR, T0O port toggles. Also the timer 0 outputs PWM waveform through PWM0O port in the PWM mode.

Table 11-5 Timer 0 Operating Modes

T0EN	T0MS[1:0]	T0CK[2:0]	Timer 0
1	00	XXX	8 Bit Timer/Counter Mode
1	01	XXX	8 Bit PWM Mode
1	1X	XXX	8 Bit Capture Mode

11.5.2 8-Bit Timer/Counter Mode

The 8-bit timer/counter mode is selected by control register as shown in Figure 11.6.

The 8-bit timer have counter and data register. The counter register is increased by internal or external clock input. Timer 0 can use the input clock with one of 2, 4, 8, 32, 128, 512 and 2048 prescaler division rates (T0CK[2:0]). When the value of T0CNT and T0DR is identical in timer 0, a match signal is generated and the interrupt of Timer 0 occurs. T0CNT value is automatically cleared by match signal. It can be also cleared by software (T0CC).

The external clock (EC0) counts up the timer at the rising edge. If the EC0 is selected as a clock source by T0CK[2:0], EC0 port should be set to the input port by P26IO bit.

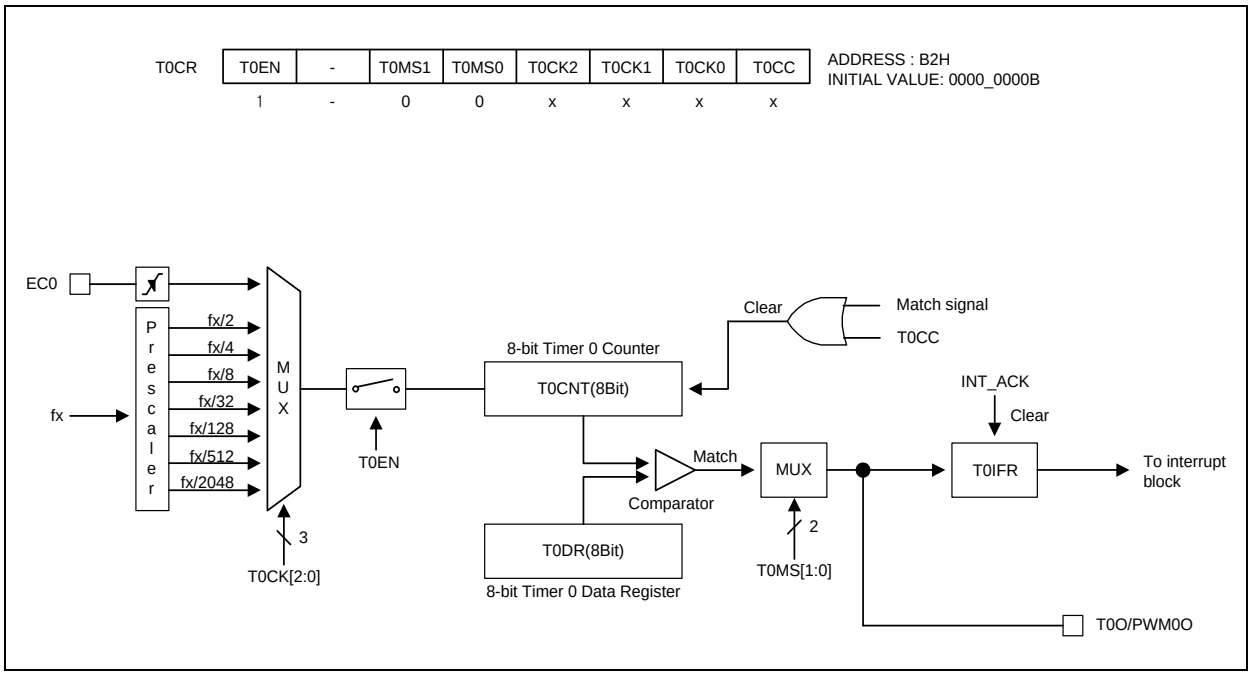


Figure 11.6 8-Bit Timer/Counter Mode for Timer 0

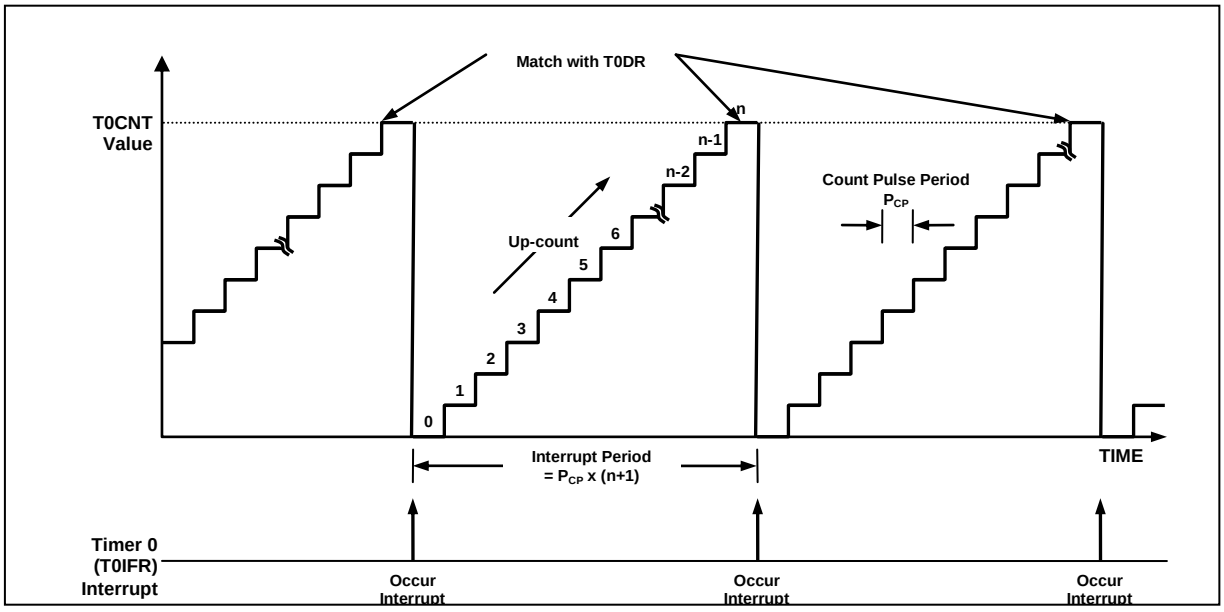


Figure 11.7 8-Bit Timer/Counter 0 Example

11.5.3 8-Bit PWM Mode

The timer 0 has a high speed PWM (Pulse Width Modulation) function. In PWM mode, T0O/PWM0O pin outputs up to 8-bit resolution PWM output. This pin should be configured as a PWM output by setting the T0O/PWM0O function by P3FSR[5] bit. In the 8-bit timer/counter mode, a match signal is generated when the counter value is identical to the value of T0DR. When the value of T0CNT and T0DR is identical in timer 0, a match signal is generated and the interrupt of timer 0 occurs. In PWM mode, the match signal does not clear the counter. Instead, it runs continuously, overflowing at “FFH”, and then continues incrementing from “00H”. The timer 0 overflow interrupt is generated whenever a counter overflow occurs. T0CNT value is cleared by software (T0CC) bit.

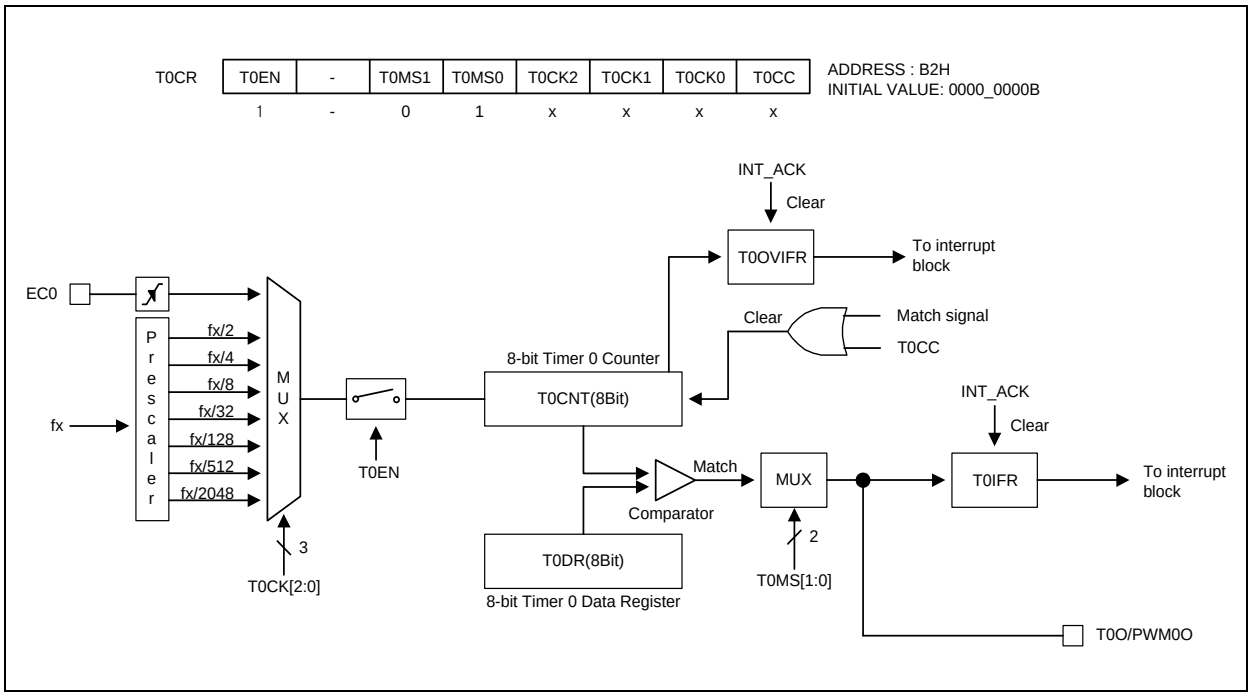


Figure 11.8 8-Bit PWM Mode for Timer 0

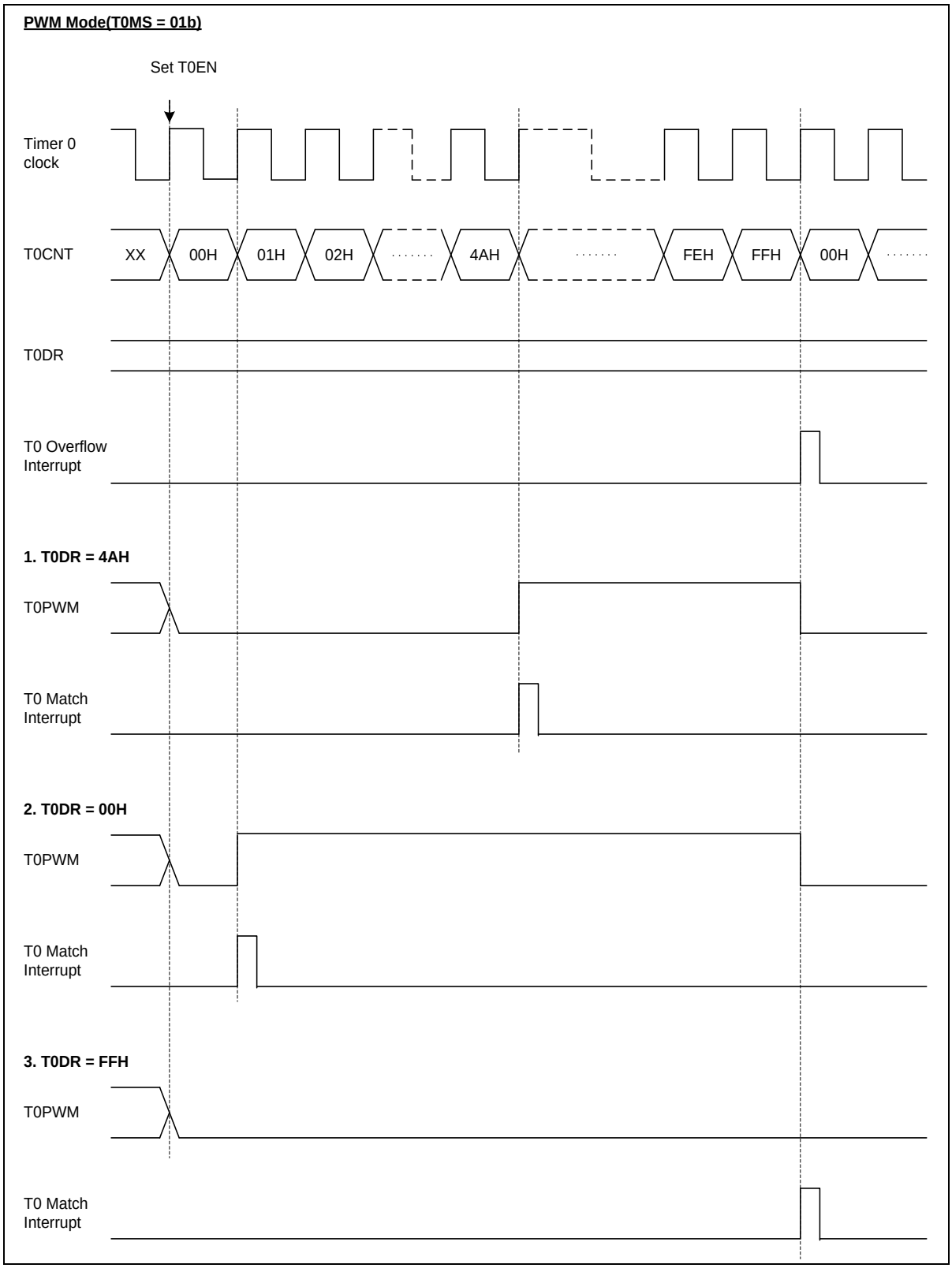


Figure 11.9 PWM Output Waveforms in PWM Mode for Timer 0

11.5.4 8-Bit Capture Mode

The timer 0 capture mode is set by T0MS[1:0] as '1x'. The clock source can use the internal/external clock. Basically, it has the same function as the 8-bit timer/counter mode and the interrupt occurs when T0CNT is equal to T0DR. T0CNT value is automatically cleared by match signal and it can be also cleared by software (T0CC).

This timer interrupt in capture mode is very useful when the pulse width of captured signal is wider than the maximum period of timer.

The capture result is loaded into T0CDR. In the timer 0 capture mode, timer 0 output (T0O) waveform is not available.

According to EIPOL1 registers setting, the external interrupt EINT10 function is chosen. Of cource, the EINT10 pin must be set to an input port.

T0CDR and T0DR are in the same address. In the capture mode, reading operation reads T0CDR, not T0DR and writing operation will update T0DR.

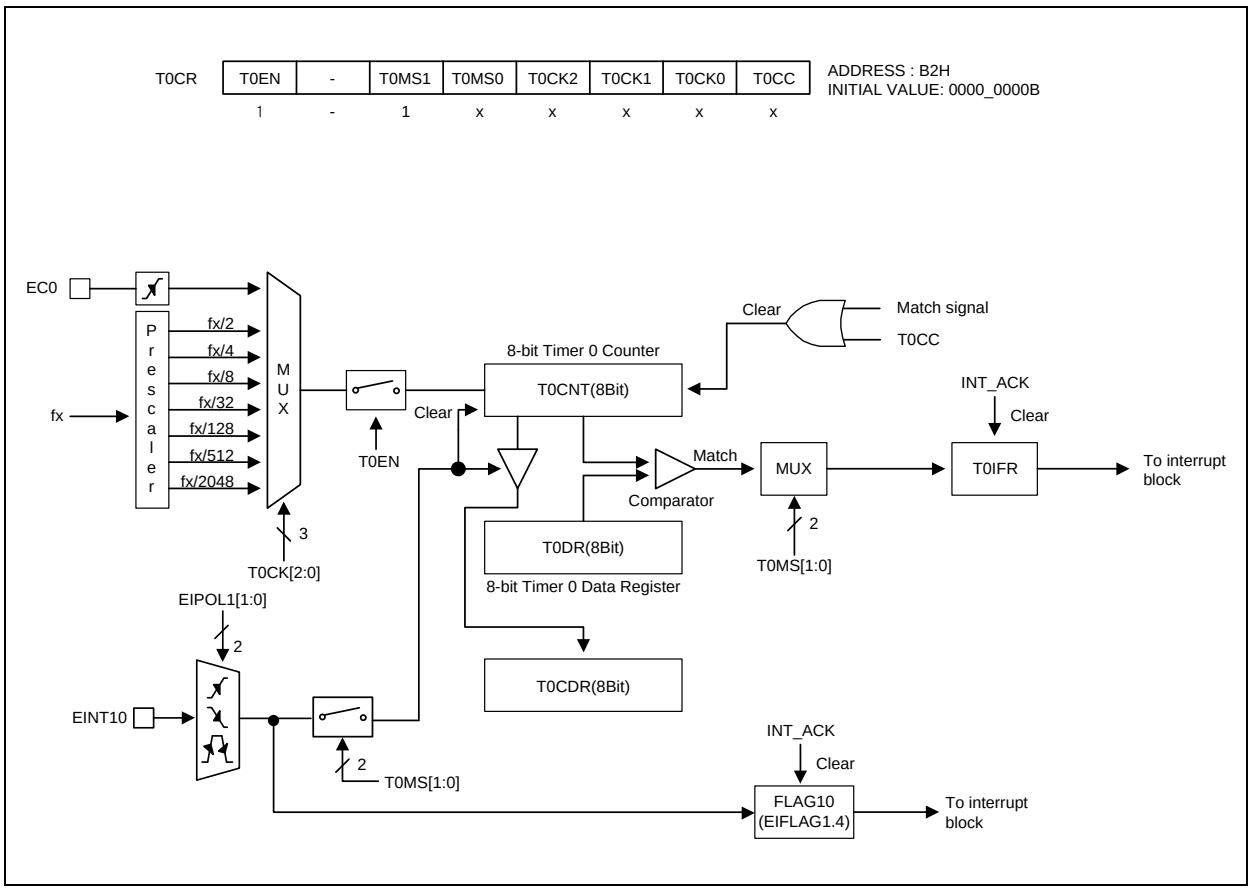


Figure 11.10 8-Bit Capture Mode for Timer 0

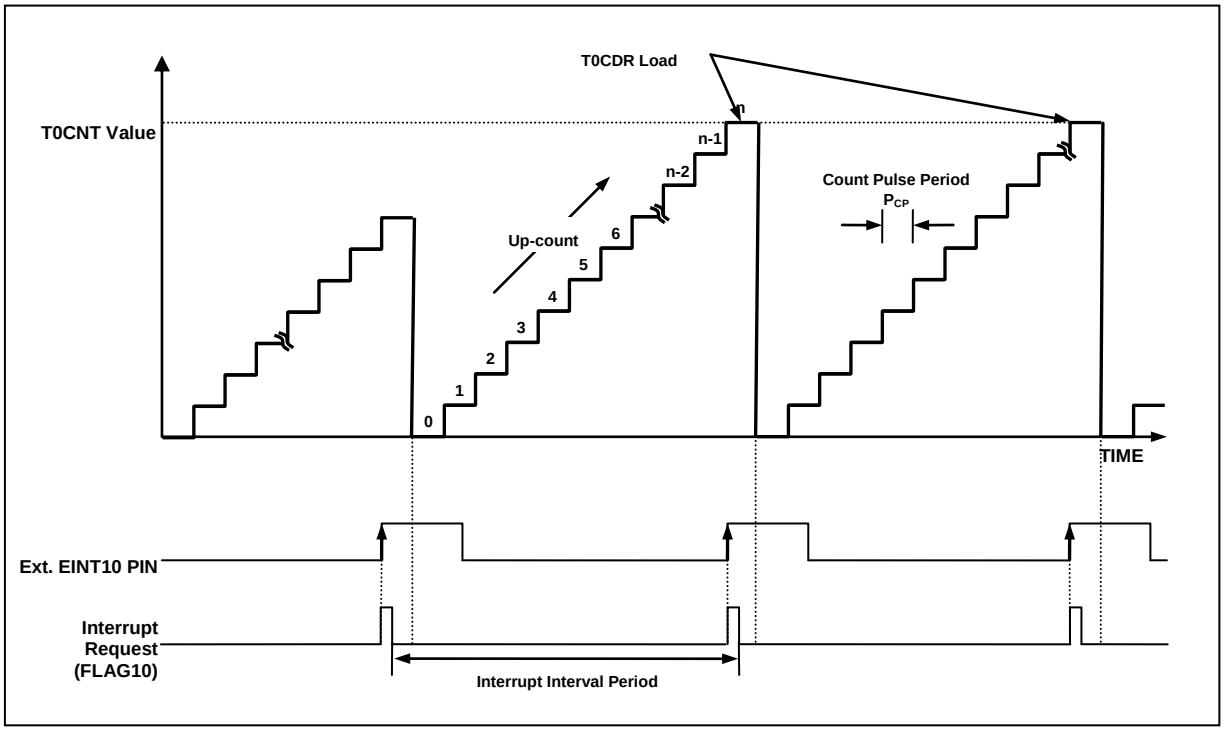


Figure 11.11 Input Capture Mode Operation for Timer 0

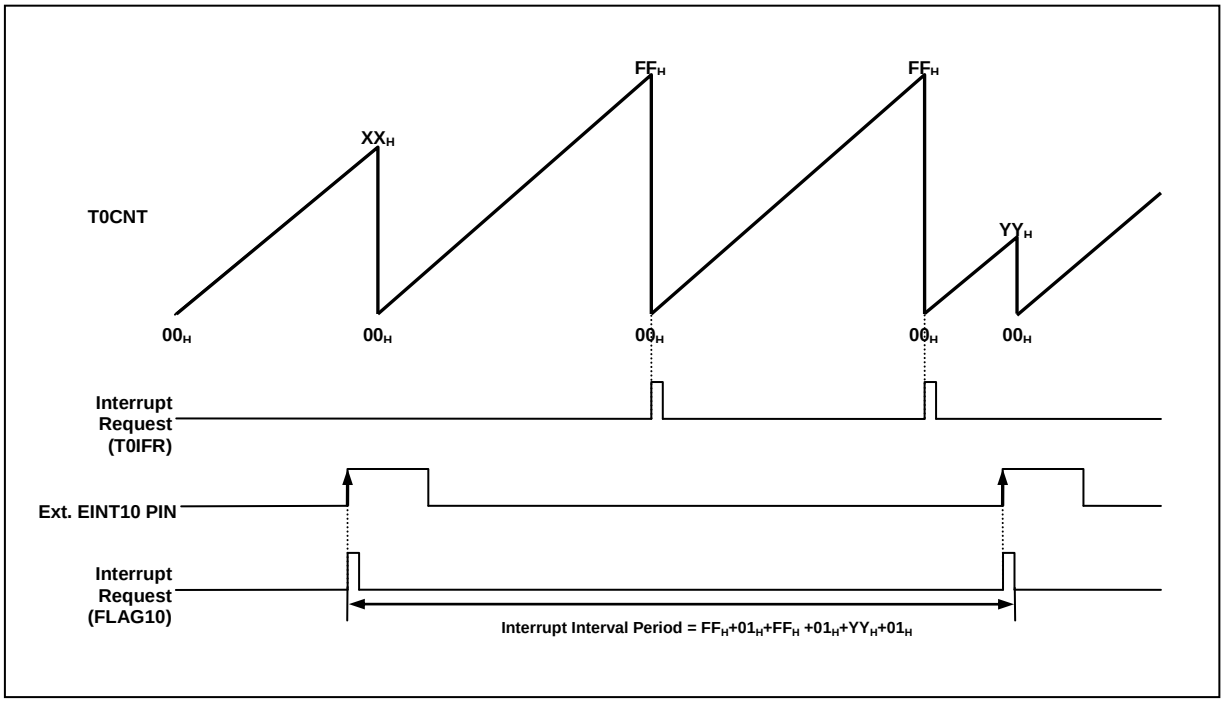


Figure 11.12 Express Timer Overflow in Capture Mode

11.5.5 Block Diagram

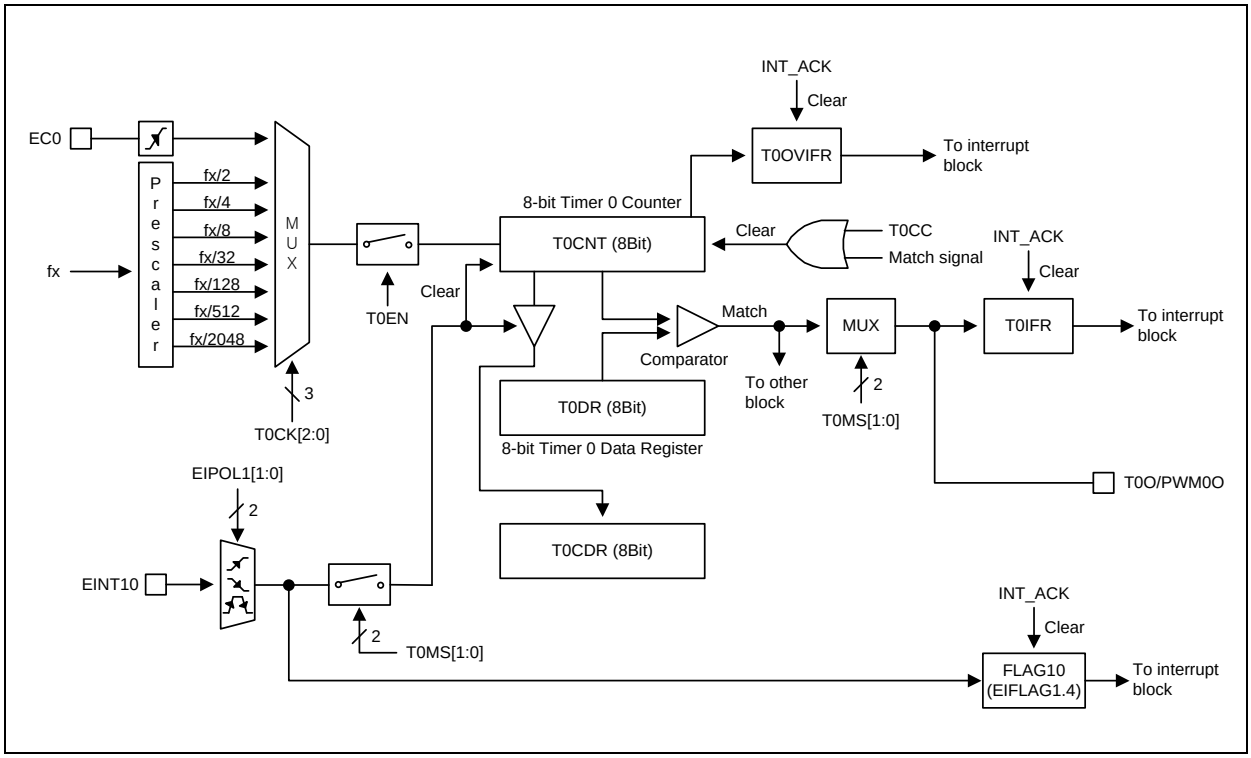


Figure 11.13 8-Bit Timer 0 Block Diagram

11.5.6 Register Map

Table 11-6 Timer 0 Register Map

Name	Address	Dir	Default	Description
T0CNT	B3H	R	00H	Timer 0 Counter Register
T0DR	B4H	R/W	FFH	Timer 0 Data Register
T0CDR	B4H	R	00H	Timer 0 Capture Data Register
T0CR	B2H	R/W	00H	Timer 0 Control Register

11.5.6.1 Timer/Counter 0 Register Description

The timer/counter 0 register consists of timer 0 counter register (T0CNT), timer 0 data register (T0DR), timer 0 capture data register (T0CDR), and timer 0 control register (T0CR). T0IFR and T0OVIFR bits are in the internal interrupt flag register (IIFLAG).

11.5.6.2 Register Description for Timer/Counter 0

T0CNT (Timer 0 Counter Register) : B3H

7	6	5	4	3	2	1	0
T0CNT7	T0CNT6	T0CNT5	T0CNT4	T0CNT3	T0CNT2	T0CNT1	T0CNT0
R	R	R	R	R	R	R	R

Initial value : 00H

T0CNT[7:0] T0 Counter

T0DR (Timer 0 Data Register) : B4H

7	6	5	4	3	2	1	0
T0DR7	T0DR6	T0DR5	T0DR4	T0DR3	T0DR2	T0DR1	T0DR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T0DR[7:0] T0 Data

T0CDR (Timer 0 Capture Data Register: Read Case, Capture mode only) : B4H

7	6	5	4	3	2	1	0
T0CDR7	T0CDR6	T0CDR5	T0CDR4	T0CDR3	T0CDR2	T0CDR1	T0CDR0
R	R	R	R	R	R	R	R

Initial value : 00H

T0CDR[7:0] T0 Capture Data

T0CR (Timer 0 Control Register) : B2H

7	6	5	4	3	2	1	0
T0EN	–	T0MS1	T0MS0	T0CK2	T0CK1	T0CK0	T0CC
R/W	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

T0EN Control Timer 0

0	Timer 0 disable
1	Timer 0 enable

T0MS[1:0] Control Timer 0 Operation Mode

T0MS1	T0MS0	Description
0	0	Timer/counter mode (T0O: toggle at match)
0	1	PWM mode (The overflow interrupt can occur)
1	x	Capture mode (The match interrupt can occur)

T0CK[2:0] Select Timer 0 clock source. fx is a system clock frequency

T0CK2	T0CK1	T0CK0	Description
0	0	0	fx/2
0	0	1	fx/4
0	1	0	fx/8
0	1	1	fx/32
1	0	0	fx/128
1	0	1	fx/512
1	1	0	fx/2048
1	1	1	External Clock (EC0)

T0CC Clear timer 0 Counter

0	No effect
1	Clear the Timer 0 counter (When write, automatically cleared “0” after being cleared counter)

NOTE) Refer to the internal interrupt flag register (IIFLAG) for the T0 interrupt flags.

11.6 Timer 1

11.6.1.1 Overview

The 16-bit timer 1 consists of multiplexer, timer 1 A data register high/low, timer 1 B data register high/low and timer 1 control register high/low (T1ADRH, T1ADRL, T1BDRH, T1BDRL, T1CRH, T1CRL).

It has four operating modes:

- 16-bit timer/counter mode
- 16-bit capture mode
- 16-bit PPG output mode (one-shot mode)
- 16-bit PPG output mode (repeat mode)

The timer/counter 1 can be clocked by an internal or an external clock source (EC1). The clock source is selected by clock selection logic which is controlled by the clock selection bits (T1CK[2:0]).

- TIMER 1 clock source: f_X/1, 2, 4, 8, 64, 512, 2048 and EC1

In the capture mode, by EINT11, the data is captured into input capture data register (T1BDRH/T1BDRL). Timer 1 outputs the comparision result between counter and data register through T1O port in timer/counter mode. Also Ttimer 1 outputs PWM wave form through PWM1O port in the PPG mode.

Table 11-7 Timer 1 Operating Modes

T1EN	P1FSRL[4:3]	T1MS[1:0]	T1CK[2:0]	Timer 1
1	01	00	XXX	16 Bit Timer/Counter Mode
1	00	01	XXX	16 Bit Capture Mode
1	01	10	XXX	16 Bit PPG Mode (one-shot mode)
1	01	11	XXX	16 Bit PPG Mode (repeat mode)

11.6.2 16-Bit Timer/Counter Mode

The 16-bit timer/counter mode is selected by control register as shown in Figure 11.14.

The 16-bit timer have counter and data register. The counter register is increased by internal or external clock input. Timer 1 can use the input clock with one of 1, 2, 4, 8, 64, 512 and 2048 prescaler division rates (T1CK[2:0]). When the value of T1CNTH, T1CNTL and the value of T1ADRH, T1ADRL are identical in Timer 1 respectively, a match signal is generated and the interrupt of Timer 1 occurs. The T1CNTH, T1CNTL value is automatically cleared by match signal. It can be also cleared by software (T1CC).

The external clock (EC1) counts up the timer at the rising edge. If the EC1 is selected as a clock source by T1CK[2:0], EC1 port should be set to the input port by P11IO bit.

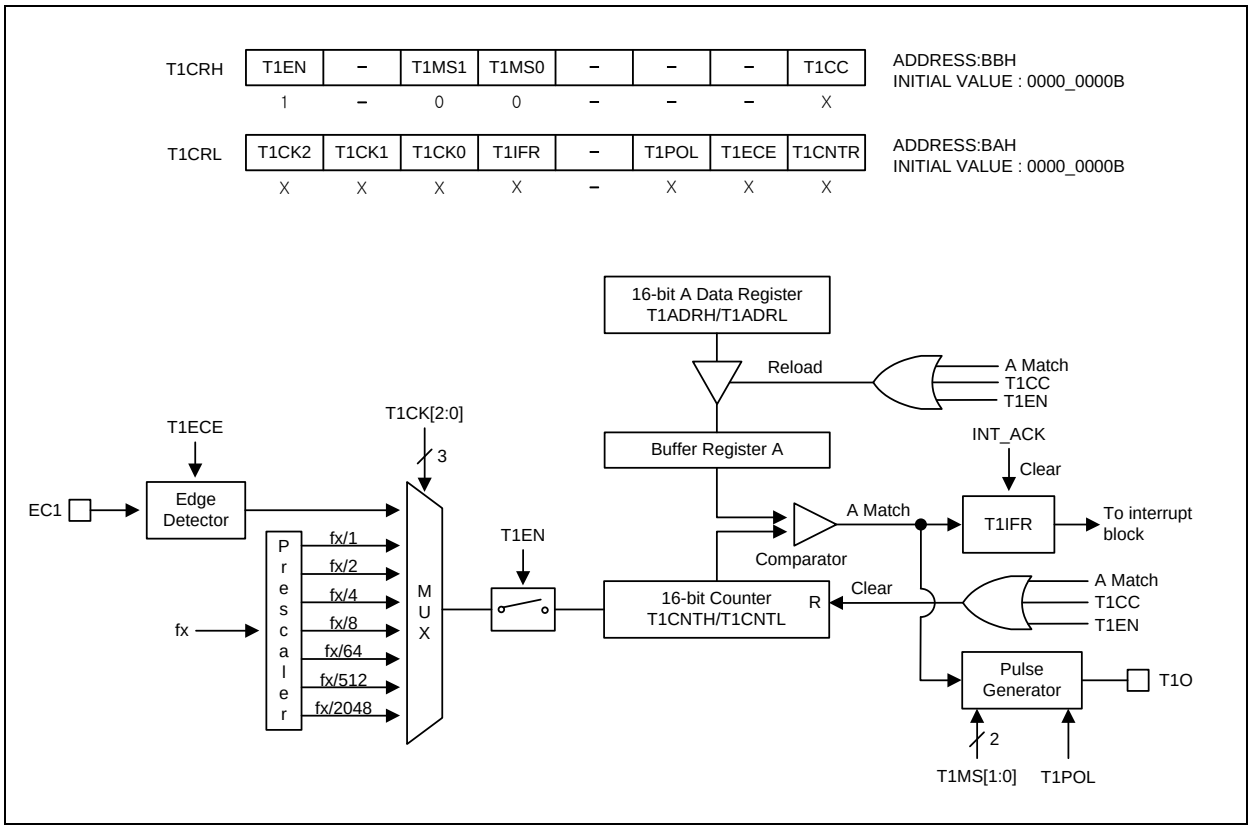


Figure 11.14 16-Bit Timer/Counter Mode for Timer 1

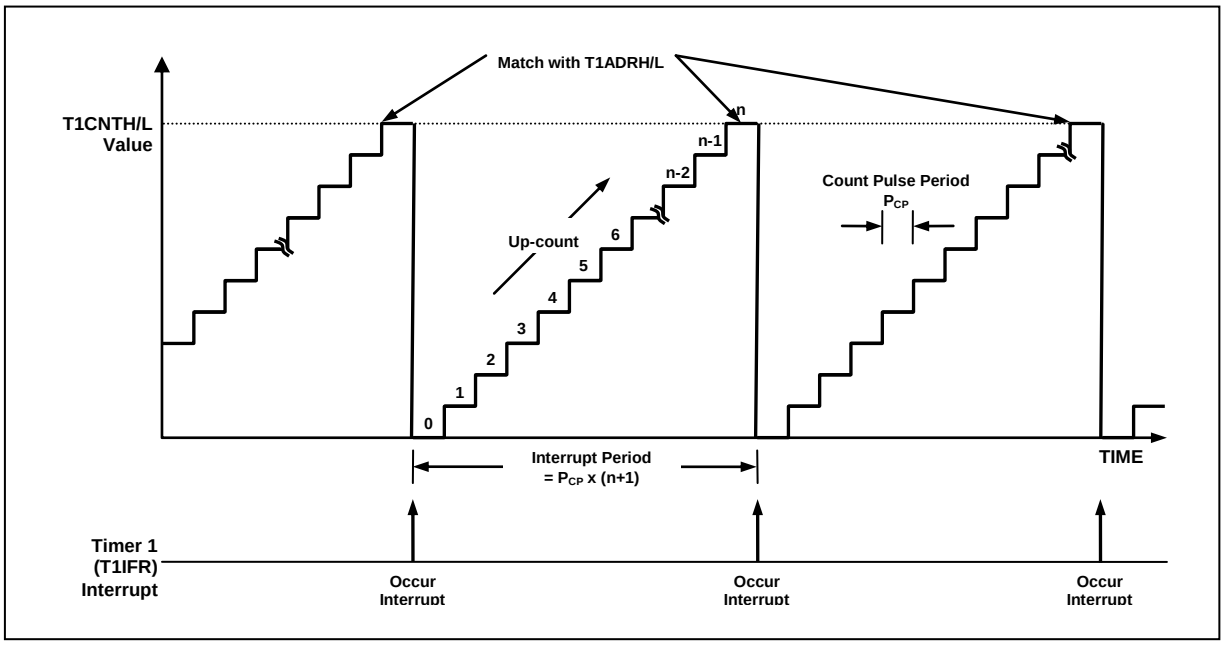


Figure 11.15 16-Bit Timer/Counter 1 Example

11.6.3 16-Bit Capture Mode

The 16-bit timer 1 capture mode is set by T1MS[1:0] as '01'. The clock source can use the internal/external clock. Basically, it has the same function as the 16-bit timer/counter mode and the interrupt occurs when T1CNTH/T1CNTL is equal to T1ADRH/T1ADRL. The T1CNTH, T1CNTL values are automatically cleared by match signal. It can be also cleared by software (T1CC).

This timer interrupt in capture mode is very useful when the pulse width of captured signal is wider than the maximum period of timer.

The capture result is loaded into T1BDRH/T1BDRL.

According to EIPOL1 registers setting, the external interrupt EINT11 function is chosen. Of cource, the EINT11 pin must be set as an input port.

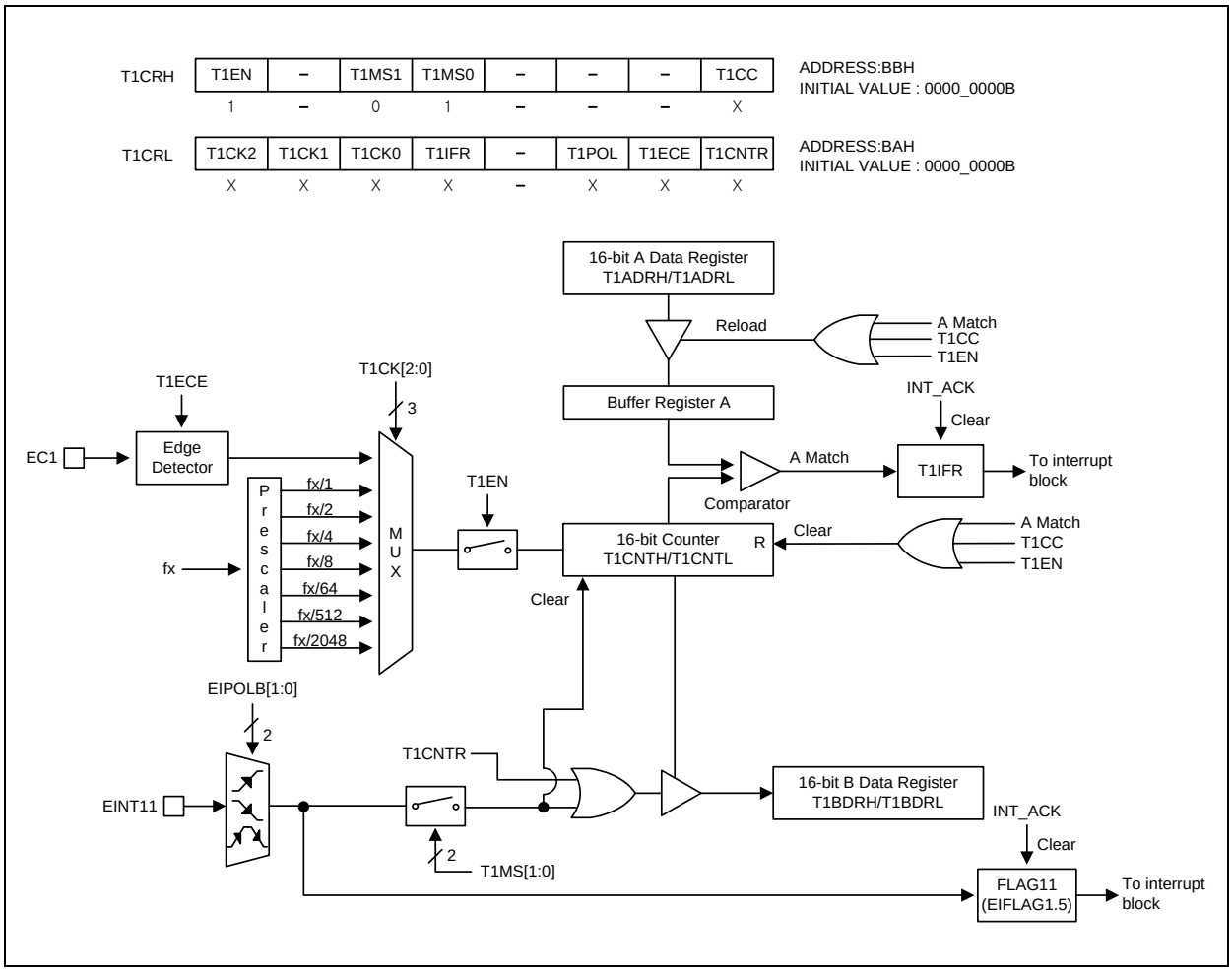


Figure 11.16 16-Bit Capture Mode for Timer 1

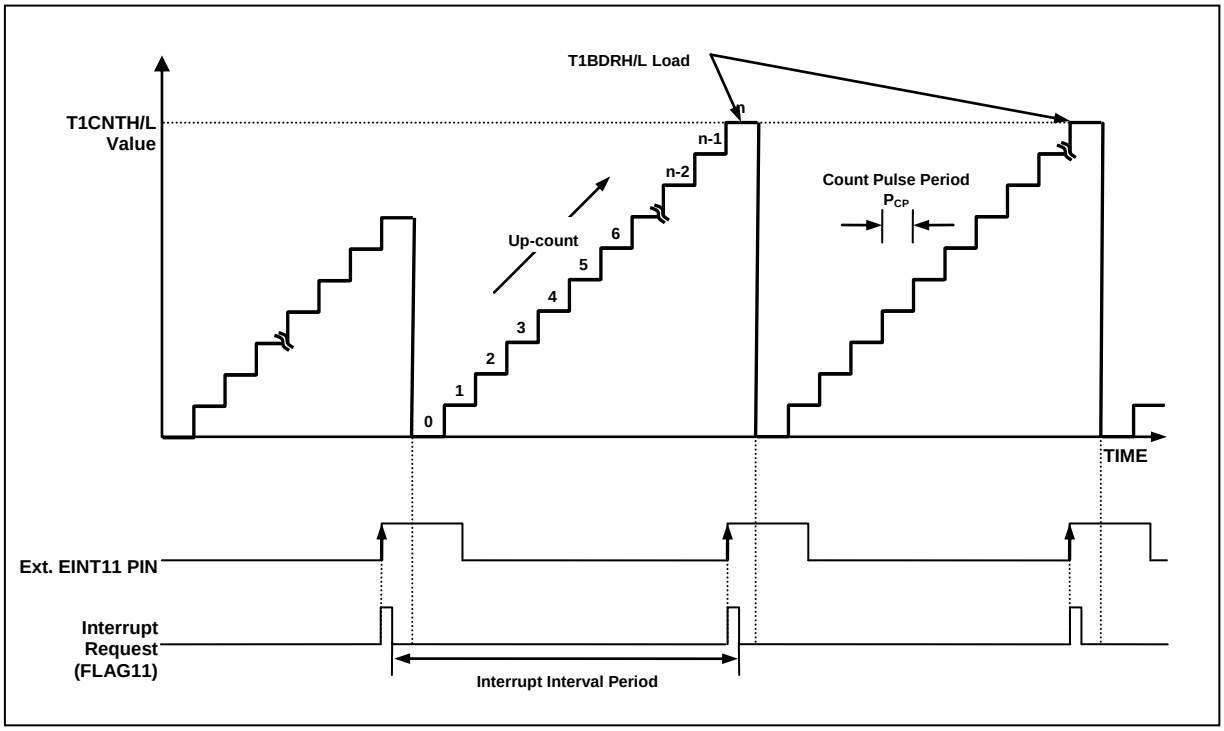


Figure 11.17 Input Capture Mode Operation for Timer 1

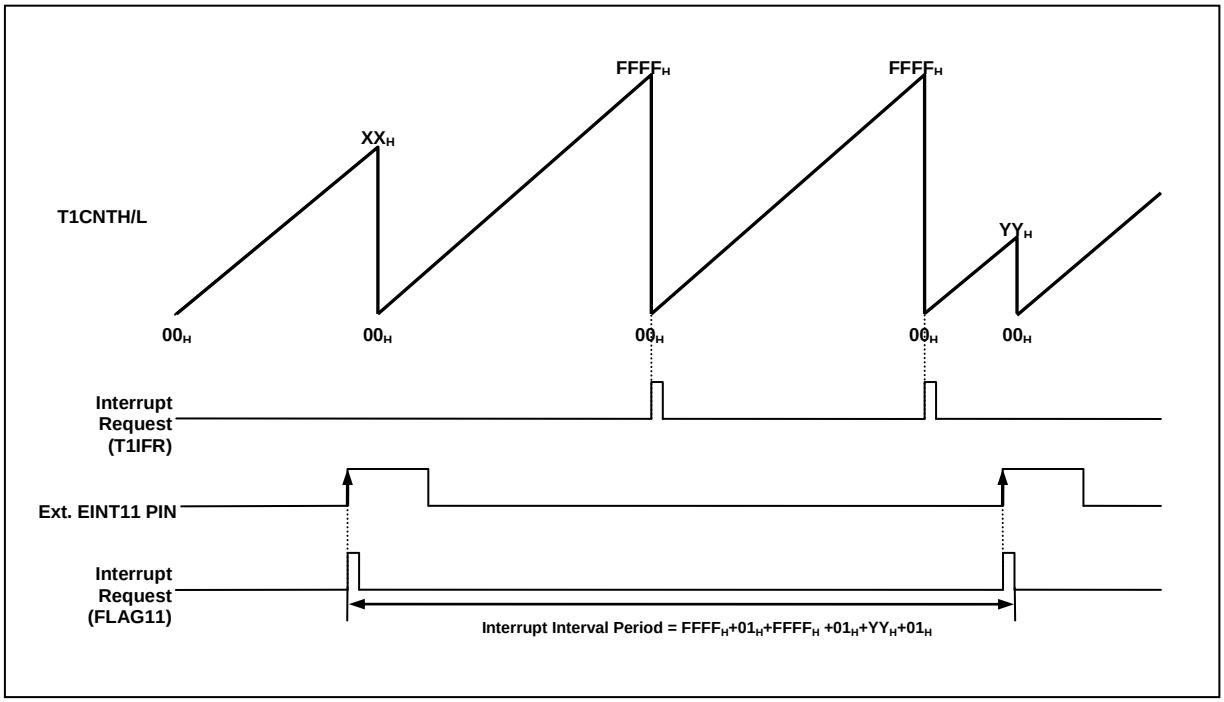
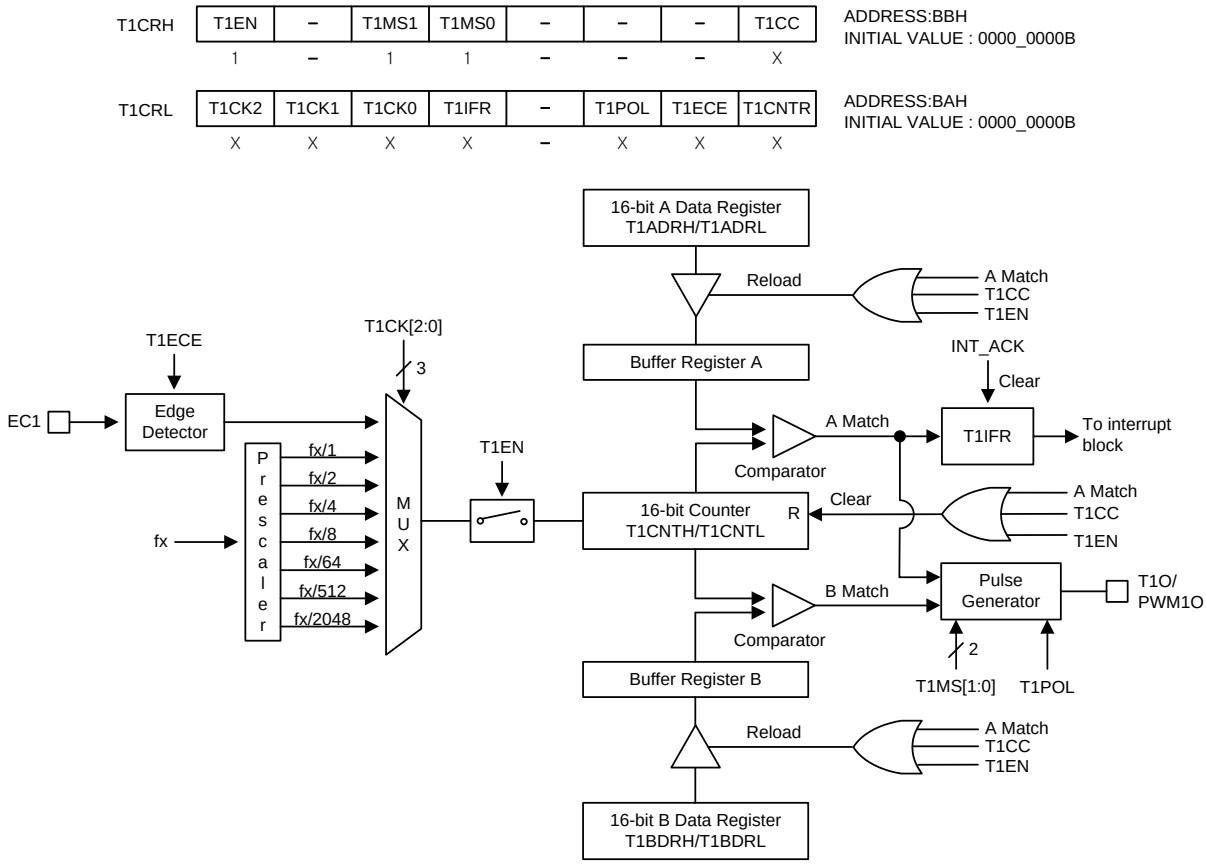


Figure 11.18 Express Timer Overflow in Capture Mode

11.6.4 16-Bit PPG Mode

The timer 1 has a PPG (Programmable Pulse Generation) function. In PPG mode, T1O/PWM1O pin outputs up to 16-bit resolution PWM output. This pin should be configured as a PWM output by setting P1FSRL[4:3] to '01'. The period of the PWM output is determined by the T1ADRH/T1ADRL. And the duty of the PWM output is determined by the T1BDRH/T1BDRL.



NOTE) The T1EN is automatically cleared to logic "0" after one pulse is generated at a PPG one-shot mode.

Figure 11.19 16-Bit PPG Mode for Timer 1

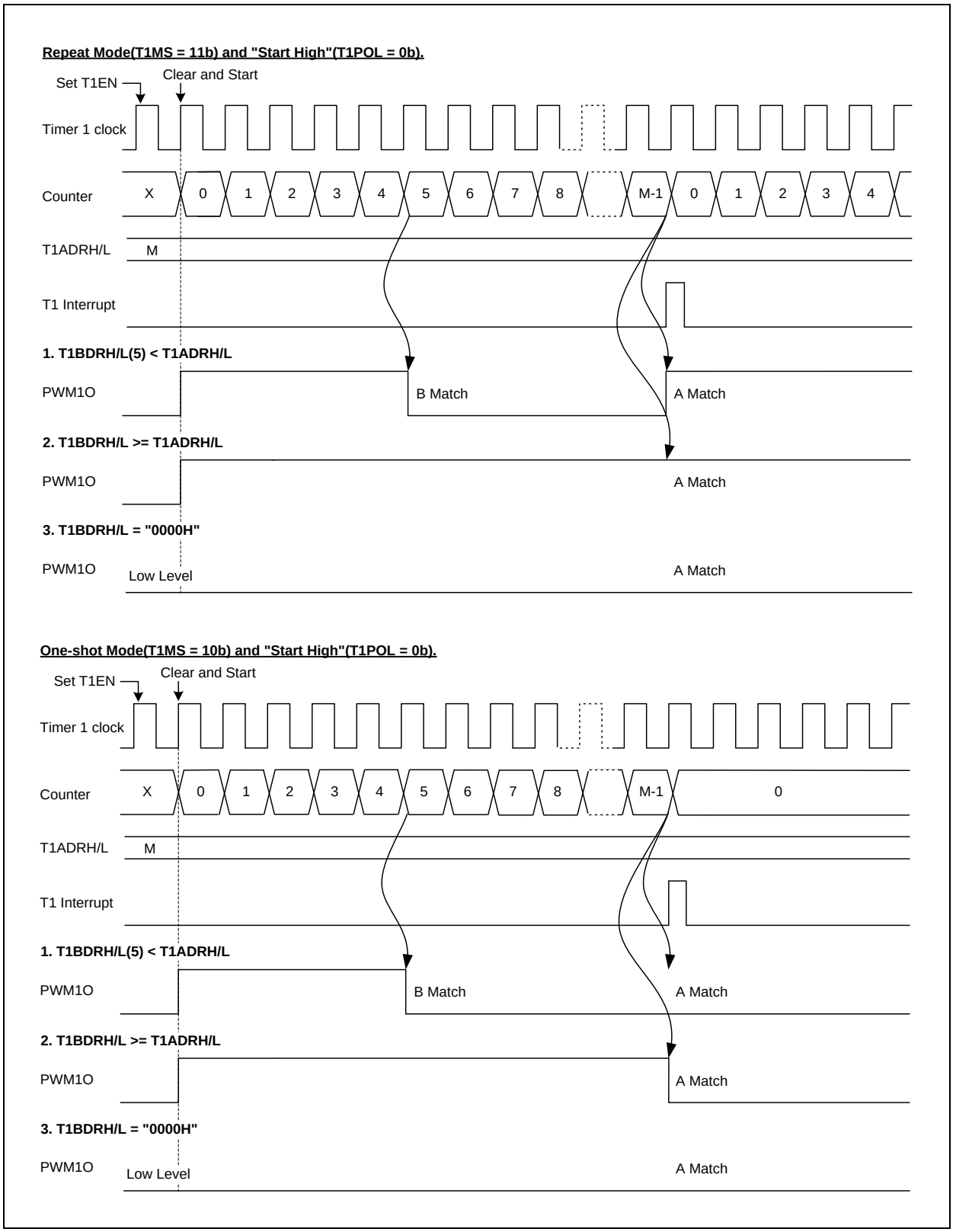


Figure 11.20 16-Bit PPG Mode Timming chart for Timer 1

11.6.5 Block Diagram

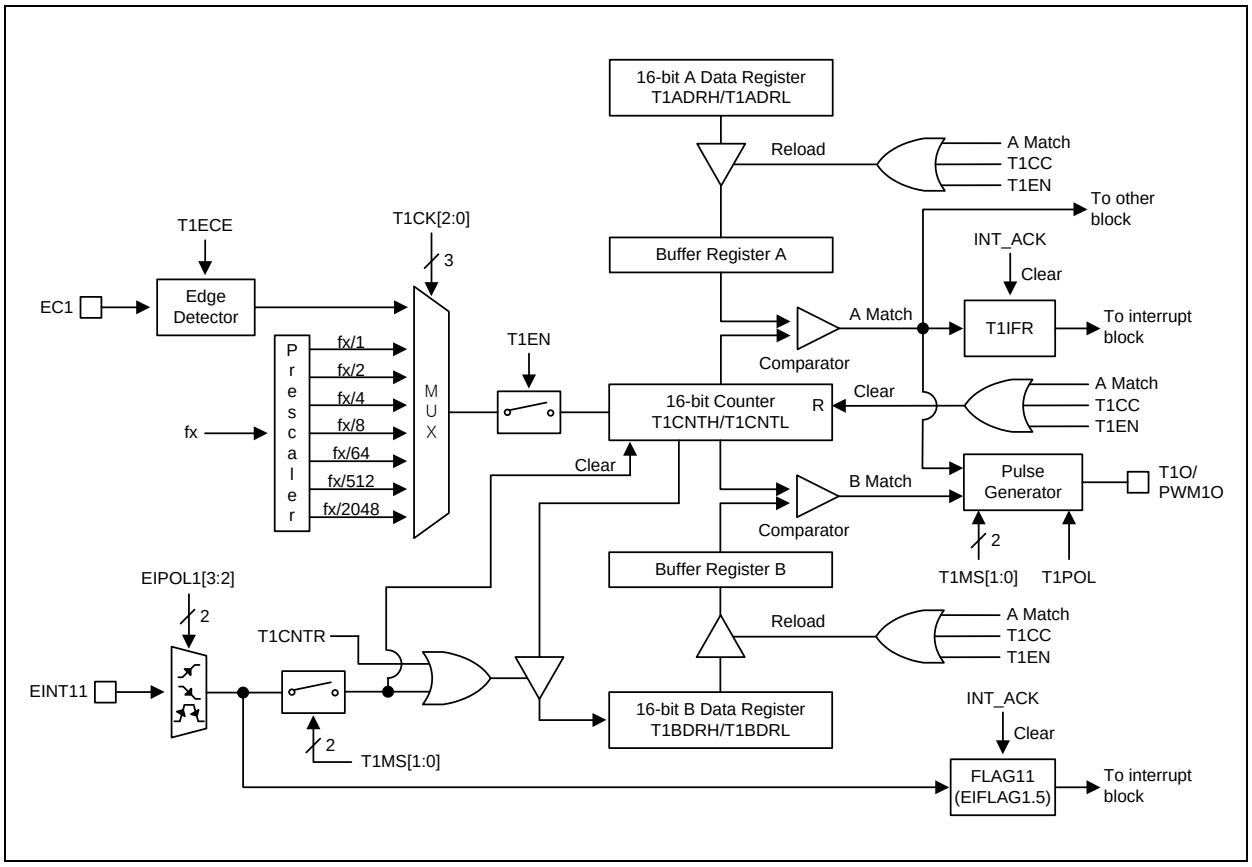


Figure 11.21 16-Bit Timer 1 Block Diagram

11.6.6 Register Map

Table 11-8 Timer 2 Register Map

Name	Address	Dir	Default	Description
T1ADRH	BDH	R/W	FFH	Timer 1 A Data High Register
T1ADRL	BCH	R/W	FFH	Timer 1 A Data Low Register
T1BDRH	BFH	R/W	FFH	Timer 1 B Data High Register
T1BDRL	BEH	R/W	FFH	Timer 1 B Data Low Register
T1CRH	BBH	R/W	00H	Timer 1 Control High Register
T1CRL	BAH	R/W	00H	Timer 1 Control Low Register

11.6.6.1 Timer/Counter 1 Register Description

The timer/counter 1 register consists of timer 1 A data high register (T1ADRH), timer 1 A data low register (T1ADRL), timer 1 B data high register (T1BDRH), timer 1 B data low register (T1BDRL), timer 1 control high register (T1CRH) and timer 1 control low register (T1CRL).

11.6.6.2 Register Description for Timer/Counter 1

T1ADRH (Timer 1 A data High Register) : BDH

7	6	5	4	3	2	1	0
T1ADRH7	T1ADRH6	T1ADRH5	T1ADRH4	T1ADRH3	T1ADRH2	T1ADRH1	T1ADRH0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T1ADRH[7:0] T1 A Data High Byte

T1ADRL (Timer 1 A Data Low Register) : BCH

7	6	5	4	3	2	1	0
T1ADRL7	T1ADRL6	T1ADRL5	T1ADRL4	T1ADRL3	T1ADRL2	T1ADRL1	T1ADRL0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T1ADRL[7:0] T1 A Data Low Byte

NOTE) Do not write “0000H” in the T1ADRH/T1ADRL register when PPG mode

T1BDRH (Timer 1 B Data High Register) : BFH

7	6	5	4	3	2	1	0
T1BDRH7	T1BDRH6	T1BDRH5	T1BDRH4	T1BDRH3	T1BDRH2	T1BDRH1	T1BDRH0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T1BDRH[7:0] T1 B Data High Byte

T1BDRL (Timer 1 B Data Low Register) : BEH

7	6	5	4	3	2	1	0
T1BDRL7	T1BDRL6	T1BDRL5	T1BDRL4	T1BDRL3	T1BDRL2	T1BDRL1	T1BDRL0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T1BDRL[7:0] T1 B Data Low Byte

T1CRH (Timer 1 Control High Register) : BBH

7	6	5	4	3	2	1	0
T1EN	–	T1MS1	T1MS0	–	–	–	T1CC
R/W	–	R/W	R/W	–	–	–	R/W

Initial value : 00H

T1EN Control Timer 1

0 Timer 1 disable

1 Timer 1 enable (Counter clear and start)

T1MS[1:0] Control Timer 1 Operation Mode

T1MS1	T1MS0	Description
0	0	Timer/counter mode (T1O: toggle at A match)
0	1	Capture mode (The A match interrupt can occur)
1	0	PPG one-shot mode (PWM1O)
1	1	PPG repeat mode (PWM1O)

T1CC Clear Timer 1 Counter

0 No effect

1 Clear the Timer 1 counter (When write, automatically cleared “0” after being cleared counter)

T1CRL (Timer 1 Control Low Register) : BAH

7	6	5	4	3	2	1	0
T1CK2	T1CK1	T1CK0	T1IFR	–	T1POL	T1ECE	T1CNTR
R/W	R/W	R/W	R/W	–	R/W	R/W	R/W

Initial value : 00H

T1CK[2:0] Select Timer 1 clock source. fx is main system clock frequency

T1CK2	T1CK1	T1CK0	Description
0	0	0	fx/2048
0	0	1	fx/512
0	1	0	fx/64
0	1	1	fx/8
1	0	0	fx/4
1	0	1	fx/2
1	1	0	fx/1
1	1	1	External clock (EC1)

T1IFR When T1 Interrupt occurs, this bit becomes ‘1’. For clearing bit, write ‘0’ to this bit or auto clear by INT_ACK signal.

0 T1 Interrupt no generation

1 T1 Interrupt generation

T1POL T1O/PWM1O Polarity Selection

0 Start High (T1O/PWM1O is low level at disable)

1 Start Low (T1O/PWM1O is high level at disable)

T1ECE Timer 1 External Clock Edge Selection

0 External clock falling edge

1 External clock rising edge

T1CNTR Timer 1 Counter Read Control

0 No effect

1 Load the counter value to the B data register (When write, automatically cleared “0” after being loaded)

11.7 Timer 2

11.7.1.1 Overview

The 16-bit timer 2 consists of multiplexer, timer 2 A data high/low register, timer 2 B data high/low register and timer 2 control high/low register (T2ADRH, T2ADRL, T2BDRH, T2BDRL, T2CRH, T2CRL).

It has four operating modes:

- 16-bit timer/counter mode
- 16-bit capture mode
- 16-bit PPG output mode (one-shot mode)
- 16-bit PPG output mode (repeat mode)

The timer/counter 2 can be clocked by an internal or an external clock source (EC2) or T1 A Match (timer 1 A match signal). The clock source is selected by clock selection logic which is controlled by the clock selection bits (T2CK[2:0]).

- TIMER 2 clock source: f_X/1, 2, 4, 8, 64, 512, 2048, EC2 and T1 A Match

In the capture mode, by EINT12, the data is captured into input capture data register (T2BDRH/T2BDRL). In timer/counter mode, whenever counter value is equal to T2ADRH/L, T2O port toggles. Also the timer 2 outputs PWM wave form to PWM2O port in the PPG mode.

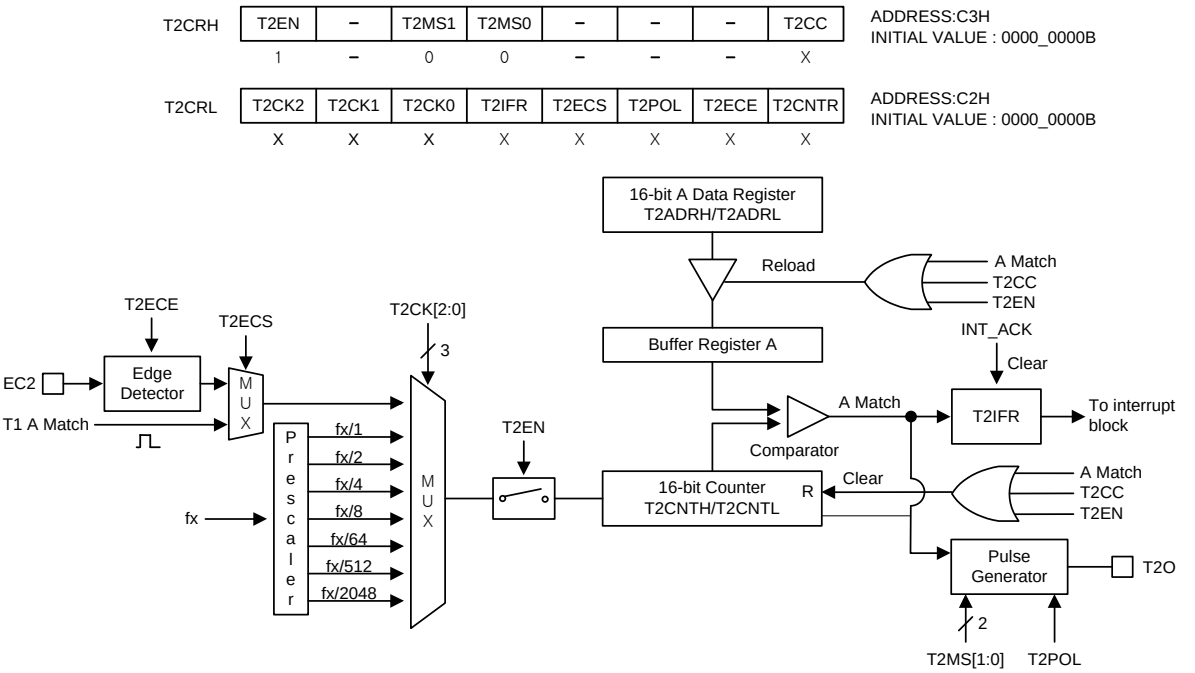
Table 11-9 Timer 2 Operating Modes

T2EN	P1FSRL[6:5]	T2MS[1:0]	T2CK[2:0]	Timer 2
1	01	00	XXX	16 Bit Timer/Counter Mode
1	00	01	XXX	16 Bit Capture Mode
1	01	10	XXX	16 Bit PPG Mode (one-shot mode)
1	01	11	XXX	16 Bit PPG Mode (repeat mode)

11.7.2 16-Bit Timer/Counter Mode

The 16-bit timer/counter mode is selected by control register as shown in Figure 11.22.

The 16-bit timer have counter and data register. The counter register is increased by internal or external clock(EC2) or timer 1 A match clock input. Timer 2 can use the input clock with one of 1, 2, 4, 8, 64, 512 and 2048 prescaler division rates, EC2 and T1 A Match (T2CK[2:0]). When the values of T2CNTH/T2CNTL and T2ADRH/T2ADRL are identical in timer 2, a match signal is generated and the interrupt of Timer 2 occurs. The T2CNTH/T2CNTL values are automatically cleared by match signal. It can be also cleared by software (T2CC).



NOTE) T1 A Match is a pulse for the timer 2 clock source if it is selected.

Figure 11.22 16-Bit Timer/Counter Mode for Timer 2

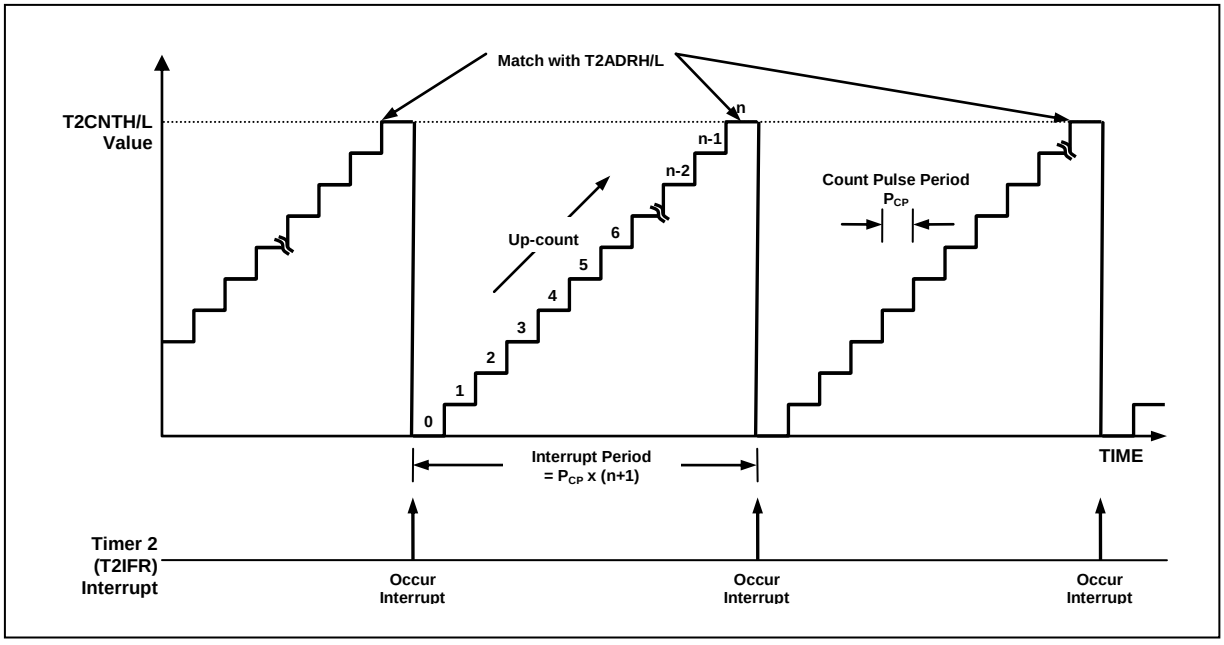


Figure 11.23 16-Bit Timer/Counter 2 Example

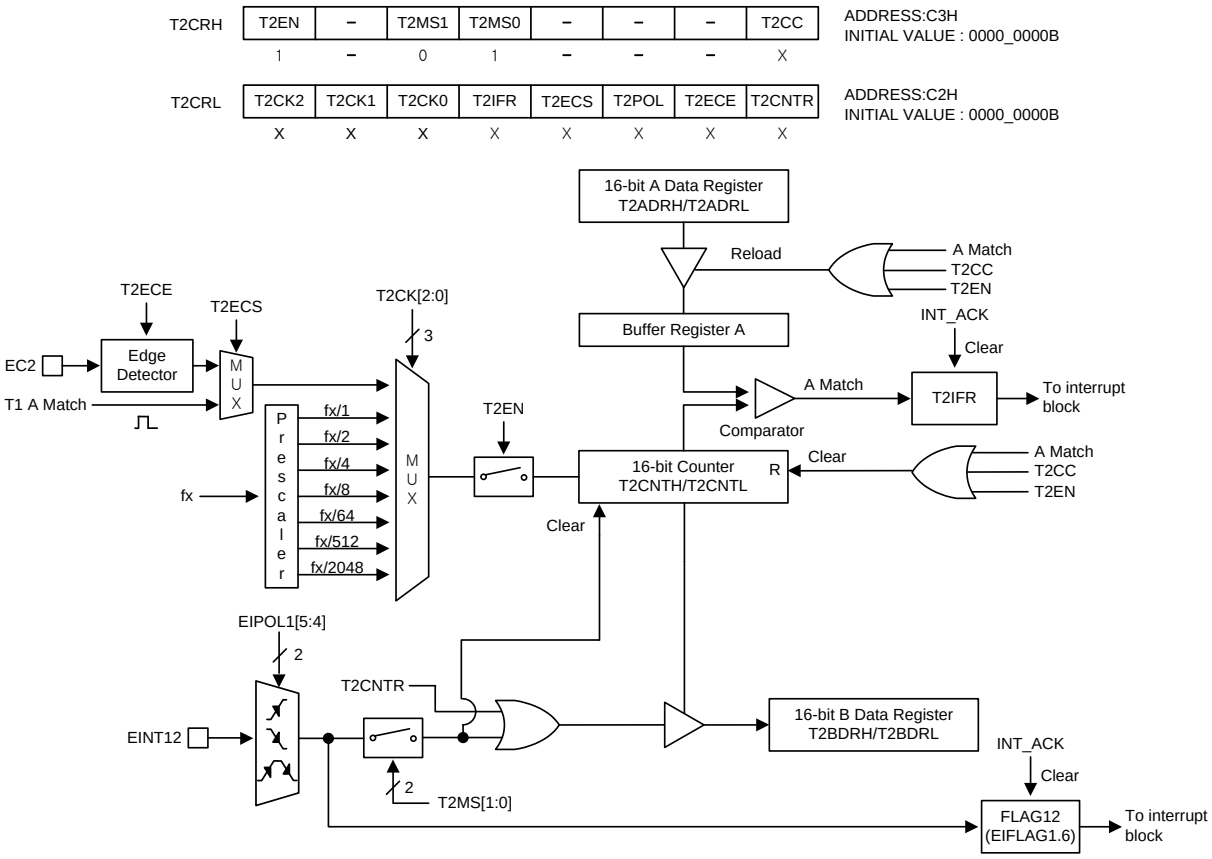
11.7.3 16-Bit Capture Mode

The timer 2 capture mode is set by T2MS[1:0] as '01'. The clock source can use the internal clock. Basically, it has the same function as the 16-bit timer/counter mode and the interrupt occurs when T2CNTH/T2CNTL is equal to T2ADRH/T2ADRL. T2CNTH/T2CNTL values are automatically cleared by match signal and it can be also cleared by software (T2CC).

This timer interrupt in capture mode is very useful when the pulse width of captured signal is wider than the maximum period of timer.

The capture result is loaded into T2BDRH/T2BDRL. In the timer 2 capture mode, timer 2 output(T2O) waveform is not available.

According to EIPOL1 registers setting, the external interrupt EINT12 function is chosen. Of cource, the EINT12 pin must be set to an input port.



NOTE) T1 A Match is a pulse for the timer 2 clock source if it is selected.

Figure 11.24 16-Bit Capture Mode for Timer 2

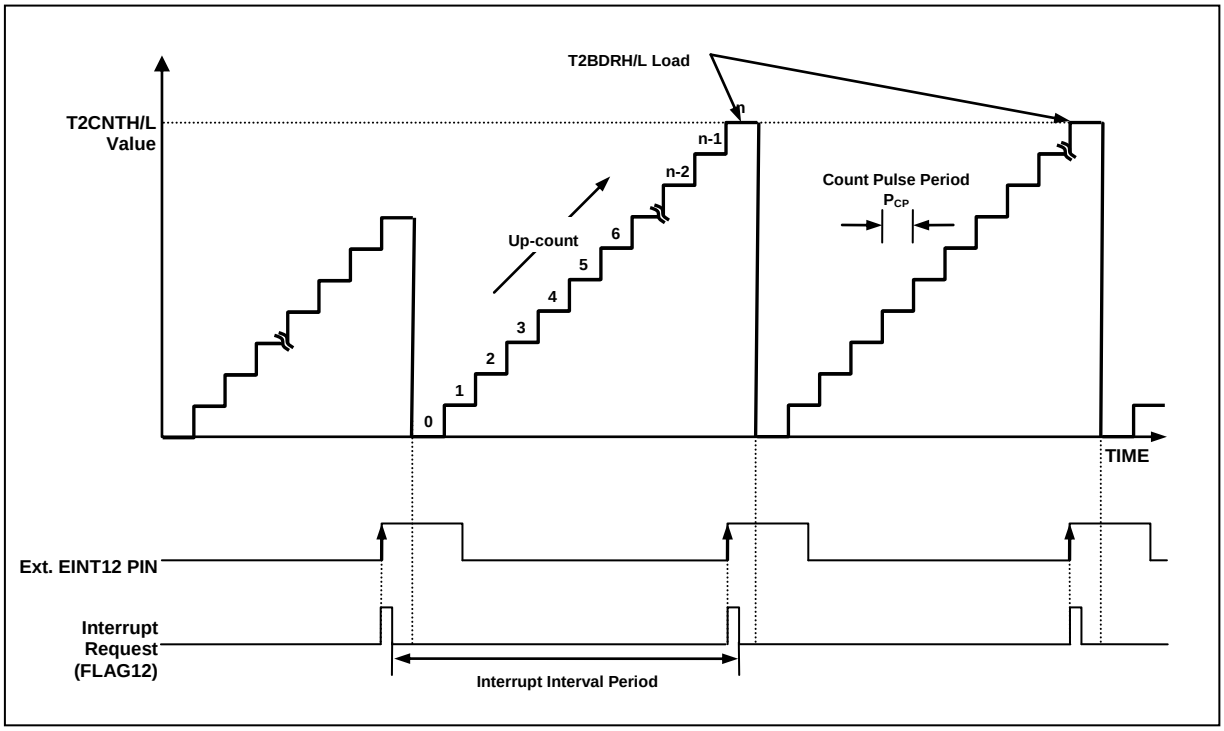


Figure 11.25 Input Capture Mode Operation for Timer 2

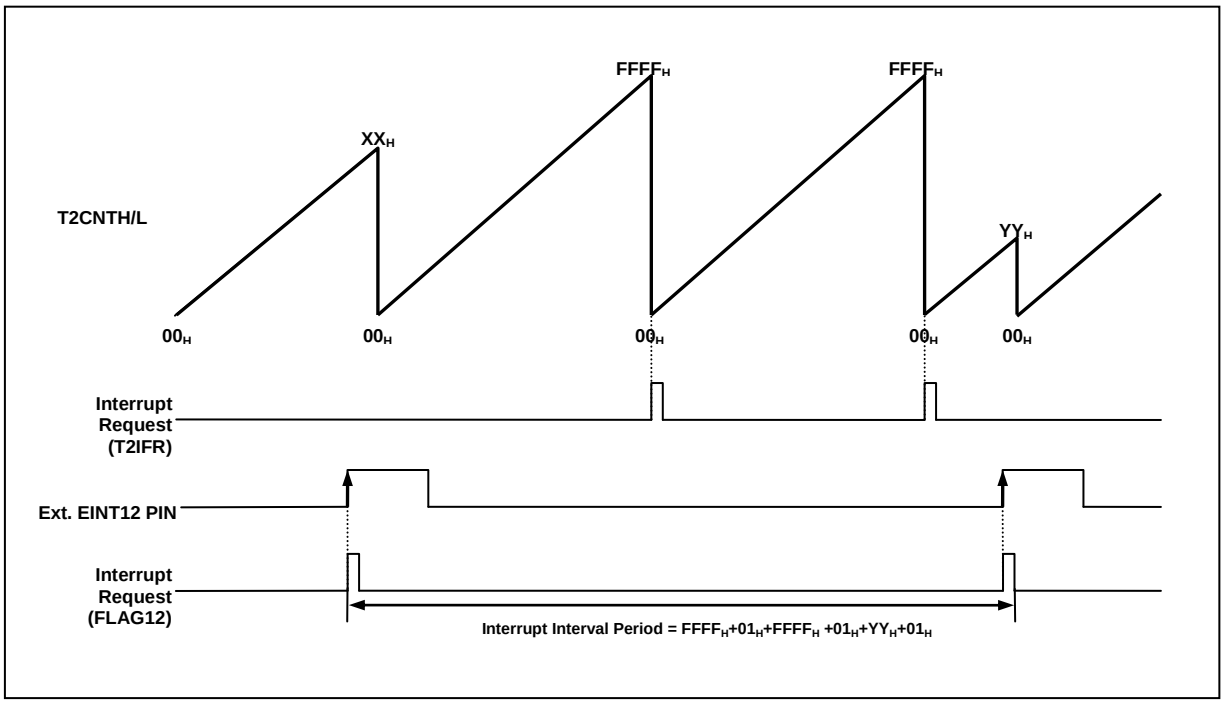
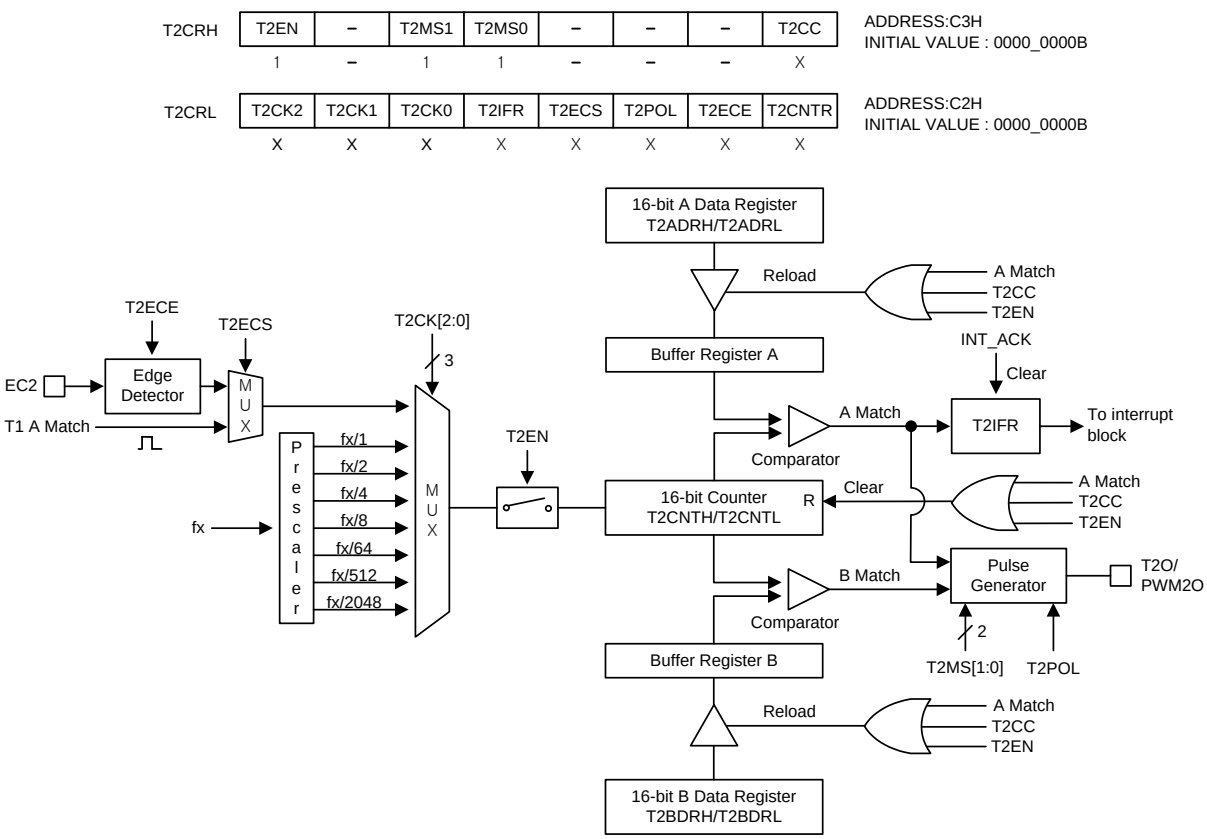


Figure 11.26 Express Timer Overflow in Capture Mode

11.7.4 16-Bit PPG Mode

The timer 2 has a PPG (Programmable Pulse Generation) function. In PPG mode, the T2O/PWM2O pin outputs up to 16-bit resolution PWM output. This pin should be configured as a PWM output by set P1FSRL[6:5] to '01'. The period of the PWM output is determined by the T2ADRH/T2ADRL. And the duty of the PWM output is determined by the T2BDRH/T2BDRL.



NOTES)

1. The T2EN is automatically cleared to logic "0" after one pulse is generated at a PPG one-shot mode.
2. T1 A Match is a pulse for the timer 2 clock source if it is selected.

Figure 11.27 16-Bit PPG Mode for Timer 2

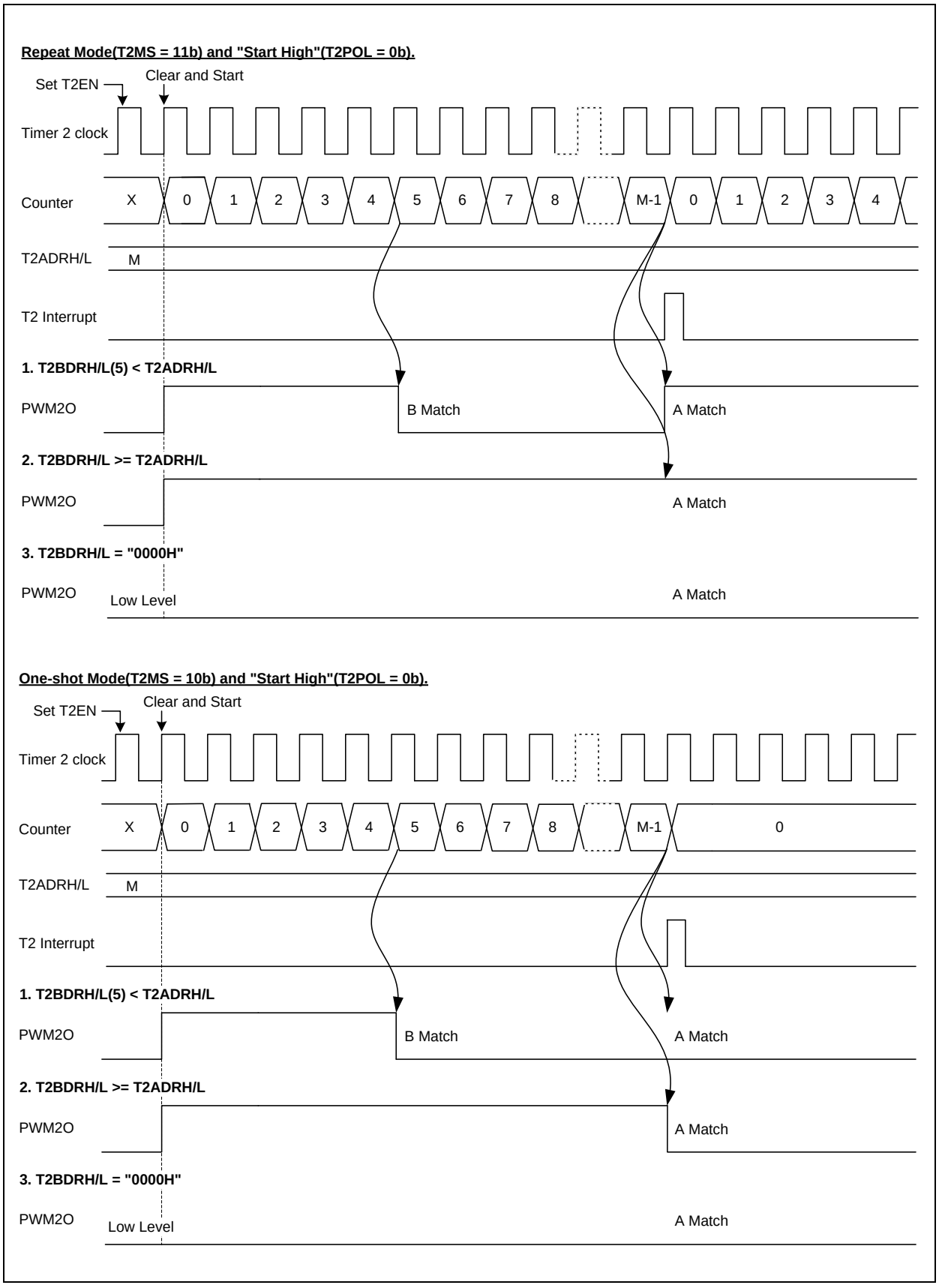
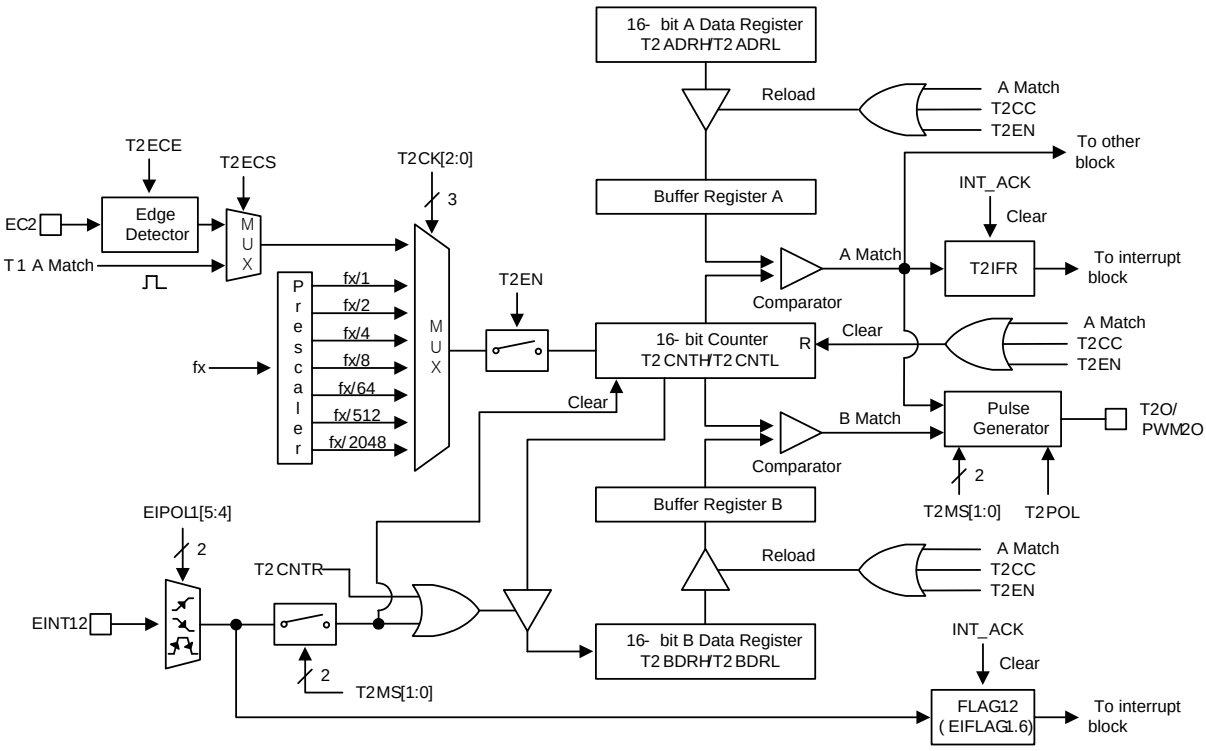


Figure 11.28 16-Bit PPG Mode Timming chart for Timer 2

11.7.5 Block Diagram



NOTE) T1 A Match is a pulse for the timer 2 clock source if it is selected.

Figure 11.29 16-Bit Timer 2 Block Diagram

11.7.6 Register Map

Table 11-10 Timer 3 Register Map

Name	Address	Dir	Default	Description
T2ADRH	C5H	R/W	FFH	Timer 2 A Data High Register
T2ADRL	C4H	R/W	FFH	Timer 2 A Data Low Register
T2BDRH	C7H	R/W	FFH	Timer 2 B Data High Register
T2BDRL	C6H	R/W	FFH	Timer 2 B Data Low Register
T2CRH	C3H	R/W	00H	Timer 2 Control High Register
T2CRL	C2H	R/W	00H	Timer 2 Control Low Register

11.7.6.1 Timer/Counter 2 Register Description

The timer/counter 2 register consists of timer 2 A data high register (T2ADRH), timer 2 A data low register (T2ADRL), timer 2 B data high register (T2BDRH), timer 2 B data low register (T2BDRL), timer 2 control high register (T2CRH) and timer 2 control low register (T2CRL).

11.7.6.2 Register Description for Timer/Counter 2

T2ADRH (Timer 2 A data High Register) : C5H

7	6	5	4	3	2	1	0
T2ADRH7	T2ADRH6	T2ADRH5	T2ADRH4	T2ADRH3	T2ADRH2	T2ADRH1	T2ADRH0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T2ADRH[7:0] T2 A Data High Byte

T2ADRL (Timer 2 A Data Low Register) : C4H

7	6	5	4	3	2	1	0
T2ADRL7	T2ADRL6	T2ADRL5	T2ADRL4	T2ADRL3	T2ADRL2	T2ADRL1	T2ADRL0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T2ADRL[7:0] T2 A Data Low Byte

NOTE) Do not write “0000H” in the T2ADRH/T2ADRL register when PPG mode.

T2BDRH (Timer 2 B Data High Register) : C7H

7	6	5	4	3	2	1	0
T2BDRH7	T2BDRH6	T2BDRH5	T2BDRH4	T2BDRH3	T2BDRH2	T2BDRH1	T2BDRH0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T2BDRH[7:0] T2 B Data High Byte

T2BDRL (Timer 2 B Data Low Register) : C6H

7	6	5	4	3	2	1	0
T2BDRL7	T2BDRL6	T2BDRL5	T2BDRL4	T2BDRL3	T2BDRL2	T2BDRL1	T2BDRL0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

T2BDRL[7:0] T2 B Data Low

T2CRH (Timer 2 Control High Register) : C3H

7	6	5	4	3	2	1	0
T2EN	–	T2MS1	T2MS0	–	–	–	T2CC
R/W	–	R/W	R/W	–	–	–	R/W

Initial value : 00H

T2EN Control Timer 2

0 Timer 2 disable

1 Timer 2 enable (Counter clear and start)

T2MS[1:0] Control Timer 2 Operation Mode

T2MS1	T2MS0	Description
0	0	Timer/counter mode (T2O: toggle at A match)
0	1	Capture mode (The A match interrupt can occur)
1	0	PPG one-shot mode (PWM2O)
1	1	PPG repeat mode (PWM2O)

T2CC Clear Timer 2 Counter

0 No effect

1 Clear the Timer 2 counter (When write, automatically cleared “0” after being cleared counter)

T2CRL (Timer 2 Control Low Register) : C2H

7	6	5	4	3	2	1	0
T2CK2	T2CK1	T2CK0	T2IFR	T2ECS	T2POL	T2ECE	T2CNTR
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

T2CK[2:0] Select Timer 2 clock source. fx is main system clock frequency

T2CK2	T2CK1	T2CK0	Description
0	0	0	fx/2048
0	0	1	fx/512
0	1	0	fx/64
0	1	1	fx/8
1	0	0	fx/4
1	0	1	fx/2
1	1	0	fx/1
1	1	1	Selected clock by T2ECS bit

T2IFR When T2 Match Interrupt occurs, this bit becomes ‘1’. For clearing bit, write ‘0’ to this bit or auto clear by INT_ACK signal.

0 T2 interrupt no generation

1 T2 interrupt generation

T2ECS Timer 2 External Clock Selection

0 Select external clock(EC2)

1 Select Timer 1 A match

T2POL T2O/PWM2O Polarity Selection

0 Start High (T2O/PWM2O is low level at disable)

1 Start Low (T2O/PWM2O is high level at disable)

T2ECE Timer 2 External Clock Edge Selection

0 External clock falling edge

1 External clock rising edge

T2CNTR Timer 2 Counter Read Control

0 No effect

1 Load the counter value to the B data register (When write, automatically cleared “0” after being loaded)

11.8 Buzzer Driver

11.8.1 Overview

The Buzzer consists of 8 bit counter, buzzer data register (BUZDR), and buzzer control register (BUZCR). The Square Wave (61.035Hz~125.0 kHz @8MHz) is outputted through P11/BUZO pin. The buzzer data register (BUZDR) controls the bsuzzer frequency (look at the following expression). In buzzer control register (BUZCR), BUCK[2:0] selects source clock divided by prescaler.

$$f_{BUZ}(Hz) = \frac{Oscillator\,Frequency}{2 \times PrescalerRatio \times (BUZDR + 1)}$$

Table 11-11 Buzzer Frequency at 8 MHz

BUZDR[7:0]	Buzzer Frequency (kHz)			
	BUZCR[3:1]=000	BUZCR[3:1]=001	BUZCR[3:1]=010	BUZCR[3:1]=011
0000_0000	125kHz	62.5kHz	31.25kHz	15.625kHz
0000_0001	62.5kHz	31.25kHz	15.625kHz	7.812kHz
…	…	…	…	…
1111_1101	492.126Hz	246.063Hz	123.031Hz	61.515Hz
1111_1110	490.196Hz	245.098Hz	122.549Hz	61.274Hz
1111_1111	488.281Hz	244.141Hz	122.07Hz	61.035Hz

11.8.2 Block Diagram

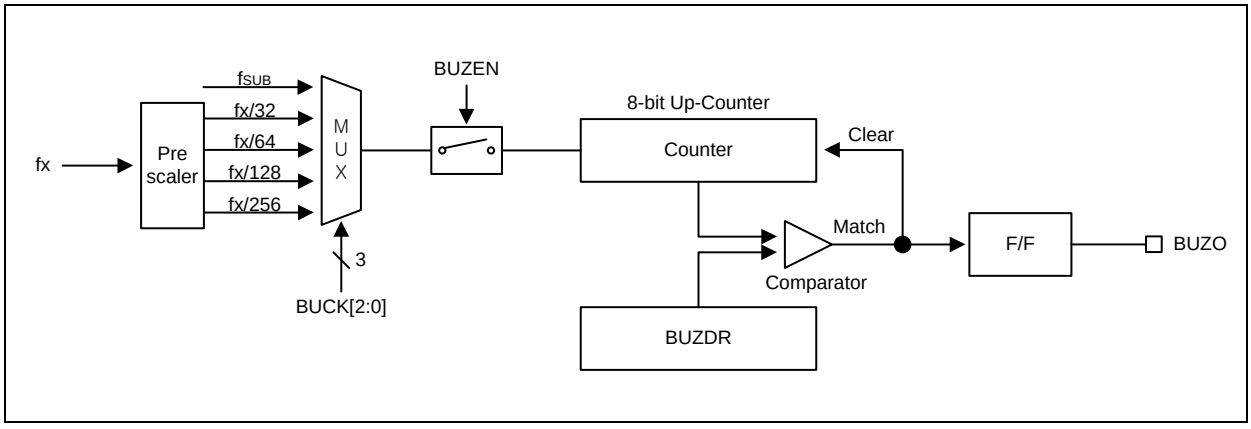


Figure 11.30 Buzzer Driver Block Diagram

11.8.3 Register Map

Table 11-12 Buzzer Driver Register Map

Name	Address	Dir	Default	Description
BUZDR	8FH	R/W	FFH	Buzzer Data Register
BUZCR	97H	R/W	00H	Buzzer Control Register

11.8.4 Buzzer Driver Register Description

Buzzer driver consists of buzzer data register (BUZDR) and buzzer control register (BUZCR).

11.8.5 Register Description for Buzzer Driver

BUZDR (Buzzer Data Register) : 8FH

7	6	5	4	3	2	1	0
BUZDR7	BUZDR6	BUZDR5	BUZDR4	BUZDR3	BUZDR2	BUZDR1	BUZDR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

BUZDR[7:0] This bits control the Buzzer frequency
Its resolution is 00H ~ FFH

BUZCR (Buzzer Control Register) : 97H

7	6	5	4	3	2	1	0
–	–	–	–	BUCK2	BUCK1	BUCK0	BUZEN
–	–	–	–	R/W	R/W	R/W	R/W

Initial value : 00H

BUCK[2:0] Buzzer Driver Source Clock Selection

BUCK2	BUCK1	BUCK0	Description
0	0	0	fx/32
0	0	1	fx/64
0	1	0	fx/128
0	1	1	fx/256
1	x	x	f_{SUB} (External Sub OSC)

BUZEN Buzzer Driver Operation Control

0	Buzzer Driver disable
1	Buzzer Driver enable

NOTE) fx: System clock oscillation frequency.

11.9 12-Bit A/D Converter

11.9.1 Overview

The analog-to-digital converter (A/D) allows conversion of an analog input signal to corresponding 12-bit digital value. The A/D module has fifteen analog inputs. The output of the multiplexer is the input into the converter which generates the result through successive approximation. The A/D module has four registers which are the A/D converter control high register (ADCCRH), A/D converter control low register (ADCCRL), A/D converter data high register (ADCDRH), and A/D converter data low register (ADCDRL). The channels to be converted are selected by setting ADSEL[3:0]. To execute A/D conversion, TRIG[1:0] bits should be set to 'xx'. The register ADCDRH and ADCDRL contains the results of the A/D conversion. When the conversion is completed, the result is loaded into the ADCDRH and ADCDRL, the A/D conversion status bit AFLAG is set to '1', and the A/D interrupt is set. During A/D conversion, AFLAG bit is read as '0'.

11.9.2 Conversion Timing

The A/D conversion process requires 4 steps (4 clock edges) to convert each bit and 10 clocks to set up A/D conversion. Therefore, total of 58 clocks are required to complete a 12-bit conversion: When fxx/8 is selected for conversion clock with a 12MHz fxx clock frequency, one clock cycle is 0.66 μs. Each bit conversion requires 4 clocks, the conversion rate is calculated as follows:

4 clocks/bit × 12 bits + set-up time = 58 clocks,

58 clock × 0.66 μs = 38.28 μs at 1.5 MHz (12 MHz/8)

NOTE) The A/D converter needs at least 20 μs for conversion time. So you must set the conversion time more than 20 μs.

11.9.3 Block Diagram

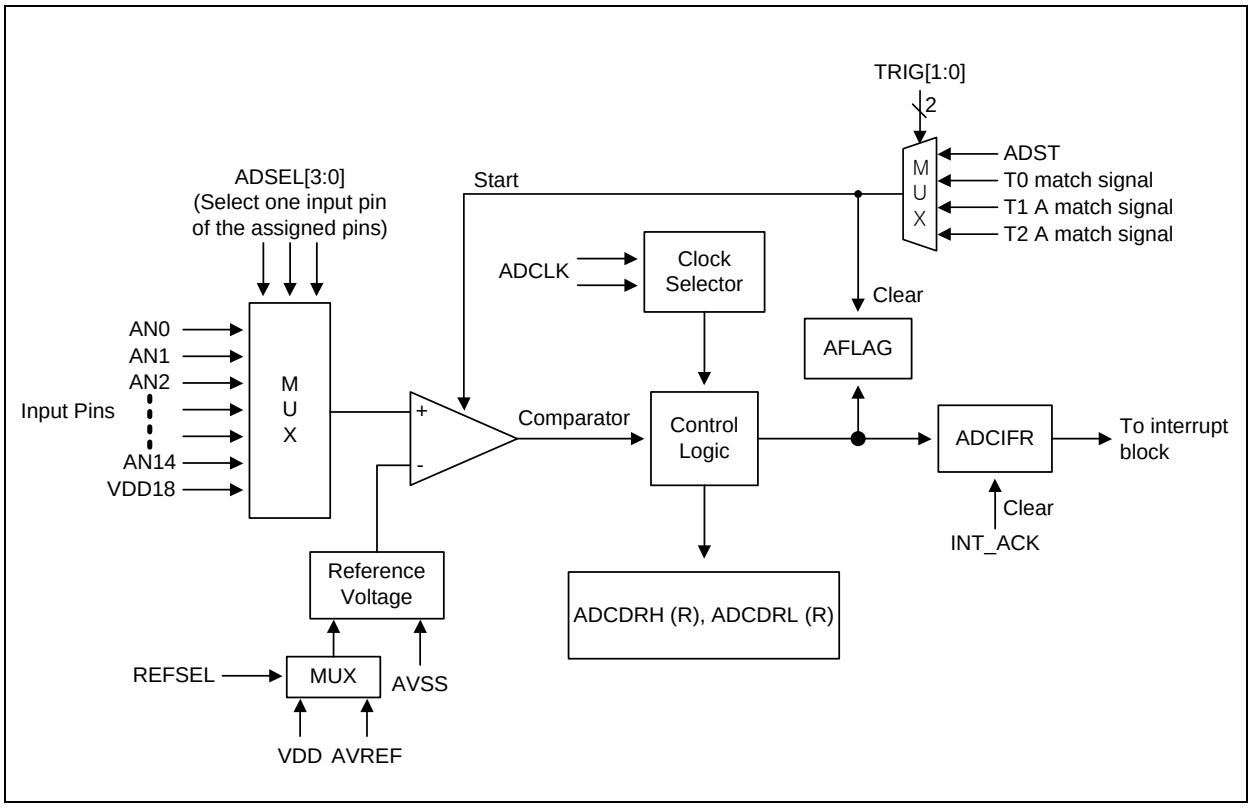


Figure 11.31 12-bit ADC Block Diagram

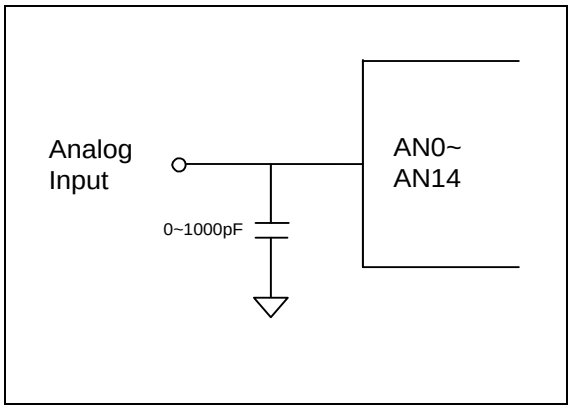


Figure 11.32 A/D Analog Input Pin with Capacitor

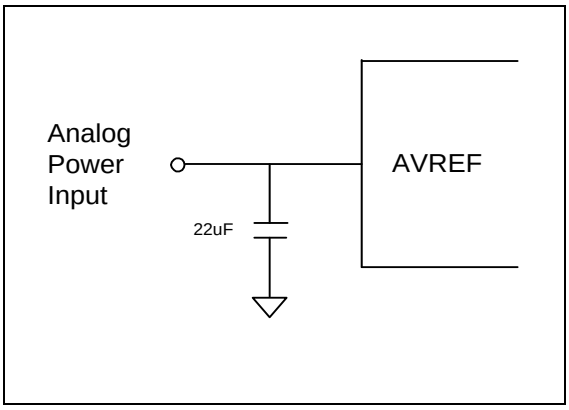


Figure 11.33 A/D Power (AVREF) Pin with Capacitor

11.9.4 ADC Operation

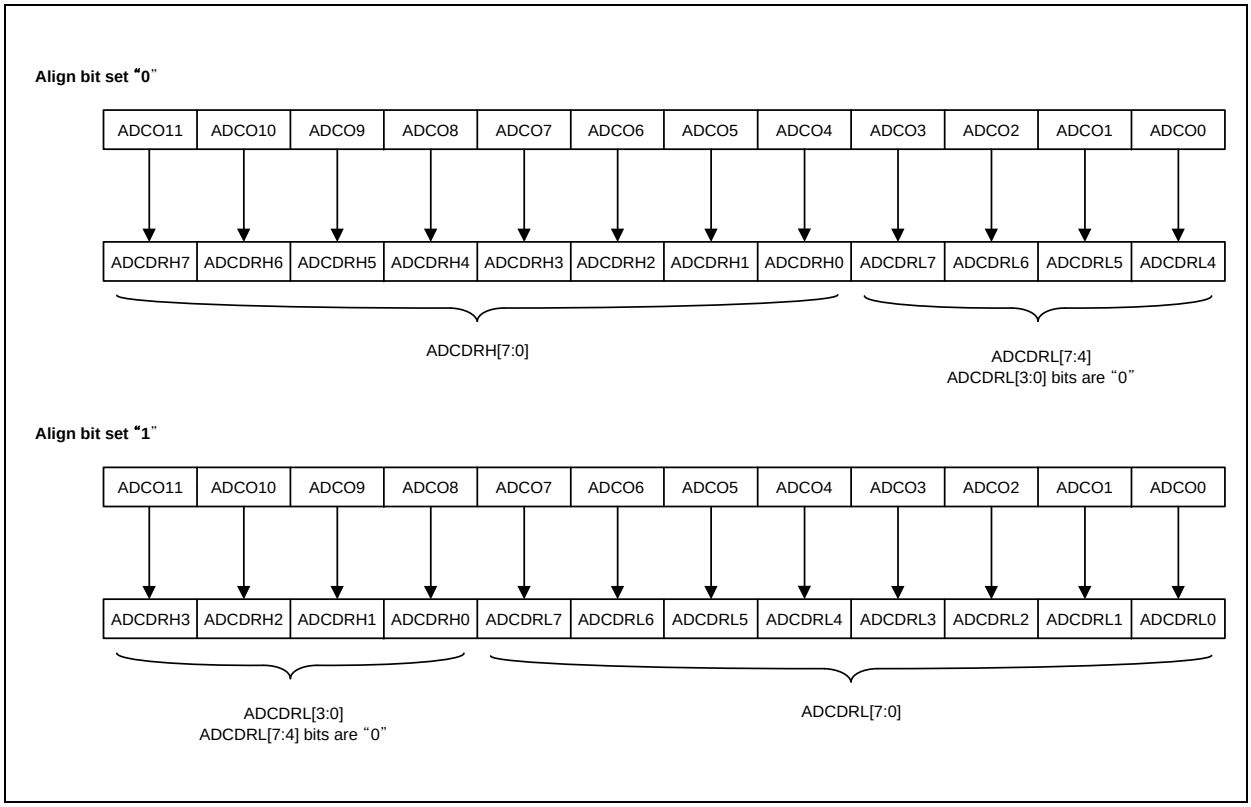


Figure 11.34 ADC Operation for Align Bit

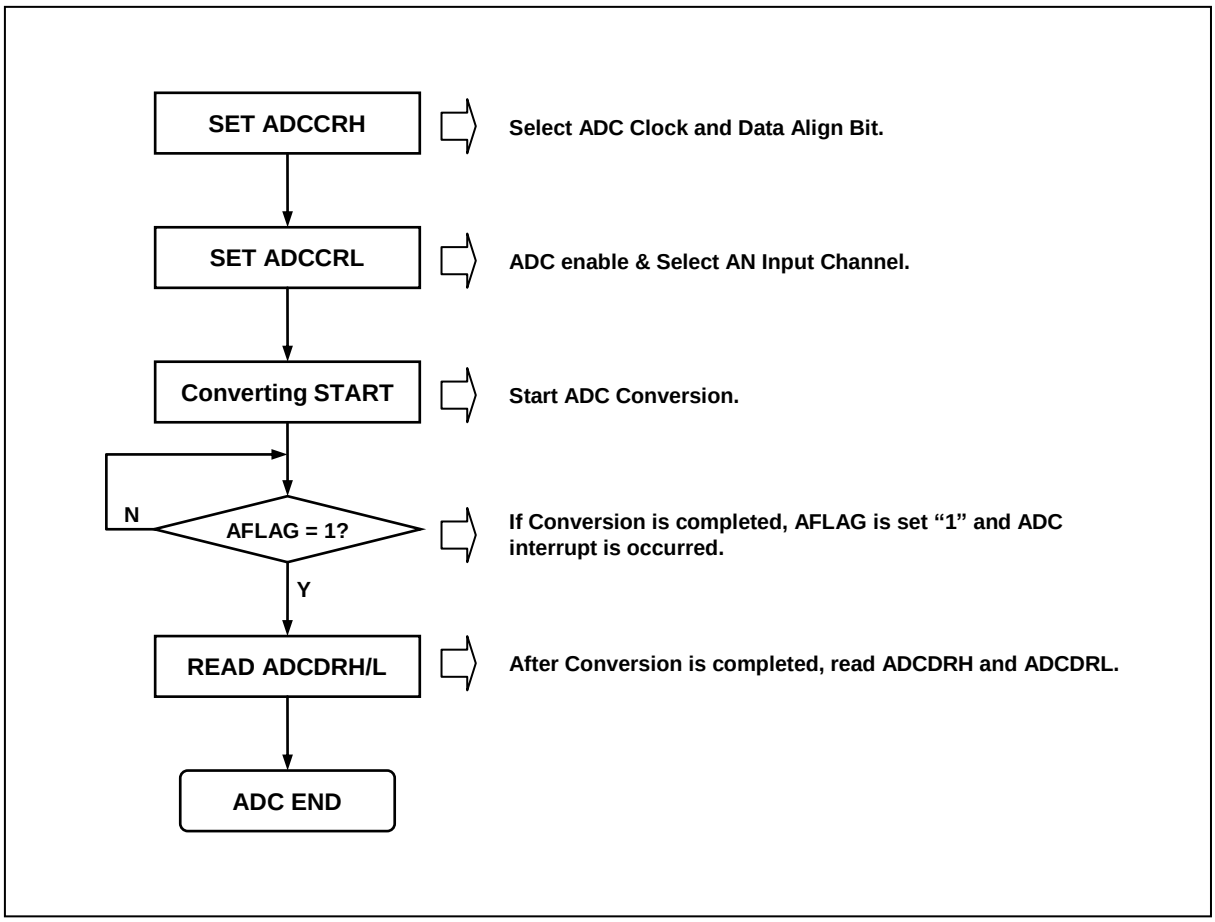


Figure 11.35 A/D Converter Operation Flow

11.9.5 ADC Power-down Wake-up Function

The A/D converter has ADC power-down wake-up function. The function includes two pull-up resistors for wake-up from power-down mode. The corresponging pull-up resistor which is selected as an ADC input function by P0FSR/P1FSRL/P1FSRH register is enabled during power-down mode(IDLE, STOP) if ANnRS[1:0] is not “00b”. An ADC wake-up interrupt can occur by a falling edge(VIL) of key inputs during power-down mode(IDLE, STOP) if ANnWEN bit is ‘1’. Where n = 0, 1, 2,,,,,,,,,,,, and 14.

11.9.6 ADC Power-down Wake-up Function Block Diagram

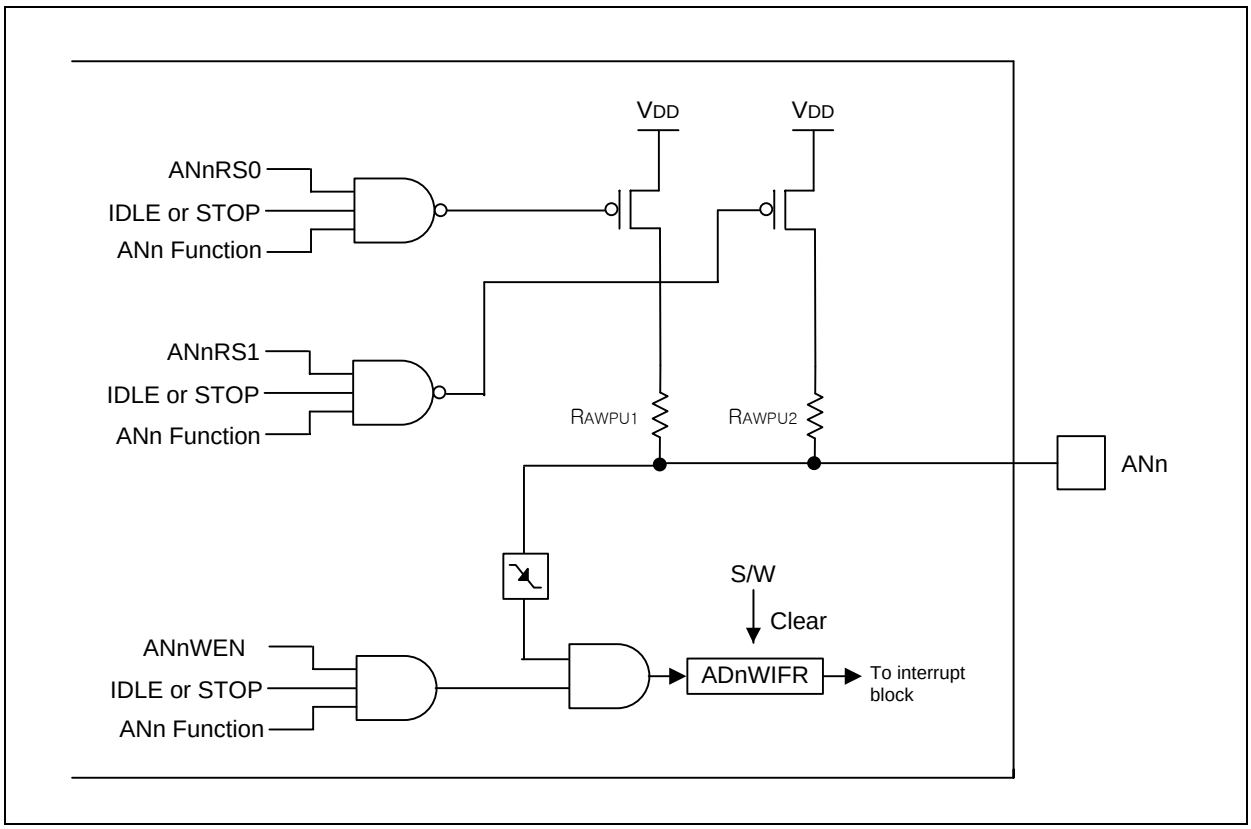


Figure 11.36 ADC Power-down Wake-up Function Block Diagram

NOTES) 1. AN0~AN14 Function can be controlled by P0FSR, P1FSRL, and P1FSRH.
2. The pull-up resistor of P0/P1 can be enabled by P0PU/P1PU register. So, Be careful of each P0/P1 pull-up resistor. If a pull-up resistor of P0/P1 is enabled, the corresponding pin will be changed the equivalent resistor value by it.
3. ADC wake-up interrupt can occur by a falling edge(VIL) of selected ANn pins.
4. ADC path is off when it is power-down mode and ADC wake-up interrupt path is on during power-down mode when ANnWEN bit is ‘1’.
5. Where n = 0, 1, 2,,,,,,,,,,,, and 14.

11.9.7 ADC Power-down Wake-up Function Operation

To use ADC power-down wake-up function in case of AN0 and a wake-up pull-up resistor 150kΩ, follow the recommended steps below.

1. Select AN0 function by P0FSR0 bit set to ‘1’ in P0FSR register. Disable P00’s pull-up resistor (P00PU).
2. Enable pull-up resistor 150kΩ by AN0RS[1:0] bits of ADWRCR0 register set to ‘01b’ for AN0.
3. Enable ADC wake-up interrupt by AN0WEN bit of ADWCRL register set to ‘1’ for AN0.
4. Enter the power-down(idle or stop) mode.
5. If it occurrs the falling edge(VIL) of key input through AN0, an ADC wake-up interrupt will be requested and released from power-down mode.
6. At this time, ADC wake-up interrupt flag for AN0, AN0WIFR bit of ADWIFRL register becomes ‘1’. The flag is cleared only by writing a ‘0’ to the bit. So, the flag should be cleared by software.

11.9.8 Application circuit for ADC Key Input by resistor string.

The resistor Rs needs to use the “ADC power-down wake-up function". The resistor prevents the ADC input pin from floating when the CPU goes into power-down mode. If Rs >> R1, the equivalent resistor of Rs//R1 depends on the resistor R1. So, the resistor Rs had better use highly greater value than the R1 resistor.

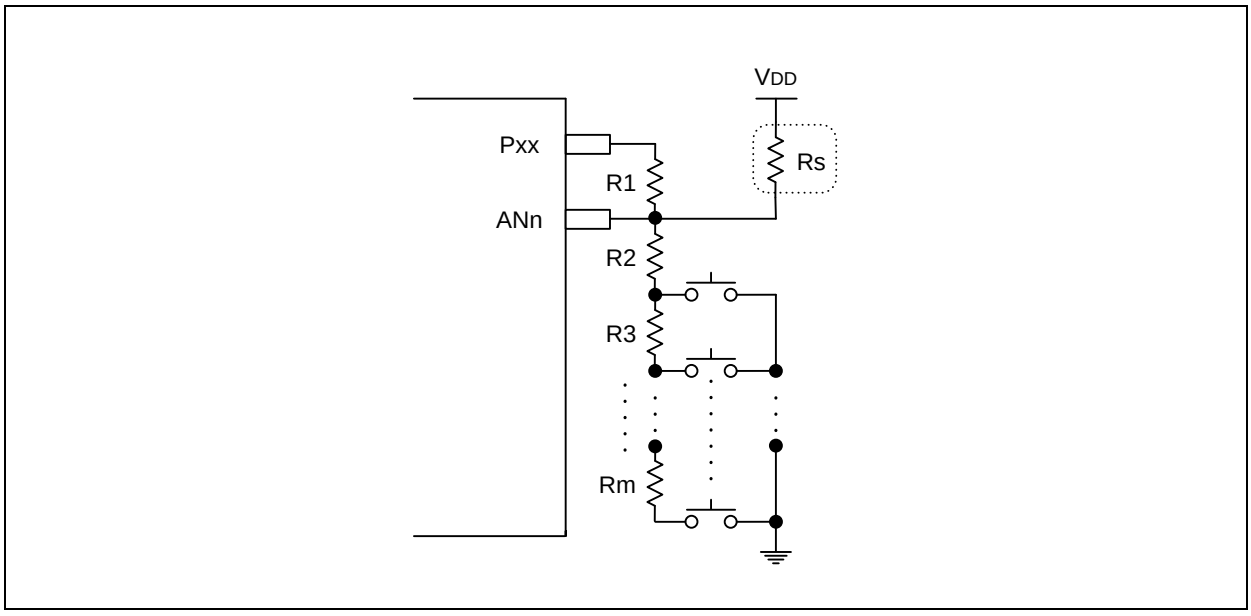


Figure 11.37 Application circuit for ADC Key Input by resistor string

NOTES) 1. The Rs about 1MΩ recommended.
2. Pxx is normal I/O pin.
3. Where n = 0, 1, 2,,,,,,,,,,,, and 14.

11.9.9 Register Map

Table 11-13 ADC Register Map

Name	Address	Dir	Default	Description
ADCDRH	9FH	R	xxH	A/D Converter Data High Register
ADCDRL	9EH	R	xxH	A/D Converter Data Low Register
ADCCRH	9DH	R/W	00H	A/D Converter Control High Register
ADCCRL	9CH	R/W	00H	A/D Converter Control Low Register
ADWRCR0	F2H	R/W	00H	ADC Wake-up Resistor Control Register 0
ADWRCR1	F3H	R/W	00H	ADC Wake-up Resistor Control Register 1
ADWRCR2	F4H	R/W	00H	ADC Wake-up Resistor Control Register 2
ADWRCR3	F5H	R/W	00H	ADC Wake-up Resistor Control Register 3
ADWCRH	F7H	R/W	00H	ADC Wake-up Control High Register
ADWCRL	F6H	R/W	00H	ADC Wake-up Control Low Register
ADWIFRH	DDH	R/W	00H	ADC Wake-up Interrupt Flag High Register
ADWIFRL	DCH	R/W	00H	ADC Wake-up Interrupt Flag Low Register

11.9.10 ADC Register Description

The ADC register consists of A/D converter data high register (ADCDRH), A/D converter data low register (ADCDRL), A/D converter control high register (ADCCRH), A/D converter control low register (ADCCRL), ADC wake-up resistor control register 0 (ADWRCR0), ADC wake-up resistor control register 1 (ADWRCR1), ADC wake-up resistor control register 2 (ADWRCR2), ADC wake-up resistor control register 3 (ADWRCR3), ADC wake-up control high register (ADWCRH), ADC wake-up control low register (ADWCRL), ADC wake-up interrupt flag high register (ADWIFRH), and ADC wake-up interrupt flag low register (ADWIFRL).

11.9.11 Register Description for ADC

ADCDRH (A/D Converter Data High Register) : 9FH

7	6	5	4	3	2	1	0
ADDM11	ADDM10	ADDM9	ADDM8	ADDM7 ADDL11	ADDM6 ADDL10	ADDM5 ADDL9	ADDM4 ADDL8
R	R	R	R	R	R	R	R

Initial value : xxH

ADDM[11:4] MSB align, A/D Converter High Data (8-bit)

ADDL[11:8] LSB align, A/D Converter High Data (4-bit)

ADCDRL (A/D Converter Data Low Register) : 9EH

7	6	5	4	3	2	1	0
ADDM3 ADDL7	ADDM2 ADDL6	ADDM1 ADDL5	ADDM0 ADDL4	ADDL3	ADDL2	ADDL1	ADDL0
R	R	R	R	R-	R	R	R

Initial value : xxH

ADDM[3:0] MSB align, A/D Converter Low Data (4-bit)

ADDL[7:0] LSB align, A/D Converter Low Data (8-bit)

ADCCRH (A/D Converter High Register) : 9DH

7	6	5	4	3	2	1	0
ADCIFR	–	–	TRIG1	TRIG0	ALIGN	CKSEL1	CKSEL0
R/W	–	–	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

ADCIFR — When ADC interrupt occurs, this bit becomes '1'. For clearing bit, write '0' to this bit or auto clear by INT_ACK signal.

0	ADC Interrupt no generation
1	ADC Interrupt generation

TRIG[1:0] — A/D Trigger Signal Selection(The ADC module is automatically disabled at stop mode)

TRIG1	TRIG0	Description
0	0	ADST
0	1	Timer 0 match signal
1	0	Timer 1 A match signal
1	1	Timer 2 A match signal

ALIGN — A/D Converter data align selection.

0	MSB align (ADCDRH[7:0], ADCDRL[7:4])
1	LSB align (ADCRDH[3:0], ADCDRL[7:0])

CKSEL[1:0] — A/D Converter Clock selection

CKSEL1	CKSEL0	Description
0	0	fx/1
0	1	fx/2
1	0	fx/4
1	1	fx/8

ADCCRL (A/D Converter Counter Low Register) : 9CH

7	6	5	4	3	2	1	0
STBY	ADST	REFSEL	AFLAG	ADSEL3	ADSEL2	ADSEL1	ADSEL0
R/W	R/W	R/W	R	R/W	R/W	R/W	R/W

Initial value : 00H

STBY Control Operation of A/D
(The ADC module is automatically disabled at stop mode)
0 ADC module disable
1 ADC module enable

ADST Control A/D Conversion start.
0 No effect
1 Trigger signal generation for conversion start

REFSEL A/D Converter Reference Selection
0 Internal Reference (VDD)
1 External Reference (AVREF)

AFLAG A/D Converter Operation State (This bit is cleared to '0' when the STBY bit is set to '0' or when the CPU is at STOP mode)
0 During A/D Conversion
1 A/D Conversion finished

ADSEL[3:0] A/D Converter input selection

ADSEL3	ADSEL2	ADSEL1	ADSEL0	Description
0	0	0	0	AN0
0	0	0	1	AN1
0	0	1	0	AN2
0	0	1	1	AN3
0	1	0	0	AN4
0	1	0	1	AN5
0	1	1	0	AN6
0	1	1	1	AN7
1	0	0	0	AN8
1	0	0	1	AN9
1	0	1	0	AN10
1	0	1	1	AN11
1	1	0	0	AN12
1	1	0	1	AN13
1	1	1	0	AN14
1	1	1	1	VDD18

ADWRCR0 (ADC Wake-up Resistor Control Register 0): F2H

7	6	5	4	3	2	1	0
AN3RS1	AN3RS0	AN2RS1	AN2RS0	AN1RS1	AN1RS0	AN0RS1	AN0RS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

ADWRCR0[7:0] ADC Wake-up Resistor selection for ANn input

ANnRS[1:0]		300kΩ Resistor	150kΩ Resistor
0	0	Disable	Disable
0	1	Disable	Enable
1	0	Enable	Disable
1	1	Enable	Enable

Where n = 0, 1, 2, and 3

ADWRCR1 (ADC Wake-up Resistor Control Register 1): F3H

7	6	5	4	3	2	1	0
AN7RS1	AN7RS0	AN6RS1	AN6RS0	AN5RS1	AN5RS0	AN4RS1	AN4RS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

ADWRCR1[7:0] ADC Wake-up Resistor selection for ANn input

ANnRS[1:0]		300kΩ Resistor	150kΩ Resistor
0	0	Disable	Disable
0	1	Disable	Enable
1	0	Enable	Disable
1	1	Enable	Enable

Where n = 4, 5, 6, and 7

ADWRCR2 (ADC Wake-up Resistor Control Register 2): F4H

7	6	5	4	3	2	1	0
AN11RS1	AN11RS0	AN10RS1	AN10RS0	AN9RS1	AN9RS0	AN8RS1	AN8RS0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

ADWRCR2[7:0] ADC Wake-up Resistor selection for ANn input

ANnRS[1:0]		300kΩ Resistor	150kΩ Resistor
0	0	Disable	Disable
0	1	Disable	Enable
1	0	Enable	Disable
1	1	Enable	Enable

Where n = 8, 9, 10, and 11

ADWRCR3 (ADC Wake-up Resistor Control Register 3): F5H

7	6	5	4	3	2	1	0
–	–	AN14RS1	AN14RS0	AN13RS1	AN13RS0	AN12RS1	AN12RS0
–	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

ADWRCR3[5:0] ADC Wake-up Resistor selection for ANn input

ANnRS[1:0]		300kΩ Resistor	150kΩ Resistor
0	0	Disable	Disable
0	1	Disable	Enable
1	0	Enable	Disable
1	1	Enable	Enable

Where n = 12, 13, and 14

ADWCRH (ADC Wake-up Control High Register): F7H

7	6	5	4	3	2	1	0
–	AN14WEN	AN13WEN	AN12WEN	AN11WEN	AN10WEN	AN9WEN	AN8WEN
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

ADWCRH[6:0] Enable or Disable ADC Wake-up Function for ANn input

ANnWEN	Description
0	Disable
1	Enable

Where n = 8, 9, 10, 11, 12, 13, and 14

ADWCRL (ADC Wake-up Control Low Register): F6H

7	6	5	4	3	2	1	0
AN7WEN	AN6WEN	AN5WEN	AN4WEN	AN3WEN	AN2WEN	AN1WEN	AN0WEN
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

ADWCRL[7:0] Enable or Disable ADC Wake-up Function for ANn input

ANnWEN	Description
0	Disable
1	Enable

Where n = 0, 1, 2, 3, 4, 5, 6, and 7

ADWIFRH (ADC Wake-up Interrupt Flag High Register): DDH

7	6	5	4	3	2	1	0
–	AN14WIFR	AN13WIFR	AN12WIFR	AN11WIFR	AN10WIFR	AN9WIFR	AN8WIFR
–	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

ADWIFRH[6:0] When a ADC wake-up interrupt AN14 ~ AN8 is occurred, the flag becomes '1'. The flag is cleared only by writing a '0' to the bit. So, the flag should be cleared by software.

0 ADC wake-up interrupt AN14 ~ AN8 not occurred

1 ADC wake-up interrupt AN14 ~ AN8 occurred

ADWIFRL (ADC Wake-up Interrupt Flag Low Register): DCH

7	6	5	4	3	2	1	0
AN7WIFR	AN6WIFR	AN5WIFR	AN4WIFR	AN3WIFR	AN2WIFR	AN1WIFR	AN0WIFR
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value: 00H

ADWIFRL[7:0] When a ADC wake-up interrupt AN7 ~ AN0 is occurred, the flag becomes '1'. The flag is cleared only by writing a '0' to the bit. So, the flag should be cleared by software.

0 ADC wake-up interrupt AN7 ~ AN0 not occurred

1 ADC wake-up interrupt AN7 ~ AN0 occurred

11.10 SPI

11.10.1 Overview

There is serial peripheral interface (SPI) one channel in MC96F8316. The SPI allows synchronous serial data transfer between the external serial devices. It can do Full-duplex communication by 4-wire (MOSI, MISO, SCK, SS), support master/slave mode, can select serial clock (SCK) polarity, phase and whether LSB first data transfer or MSB first data transfer.

11.10.2 Block Diagram

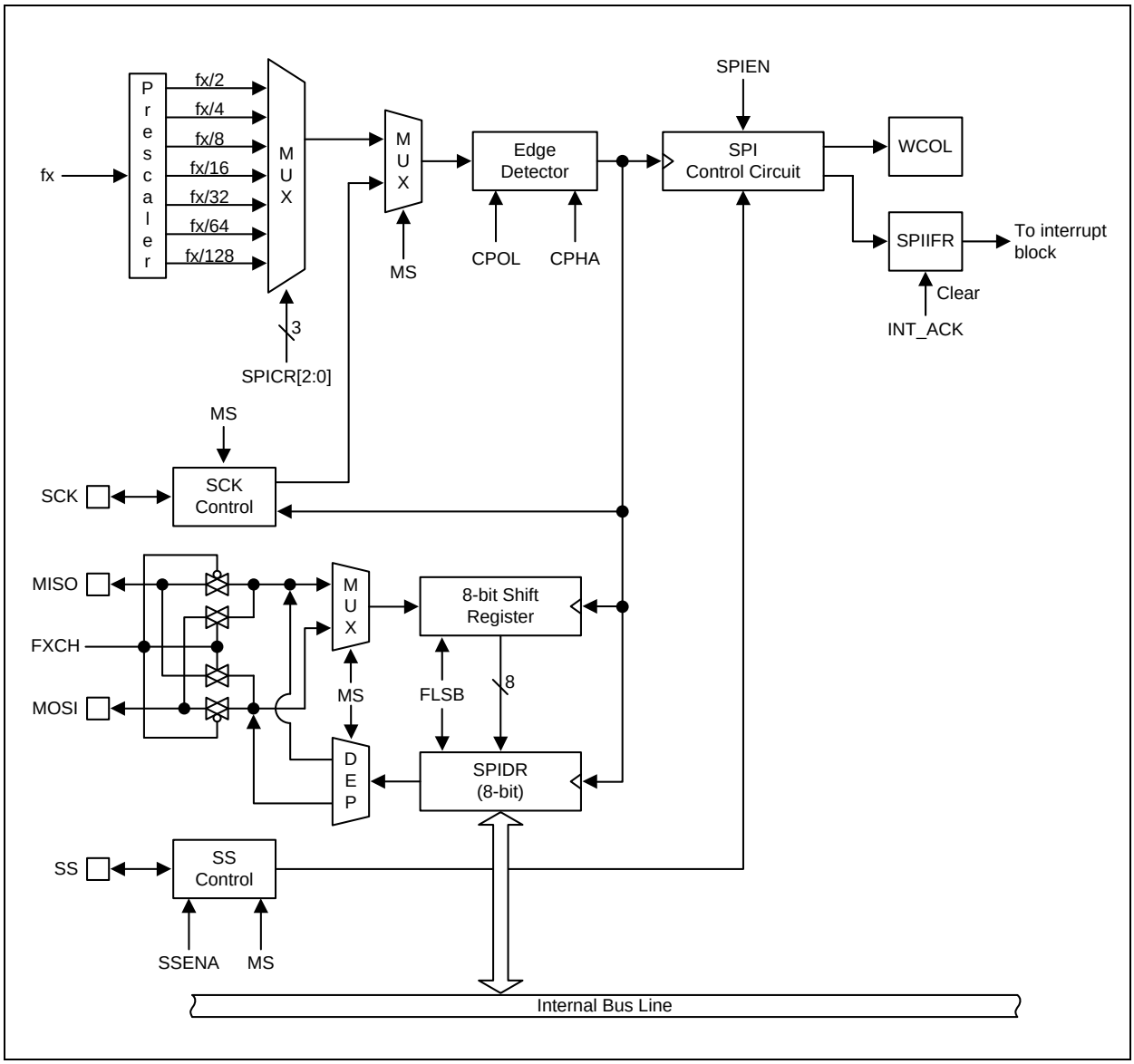


Figure 11.38 SPI Block Diagram

11.10.3 Data Transmit / Receive Operation

User can use SPI for serial data communication by following step

1. Select SPI operation mode(master/slave, polarity, phase) by control register SPICR.
2. When the SPI is configured as a Master, it selects a Slave by SS signal (active low).

   When the SPI is configured as a Slave, it is selected by SS signal incoming from Master
3. When the user writes a byte to the data register SPIDR, SPI will start an operation.
4. In this time, if the SPI is configured as a Master, serial clock will come out of SCK pin. And Master shifts the eight bits into the Slave (transmit), Slave shifts the eight bits into the Master at the same time (receive). If the SPI is configured as a Slave, serial clock will come into SCK pin. And Slave shifts the eight bits into the Master (transmit), Master shifts the eight bits into the Slave at the same time (receive).
5. When transmit/receive is done, SPIIFR bit will be set. If the SPI interrupt is enabled, an interrupt is requested. And SPIIFR bit is cleared by hardware when executing the corresponding interrupt. If SPI interrupt is disable, SPIIFR bit is cleared when user read the status register SPISR, and then access (read/write) the data register SPIDR.

11.10.4 SS pin function

1. When the SPI is configured as a Slave, the SS pin is always input. If LOW signal come into SS pin, the SPI logic is active. And if ‘HIGH’ signal come into SS pin, the SPI logic is stop. In this time, SPI logic will be reset, and invalidated any received data.
2. When the SPI is configured as a Master, the user can select the direction of the SS pin by port direction register (P17IO). If the SS pin is configured as an output, user can use general P17IO output mode. If the SS pin is configured as an input, ‘HIGH’ signal must come into SS pin to guarantee Master operation. If ‘LOW’ signal come into SS pin, the SPI logic interprets this as another master selecting the SPI as a slave and starting to send data to it. To avoid bus contention, MSB bit of SPICR will be cleared and the SPI becomes a Slave and then, SPIIFR bit of SPISR will be set, and if the SPI interrupt is enabled, an interrupt is requested.

NOTES)

- When the SS pin is configured as an output at Master mode, SS pin’s output value is defined by user’s software (P17IO). Before SPICR setting, the direction of SS pin must be defined
- If you don’t need to use SS pin, clear the SSENA bit of SPISR. So, you can use disabled pin by P17IO freely. In this case, SS signal is driven by ‘HIGH’ or ‘LOW’ internally. In other words, master is ‘HIGH’, salve is ‘LOW’
- When SS pin is configured as input, if ‘HIGH’ signal come into SS pin, SS_HIGH flag bit will be set. And you can clear it by writing ‘0’.

11.10.5 SPI Timing Diagram

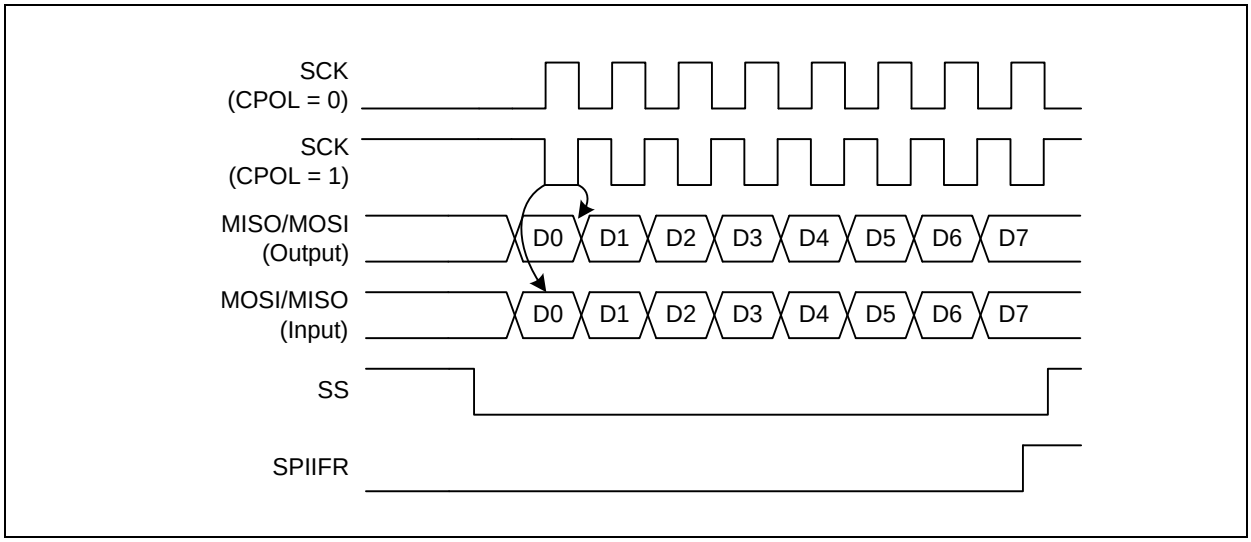


Figure 11.39 SPI Transmit/Receive Timing Diagram at CPHA = 0

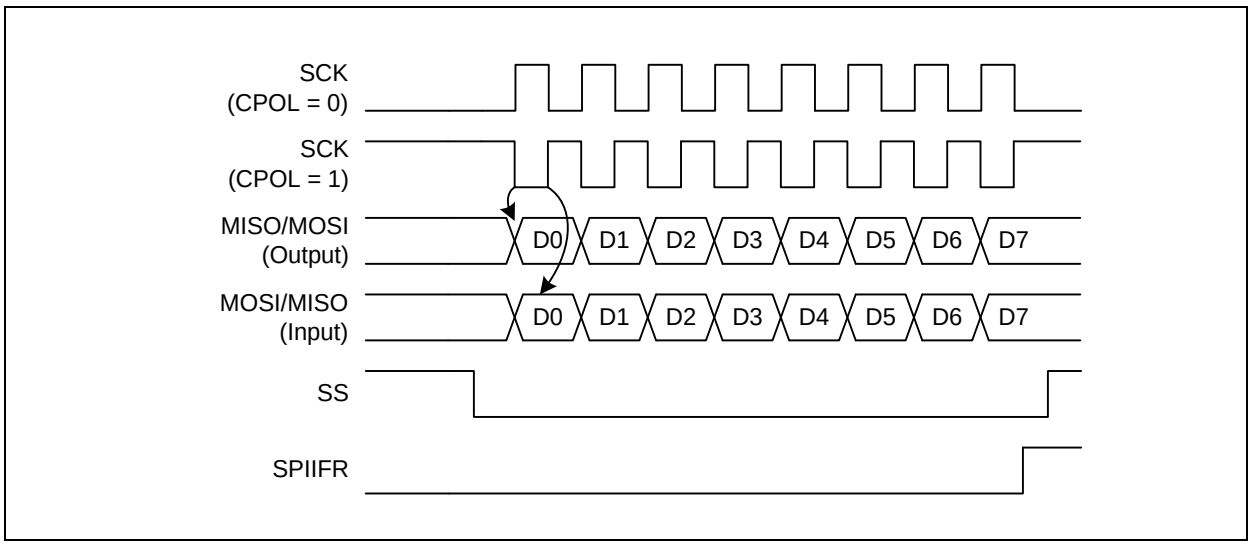


Figure 11.40 SPI Transmit/Receive Timing Diagram at CPHA = 1

11.10.6 Register Map

Table 11-14 SPI Register Map

Name	Address	Dir	Default	Description
SPISR	B7H	R/W	00H	SPI Status Register
SPIDR	B6H	R/W	00H	SPI Data Register
SPICR	B5H	R/W	00H	SPI Control Register

11.10.7 SPI Register Description

The SPI register consists of SPI control register (SPICR), SPI status register (SPISR) and SPI data register (SPIDR)

11.10.8 Register Description for SPI

SPIDR (SPI Data Register) : B6H

7	6	5	4	3	2	1	0
SPIDR7	SPIDR6	SPIDR5	SPIDR4	SPIDR3	SPIDR2	SPIDR1	SPIDR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

SPIDR [7:0] SPI Data
When it is written a byte to this data register, the SPI will start an operation.

SPISR (SPI Status Register) : B7H

7	6	5	4	3	2	1	0
SPIIFR	WCOL	SS_HIGH	–	FXCH	SSENA	–	–
R/W	R	R/W	–	R/W	R/W	–	–

Initial value : 00H

SPIIFR — When SPI Interrupt occurs, this bit becomes '1'. IF SPI interrupt is enable, this bit is auto cleared by INT_ACK signal. And if SPI Interrupt is disable, this bit is cleared when the status register SPISR is read, and then access (read/write) the data register SPIDR

0 SPI Interrupt no generation

1 SPI Interrupt generation

WCOL — This bit is set if any data are written to the data register SPIDR during transfer. This bit is cleared when the status register SPISR is read, and then access (read/write) the data register SPIDR

0 No collision

1 Collision

SS_HIGH — When the SS pin is configured as input, if "HIGH" signal comes into the pin, this flag bit will be set.

0 Cleared when '0' is written

1 No effect when '1' is written

FXCH — SPI port function exchange control bit.

0 No effect

1 Exchange MOSI and MISO function

SSENA — This bit controls the SS pin operation

0 Disable

1 Enable (The P17 should be a normal input)

SPICR (SPI Control Register) : B5H

7	6	5	4	3	2	1	0
SPIEN	FLSB	MS	CPOL	CPHA	DSCR	SCR1	SCR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

SPIEN — This bit controls the SPI operation

0 Disable SPI operation

1 Enable SPI operation

FLSB — This bit selects the data transmission sequence

0 MSB first

1 LSB first

MS — This bit selects whether Master or Slave mode

0 Slave mode

1 Master mode

CPOL
CPHA — This two bits control the serial clock (SCK) mode.

Clock polarity(CPOL) bit determine SCK's value at idle mode.

Clcok phase (CPHA) bit determine if data are sampled on the leading or trailing edge of SCK.

CPOL	CPHA	Leading edge	Trailing edge
0	0	Sample (Rising)	Setup (Falling)
0	1	Setup (Rising)	Sample (Falling)
1	0	Sample (Falling)	Setup (Rising)
1	1	Setup (Falling)	Sample (Rising)

DSCR
SCR[2:0] — These three bits select the SCK rate of the device configured as a master. When DSCR bit is written one, SCK will be doubled in master mode.

DSCR	SCR1	SCR0	SCK frequency
0	0	0	fx/4
0	0	1	fx/16
0	1	0	fx/64
0	1	1	fx/128
1	0	0	fx/2
1	0	1	fx/8
1	1	0	fx/32
1	1	1	fx/64

11.11 UART

11.11.1 Overview

The universal asynchronous serial receiver and transmitter (UART) is a highly flexible serial communication device. The main features are listed below.

- Full Duplex Operation (Independent Serial Receive and Transmit Registers)
- Baud Rate Generator
- Supports Serial Frames with 5, 6, 7, 8, or 9 Data Bits and 1 or 2 Stop Bits
- Odd or Even Parity Generation and Parity Check Supported by Hardware
- Data OverRun Detection
- Framing Error Detection
- Three Separate Interrupts on TX Complete, TX Data Register Empty and RX Complete

UART has baud rate generator, transmitter and receiver. The baud rate generator for asynchronous operation. The Transmitter consists of a single write buffer, a serial shift register, parity generator and control logic for handling different serial frame formats. The write buffer allows continuous transfer of data without any delay between frames. The receiver is the most complex part of the UART module due to its clock and data recovery units. The recovery unit is used for asynchronous data reception. In addition to the recovery unit, the receiver includes a parity checker, a shift register, a two-level receive FIFO (UARTDR) and control logic. The receiver supports the same frame formats as the transmitter and can detect frame error, data overrun and parity errors.

11.11.2 Block Diagram

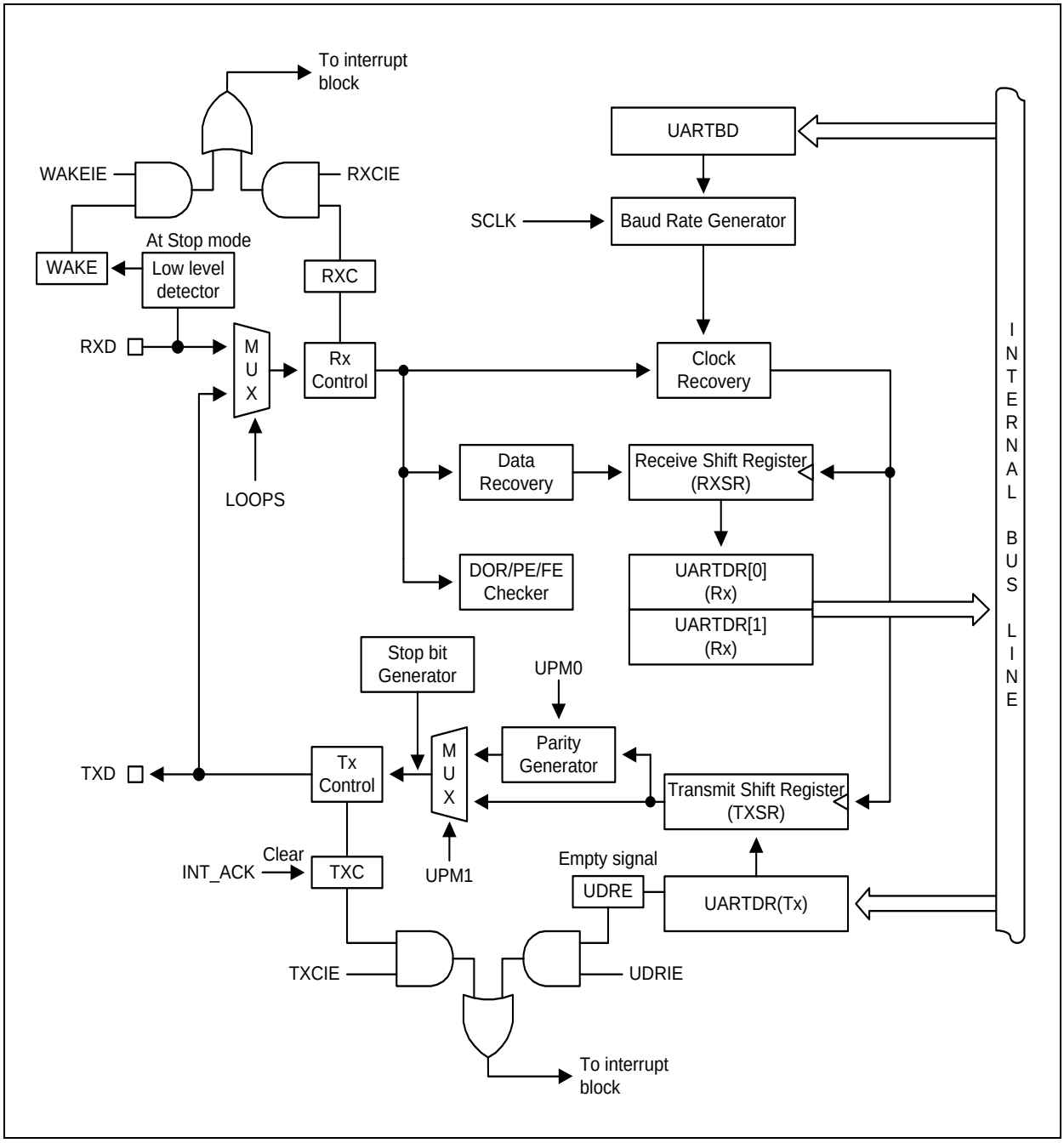


Figure 11.41 UART Block Diagram

11.11.3 Clock Generation

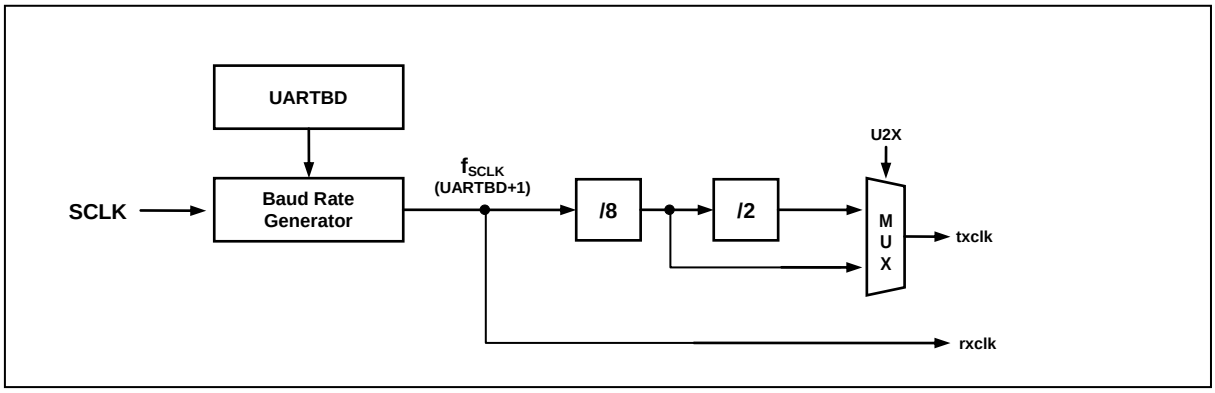


Figure 11.42 Clock Generation Block Diagram

The clock generation logic generates the base clock for the transmitter and receiver.

Following table shows equations for calculating the baud rate (in bps).

Table 11-15 Equations for Calculating Baud Rate Register Setting

Operating Mode	Equation for Calculating Baud Rate
Normal Mode(U2X=0)	$\text{Baud Rate} = \frac{\text{fx}}{16(\text{UARTBD} + 1)}$
Double Speed Mode(U2X=1)	$\text{Baud Rate} = \frac{\text{fx}}{8(\text{UARTBD} + 1)}$

11.11.4 Data format

A serial frame is defined to be one character of data bits with synchronization bits (start and stop bits), and optionally a parity bit for error detection.

The UART supports all 30 combinations of the following as valid frame formats.

- 1 start bit
- 5, 6, 7, 8 or 9 data bits
- no, even or odd parity bit
- 1 or 2 stop bits

A frame starts with the start bit followed by the least significant data bit (LSB). Then the next data bits, up to nine, are succeeding, ending with the most significant bit (MSB). If parity function is enabled, the parity bit is inserted between the last data bit and the stop bit. A high-to-low transition on data pin is considered as start bit. When a complete frame is transmitted, it can be directly followed by a new frame, or the communication line can be set to an idle state. The idle means high state of data pin. The following figure shows the possible combinations of the frame formats. Bits inside brackets are optional.

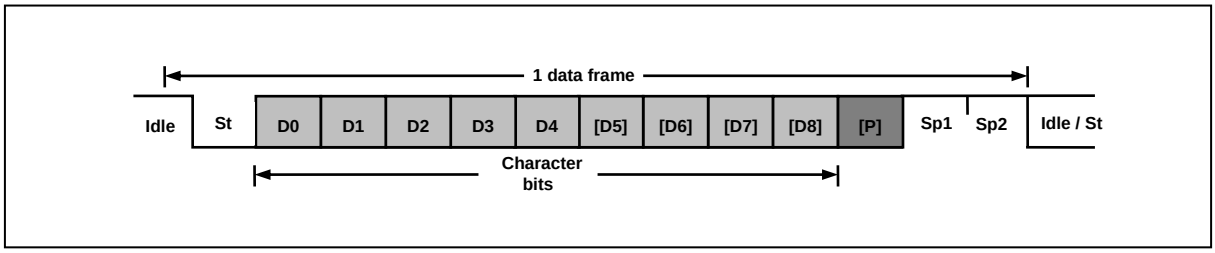


Figure 11.43 Frame Format

1 data frame consists of the following bits

- Idle No communication on communication line (TxD/RxD)
- St Start bit (Low)
- Dn Data bits (0~8)
- Parity bit ---------- Even parity, Odd parity, No parity
- Stop bit(s) ---------- 1 bit or 2 bits

The frame format used by the UART is set by the USIZE[2:0], UPM[1:0] and USBS bits in UARTCR1 and UARTCR3 register. The Transmitter and Receiver use the same setting.

11.11.5 Parity bit

The parity bit is calculated by doing an exclusive-OR of all the data bits. If odd parity is used, the result of the exclusive-or is inverted. The parity bit is located between the MSB and first stop bit of a serial frame.

$P_{even} = D_{n-1} \wedge \ldots \wedge D_3 \wedge D_2 \wedge D_1 \wedge D_0 \wedge 0$

$P_{odd} = D_{n-1} \wedge \ldots \wedge D_3 \wedge D_2 \wedge D_1 \wedge D_0 \wedge 1$

P_{even} : Parity bit using even parity

P_{odd} : Parity bit using odd parity

D_n : Data bit n of the character

11.11.6 UART Transmitter

The UART transmitter is enabled by setting the TXE bit in UARTCR2 register. When the Transmitter is enabled, the TXD pin should be set to TXD function for the serial output pin of UART by the P3FSR[1:0]. The baud-rate, operation mode and frame format must be setup once before doing any transmission.

11.11.6.1 Sending Tx data

A data transmission is initiated by loading the transmit buffer (UARTDR register I/O location) with the data to be transmitted. The data written in transmit buffer is moved to the shift register when the shift register is ready to send a new frame. The shift register is loaded with the new data if it is in idle state or immediately after the last stop bit of the previous frame is transmitted. When the shift register is loaded with new data, it will transfer one complete frame according to the settings of control registers. If the 9-bit characters are used, the ninth bit must be written to the TX8 bit in UARTCR3 register before it is loaded to the transmit buffer (UARTDR register).

11.11.6.2 Transmitter flag and interrupt

The UART transmitter has 2 flags which indicate its state. One is UART data register empty flag (UDRE) and the other is transmit complete flag (TXC). Both flags can be interrupt sources.

UDRE flag indicates whether the transmit buffer is ready to receive new data. This bit is set when the transmit buffer is empty and cleared when the transmit buffer contains data to be transmitted but has not yet been moved into the shift register. And also this flag can be cleared by writing ‘0’ to this bit position. Writing ‘1’ to this bit position is prevented.

When the data register empty interrupt enable (UDRIE) bit in UARTCR2 register is set and the global interrupt is enabled, UART data register empty interrupt is generated while UDRE flag is set.

The transmit complete (TXC) flag bit is set when the entire frame in the transmit shift register has been shifted out and there is no more data in the transmit buffer. The TXC flag is automatically cleared when the transmit complete interrupt service routine is executed, or it can be cleared by writing ‘0’ to TXC bit in UARTST register.

When the transmit complete interrupt enable (TXCIE) bit in UARTCR2 register is set and the global interrupt is enabled, UART transmit complete interrupt is generated while TXC flag is set.

11.11.6.3 Parity Generator

The parity generator calculates the parity bit for the serial frame data to be sent. When parity bit is enabled (UPM[1]=1), the transmitter control logic inserts the parity bit between the MSB and the first stop bit of the frame to be sent.

11.11.6.4 Disabling Transmitter

Disabling the transmitter by clearing the TXE bit will not become effective until ongoing transmission is completed. When the Transmitter is disabled, the TXD pin can be used as a normal general purpose I/O (GPIO).

11.11.7 UART Receiver

The UART receiver is enabled by setting the RXE bit in the UARTCR2 register. When the receiver is enabled, the RXD pin should be set to the input port for the serial input pin of UART by P31IO bit. The baud-rate, mode of operation and frame format must be set before serial reception.

11.11.7.1 Receiving Rx data

The receiver starts data reception when it detects a valid start bit (LOW) on RXD pin. Each bit after start bit is sampled at pre-defined baud-rate (asynchronous) and shifted into the receive shift register until the first stop bit of a frame is received. Even if there's 2^{nd} stop bit in the frame, the 2^{nd} stop bit is ignored by the receiver. That is, receiving the first stop bit means that a complete serial frame is present in the receiver shift register and contents of the shift register are to be moved into the receive buffer. The receive buffer is read by reading the UARTDR register.

If 9-bit characters are used (USIZE[2:0] = "111"), the ninth bit is stored in the RX8 bit position in the UARTCR3 register. The 9^{th} bit must be read from the RX8 bit before reading the low 8 bits from the UARTDR register. Likewise, the error flags FE, DOR, PE must be read before reading the data from UARTDR register. It's because the error flags are stored in the same FIFO position of the receive buffer.

11.11.7.2 Receiver Flag and Interrupt

The UART receiver has one flag that indicates the receiver state.

The receive complete (RXC) flag indicates whether there are unread data in the receive buffer. This flag is set when there are unread data in the receive buffer and cleared when the receive buffer is empty. If the receiver is disabled (RXE=0), the receiver buffer is flushed and the RXC flag is cleared.

When the receive complete interrupt enable (RXCIE) bit in the UARTCR2 register is set and global interrupt is enabled, the UART receiver complete interrupt is generated while RXC flag is set.

The UART receiver has three error flags which are frame error (FE), data overrun (DOR) and parity error (PE). These error flags can be read from the UARTST register. As received data are stored in the 2-level receive buffer, these error flags are also stored in the same position of receive buffer. So, before reading received data from UARTDR register, read the UARTST register first which contains error flags.

The frame error (FE) flag indicates the state of the first stop bit. The FE flag is '0' when the stop bit was correctly detected as '1', and the FE flag is '1' when the stop bit was incorrect, i.e. detected as '0'. This flag can be used for detecting out-of-sync conditions between data frames.

The data overrun (DOR) flag indicates data loss due to a receive buffer full condition. DOR occurs when the receive buffer is full, and another new data is present in the receive shift register which are to be stored into the receive buffer. After the DOR flag is set, all the incoming data are lost. To prevent data loss or clear this flag, read the receive buffer.

The parity error (PE) flag indicates that the frame in the receive buffer had a parity error when received. If parity check function is not enabled (UPM[1]=0), the PE bit is always read '0'.

11.11.7.3 Parity Checker

If parity bit is enabled (UPM[1]=1), the Parity Checker calculates the parity of the data bits in incoming frame and compares the result with the parity bit from the received serial frame.

11.11.7.4 Disabling Receiver

In contrast to transmitter, disabling the Receiver by clearing RXE bit makes the Receiver inactive immediately. When the receiver is disabled, the receiver flushes the receive buffer, the remaining data in the buffer is all reset, and the RXD pin can be used as a normal general purpose I/O (GPIO).

11.11.7.5 Asynchronous Data Reception

To receive asynchronous data frame, the UART includes a clock and data recovery unit. The clock recovery logic is used for synchronizing the internally generated baud-rate clock to the incoming asynchronous serial frame on the RXD pin.

The data recovery logic samples and low pass filters the incoming bits, and this removes the noise of RXD pin.

The next figure illustrates the sampling process of the start bit of an incoming frame. The sampling rate is 16 times the baud-rate for normal mode(U2X=0) and 8 times the baud-rate for double speed mode (U2X=1). The horizontal arrows show the synchronization variation due to the asynchronous sampling process. Note that larger time variation is shown when using the double speed mode.

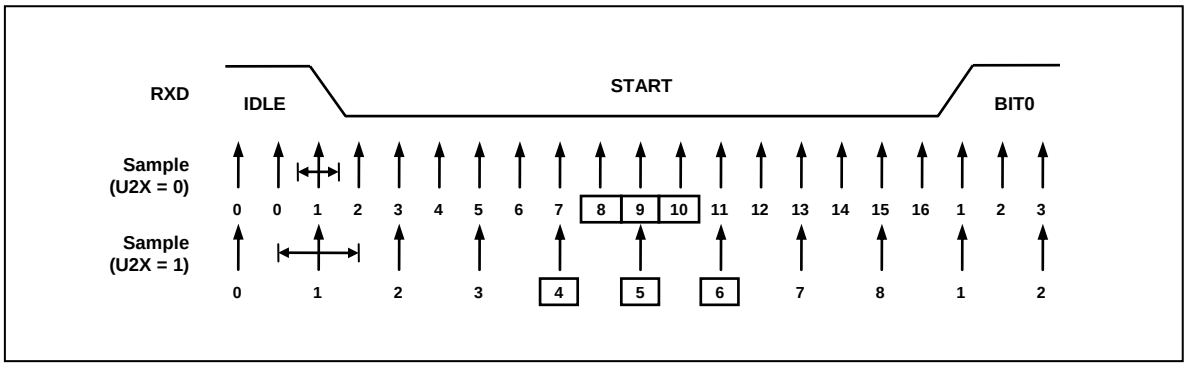


Figure 11.44 Start Bit Sampling

When the receiver is enabled (RXE=1), the clock recovery logic tries to find a high-to-low transition on the RXD line, the start bit condition. After detecting high to low transition on RXD line, the clock recovery logic uses samples 8, 9, and 10 for normal mode, and samples 4, 5, and 6 for double speed mode to decide if a valid start bit is received. If more than 2 samples have logical low level, it is considered that a valid start bit is detected and the internally generated clock is synchronized to the incoming data frame. And the data recovery can begin. The synchronization process is repeated for each start bit.

As described above, when the receiver clock is synchronized to the start bit, the data recovery can begin. Data recovery process is almost similar to the clock recovery process. The data recovery logic samples 16 times for each incoming bits for normal mode and 8 times for double speed mode. And uses sample 8, 9, and 10 to decide data value for normal mode, and samples 4, 5, and 6 for double speed mode. If more than 2 samples have low levels, the received bit is considered to a logic ‘0’ and if more than 2 samples have high levels, the received bit is considered to a logic ‘1’. The data recovery process is then repeated until a complete frame is received including the first stop bit. The decided bit value is stored in the receive shift register in order. Note that the Receiver only uses the first stop bit of a frame. Internally, after receiving the first stop bit, the Receiver is in idle state and waiting to find start bit.

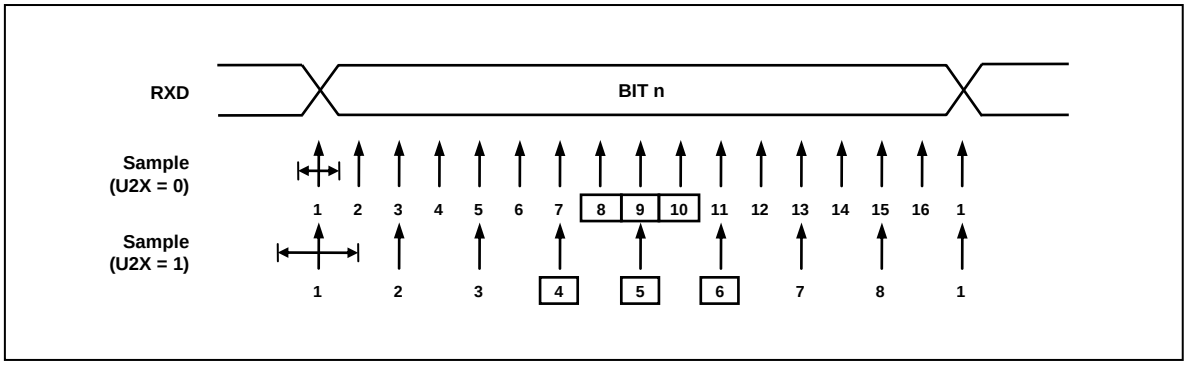


Figure 11.45 Sampling of Data and Parity Bit

The process for detecting stop bit is like clock and data recovery process. That is, if 2 or more samples of 3 center values have high level, correct stop bit is detected, else a frame error (FE) flag is set. After deciding whether the first stop bit is valid or not, the Receiver goes to idle state and monitors the RXD line to check a valid high to low transition is detected (start bit detection).

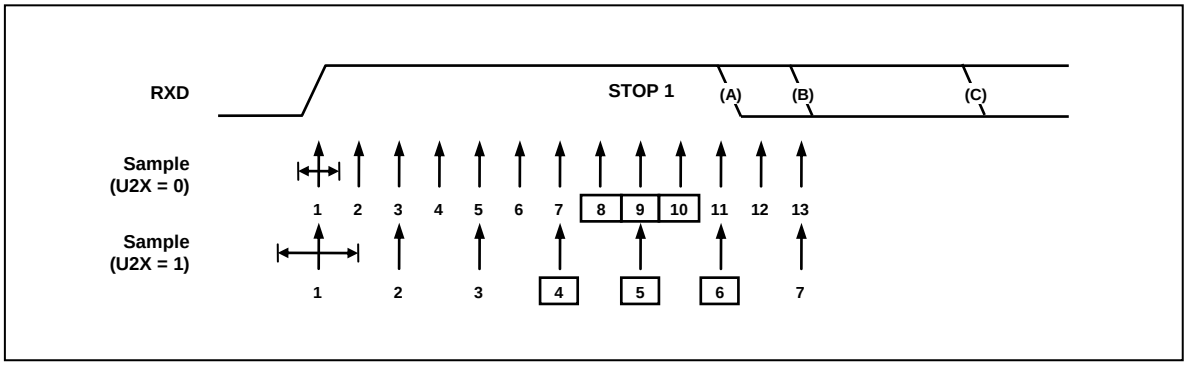


Figure 11.46 Stop Bit Sampling and Next Start Bit Sampling

11.11.8 Register Map

Table 11-16 UART Register Map

Name	Address	Dir	Default	Description
UARTBD	E6H	R/W	FFH	UART Baud Rate Generation Register
UARTDR	E7H	R/W	00H	UART Data Register
UARTCR1	E2H	R/W	00H	UART Control Register 1
UARTCR2	E3H	R/W	00H	UART Control Register 2
UARTCR3	E4H	R/W	00H	UART Control Register 3
UARTST	E5H	R/W	80H	UART Status Register

11.11.9 UART Register Description

UART module consists of UART baud rate generation register (UARTBD), UART data register (UARTDR), UART control register 1 (UARTCR1), UART control register 2 (UARTCR2) ,UART control register 3 (UARTCR3), and UART status register (UARTST).

11.11.10 Register Description for UART

UARTBD (UART Baud Rate Generation Register) : E6H

7	6	5	4	3	2	1	0
UARTBD7	UARTBD6	UARTBD5	UARTBD4	UARTBD3	UARTBD2	UARTBD1	UARTBD0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : FFH

UARTBD [7:0] The value in this register is used to generate internal baud rate. To prevent malfunction, do not write ‘0’.

UARTDR (UART Data Register) : E7H

7	6	5	4	3	2	1	0
UARTDR7	UARTDR6	UARTDR5	UARTDR4	UARTDR3	UARTDR2	UARTDR1	UARTDR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

UARTDR [7:0] The UART Transmit Buffer and Receive Buffer share the same I/O address with this DATA register. The Transmit Data Buffer is the destination for data written to the UARTDR register. Reading the UARTDR register returns the contents of the Receive Buffer.

Write this register only when the UDRE flag is set.

UARTCR1 (UART Control Register 1) : E2H

7	6	5	4	3	2	1	0
-	-	UPM1	UPM0	USIZE2	USIZE1	USIZE0	-
-	-	R/W	R/W	R/W	R/W	R/W	-

Initial value : 00H

UPM[1:0] Selects Parity Generation and Check methods

UPM1	UPM0	Parity
0	0	No Parity
0	1	Reserved
1	0	Even Parity
1	1	Odd Parity

USIZE[2:0] Selects the Length of Data Bits in Frame

USIZE2	USIZE1	USIZE0	Data Length
0	0	0	5 bit
0	0	1	6 bit
0	1	0	7 bit
0	1	1	8 bit
1	1	1	9 bit
Other values			Reserved

UARTCR2 (UART Control Register 2) : E3H

7	6	5	4	3	2	1	0
UDRIE	TXCIE	RXCIE	WAKEIE	TXE	RXE	UARTEN	U2X
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

UDRIE Interrupt enable bit for UART Data Register Empty
- 0 Interrupt from UDRE is inhibited (use polling)
- 1 When UDRE is set, request an interrupt

TXCIE Interrupt enable bit for Transmit Complete
- 0 Interrupt from TXC is inhibited (use polling)
- 1 When TXC is set, request an interrupt

RXCIE Interrupt enable bit for Receive Complete
- 0 Interrupt from RXC is inhibited (use polling)
- 1 When RXC is set, request an interrupt

WAKEIE Interrupt enable bit for Wake in STOP mode. When device is in stop mode, if RXD goes to LOW level, an interrupt can be requested to wake-up system. At that time the UDRIE bit and UARTST register value should be set to '0b' and "00H", respectively.
- 0 Interrupt from Wake is inhibited
- 1 When WAKE is set, request an interrupt

TXE Enables the transmitter unit
- 0 Transmitter is disabled
- 1 Transmitter is enabled

RXE Enables the receiver unit
- 0 Receiver is disabled
- 1 Receiver is enabled

UARTEN Activate UART module by supplying clock. When one of TXE and RXE values is "1", the UARTEN bit always set to "1".
- 0 UART is disabled (clock is halted)
- 1 UART is enabled

U2X This bit selects receiver sampling rate.
- 0 Normal Asynchronous operation
- 1 Double Speed Asynchronous operation

UARTCR3 (UART Control Register 3) : E4H

7	6	5	4	3	2	1	0
-	LOOPS	-	-	-	USBS	TX8	RX8
-	R/W	-	-	-	R/W	R/W	R

Initial value : 00H

LOOPS	Controls the Loop Back Mode of UART, for test mode	
	0	Normal operation
	1	Loop Back mode
USBS	Selects the length of stop bit.	
	0	1 Stop Bit
	1	2 Stop Bit
TX8	The ninth bit of data frame in UART. Write this bit first before loading the UARTDR register	
	0	MSB (9^{th} bit) to be transmitted is '0'
	1	MSB (9^{th} bit) to be transmitted is '1'
RX8	The ninth bit of data frame in UART. Read this bit first before reading the receive buffer	
	0	MSB (9^{th} bit) received is '0'
	1	MSB (9^{th} bit) received is '1'

UARTST (UART Status Register) : E5H

7	6	5	4	3	2	1	0
UDRE	TXC	RXC	WAKE	SOFTRST	DOR	FE	PE
R/W	R/W	R	R/W	R/W	R	R/W	R/W

Initial value : 80H

UDRE — The UDRE flag indicates if the transmit buffer (UARTDR) is ready to receive new data. If UDRE is '1', the buffer is empty and ready to be written. This flag can generate a UDRE interrupt.

0 Transmit buffer is not empty.

1 Transmit buffer is empty.

TXC — This flag is set when the entire frame in the transmit shift register has been shifted out and there is no new data currently present in the transmit buffer. This flag is automatically cleared when the interrupt service routine of a TXC interrupt is executed. This flag can generate a TXC interrupt.

0 Transmission is ongoing.

1 Transmit buffer is empty and the data in transmit shift register are shifted out completely.

RXC — This flag is set when there are unread data in the receive buffer and cleared when all the data in the receive buffer are read. The RXC flag can be used to generate a RXC interrupt.

0 There is no data unread in the receive buffer

1 There are more than 1 data in the receive buffer

WAKE — This flag is set when the RXD pin is detected low while the CPU is in stop mode. This flag can be used to generate a WAKE interrupt. This bit should be cleared by program software.

0 No WAKE interrupt is generated.

1 WAKE interrupt is generated.

SOFTRST — This is an internal reset and only has effect on UART. Writing '1' to this bit initializes the internal logic of UART and this bit is automatically cleared.

0 No operation

1 Reset UART

DOR — This bit is set if a Data OverRun occurs. While this bit is set, the incoming data frame is ignored. This flag is valid until the receive buffer is read.

0 No Data OverRun

1 Data OverRun detected

FE — This bit is set if the first stop bit of next character in the receive buffer is detected as '0'. This bit is valid until the receive buffer is read.

0 No Frame Error

1 Frame Error detected

PE — This bit is set if the next character in the receive buffer has a Parity Error to be received while Parity Checking is enabled. This bit is valid until the receive buffer is read.

0 No Parity Error

1 Parity Error detected

11.11.11 Baud Rate setting (example)

Table 11-17 Examples of UARTBD Settings for Commonly Used Oscillator Frequencies

Baud Rate	fx=1.00MHz		fx=1.8432MHz		fx=2.00MHz	
	UARTBD	ERROR	UARTBD	ERROR	UARTBD	ERROR
2400	25	0.2%	47	0.0%	51	0.2%
4800	12	0.2%	23	0.0%	25	0.2%
9600	6	-7.0%	11	0.0%	12	0.2%
14.4k	3	8.5%	7	0.0%	8	-3.5%
19.2k	2	8.5%	5	0.0%	6	-7.0%
28.8k	1	8.5%	3	0.0%	3	8.5%
38.4k	1	-18.6%	2	0.0%	2	8.5%
57.6k	-	-	1	-25.0%	1	8.5%
76.8k	-	-	1	0.0%	1	-18.6%
115.2k	-	-	-	-	-	-
230.4k	-	-	-	-	-	-

(continued)

Baud Rate	fx=3.6864MHz		fx=4.00MHz		fx=7.3728MHz	
	UARTBD	ERROR	UARTBD	ERROR	UARTBD	ERROR
2400	95	0.0%	103	0.2%	191	0.0%
4800	47	0.0%	51	0.2%	95	0.0%
9600	23	0.0%	25	0.2%	47	0.0%
14.4k	15	0.0%	16	2.1%	31	0.0%
19.2k	11	0.0%	12	0.2%	23	0.0%
28.8k	7	0.0%	8	-3.5%	15	0.0%
38.4k	5	0.0%	6	-7.0%	11	0.0%
57.6k	3	0.0%	3	8.5%	7	0.0%
76.8k	2	0.0%	2	8.5%	5	0.0%
115.2k	1	0.0%	1	8.5%	3	0.0%
230.4k	-	-	-	-	1	0.0%
250k	-	-	-	-	1	-7.8%
0.5M	-	-	-	-	-	-

(continued)

Baud Rate	fx=8.00MHz		fx=11.0592MHz	
	UARTBD	ERROR	UARTBD	ERROR
2400	207	0.2%	-	-
4800	103	0.2%	143	0.0%
9600	51	0.2%	71	0.0%
14.4k	34	-0.8%	47	0.0%
19.2k	25	0.2%	35	0.0%
28.8k	16	2.1%	23	0.0%
38.4k	12	0.2%	17	0.0%
57.6k	8	-3.5%	11	0.0%
76.8k	6	-7.0%	8	0.0%
115.2k	3	8.5%	5	0.0%
230.4k	1	8.5%	2	0.0%
250k	1	0.0%	2	-7.8%
0.5M	-	-	-	-
1M	-	-	-	-

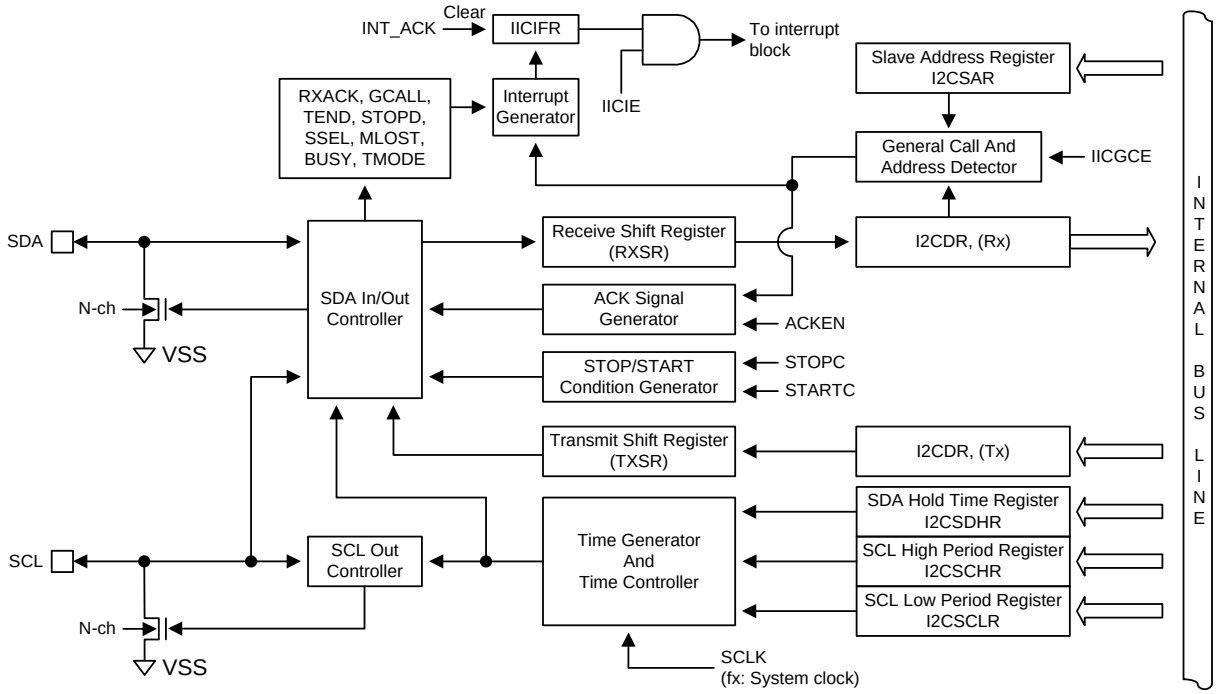
11.12 I2C

11.12.1 Overview

The I2C is one of industrial standard serial communicatin protocols, and which uses 2 bus lines Serial Data Line (SDA) and Serial Clock Line (SCL) to exchange data. Because both SDA and SCL lines are open-drain output, each line needs pull-up resistor. The features are as shown below.

- Compatible with I2C bus standard
- Multi-master operation
- Up to 400kHz data transfer read speed
- 7 bit address
- Support two slave address
- Both master and slave operation
- Bus busy detection

11.12.2 I2C Block Diagram



NOTE) When the corresponding port is an sub-function for SCL/SDA pin, the SCL/SDA pins are automatically set to the N-channel open-drain outputs and the input latch is read in the case of reading the pins. The corresponding pull-up resistor is determined by the control register.

Figure 11.47 I2C Block Diagram

11.12.3 I2C Bit Transfer

The data on the SDA line must be stable during HIGH period of the clock, SCL. The HIGH or LOW state of the data line can only change when the clock signal on the SCL line is LOW. The exceptions are START(S), repeated START(Sr) and STOP(P) condition where data line changes when clock line is high.

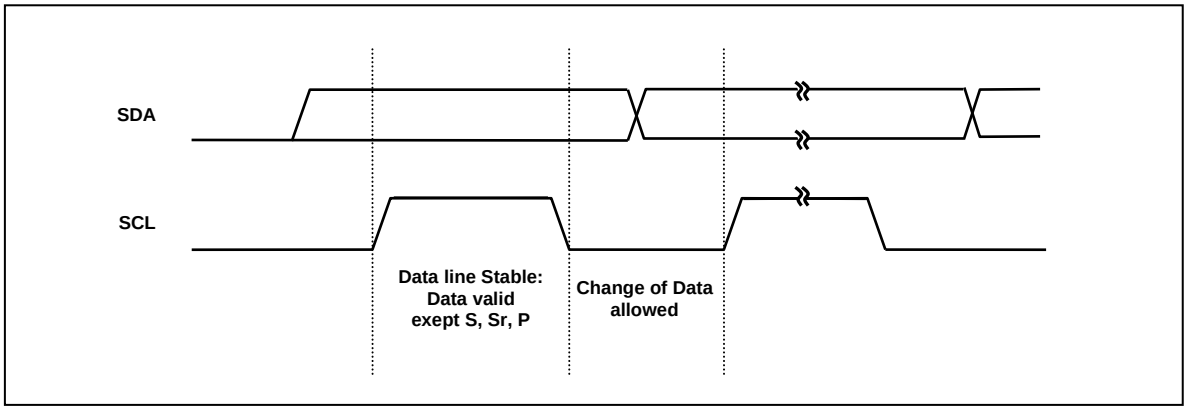


Figure 11.48 Bit Transfer on the I2C-Bus

11.12.4 Start / Repeated Start / Stop

One master can issue a START (S) condition to notice other devices connected to the SCL, SDA lines that it will use the bus. A STOP (P) condition is generated by the master to release the bus lines so that other devices can use it.

A high to low transition on the SDA line while SCL is high defines a START (S) condition.
A low to high transition on the SDA line while SCL is high defines a STOP (P) condition.

START and STOP conditions are always generated by the master. The bus is considered to be busy after START condition. The bus is considered to be free again after STOP condition, ie, the bus is busy between START and STOP condition. If a repeated START condition (Sr) is generated instead of STOP condition, the bus stays busy. So, the START and repeated START conditions are functionally identical.

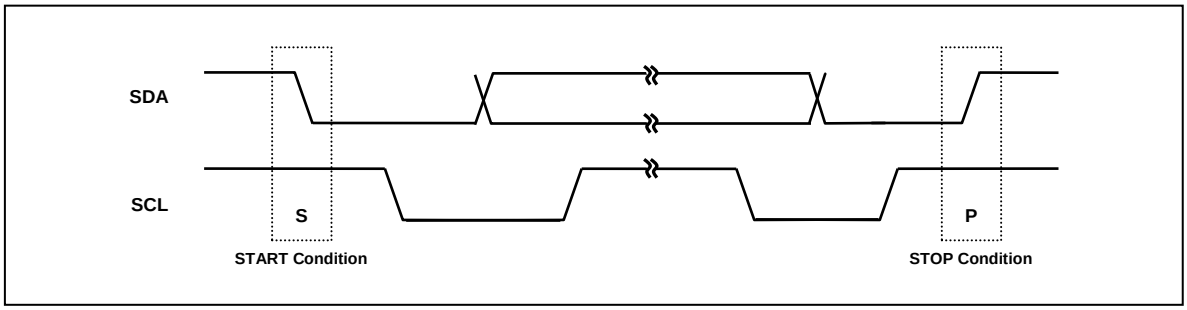


Figure 11.49 START and STOP Condition

11.12.5 Data Transfer

Every byte put on the SDA line must be 8-bits long. The number of bytes that can be transmitted per transfer is unlimited. Each byte has to be followed by an acknowledge bit. Data is transferred with the most significant bit (MSB) first. If a slave can't receive or transmit another complete byte of data until it has performed some other function, it can hold the clock line SCL LOW to force the master into a wait state. Data transfer then continues when the slave is ready for another byte of data and releases clock line SCL.

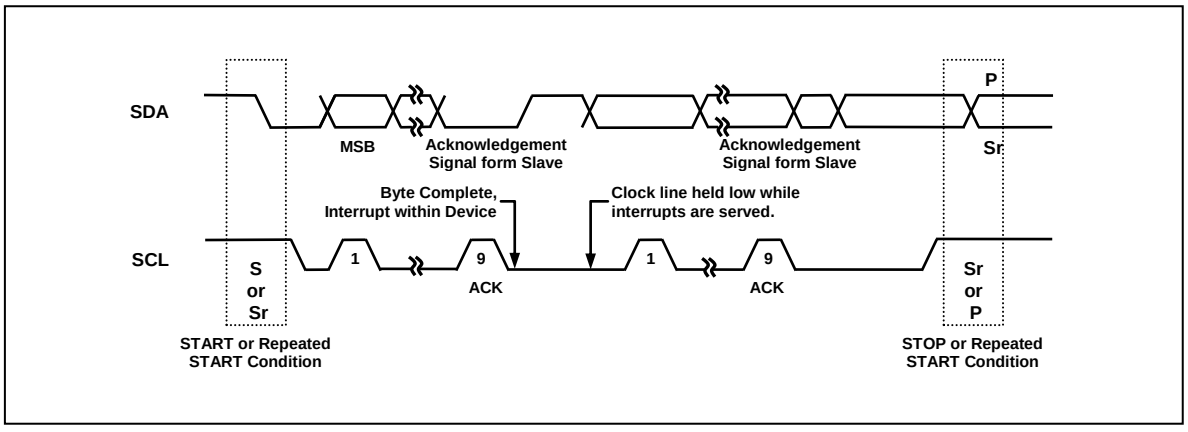


Figure 11.50 Data Transfer on the I2C-Bus

11.12.6 I2C Acknowledge

The acknowledge related clock pulse is generated by the master. The transmitter releases the SDA line (HIGH) during the acknowledge clock pulse. The receiver must pull down the SDA line during the acknowledge clock pulse so that it remains stable LOW during the HIGH period of this clock pulse. When a slave is addressed by a master (Address Packet), and if it is unable to receive or transmit because it's performing some real time function, the data line must be left HIGH by the slave. And also, when a slave addressed by a master is unable to receive more data bits, the slave receiver must release the SDA line (Data Packet). The master can then generate either a STOP condition to abort the transfer, or a repeated START condition to start a new transfer.

If a master receiver is involved in a transfer, it must signal the end of data to the slave transmitter by not generating an acknowledge on the last byte that was clocked out of the slave. The slave transmitter must release the data line to allow the master to generate a STOP or repeated START condition.

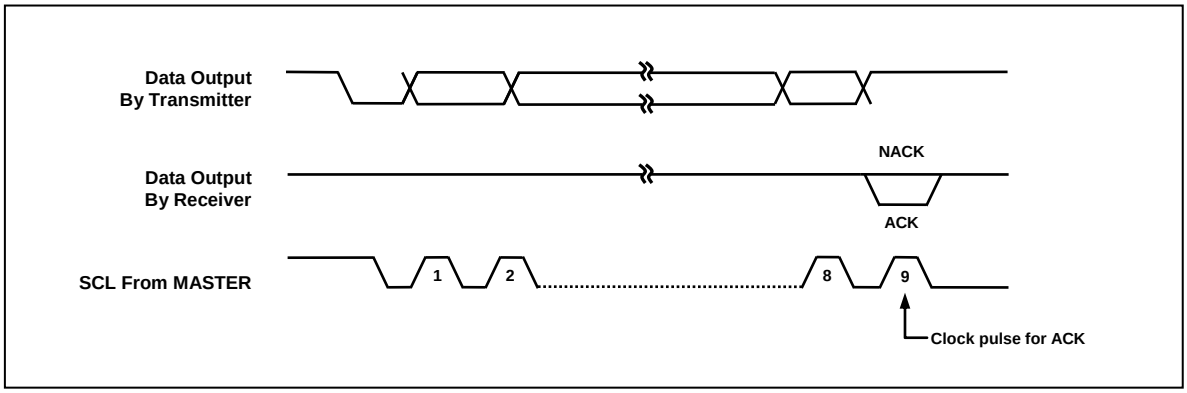


Figure 11.51 Acknowledge on the I2C-Bus

11.12.7 Synchronization / Arbitration

Clock synchronization is performed using the wired-AND connection of I2C interfaces to the SCL line. This means that a HIGH to LOW transition on the SCL line will cause the devices concerned to start counting off their LOW period and it will hold the SCL line in that state until the clock HIGH state is reached. However the LOW to HIGH transition of this clock may not change the state of the SCL line if another clock is still within its LOW period. In this way, a synchronized SCL clock is generated with its LOW period determined by the device with the longest clock LOW period, and its HIGH period determined by the one with the shortest clock HIGH period.

A master may start a transfer only if the bus is free. Two or more masters may generate a START condition. Arbitration takes place on the SDA line, while the SCL line is at the HIGH level, in such a way that the master which transmits a HIGH level, while another master is transmitting a LOW level will switch off its DATA output state because the level on the bus doesn't correspond to its own level. Arbitration continues for many bits until a winning master gets the ownership of I2C bus. Its first stage is comparison of the address bits.

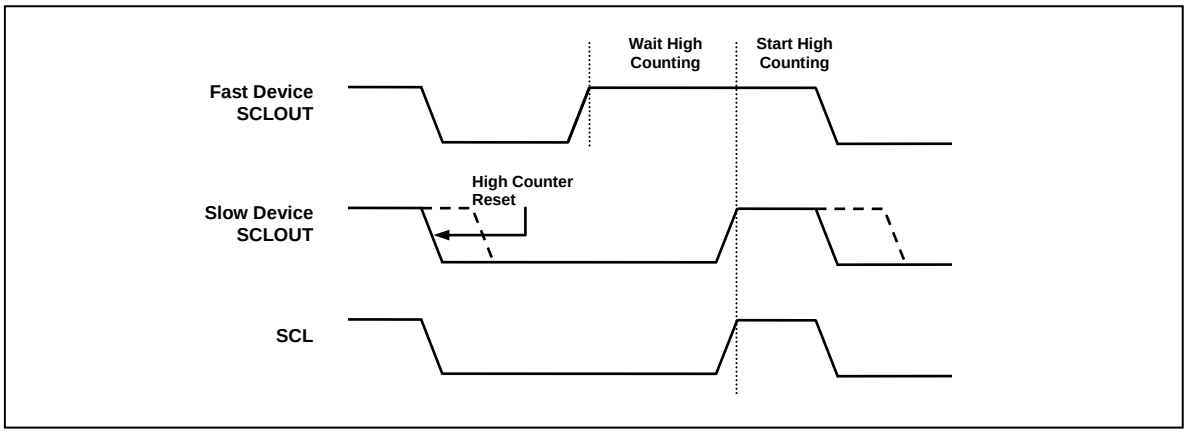


Figure 11.52 Clock Synchronization during Arbitration Procedure

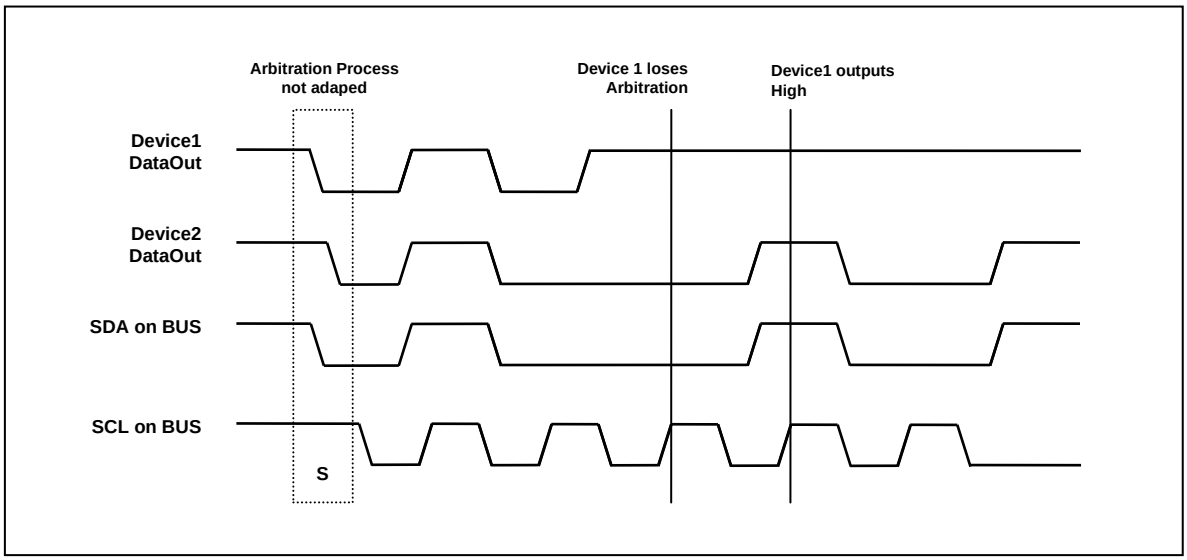


Figure 11.53 Arbitration Procedure of Two Masters

11.12.8 Operation

The I2C is byte-oriented and interrupt based. Interrupts are issued after all bus events except for a transmission of a START condition. Because the I2C is interrupt based, the application software is free to carry on other operations during a I2C byte transfer.

Note that when a I2C interrupt is generated, IICIFR flag in IIFLAG register is set, it is cleared by writing an any value to I2CSR. When I2C interrupt occurs, the SCL line is hold LOW until writing any value to I2CSR. When the IICIFR flag is set, the I2CSR contains a value indicating the current state of the I2C bus. According to the value in I2CSR, software can decide what to do next.

I2C can operate in 4 modes by configuring master/slave, transmitter/receiver. The operating mode is configured by a winning master. A more detailed explanation follows below.

11.12.8.1 Master Transmitter

To operate I2C in master transmitter, follow the recommended steps below.

7. Enable I2C by setting IICEN bit in I2CCR. This provides main clock to the peripheral.
8. Load SLA+W into the I2CDR where SLA is address of slave device and W is transfer direction from the viewpoint of the master. For master transmitter, W is '0'. Note that I2CDR is used for both address and data.
9. Configure baud rate by writing desired value to both I2CSCLR and I2CSCHR for the Low and High period of SCL line.
10. Configure the I2CSDHR to decide when SDA changes value from falling edge of SCL. If SDA should change in the middle of SCL LOW period, load half the value of I2CSCLR to the I2CSDHR.
11. Set the STARTC bit in I2CCR. This transmits a START condition. And also configure how to handle interrupt and ACK signal. When the STARTC bit is set, 8-bit data in I2CDR is transmitted out according to the baud-rate.
12. This is ACK signal processing stage for address packet transmitted by master. When 7-bit address and 1-bit transfer direction is transmitted to target slave device, the master can know whether the slave acknowledged or not in the 9th high period of SCL. If the master gains bus mastership, I2C generates GCALL interrupt regardless of the reception of ACK from the slave device. When I2C loses bus mastership during arbitration process, the MLOST bit in I2CSR is set, and I2C waits in idle state or can be operate as an addressed slave. To operate as a slave when the MLOST bit in I2CSR is set, the ACKEN bit in I2CCR must be set and the received 7-bit address must equal to the SLA bits in I2CSAR. In this case I2C operates as a slave transmitter or a slave receiver (go to appropriate section). In this stage, I2C holds the SCL LOW. This is because to decide whether I2C continues serial transfer or stops communication. The following steps continue assuming that I2C does not lose mastership during first data transfer.

    I2C (Master) can choose one of the following cases regardless of the reception of ACK signal from slave.

    1) Master receives ACK signal from slave, so continues data transfer because slave can receive more data from master. In this case, load data to transmit to I2CDR.
    2) Master stops data transfer even if it receives ACK signal from slave. In this case, set the STOPC bit in I2CCR.
    3) Master transmits repeated START condition with not checking ACK signal. In this case, load SLA+R/W into the I2CDR and set STARTC bit in I2CCR.

    After doing one of the actions above, write any arbitrary to I2CSR to release SCL line. In case of 1), move to step 7. In case of 2), move to step 9 to handle STOP interrupt. In case of 3), move to step 6 after transmitting the data in I2CDR and if transfer direction bit is '1' go to master receiver section.
13. 1-Byte of data is being transmitted. During data transfer, bus arbitration continues.
14. This is ACK signal processing stage for data packet transmitted by master. I2C holds the SCL LOW. When I2C loses bus mastership while transmitting data arbitrating other masters, the MLOST bit in I2CSR is set. If then, I2C waits in idle state. When the data in I2CDR is transmitted completely, I2C generates TEND interrupt.

    I2C can choose one of the following cases regardless of the reception of ACK signal from slave.

    1) Master receives ACK signal from slave, so continues data transfer because slave can receive more data from master. In this case, load data to transmit to I2CDR.
    2) Master stops data transfer even if it receives ACK signal from slave. In this case, set the STOPC bit in I2CCR.
    3) Master transmits repeated START condition with not checking ACK signal. In this case, load SLA+R/W into the I2CDR and set the STARTC bit in I2CCR.

    After doing one of the actions above, write any arbitrary to I2CSR to release SCL line. In case of 1), move to step 7. In case of 2), move to step 9 to handle STOP interrupt. In case of 3), move to step 6 after transmitting the data in I2CDR, and if transfer direction bit is '1' go to master receiver section.
15. This is the final step for master transmitter function of I2C, handling STOP interrupt. The STOP bit indicates that data transfer between master and slave is over. To clear I2CSR, write any value to I2CSR. After this, I2C enters idle state.

The next figure depicts above process for master transmitter operation of I2C.

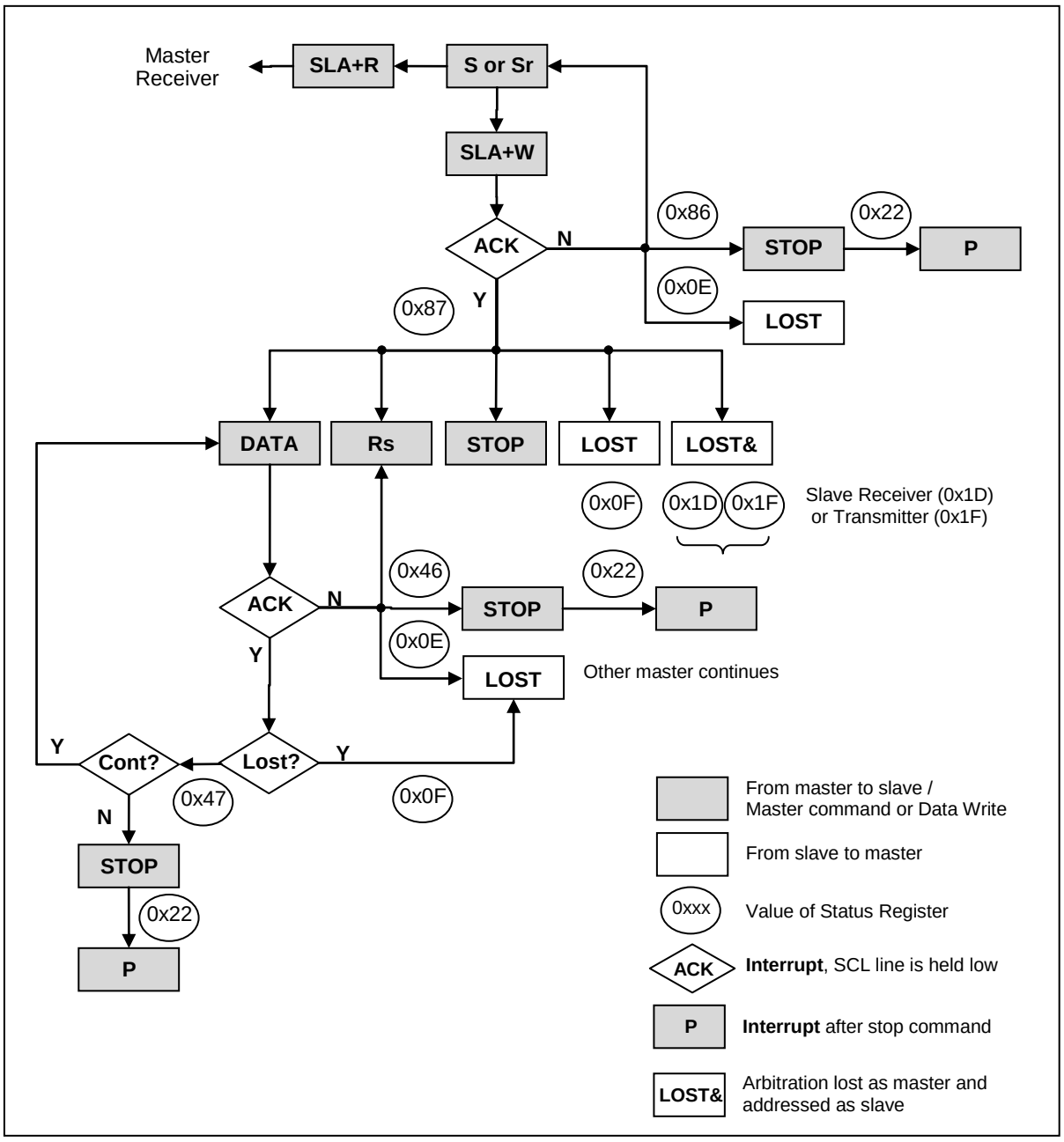


Figure 11.54 Formats and States in the Master Transmitter Mode

11.12.8.2 Master Receiver

To operate I2C in master receiver, follow the recommended steps below.

1. Enable I2C by setting IICEN bit in I2CCR. This provides main clock to the peripheral.
2. Load SLA+R into the I2CDR where SLA is address of slave device and R is transfer direction from the viewpoint of the master. For master receiver, R is '1'. Note that I2CDR is used for both address and data.
3. Configure baud rate by writing desired value to both I2CSCLR and I2CSCHR for the Low and High period of SCL line.
4. Configure the I2CSDHR to decide when SDA changes value from falling edge of SCL. If SDA should change in the middle of SCL LOW period, load half the value of I2CSCLR to the I2CSDHR.
5. Set the STARTC bit in I2CCR. This transmits a START condition. And also configure how to handle interrupt and ACK signal. When the STARTC bit is set, 8-bit data in I2CDR is transmitted out according to the baud-rate.
6. This is ACK signal processing stage for address packet transmitted by master. When 7-bit address and 1-bit transfer direction is transmitted to target slave device, the master can know whether the slave acknowledged or not in the 9th high period of SCL. If the master gains bus mastership, I2C generates GCALL interrupt regardless of the reception of ACK from the slave device. When I2C loses bus mastership during arbitration process, the MLOST bit in I2CSR is set, and I2C waits in idle state or can be operate as an addressed slave. To operate as a slave when the MLOST bit in I2CSR is set, the ACKEN bit in I2CCR must be set and the received 7-bit address must equal to the SLA bits in I2CSAR. In this case I2C operates as a slave transmitter or a slave receiver (go to appropriate section). In this stage, I2C holds the SCL LOW. This is because to decide whether I2C continues serial transfer or stops communication. The following steps continue assuming that I2C does not lose mastership during first data transfer.

   I2C (Master) can choose one of the following cases according to the reception of ACK signal from slave.

   1) Master receives ACK signal from slave, so continues data transfer because slave can prepare and transmit more data to master. Configure ACKEN bit in I2CCR to decide whether I2C ACKnowledges the next data to be received or not.
   2) Master stops data transfer because it receives no ACK signal from slave. In this case, set the STOPC bit in I2CCR.
   3) Master transmits repeated START condition due to no ACK signal from slave. In this case, load SLA+R/W into the I2CDR and set STARTC bit in I2CCR.

   After doing one of the actions above, write arbitrary value to I2CSR to release SCL line. In case of 1), move to step 7. In case of 2), move to step 9 to handle STOP interrupt. In case of 3), move to step 6 after transmitting the data in I2CDR and if transfer direction bit is '0' go to master transmitter section.

7. 1-Byte of data is being received.
8. This is ACK signal processing stage for data packet transmitted by slave. I2C holds the SCL LOW. When 1-Byte of data is received completely, I2C generates TEND interrupt.

   I2C0 can choose one of the following cases according to the RXACK flag in I2CSR.

   1) Master continues receiving data from slave. To do this, set ACKEN bit in I2CCR to ACKnowledge the next data to be received.
   2) Master wants to terminate data transfer when it receives next data by not generating ACK signal. This can be done by clearing ACKEN bit in I2CCR.
   3) Because no ACK signal is detected, master terminates data transfer. In this case, set the STOPC bit in I2CCR.
   4) No ACK signal is detected, and master transmits repeated START condition. In this case, load SLA+R/W into the I2CDR and set the STARTC bit in I2CCR.

   After doing one of the actions above, write arbitrary value to I2CSR to release SCL line. In case of 1) and 2), move to step 7. In case of 3), move to step 9 to handle STOP interrupt. In case of 4), move to step 6 after transmitting the data in I2CDR, and if transfer direction bit is '0' go to master transmitter section.
9. This is the final step for master receiver function of I2C, handling STOP interrupt. The STOP bit indicates that data transfer between master and slave is over. To clear I2CSR, write any value to I2CSR. After this, I2C enters idle state.

The processes described above for master receiver operation of I2C can be depicted as the following figure.

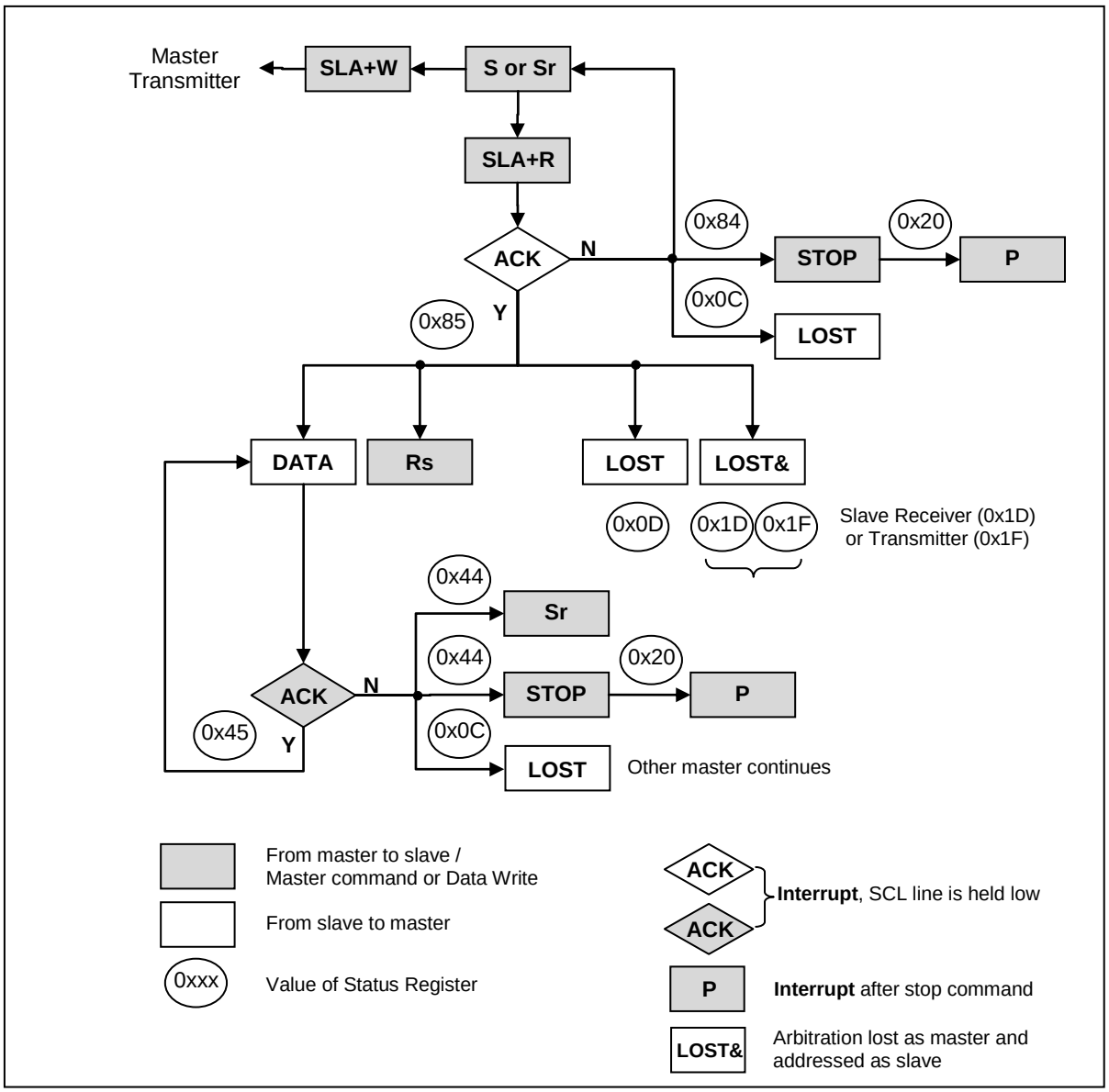


Figure 11.55 Formats and States in the Master Receiver Mode

11.12.8.3 I2C Slave Transmitter

To operate I2C in slave transmitter, follow the recommended steps below.

1. If the main operating clock (SCLK) of the system is slower than that of SCL, load value 0x00 into I2CSDHR to make SDA change within one system clock period from the falling edge of SCL. Note that the hold time of SDA is calculated by SDAH x period of SCLK where SDAH is multiple of number of SCLK coming from I2CSDHR. When the hold time of SDA is longer than the period of SCLK, I2C (slave) cannot transmit serial data properly.
2. Enable I2C by setting IICIE bit and IICEN bit in I2CCR. This provides main clock to the peripheral.
3. When a START condition is detected, I2C receives one byte of data and compares it with SLA bits in I2CSAR. If the GCALLEN bit in I2CSAR is enabled, I2C compares the received data with value 0x00, the general call address.
4. If the received address does not equal to SLA bits in I2CSAR, I2C enters idle state ie, waits for another START condition. Else if the address equals to SLA bits and the ACKEN bit is enabled, I2C generates SSEL interrupt and the SCL line is held LOW. Note that even if the address equals to SLA bits, when the ACKEN bit is disabled, I2C enters idle state. When SSEL interrupt occurs, load transmit data to I2CDR and write arbitrary value to I2CSR to release SCL line.
5. 1-Byte of data is being transmitted.
6. In this step, I2C generates TEND interrupt and holds the SCL line LOW regardless of the reception of ACK signal from master. Slave can select one of the following cases.

   1) No ACK signal is detected and I2C waits STOP or repeated START condition.
   2) ACK signal from master is detected. Load data to transmit into I2CDR.

   After doing one of the actions above, write arbitrary value to I2CSR to release SCL line. In case of 1) move to step 7 to terminate communication. In case of 2) move to step 5. In either case, a repeated START condition can be detected. For that case, move step 4.
7. This is the final step for slave transmitter function of I2C, handling STOP interrupt. The STOPC bit indicates that data transfer between master and slave is over. To clear I2CSR, write any value to I2CSR. After this, I2C enters idle state.

The next figure shows flow chart for handling slave transmitter function of I2C.

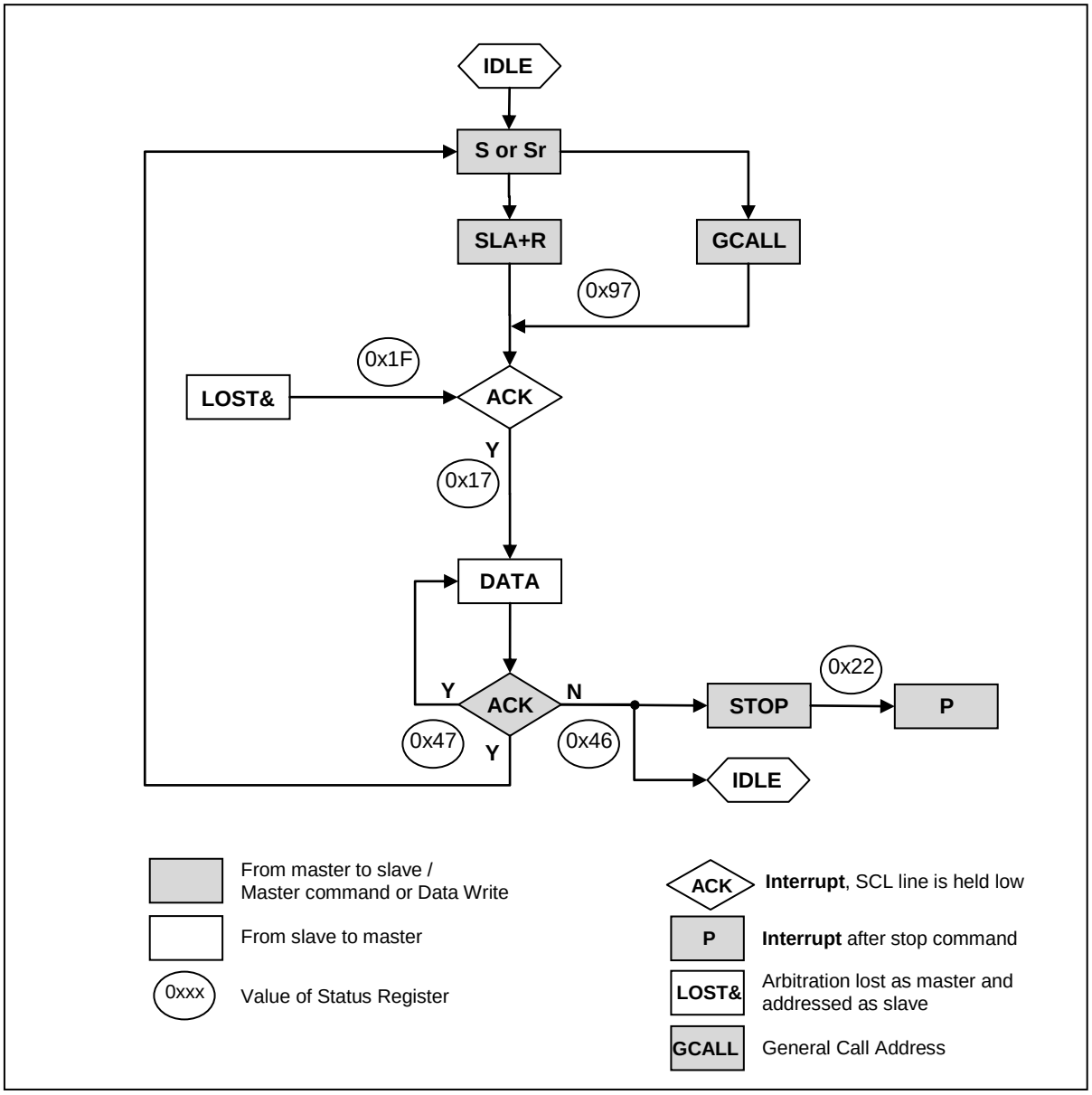


Figure 11.56 Formats and States in the Slave Transmitter Mode

11.12.8.4 Slave Receiver

To operate I2C in slave receiver, follow the recommended steps below.

1. If the main operating clock (SCLK) of the system is slower than that of SCL, load value 0x00 into I2CSDHR to make SDA change within one system clock period from the falling edge of SCL. Note that the hold time of SDA is calculated by SDAH x period of SCLK where SDAH is multiple of number of SCLK coming from I2CSDHR. When the hold time of SDA is longer than the period of SCLK, I2C (slave) cannot transmit serial data properly.
2. Enable I2C by setting IICIE bit and USIEN bit in I2CCR. This provides main clock to the peripheral.
3. When a START condition is detected, I2C receives one byte of data and compares it with SLA bits in I2CSAR. If the GCALLEN bit in I2CSAR is enabled, I2C compares the received data with value 0x00, the general call address.
4. If the received address does not equal to SLA bits in I2CSAR, I2C enters idle state ie, waits for another START condition. Else if the address equals to SLA bits and the ACKEN bit is enabled, I2C generates SSEL interrupt and the SCL line is held LOW. Note that even if the address equals to SLA bits, when the ACKEN bit is disabled, I2C enters idle state. When SSEL interrupt occurs and I2C is ready to receive data, write arbitrary value to I2CSR to release SCL line.
5. 1-Byte of data is being received.
6. In this step, I2C generates TEND interrupt and holds the SCL line LOW regardless of the reception of ACK signal from master. Slave can select one of the following cases.

   1) No ACK signal is detected (ACKEN=0) and I2C waits STOP or repeated START condition.
   2) ACK signal is detected (ACKEN=1) and I2C can continue to receive data from master.

   After doing one of the actions above, write arbitrary value to I2CSR to release SCL line. In case of 1) move to step 7 to terminate communication. In case of 2) move to step 5. In either case, a repeated START condition can be detected. For that case, move step 4.
7. This is the final step for slave receiver function of I2C, handling STOP interrupt. The STOPC bit indicates that data transfer between master and slave is over. To clear I2CSR, write any value to I2CSR. After this, I2C enters idle state.

The process can be depicted as following figure when I2C operates in slave receiver mode.

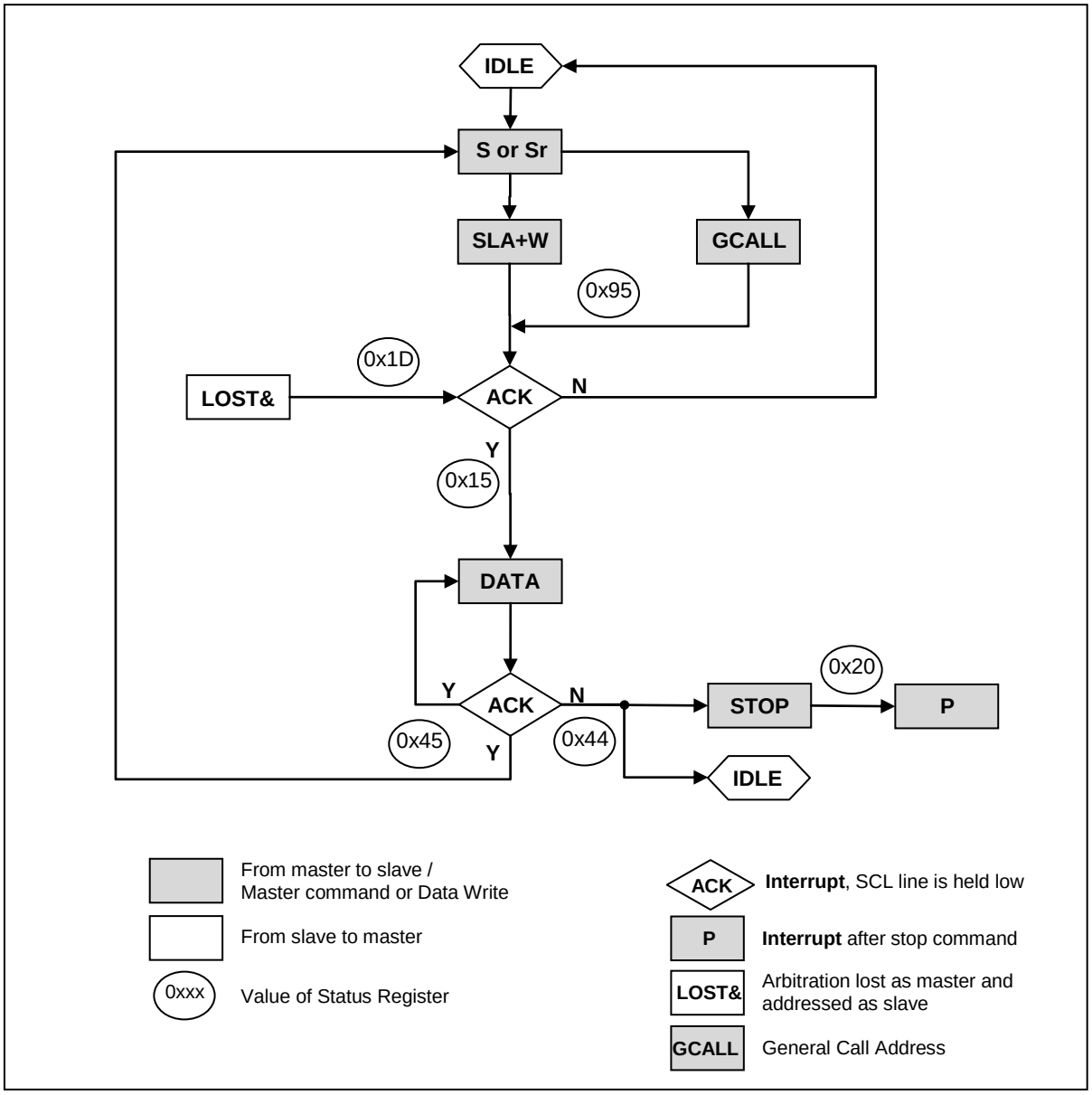


Figure 11.57 Formats and States in the Slave Receiver Mode

11.12.10 Register Map

Table 11-18 I2C Register Map

Name	Address	Dir	Default	Description
I2CCR	E9H	R/W	00H	I2C Control Register
I2CSR	EAH	R/W	00H	I2C Status Register
I2CSAR0	EBH	R/W	00H	I2C Slave Address 0 Register
I2CSAR1	F1H	R/W	00H	I2C Slave Address 1 Register
I2CDR	ECH	R/W	00H	I2C Data Register
I2CSDHR	EDH	R/W	01H	I2C SDA Hold Time Register
I2CSCLR	EEH	R/W	3FH	I2C SCL Low Period Register
I2CSCHR	EFH	R/W	3FH	I2C SCL High Period Register

11.12.11 I2C Register Description

I2C module consists of I2C control register (I2CCR), I2C status register (I2CSR), I2C slave address 0/1 register (I2CSAR0/I2CSAR1), I2C data register (I2CDR), I2C SDA hold time register (I2CSDHR), I2C SCL low period register (I2CSCLR), and I2C SCL high period Register (I2CSCHR).

11.12.12 Register Description for I2C

I2CDR (I2C Data Register) : ECH

7	6	5	4	3	2	1	0
I2CDR7	I2CDR6	I2CDR5	I2CDR4	I2CDR3	I2CDR2	I2CDR1	I2CDR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

I2CDR[7:0]	The I2CDR transmit buffer and receive buffer share the same I/O address with this DATA register. The transmit data buffer is the destination for data written to the I2CDR register. Reading the I2CDR register returns the contents of the receive buffer.

I2CSDHR (I2C SDA Hold Time Register) : EDH

7	6	5	4	3	2	1	0
I2CSDHR7	I2CSDHR6	I2CSDHR5	I2CSDHR4	I2CSDHR3	I2CSDHR2	I2CSDHR1	I2CSDHR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 01H

I2CSDHR[7:0] The register is used to control SDA output timing from the falling edge of SCL.

Note that SDA is changed after t_{SCLK} X (I2CSDHR+2), in master mode, load half the value of I2CSCLR to this register to make SDA change in the middle of SCL.

In slave mode, configure this register regarding the frequency of SCL from master.

The SDA is changed after tsclk X (I2CSDHR+2) in master mode. So, to insure operation in slave mode, the value

t_{SCLK} X (I2CSDHR +2) must be smaller than the period of SCL.

I2CSCHR (I2C SCL High Period Register) : EFH

7	6	5	4	3	2	1	0
I2CSCHR7	I2CSCHR6	I2CSCHR5	I2CSCHR4	I2CSCHR3	I2CSCHR2	I2CSCHR1	I2CSCHR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 3FH

I2CSCHR[7:0] This register defines the high period of SCL in master mode.

The base clock is SCLK, the system clock, and the period is calculated by the formula: t_{SCLK} X (4 X I2CSCHR + 2) where

t_{SCLK} is the period of SCLK.

So, the operating frequency of I2C master mode is calculated by the following equation.

$$f_{I2C} = \frac{1}{t_{SCLK} \text{ X } (4 \text{ X } (I2CSCLR + I2CSCHR) + 4)}$$

I2CSCLR (I2C SCL Low Period Register) : EEH

7	6	5	4	3	2	1	0
I2CSCLR7	I2CSCLR6	I2CSCLR5	I2CSCLR4	I2CSCLR3	I2CSCLR2	I2CSCLR1	I2CSCLR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 3FH

I2CSCLR[7:0] This register defines the low period of SCL in master mode.

The base clock is SCLK, the system clock, and the period is calculated by the formula: t_{SCLK} X (4 X I2CSCLR + 2) where

t_{SCLK} is the period of SCLK.

I2CSAR0 (I2C Slave Address 0 Register) : EBH

7	6	5	4	3	2	1	0
I2CSLA06	I2CSLA05	I2CSLA04	I2CSLA03	I2CSLA02	I2CSLA01	I2CSLA00	GCALL0EN
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

I2CSLA0[6:0] These bits configure the slave address 0 in slave mode.

GCALL0EN This bit decides whether I2C allows general call address or not in I2C slave mode.

0 Ignore general call address

1 Allow general call address

I2CSAR1 (I2C Slave Address 1 Register) : F1H

7	6	5	4	3	2	1	0
I2CSLA16	I2CSLA15	I2CSLA14	I2CSLA13	I2CSLA12	I2CSLA11	I2CSLA10	GCALL1EN
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

I2CSLA1[6:0] These bits configure the slave address 1 in slave mode.

GCALL1EN This bit decides whether I2C allows general call address or not in I2C slave mode.

0 Ignore general call address

1 Allow general call address

I2CCR (I2C Control Register) : E9H

7	6	5	4	3	2	1	0
IICRST	IICEN	TXDLYENB	IICIE	ACKEN	IMASTER	STOPC	STARTC
R/W	R/W	R/W	R/W	R/W	R	R/W	R/W

Initial value : 00H

IICRST Initialize Internal Registers of I2C.
- 0 No effect
- 1 Initialize I2C, auto cleared

IICEN Activate I2C Function Block by Supplying.
- 0 I2C is disabled
- 1 I2C is enabled

TXDLYENB I2CSDHR register control bit
- 0 Enable I2CSDHR register
- 1 Disable I2CSDHR register

IICIE Interrupt Enable bit
- 0 Interrupt from I2C is inhibited (use polling)
- 1 Enable interrupt for I2C

ACKEN Controls ACK signal Generation at ninth SCL period.
- 0 No ACK signal is generated (SDA = 1)
- 1 ACK signal is generated (SDA = 0)

NOTES) ACK signal is output (SDA =0) for the following 3 cases.
1. When received address packet equals to I2CSLA bits in I2CSAR.
2. When received address packet equals to value 0x00 with GCALL enabled.
3. When I2C operates as a receiver (master or slave)

IMASTER Represent operating mode of I2C
- 0 I2C is in slave mode
- 1 I2C is in master mode

STOPC When I2C is master, STOP condition generation
- 0 No effect
- 1 STOP condition is to be generated

STARTC When I2C is master, START condition generation
- 0 No effect
- 1 START or repeated START condition is to be generated

NOTE) Refer to the internal interrupt flag register (IIFLAG) for the I2C interrupt flags.

I2CSR (I2C Status Register) : EAH

7	6	5	4	3	2	1	0
GCALL	TEND	STOPD	SSEL	MLOST	BUSY	TMODE	RXACK
R	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

GCALL(NOTE) This bit has different meaning depending on whether I2C is master or slave. When I2C is a master, this bit represents whether it received AACK (address ACK) from slave.

0 No AACK is received (Master mode)

1 AACK is received (Master mode)

When I2C is a slave, this bit is used to indicated general call.

0 General call address is not detected (Slave mode)

1 General call address is detected (Slave mode)

TEND(NOTE) This bit is set when 1-byte of data is transferred completely

0 1 byte of data is not completely transferred

1 1 byte of data is completely transferred

STOPD(NOTE) This bit is set when a STOP condition is detected.

0 No STOP condition is detected

1 STOP condition is detected

SSEL (NOTE) This bit is set when I2C is addressed by other master.

0 I2C is not selected as a slave

1 I2C is addressed by other master and acts as a slave

MLOST (NOTE) This bit represents the result of bus arbitration in master mode.

0 I2C maintains bus mastership

1 I2C has lost bus mastership during arbitration process

BUSY This bit reflects bus status.

0 I2C bus is idle, so a master can issue a START condition

1 I2C bus is busy

TMODE This bit is used to indicate whether I2C is transmitter or receiver.

0 I2C is a receiver

1 I2C is a transmitter

RXACK This bit shows the state of ACK signal

0 No ACK is received

1 ACK is received at ninth SCL period

NOTE) These bits can be source of interrupt.

When an I2C interrupt occurs except for STOP mode, the SCL line is hold LOW. To release SCL, write arbitrary value to I2CSR. When I2CSR is written, the TEND, STOPD, SSEL, MLOST, and RXACK bits are cleared.

12. Power Down Operation

12.1 Overview

The MC96F8316 has two power-down modes to minimize the power consumption of the device. In power down mode, power consumption is reduced considerably. The device provides three kinds of power saving functions, Main-IDLE, Sub-IDLE and STOP mode. In three modes, program is stopped.

12.2 Peripheral Operation in IDLE/STOP Mode

Table 12-1 Peripheral Operation during Power Down Mode

Peripheral	IDLE Mode	STOP Mode
CPU	ALL CPU Operation are Disable	ALL CPU Operation are Disable
RAM	Retain	Retain
Basic Interval Timer	Operates Continuously	Stop
Watch Dog Timer	Operates Continuously	Stop (Can be operated with WDTRC OSC)
Watch Timer	Operates Continuously	Stop (Can be operated with sub clock)
Timer0~2	Operates Continuously	Halted (Only when the Event Counter Mode is Enabled, Timer operates Normally)
ADC	Operates Continuously	Stop
BUZ	Operates Continuously	Stop
SPI	Operates Continuously	Only operate with external clock
UART	Operates Continuously	Stop
I2C	Operates Continuously	Only operate with external clock
Internal OSC (16MHz)	Oscillation	Stop when the system clock (fx) is f_{IRC}
WDTRC OSC (5kHz)	Can be operated with setting value	Can be operated with setting value
Main OSC (0.4~12MHz)	Oscillation	Stop when fx = f_{XIN}
Sub OSC (32.768kHz)	Oscillation	Stop when fx = f_{SUB}
I/O Port	Retain	Retain
Control Register	Retain	Retain
Address Data Bus	Retain	Retain
Release Method	By RESET, all Interrupts	By RESET, Timer Interrupt (EC0, EC1, EC2), SPI (External clock), External Interrupt, UART by RX, WT (sub clock), WDT

12.3 IDLE Mode

The power control register is set to '01h' to enter the IDLE Mode. In this mode, the internal oscillation circuits remain active. Oscillation continues and peripherals are operated normally but CPU stops. It is released by reset or interrupt. To be released by interrupt, interrupt should be enabled before IDLE mode. If using reset, because the device becomes initialized state, the registers have reset value.

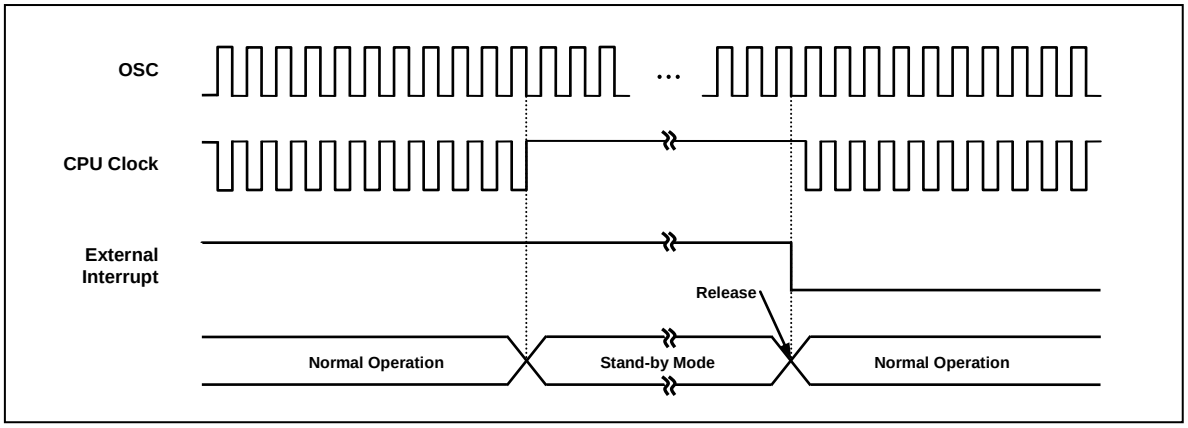


Figure 12.1 IDLE Mode Release Timing by External Interrupt

12.4 STOP Mode

The power control register is set to '03H' to enter the STOP Mode. In the stop mode, the selected oscillator, system clock and peripheral clock is stopped, but watch timer can be continued to operate with sub clock. With the clock frozen, all functions are stopped, but the on-chip RAM and control registers are held. For example, If the internal RC oscillator (f_{IRC}) is selected for the system clock and the sub clock (f_{SUB}) is oscillated, the internal RC oscillator stops oscillation and the sub clock is continuously oscillated in stop mode. At that time, the watch timer can be operated with the sub clock.

The source for exit from STOP mode is hardware reset and interrupts. The reset re-defines all the control registers.

When exit from STOP mode, enough oscillation stabilization time is required to normal operation. Figure 12.2 shows the timing diagram. When released from STOP mode, the Basic interval timer is activated on wake-up. Therefore, before STOP instruction, user must be set its relevant prescale divide ratio to have long enough time. This guarantees that oscillator has started and stabilized.

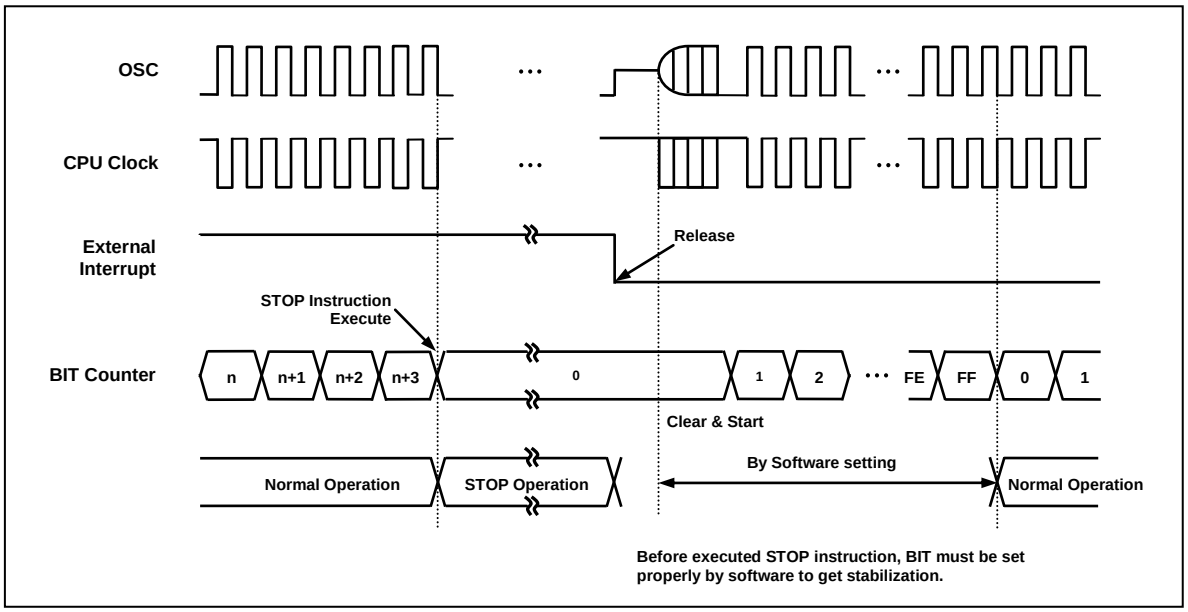


Figure 12.2 STOP Mode Release Timing by External Interrupt

12.5 Release Operation of STOP Mode

After STOP mode is released, the operation begins according to content of related interrupt register just before STOP mode start (Figure 12.3). If the global interrupt Enable Flag (IE.EA) is set to `1`, the STOP mode is released by the interrupt which each interrupt enable flag = `1` and the CPU jumps to the relevant interrupt service routine. Even if the IE.EA bit is cleared to '0', the STOP mode is released by the interrupt of which the interrupt enable flag is set to '1'.

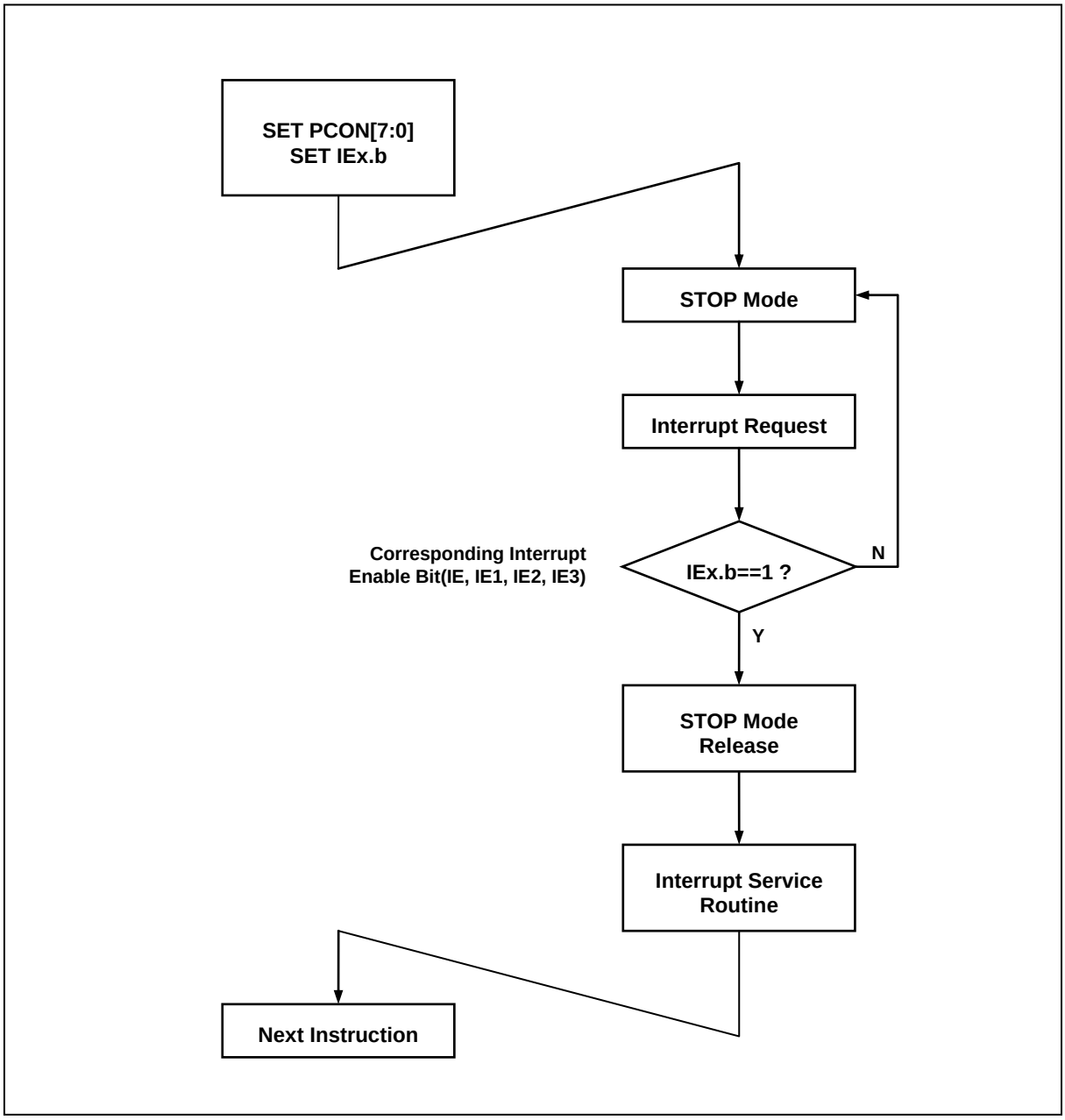


Figure 12.3 STOP Mode Release Flow

12.5.1 Register Map

Table 12-2 Power Down Operation Register Map

Name	Address	Dir	Default	Description
PCON	87H	R/W	00H	Power Control Register

12.5.2 Power Down Operation Register Description

The power down operation register consists of the power control register (PCON).

12.5.3 Register Description for Power Down Operation

PCON (Power Control Register) : 87H

7	6	5	4	3	2	1	0
PCON7	–	–	–	PCON3	PCON2	PCON1	PCON0
R/W	–	–	–	R/W	R/W	R/W	R/W

Initial value : 00H

PCON[7:0]	Power Control
01H	IDLE mode enable
03H	STOP mode enable
Other Values	Normal operation

NOTES) 1. To enter IDLE mode, PCON must be set to ‘01H’.

2. To enter STOP mode, PCON must be set to ‘03H’.

3. The PCON register is automatically cleared by a release signal in STOP/IDLE mode.

4. Three or more NOP instructions must immediately follow STOP/IDLE mode like the below examples.

```
Ex1)  MOV   PCON, #01H    ; IDLE mode
      NOP
      NOP
      NOP
       •
       •
       •
```

```
Ex2)  MOV   PCON, #03H    ; STOP mode
      NOP
      NOP
      NOP
       •
       •
       •
```

13. RESET

13.1 Overview

The following is the hardware setting value.

Table 13-1 Reset State

On Chip Hardware	Initial Value
Program Counter (PC)	0000h
Accumulator	00h
Stack Pointer (SP)	07h
Peripheral Clock	On
Control Register	Refer to the Peripheral Registers

13.2 Reset Source

The MC96F8316 has five types of reset sources. The following is the reset sources.

- External RESETB
- Power ON RESET (POR)
- WDT Overflow Reset (In the case of WDTEN = `1`)
- Low Voltage Reset (In the case of LVREN = `0 `)
- OCD Reset

13.3 RESET Block Diagram

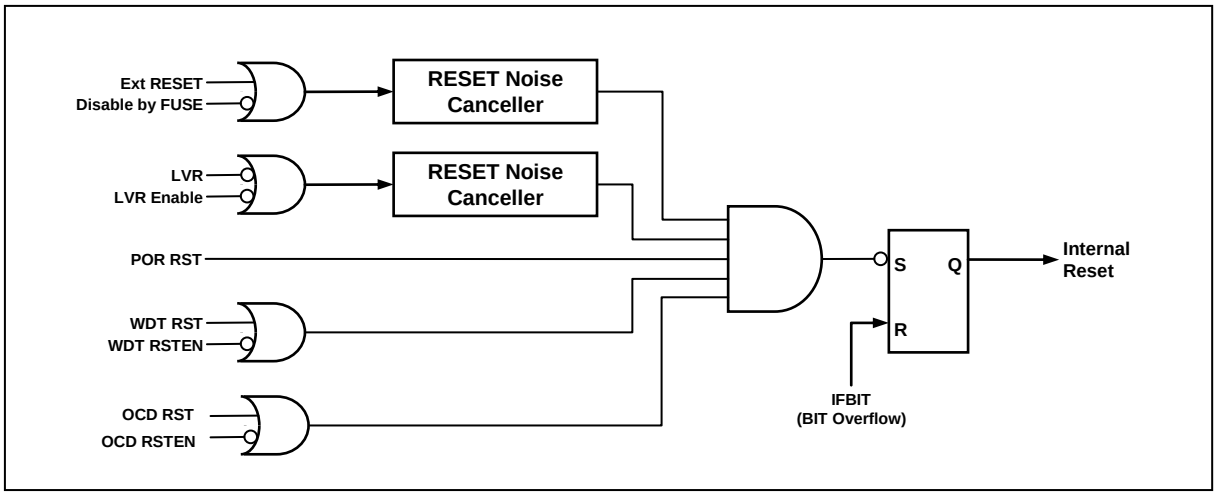


Figure 13.1 RESET Block Diagram

13.4 RESET Noise Canceller

The Figure 13.2 is the noise canceller diagram for noise cancellation of RESET. It has the noise cancellation value of about 2us (@V_{DD}=5V) to the low input of system reset.

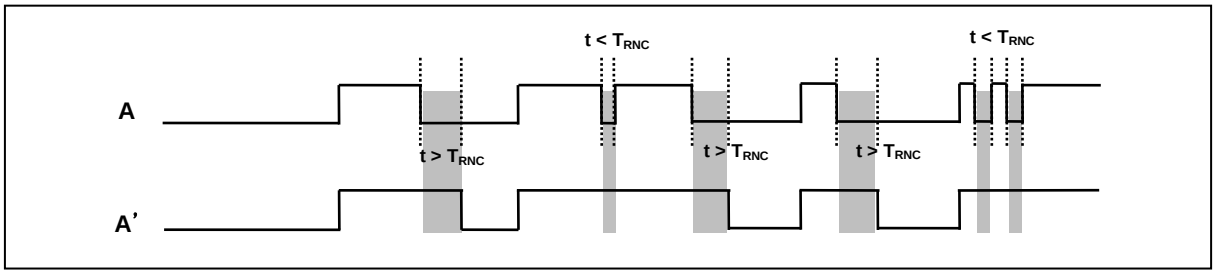


Figure 13.2 Reset noise canceller timer diagram

13.5 Power on RESET

When rising device power, the POR (Power On Reset) has a function to reset the device. If POR is used, it executes the device RESET function instead of the RESET IC or the RESET circuits.

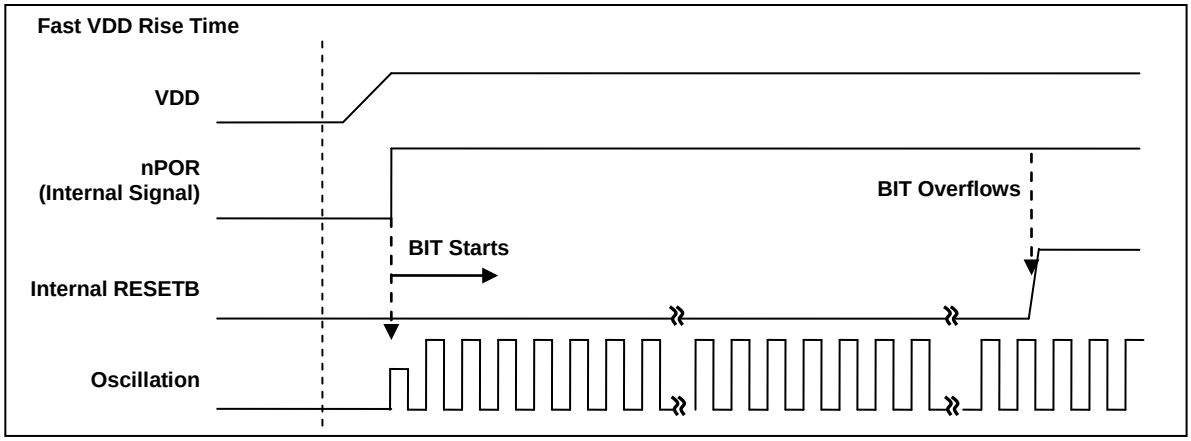


Figure 13.3 Fast VDD Rising Time

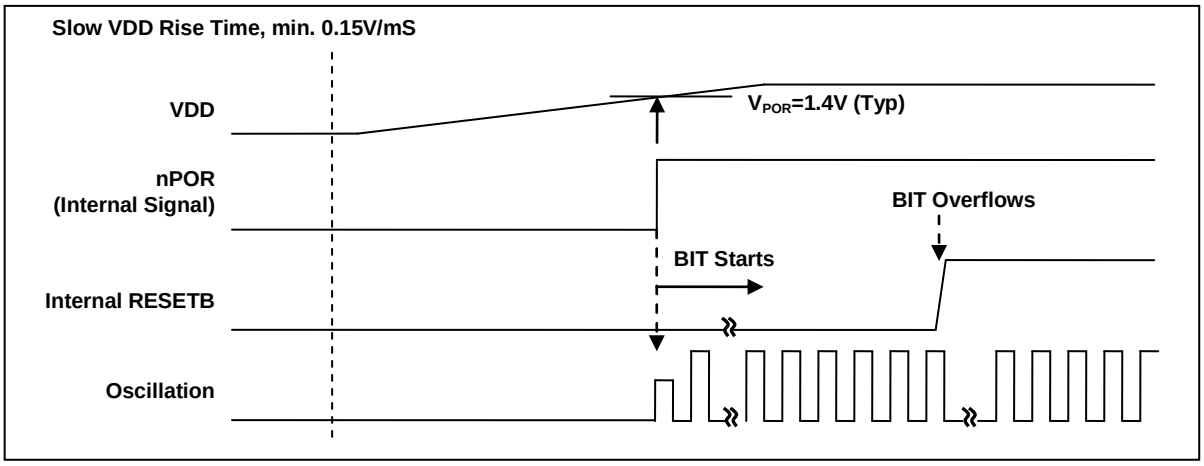


Figure 13.4 Internal RESET Release Timing On Power-Up

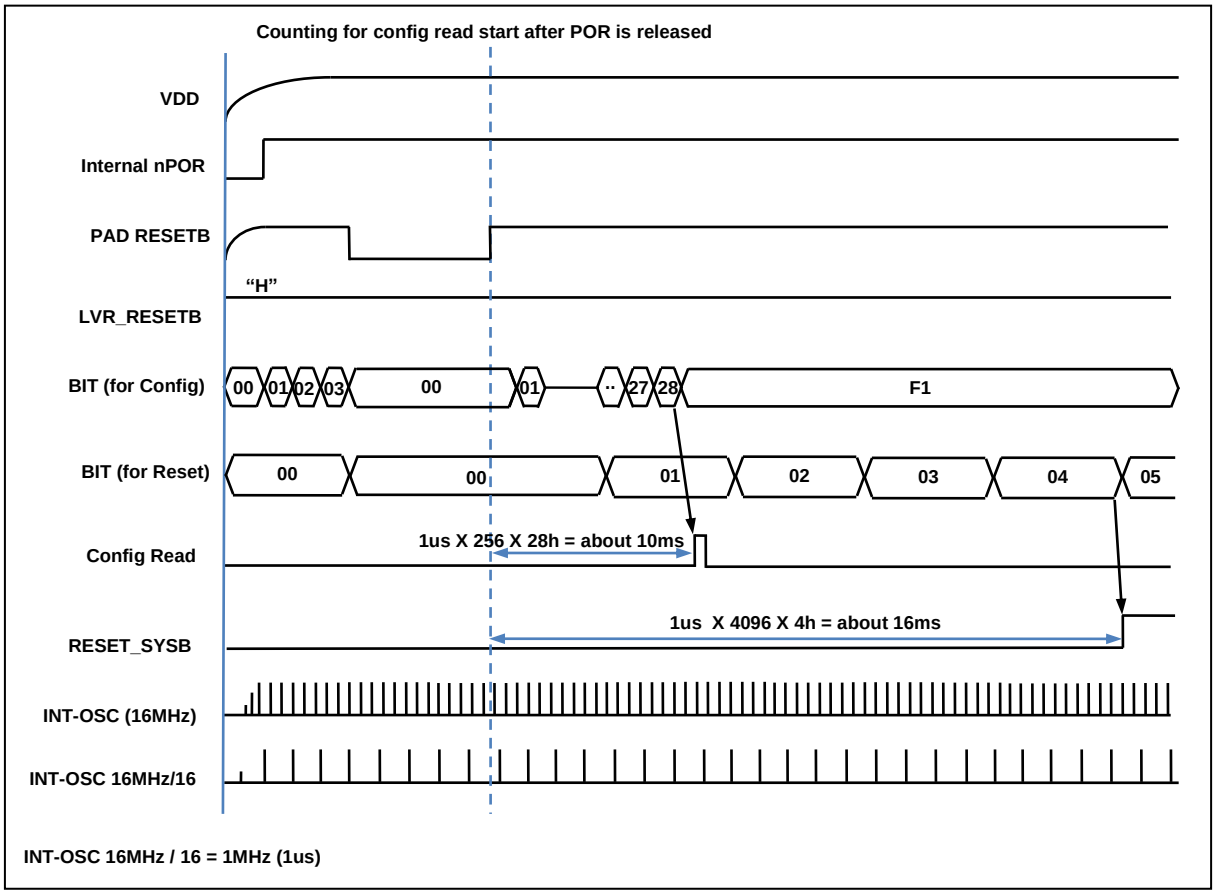


Figure 13.5 Configuration Timing when Power-on

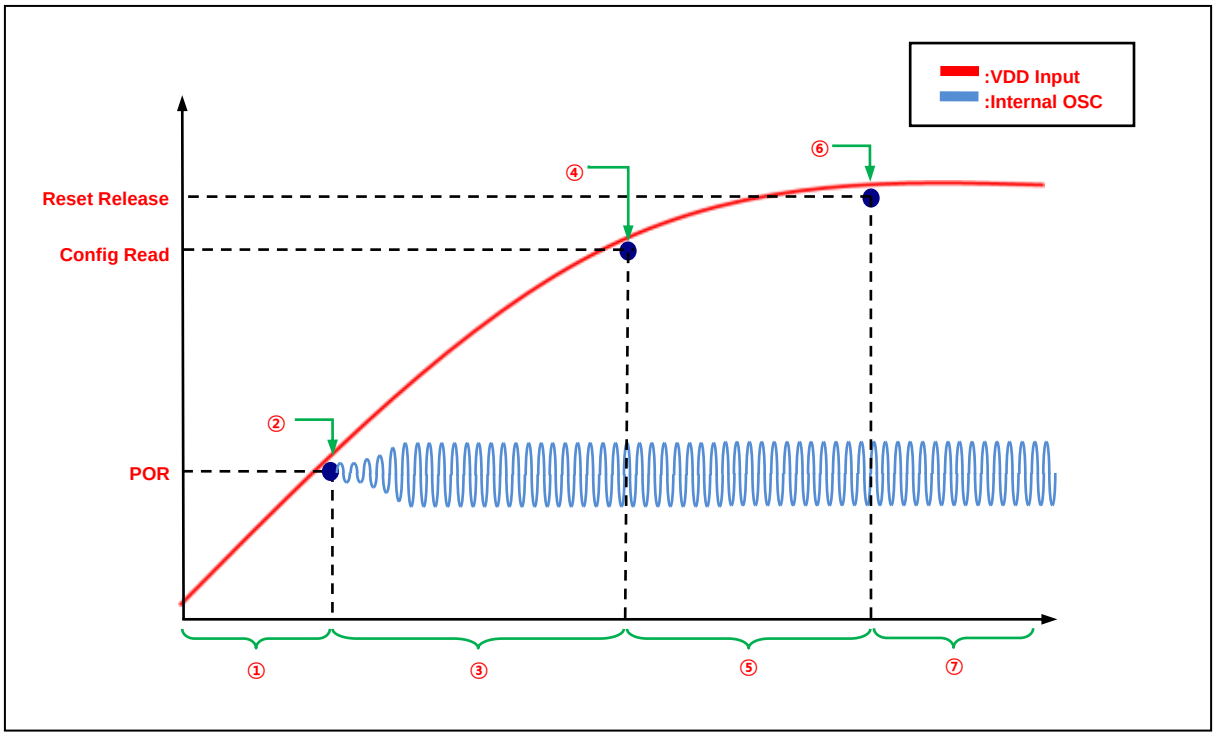


Figure 13.6 Boot Process WaveForm

Table 13-2 Boot Process Description

Process	Description	Remarks
①	-No Operation	
②	-1st POR level Detection	-about 1.4V
③	- (INT-OSC 16MHz/16)x256x28h Delay section (=10ms) -VDD input voltage must rise over than flash operating voltage for Config read	-Slew Rate >= 0.15V/ms
④	- Config read point	-about 1.5V ~ 1.6V -Config Value is determined by Writing Option
⑤	- Rising section to Reset Release Level	-16ms point after POR or Ext_reset release
⑥	- Reset Release section (BIT overflow) i) after16ms, after External Reset Release (External reset) ii) 16ms point after POR (POR only)	- BIT is used for Peripheral stability
⑦	-Normal operation	

13.6 External RESETB Input

The External RESETB is the input to a Schmitt trigger. If RESETB pin is held with low for at least 10us over within the operating voltage range and stable oscillation, it is applied and the internal state is initialized. After reset state becomes '1', it needs the stabilization time with 16ms and after the stable state, the internal RESET becomes '1'. The Reset process step needs 5 oscillator clocks. And the program execution starts at the vector address stored at address 0000H.

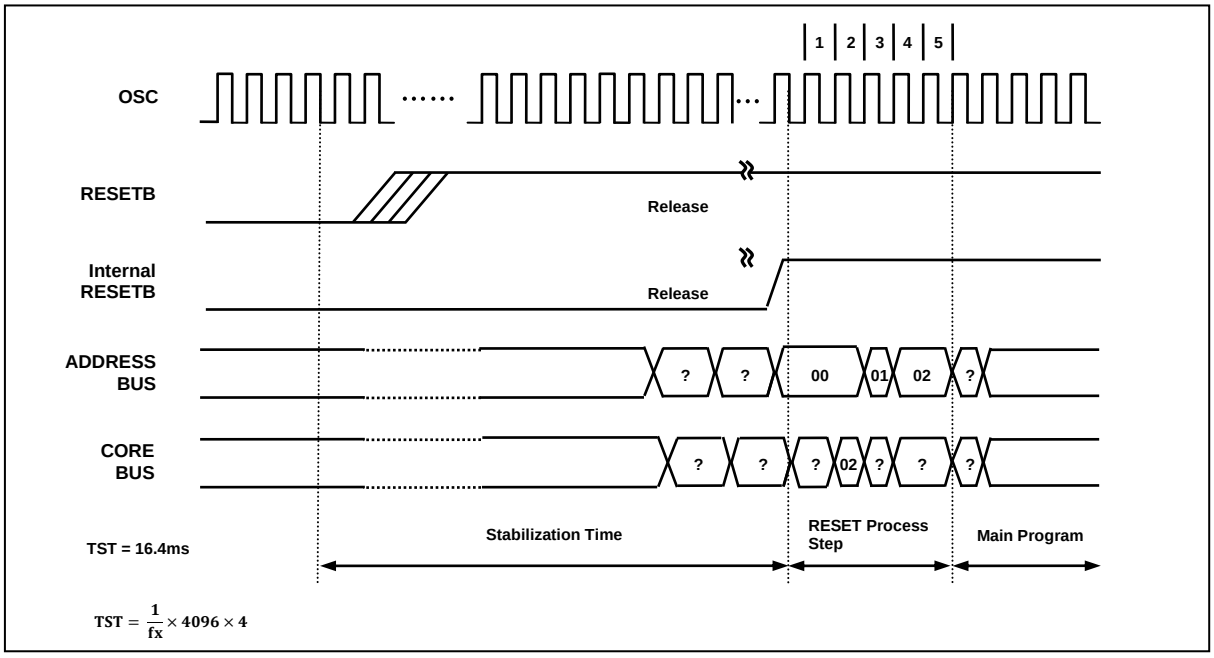


Figure 13.7 Timing Diagram after RESET

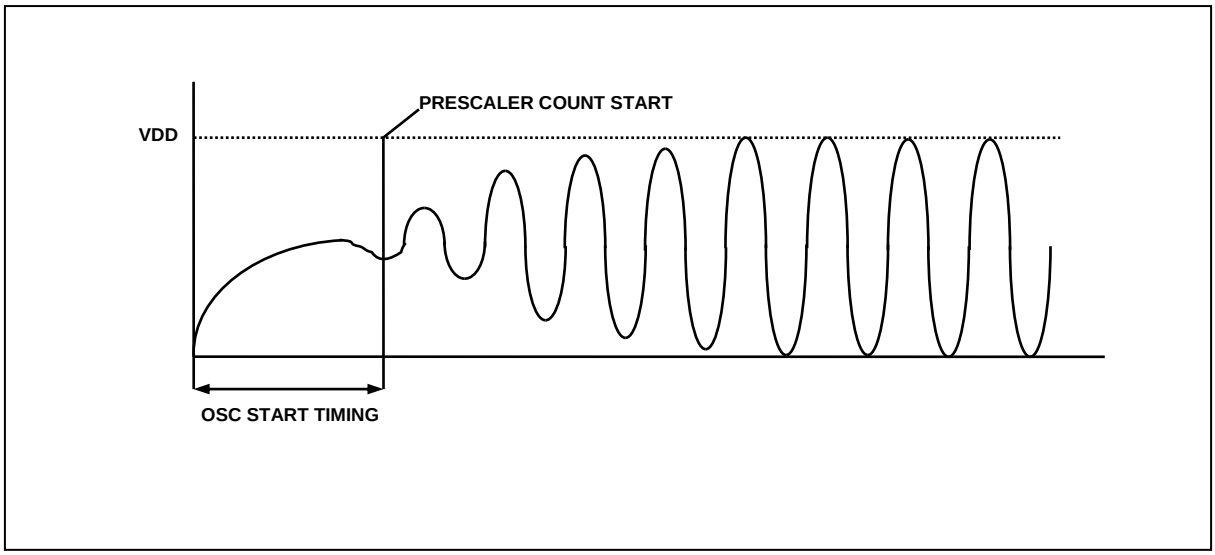


Figure 13.8 Oscillator generating waveform example

NOTE) As shown Figure 13.8, the stable generating time is not included in the start-up time.
The RESETB pin has a Pull-up register by H/W.

13.7 Brown Out Detector Processor

The MC96F8316 has an On-chip brown-out detection circuit (BOD) for monitoring the VDD level during operation by comparing it to a fixed trigger level. The trigger level for the BOD can be selected by LVRVS[3:0] bit to be 1.60V, 2.00V, 2.10V, 2.20V,2.32V, 2.44V, 2.59V, 2.75V, 2.93V, 3.14V, 3.38V, 3.67V, 4.00V, 4.40V. In the STOP mode, this will contribute significantly to the total current consumption. So to minimize the current consumption, the LVREN bit is set to off by software.

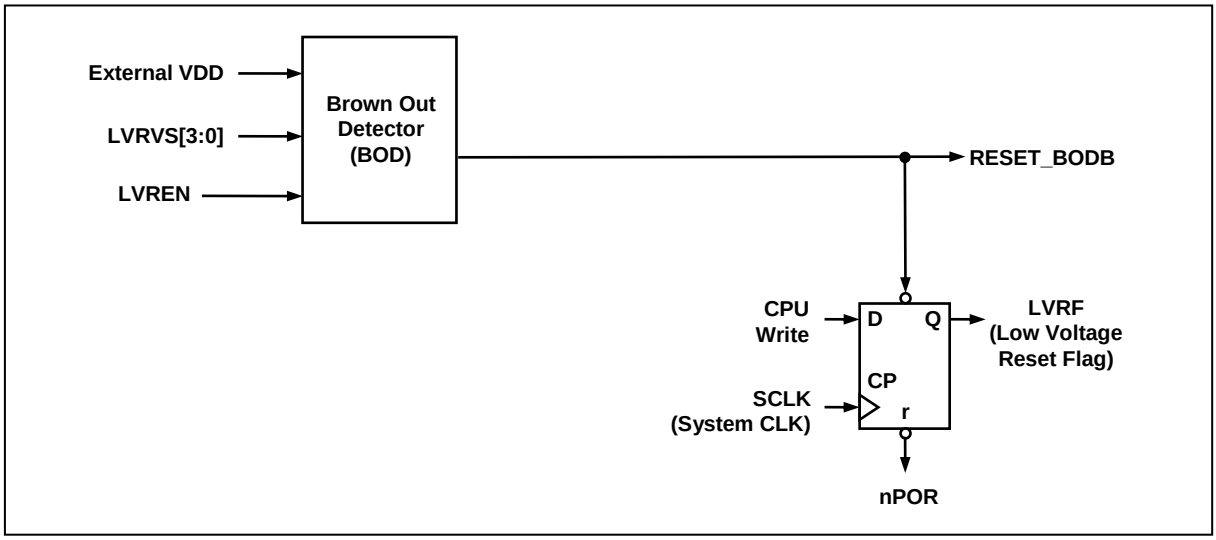


Figure 13.9 Block Diagram of BOD

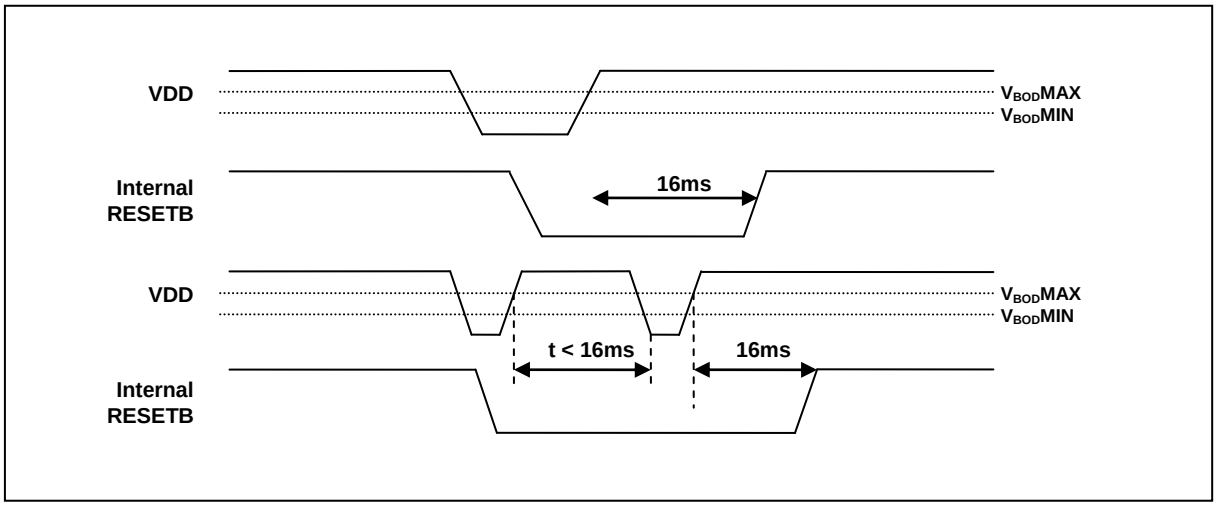


Figure 13.10 Internal Reset at the power fail situation

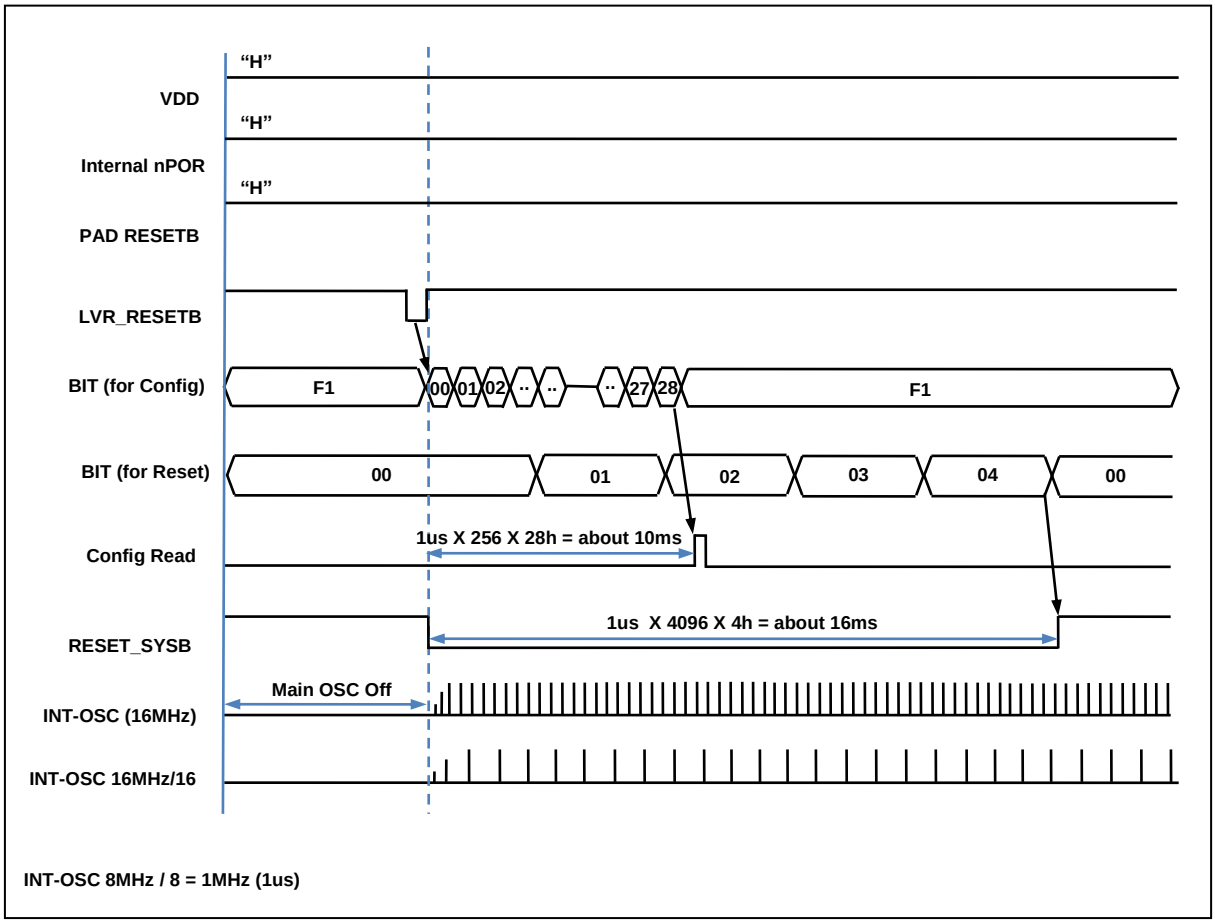


Figure 13.11 Configuration timing when BOD RESET

13.8 LVI Block Diagram

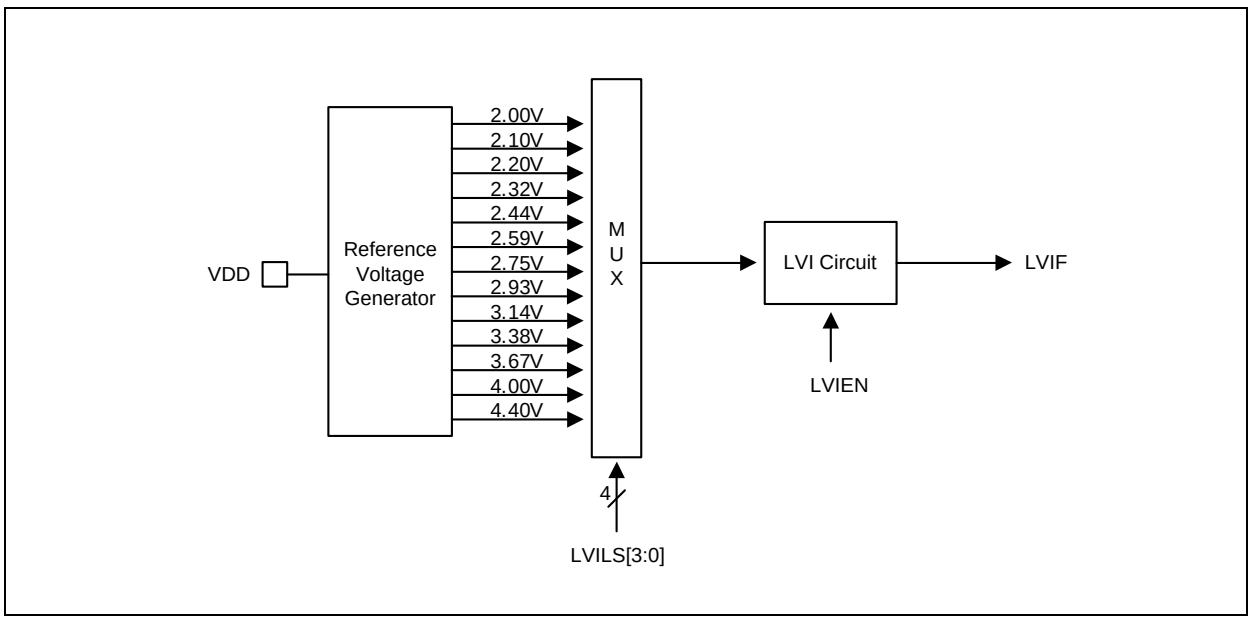


Figure 13.12 LVI Diagram

13.8.1 Register Map

Table 13-3 Reset Operation Register Map

Name	Address	Dir	Default	Description
RSTFR	E8H	R/W	80H	Reset Flag Register
LVRCR	D8H	R/W	00H	Low Voltage Reset Control Register
LVICR	86H	R/W	00H	Low Voltage Indicator Control Register

13.8.2 Reset Operation Register Description

The reset control register consists of the reset flag register (RSTFR), low voltage reset control register (LVRCR), and low voltage indicator control register (LVICR).

13.8.3 Register Description for Reset Operation

RSTFR (Reset Flag Register) : E8H

7	6	5	4	3	2	1	0
PORF	EXTRF	WDTRF	OCDRF	LVRF	–	–	–
R/W	R/W	R/W	R/W	R/W	–	–	–

Initial value : 80H

PORF Power-On Reset flag bit. The bit is reset by writing '0' to this bit.
- 0 No detection
- 1 Detection

EXTRF External Reset (RESETB) flag bit. The bit is reset by writing '0' to this bit or by Power-On Reset.
- 0 No detection
- 1 Detection

WDTRF Watch Dog Reset flag bit. The bit is reset by writing '0' to this bit or by Power-On Reset.
- 0 No detection
- 1 Detection

OCDRF On-Chip Debug Reset flag bit. The bit is reset by writing '0' to this bit or by Power-On Reset.
- 0 No detection
- 1 Detection

LVRF Low Voltage Reset flag bit. The bit is reset by writing '0' to this bit or by Power-On Reset.
- 0 No detection
- 1 Detection

NOTES) 1. When the Power-On Reset occurs, the PORF bit is only set to "1", the other flag (WDTRF and OCDRF) bits are all cleared to "0".

2. When the Power-On Reset occurs, the EXTRF bit is unknown, At that time, the EXTRF bit can be set to "1" when External Reset (RESETB) occurs.

3. When the Power-On Reset occurs, the LVRF bit is unknown, At that time, the LVRF bit can be set to "1" when LVR Reset occurs.

4. When a reset except the POR occurs, the corresponding flag bit is only set to "1", the other flag bits are kept in the previous values.

LVRCR (Low Voltage Reset Control Register) : D8H

7	6	5	4	3	2	1	0
LVRST	–	–	LVRVS3	LVRVS2	LVRVS1	LVRVS0	LVREN
R/W	–	–	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

LVRST — LVR Enable when Stop Release

0 Not effect at stop release

1 LVR enable at stop release

NOTES)

When this bit is '1', the LVREN bit is cleared to '0' by stop mode to release. (LVR enable)

When this bit is '0', the LVREN bit is not effect by stop mode to release.

LVRVS[3:0] — LVR Voltage Select

LVRVS3	LVRVS2	LVRVS1	LVRVS0	Description
0	0	0	0	1.60V
0	0	0	1	2.00V
0	0	1	0	2.10V
0	0	1	1	2.20V
0	1	0	0	2.32V
0	1	0	1	2.44V
0	1	1	0	2.59V
0	1	1	1	2.75V
1	0	0	0	2.93V
1	0	0	1	3.14V
1	0	1	0	3.38V
1	0	1	1	3.67V
1	1	0	0	4.00V
1	1	0	1	4.40V
Other Values				Not available

LVREN — LVR Operation

0 LVR Enable

1 LVR Disable

NOTES) 1. The LVRVS[3:0] bits are cleared by a power-on reset but are retained by other reset signals.

2. The LVRVS[3:0] bits should be set to '0000b' while LVREN bit is "1".

LVICR (Low Voltage Indicator Control Register) : 86H

7	6	5	4	3	2	1	0
–	–	LVIF	LVIEN	LVILS3	LVILS2	LVILS1	LVILS0
–	–	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

LVIF Low Voltage Indicator Flag Bit

0 No detection

1 Detection

LVIEN LVI Enable/Disable

0 Disable

1 Enable

LVILS[3:0] LVI Level Select

LVILS3	LVILS2	LVILS1	LVILS0	Description
0	0	0	0	2.00V
0	0	0	1	2.10V
0	0	1	0	2.20V
0	0	1	1	2.32V
0	1	0	0	2.44V
0	1	0	1	2.59V
0	1	1	0	2.75V
0	1	1	1	2.93V
1	0	0	0	3.14V
1	0	0	1	3.38V
1	0	1	0	3.67V
1	0	1	1	4.00V
1	1	0	0	4.40V
Other Values				Not available

14. On-chip Debug System

14.1 Overview

14.1.1 Description

On-chip debug system (OCD) of MC96F8316 can be used for programming the non-volatile memories and on-chip debugging. Detail descriptions for programming via the OCD interface can be found in the following chapter.

Figure 14.1 shows a block diagram of the OCD interface and the On-chip Debug system.

14.1.2 Feature

- Two-wire external interface: 1-wire serial clock input, 1-wire bi-directional serial data bus
- Debugger Access to:
  - All Internal Peripheral Units
  - Internal data RAM
  - Program Counter
  - Flash and Data EEPROM Memories
- Extensive On-chip Debug Support for Break Conditions, Including
  - Break Instruction
  - Single Step Break
  - Program Memory Break Points on Single Address
  - Programming of Flash, EEPROM, Fuses, and Lock Bits through the two-wire Interface
  - On-chip Debugging Supported by Dr.Choice®
- Operating frequency

  Supports the maximum frequency of the target MCU

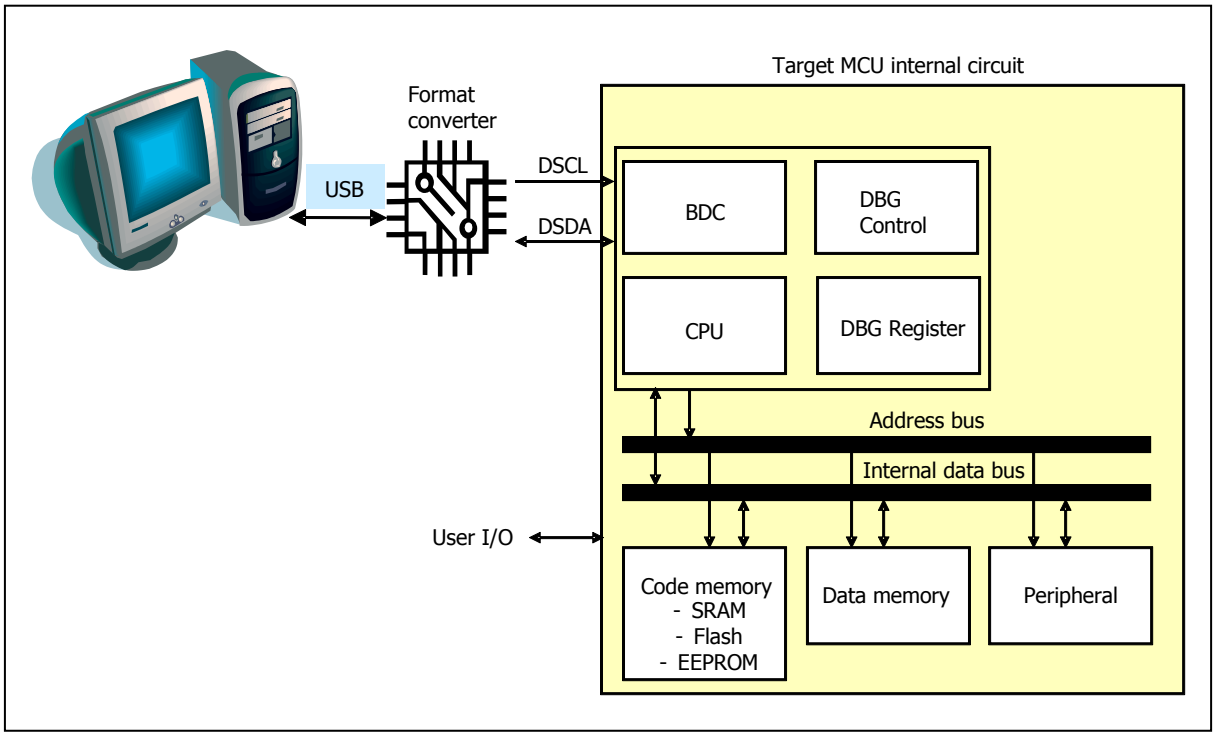


Figure 14.1 Block Diagram of On-Chip Debug System

14.2 Two-Pin External Interface

14.2.1 Basic Transmission Packet

- 10-bit packet transmission using two-pin interface.
- 1-packet consists of 8-bit data, 1-bit parity and 1-bit acknowledge.
- Parity is even of '1' for 8-bit data in transmitter.
- Receiver generates acknowledge bit as '0' when transmission for 8-bit data and its parity has no error.
- When transmitter has no acknowledge (Acknowledge bit is '1' at tenth clock), error process is executed in transmitter.
- When acknowledge error is generated, host PC makes stop condition and transmits command which has error again.
- Background debugger command is composed of a bundle of packet.
- Start condition and stop condition notify the start and the stop of background debugger command respectively.

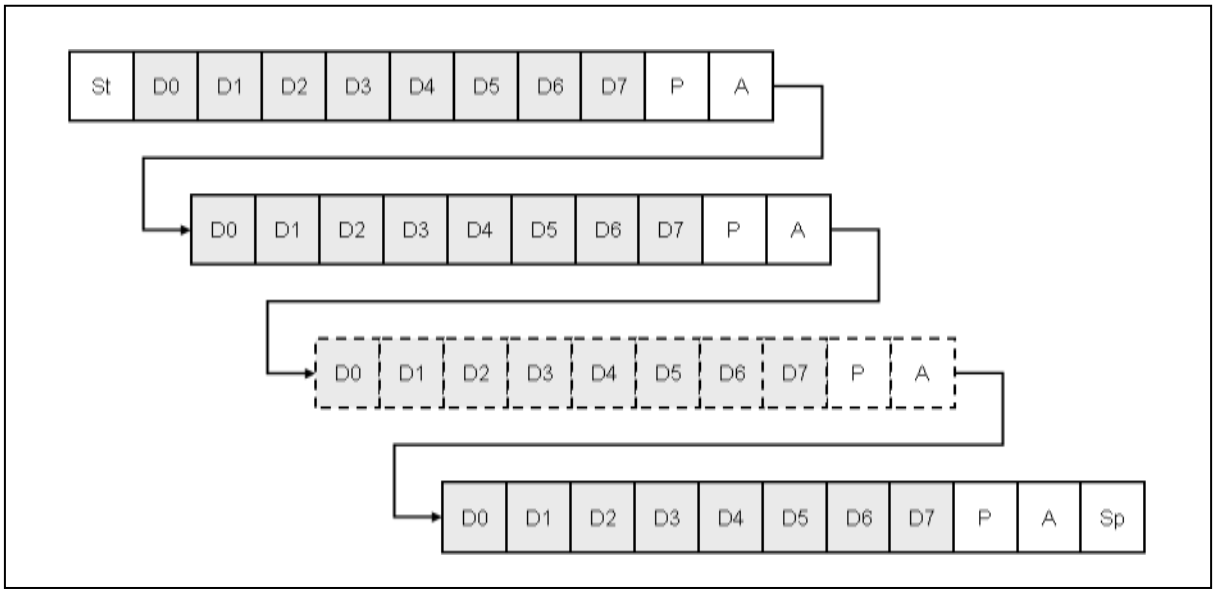


Figure 14.2 10-bit Transmission Packet

14.2.2 Packet Transmission Timing

14.2.2.1 Data Transfer

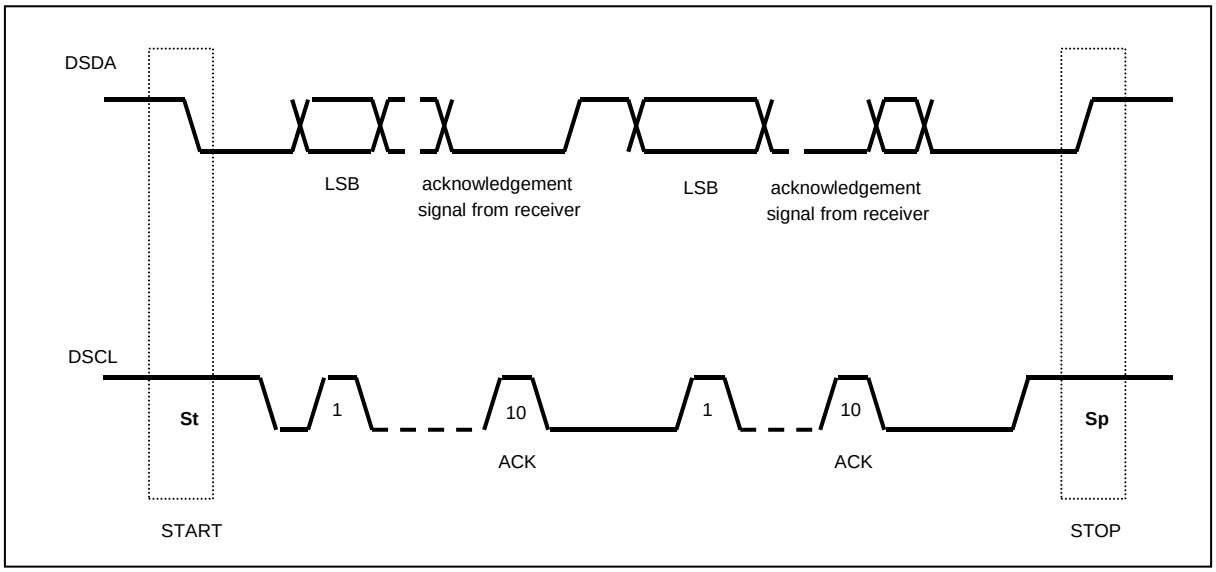


Figure 14.3 Data Transfer on the Twin Bus

14.2.2.2 Bit Transfer

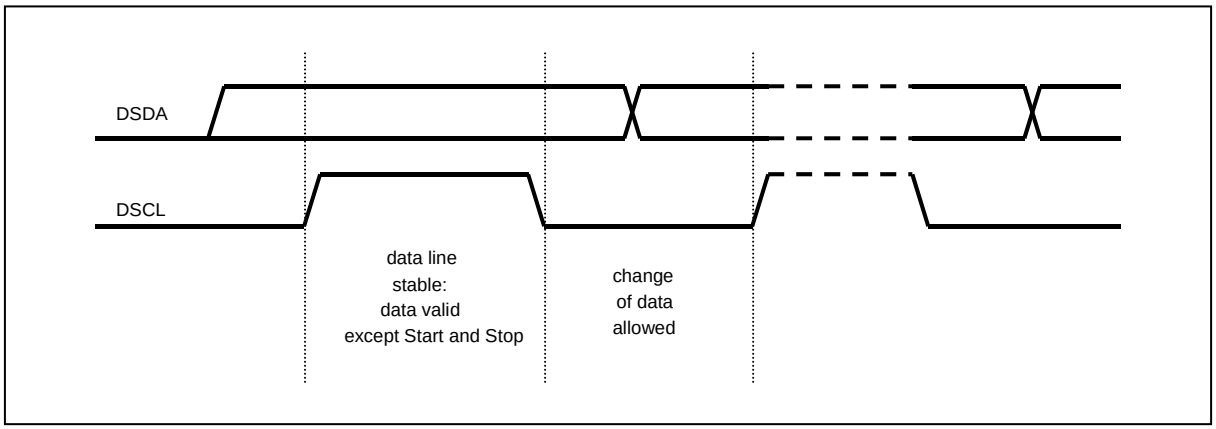


Figure 14.4 Bit Transfer on the Serial Bus

14.2.2.3 Start and Stop Condition

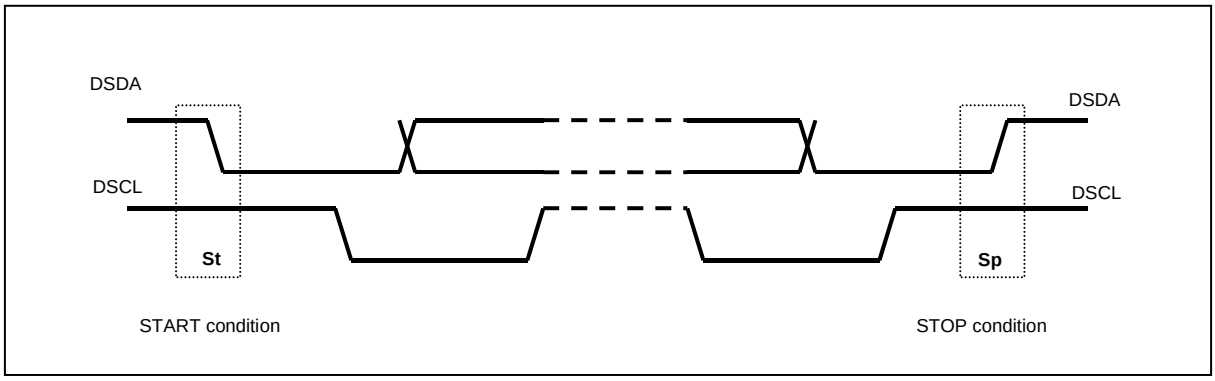


Figure 14.5 Start and Stop Condition

14.2.2.4 Acknowledge Bit

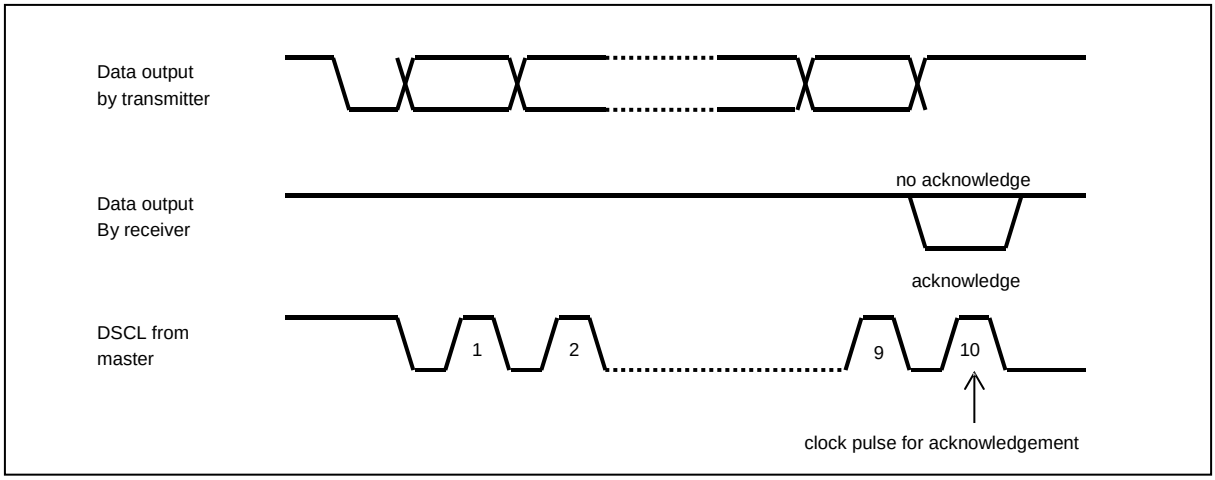


Figure 14.6 Acknowledge on the Serial Bus

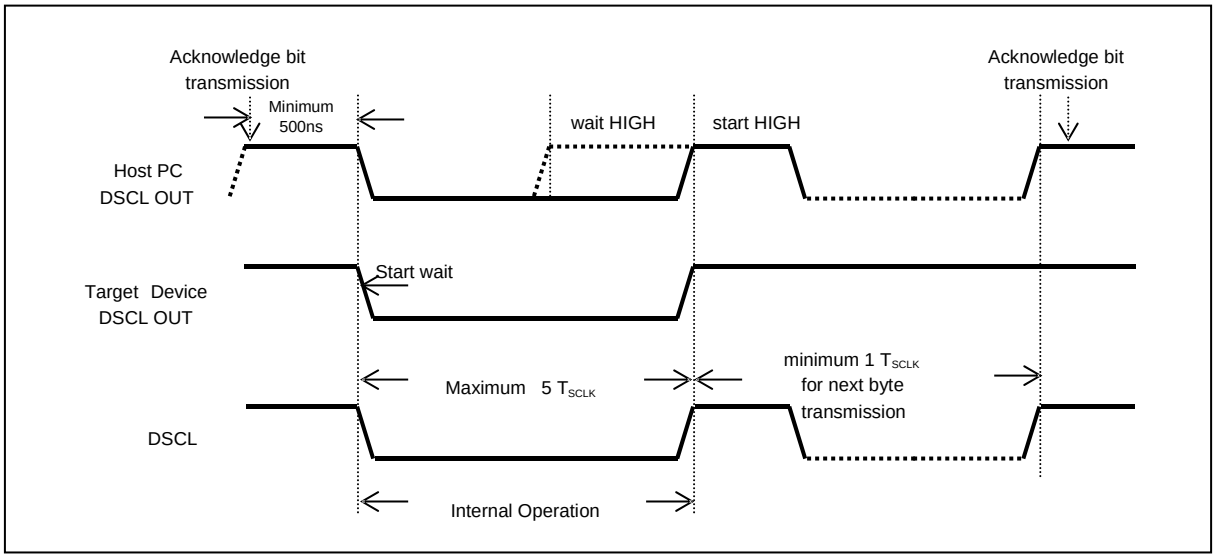


Figure 14.7 Clock Synchronization during Wait Procedure

14.2.3 Connection of Transmission

Two-pin interface connection uses open-drain (wire-AND bidirectional I/O).

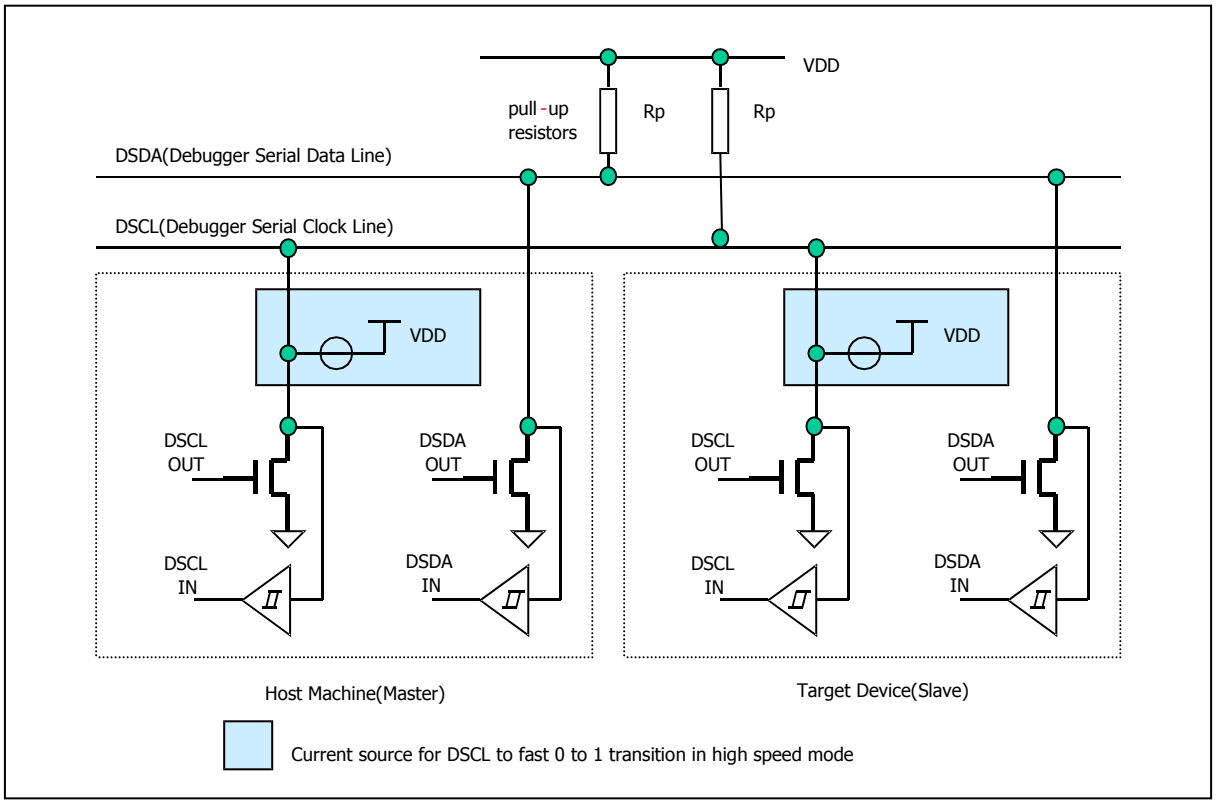


Figure 14.8 Connection of Transmission

15. Flash Memory

15.1 Overview

15.1.1 Description

MC96F8316 incorporates flash memory to which a program can be written, erased, and overwritten while mounted on the board. The flash memory can be read by ‘MOVC’ instruction and it can be programmed in OCD, serial ISP mode or user program mode.

- Flash Size : 16k bytes
- Single power supply program and erase
- Command interface for fast program and erase operation
- Up to 100,000 program/erase cycles at typical voltage and temperature for flash memory

15.1.2 Flash Program ROM Structure

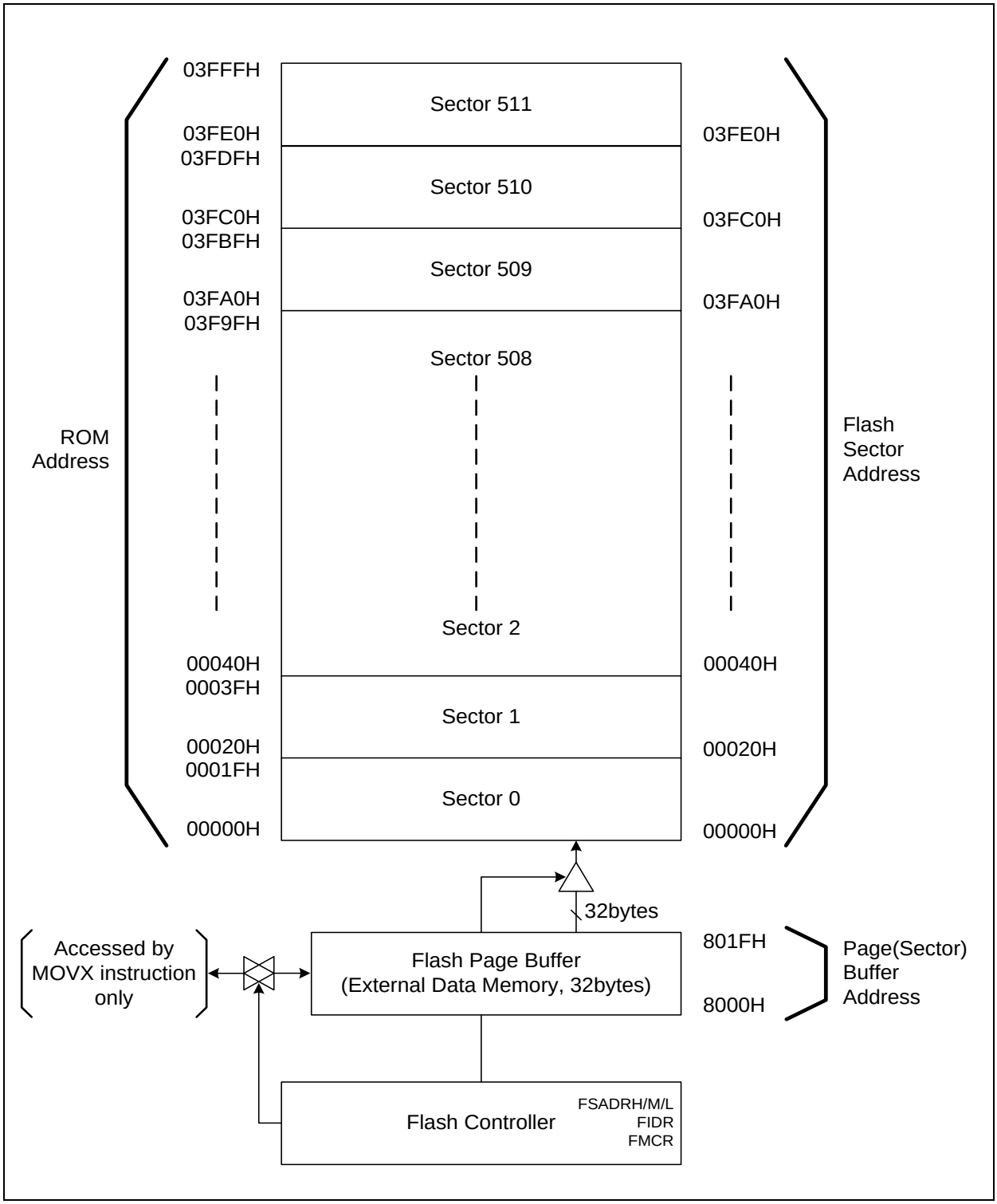


Figure 15.1 Flash Program ROM Structure

15.1.3 Register Map

Table 15-1 Flash Memory Register Map

Name	Address	Dir	Default	Description
FSADRH	FAH	R/W	00H	Flash Sector Address High Register
FSADRM	FBH	R/W	00H	Flash Sector Address Middle Register
FSADRL	FCH	R/W	00H	Flash Sector Address Low Register
FIDR	FDH	R/W	00H	Flash Identification Register
FMCR	FEH	R/W	00H	Flash Mode Control Register

15.1.4 Register Description for Flash Memory Control and Status

Flash control register consists of the flash sector address high register (FSADRH), flash sector address middle register (FSADRM), flash sector address low register (FSADRL), flash identification register (FIDR), and flash mode control register (FMCR). They are mapped to SFR area and can be accessed only in programming mode.

15.1.5 Register Description for Flash

FSADRH (Flash Sector Address High Register) : FAH

7	6	5	4	3	2	1	0
–	–	–	–	FSADRH3	FSADRH2	FSADRH1	FSADRH0
–	–	–	–	R/W	R/W	R/W	R/W

Initial value : 00H

FSADRH[3:0] Flash Sector Address High

FSADRM (Flash Sector Address Middle Register) : FBH

7	6	5	4	3	2	1	0
FSADRM7	FSADRM6	FSADRM5	FSADRM4	FSADRM3	FSADRM2	FSADRM1	FSADRM0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

FSADRM[7:0] Flash Sector Address Middle

FSADRL (Flash Sector Address Low Register) : FCH

7	6	5	4	3	2	1	0
FSADRL7	FSADRL6	FSADRL5	FSADRL4	FSADRL3	FSADRL2	FSADRL1	FSADRL0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

FSADRL[7:0] Flash Sector Address Low

FIDR (Flash Identification Register) : FDH

7	6	5	4	3	2	1	0
FIDR7	FIDR6	FIDR5	FIDR4	FIDR3	FIDR2	FIDR1	FIDR0
R/W	R/W	R/W	R/W	R/W	R/W	R/W	R/W

Initial value : 00H

FIDR[7:0] Flash Identification

Others No identification value

10100101 Identification value for a flash mode

(These bits are automatically cleared to logic ‘00H’ immediately after one time operation except “flash page buffer reset mode”)

FMCR (Flash Mode Control Register) : FEH

7	6	5	4	3	2	1	0
FMBUSY	–	–	–	–	FMCR2	FMCR1	FMCR0
R	–	–	–	–	R/W	R/W	R/W

Initial value : 00H

FMBUSY Flash Mode Busy Bit. This bit will be used for only debugger.

0 No effect when “1” is written

1 Busy

FMCR[2:0] Flash Mode Control Bits. During a flash mode operation, the CPU is hold and the global interrupt is on disable state regardless of the IE.7 (EA) bit.

FMCR2	FMCR1	FMCR0	Description
0	0	1	Select flash page buffer reset mode and start regardless of the FIDR value (Clear all 32bytes to ‘0’)
0	1	0	Select flash sector erase mode and start operation when the FIDR=”10100101b’
0	1	1	Select flash sector write mode and start operation when the FIDR=”10100101b’
1	0	0	Select flash sector hard lock and start operation when the FIDR=”10100101b’

Others Values: No operation

(These bits are automatically cleared to logic ‘00H’ immediately after one time operation)

15.1.6 Serial In-System Program (ISP) Mode

Serial in-system program uses the interface of debugger which uses two wires. Refer to chapter 14 in details about debugger

15.1.7 Protection Area (User program mode)

MC96F8316 can program its own flash memory (protection area). The protection area can not be erased or programmed. The protection areas are available only when the PAEN bit is cleared to '0', that is, enable protection area at the configure option 2 if it is needed. If the protection area isn't enabled (PAEN ='1'), this area can be used as a normal program memory.

The size of protection area can be varied by setting of configure option 2.

Table 15-2 Protection Area size

Protection Area Size Select		Size of Protection Area	Address of Protection Area
PASS1	PASS0		
0	0	3.8k Bytes	0100H – 0FFFH
0	1	1.7k Bytes	0100H – 07FFH
1	0	768 Bytes	0100H – 03FFH
1	1	256 Bytes	0100H – 01FFH

NOTE) Refer to chapter 16 in configure option control.

15.1.8 Erase Mode

The sector erase program procedure in user program mode

1. Page buffer clear (FMCR=0x01)
2. Write '0' to page buffer
3. Set flash sector address register (FSADRH/FSADRM/FSADRL).
4. Set flash identification register (FIDR).
5. Set flash mode control register (FMCR).
6. Erase verify

Program Tip – sector erase

```
            MOV     FMCR,#0x01          ;page buffer clear
            NOP                         ;Dummy instruction, This instruction must be needed.
            NOP                         ;Dummy instruction, This instruction must be needed.
            NOP                         ;Dummy instruction, This instruction must be needed.

            MOV     A,#0
            MOV     R0,#32              ;Sector size is 32bytes
            MOV     DPH,#0x80
            MOV     DPL,#0

Pgbuf_clr:  MOVX    @DPTR,A
            INC     DPTR
            DJNZ    R0, Pgbuf_clr       ;Write '0' to all page buffer

            MOV     FSADRH,#0x00
            MOV     FSADRM,#0x3F
            MOV     FSADRL,#0xA0        ;Select sector 509
            MOV     FIDR,#0xA5          ;Identification value
            MOV     FMCR,#0x02          ;Start flash erase mode
            NOP                         ;Dummy instruction, This instruction must be needed.
            NOP                         ;Dummy instruction, This instruction must be needed.
            NOP                         ;Dummy instruction, This instruction must be needed.

            MOV     A,#0                ;erase verify
            MOV     R0,#32              ;Sector size is 32bytes
            MOV     R1,#0
            MOV     DPH,#0x3F
            MOV     DPL,#0xA0

Erase_verify:
            MOVC    A,@A+DPTR
            SUBB    A,R1
            JNZ     Verify_error
            INC     DPTR
            DJNZ    R0, Erase_verify


Verify_error:
```

The Byte erase program procedure in user program mode

1. Page buffer clear (FMCR=0x01)
2. Write '0' to page buffer
3. Set flash sector address register (FSADRH/FSADRM/FSADRL).
4. Set flash identification register (FIDR).
5. Set flash mode control register (FMCR).
6. Erase verify

Program Tip – byte erase

```
MOV     FMCR,#0x01          ;page buffer clear
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.

MOV     A,#0
MOV     DPH,#0x80
MOV     DPL,#0
MOVX    @DPTR,A

MOV     DPH,#0x80
MOV     DPL,#0x05
MOVX    @DPTR,A             ;Write '0' to page buffer

MOV     FSADRH,#0x00
MOV     FSADRM,#0x3F
MOV     FSADRL,#0xA0        ;Select sector 509
MOV     FIDR,#0xA5          ;Identification value
MOV     FMCR,#0x02          ;Start flash erase mode
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.

MOV     A,#0                ;erase verify
MOV     R1,#0
MOV     DPH,#0x3F
MOV     DPL,#0xA0
MOVC    A,@A+DPTR
SUBB    A,R1                ;0x3FA0 = 0 ?
JNZ     Verify_error

MOV     A,#0
MOV     R1,#0
MOV     DPH,#0x3F
MOV     DPL,#0xA5
MOVC    A,@A+DPTR
SUBB    A,R1                ;0x3FA5 = 0 ?
JNZ     Verify_error


Verify_error:
```

15.1.9 Write Mode

The sector Write program procedure in user program mode

1. Page buffer clear (FMCR=0x01)
2. Write data to page buffer
3. Set flash sector address register (FSADRH/FSADRM/FSADRL).
4. Set flash identification register (FIDR).
5. Set flash mode control register (FMCR).
6. Erase verify

Program Tip – sector write

```
            MOV     FMCR,#0x01          ;page buffer clear
            NOP                         ;Dummy instruction, This instruction must be needed.
            NOP                         ;Dummy instruction, This instruction must be needed.
            NOP                         ;Dummy instruction, This instruction must be needed.

            MOV     A,#0
            MOV     R0,#32              ;Sector size is 32bytes
            MOV     DPH,#0x80
            MOV     DPL,#0

Pgbuf_WR:   MOVX    @DPTR,A
            INC     A
            INC     DPTR
            DJNZ    R0, Pgbuf_WR        ;Write data to all page buffer

            MOV     FSADRH,#0x00
            MOV     FSADRM,#0x3F
            MOV     FSADRL,#0xA0        ;Select sector 509
            MOV     FIDR,#0xA5          ;Identification value
            MOV     FMCR,#0x03          ;Start flash write mode
            NOP                         ;Dummy instruction, This instruction must be needed.
            NOP                         ;Dummy instruction, This instruction must be needed.
            NOP                         ;Dummy instruction, This instruction must be needed.

            MOV     A,#0                ;write verify
            MOV     R0,#32              ;Sector size is 32bytes
            MOV     R1,#0
            MOV     DPH,#0x3F
            MOV     DPL,#0xA0

Write_verify:
            MOVC    A,@A+DPTR
            SUBB    A,R1
            JNZ     Verify_error
            INC     R1
            INC     DPTR
            DJNZ    R0, Write_verify


Verify_error:
```

The Byte Write program procedure in user program mode

1. Page buffer clear (FMCR=0x01)
2. Write data to page buffer
3. Set flash sector address register (FSADRH/FSADRM/FSADRL).
4. Set flash identification register (FIDR).
5. Set flash mode control register (FMCR).
6. Erase verify

Program Tip – byte write

```
MOV     FMCR,#0x01          ;page buffer clear
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.

MOV     A,#5
MOV     DPH,#0x80
MOV     DPL,#0
MOVX    @DPTR,A             ;Write data to page buffer

MOV     A,#6
MOV     DPH,#0x80
MOV     DPL,#0x05
MOVX    @DPTR,A             ;Write data to page buffer

MOV     FSADRH,#0x00
MOV     FSADRM,#0x3F
MOV     FSADRL,#0xA0        ;Select sector 509
MOV     FIDR,#0xA5          ;Identification value
MOV     FMCR,#0x03          ;Start flash write mode
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.

MOV     A,#0                ;write verify
MOV     R1,#5
MOV     DPH,#0x3F
MOV     DPL,#0xA0
MOVC    A,@A+DPTR
SUBB    A,R1                ;0x3FA0 = 5 ?
JNZ     Verify_error

MOV     A,#0
MOV     R1,#6
MOV     DPH,#0x3F
MOV     DPL,#0xA5
MOVC    A,@A+DPTR
SUBB    A,R1                ;0x3FA5 = 6 ?
JNZ     Verify_error


Verify_error:
```

15.1.10 Read Mode

The Reading program procedure in user program mode

1. Load receive data from flash memory on MOVC instruction by indirectly addressing mode.

Program Tip – reading

```
MOV     A,#0
MOV     DPH,#0x3F
MOV     DPL,#0xA0           ;flash memory address

MOVC    A,@A+DPTR           ;read data from flash memory
```

15.1.11 Hard Lock Mode

The Reading program procedure in user program mode

1. Set flash identification register (FIDR).
2. Set flash mode control register (FMCR).

Program Tip – reading

```
MOV     FIDR,#0xA5          ;Identification value
MOV     FMCR,#0x04          ;Start flash hard lock mode
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.
NOP                         ;Dummy instruction, This instruction must be needed.
```

16. Configure Option

16.1 Configure Option Control

The data for configure option should be written in the configure option area (001EH – 001FH) by programmer (Writer tools).

CONFIGURE OPTION 1 : ROM Address 001FH

7	6	5	4	3	2	1	0
R_P	HL	–	–	–	–	–	RSTS

Initial value : 00H

R_P	Read Protection	
	0	Disable “Read protection”
	1	Enable “Read protection”
HL	Hard-Lock	
	0	Disable “Hard-lock”
	1	Enable “Hard-lock”
RSTS	RESETB Select	
	0	P32 port
	1	RESETB port with a pull-up resistor

CONFIGURE OPTION 2: ROM Address 001EH

7	6	5	4	3	2	1	0
–	–	–	–	–	PAEN	PASS1	PASS0

Initial value : 00H

PAEN	Protection Area Enable/Disable		
	0	Disable Protection (Erasable by instruction)	
	1	Enable Protection (Not erasable by instruction)	
PASS [1:0]	Protection Area Size Select		
	PASS1	PASS0	Description
	0	0	3.8k Bytes (Address 0100H – 0FFFH)
	0	1	1.7k Bytes (Address 0100H – 07FFH)
	1	0	768 Bytes (Address 0100H – 03FFH)
	1	1	256 Bytes (Address 0100H – 01FFH)

17. APPENDIX

A. Instruction Table

Instructions are either 1, 2 or 3 bytes long as listed in the 'Bytes' column below.

Each instruction takes either 1, 2 or 4 machine cycles to execute as listed in the following table. 1 machine cycle comprises 2 system clock cycles.

ARITHMETIC				
Mnemonic	**Description**	**Bytes**	**Cycles**	**Hex code**
ADD A,Rn	Add register to A	1	1	28-2F
ADD A,dir	Add direct byte to A	2	1	25
ADD A,@Ri	Add indirect memory to A	1	1	26-27
ADD A,#data	Add immediate to A	2	1	24
ADDC A,Rn	Add register to A with carry	1	1	38-3F
ADDC A,dir	Add direct byte to A with carry	2	1	35
ADDC A,@Ri	Add indirect memory to A with carry	1	1	36-37
ADDC A,#data	Add immediate to A with carry	2	1	34
SUBB A,Rn	Subtract register from A with borrow	1	1	98-9F
SUBB A,dir	Subtract direct byte from A with borrow	2	1	95
SUBB A,@Ri	Subtract indirect memory from A with borrow	1	1	96-97
SUBB A,#data	Subtract immediate from A with borrow	2	1	94
INC A	Increment A	1	1	04
INC Rn	Increment register	1	1	08-0F
INC dir	Increment direct byte	2	1	05
INC @Ri	Increment indirect memory	1	1	06-07
DEC A	Decrement A	1	1	14
DEC Rn	Decrement register	1	1	18-1F
DEC dir	Decrement direct byte	2	1	15
DEC @Ri	Decrement indirect memory	1	1	16-17
INC DPTR	Increment data pointer	1	2	A3
MUL AB	Multiply A by B	1	4	A4
DIV AB	Divide A by B	1	4	84
DA A	Decimal Adjust A	1	1	D4

LOGICAL				
Mnemonic	**Description**	**Bytes**	**Cycles**	**Hex code**
ANL A,Rn	AND register to A	1	1	58-5F
ANL A,dir	AND direct byte to A	2	1	55
ANL A,@Ri	AND indirect memory to A	1	1	56-57
ANL A,#data	AND immediate to A	2	1	54
ANL dir,A	AND A to direct byte	2	1	52
ANL dir,#data	AND immediate to direct byte	3	2	53
ORL A,Rn	OR register to A	1	1	48-4F
ORL A,dir	OR direct byte to A	2	1	45
ORL A,@Ri	OR indirect memory to A	1	1	46-47
ORL A,#data	OR immediate to A	2	1	44
ORL dir,A	OR A to direct byte	2	1	42
ORL dir,#data	OR immediate to direct byte	3	2	43
XRL A,Rn	Exclusive-OR register to A	1	1	68-6F
XRL A,dir	Exclusive-OR direct byte to A	2	1	65
XRL A, @Ri	Exclusive-OR indirect memory to A	1	1	66-67

XRL A,#data	Exclusive-OR immediate to A	2	1	64
XRL dir,A	Exclusive-OR A to direct byte	2	1	62
XRL dir,#data	Exclusive-OR immediate to direct byte	3	2	63
CLR A	Clear A	1	1	E4
CPL A	Complement A	1	1	F4
SWAP A	Swap Nibbles of A	1	1	C4
RL A	Rotate A left	1	1	23
RLC A	Rotate A left through carry	1	1	33
RR A	Rotate A right	1	1	03
RRC A	Rotate A right through carry	1	1	13

DATA TRANSFER				
Mnemonic	**Description**	**Bytes**	**Cycles**	**Hex code**
MOV A,Rn	Move register to A	1	1	E8-EF
MOV A,dir	Move direct byte to A	2	1	E5
MOV A,@Ri	Move indirect memory to A	1	1	E6-E7
MOV A,#data	Move immediate to A	2	1	74
MOV Rn,A	Move A to register	1	1	F8-FF
MOV Rn,dir	Move direct byte to register	2	2	A8-AF
MOV Rn,#data	Move immediate to register	2	1	78-7F
MOV dir,A	Move A to direct byte	2	1	F5
MOV dir,Rn	Move register to direct byte	2	2	88-8F
MOV dir,dir	Move direct byte to direct byte	3	2	85
MOV dir,@Ri	Move indirect memory to direct byte	2	2	86-87
MOV dir,#data	Move immediate to direct byte	3	2	75
MOV @Ri,A	Move A to indirect memory	1	1	F6-F7
MOV @Ri,dir	Move direct byte to indirect memory	2	2	A6-A7
MOV @Ri,#data	Move immediate to indirect memory	2	1	76-77
MOV DPTR,#data	Move immediate to data pointer	3	2	90
MOVC A,@A+DPTR	Move code byte relative DPTR to A	1	2	93
MOVC A,@A+PC	Move code byte relative PC to A	1	2	83
MOVX A,@Ri	Move external data(A8) to A	1	2	E2-E3
MOVX A,@DPTR	Move external data(A16) to A	1	2	E0
MOVX @Ri,A	Move A to external data(A8)	1	2	F2-F3
MOVX @DPTR,A	Move A to external data(A16)	1	2	F0
PUSH dir	Push direct byte onto stack	2	2	C0
POP dir	Pop direct byte from stack	2	2	D0
XCH A,Rn	Exchange A and register	1	1	C8-CF
XCH A,dir	Exchange A and direct byte	2	1	C5
XCH A,@Ri	Exchange A and indirect memory	1	1	C6-C7
XCHD A,@Ri	Exchange A and indirect memory nibble	1	1	D6-D7

BOOLEAN				
Mnemonic	**Description**	**Bytes**	**Cycles**	**Hex code**
CLR C	Clear carry	1	1	C3
CLR bit	Clear direct bit	2	1	C2
SETB C	Set carry	1	1	D3
SETB bit	Set direct bit	2	1	D2
CPL C	Complement carry	1	1	B3
CPL bit	Complement direct bit	2	1	B2
ANL C,bit	AND direct bit to carry	2	2	82
ANL C,/bit	AND direct bit inverse to carry	2	2	B0

ORL C,bit	OR direct bit to carry	2	2	72
ORL C,/bit	OR direct bit inverse to carry	2	2	A0
MOV C,bit	Move direct bit to carry	2	1	A2
MOV bit,C	Move carry to direct bit	2	2	92

BRANCHING				
Mnemonic	**Description**	**Bytes**	**Cycles**	**Hex code**
ACALL addr 11	Absolute jump to subroutine	2	2	11→F1
LCALL addr 16	Long jump to subroutine	3	2	12
RET	Return from subroutine	1	2	22
RETI	Return from interrupt	1	2	32
AJMP addr 11	Absolute jump unconditional	2	2	01→E1
LJMP addr 16	Long jump unconditional	3	2	02
SJMP rel	Short jump (relative address)	2	2	80
JC rel	Jump on carry = 1	2	2	40
JNC rel	Jump on carry = 0	2	2	50
JB bit,rel	Jump on direct bit = 1	3	2	20
JNB bit,rel	Jump on direct bit = 0	3	2	30
JBC bit,rel	Jump on direct bit = 1 and clear	3	2	10
JMP @A+DPTR	Jump indirect relative DPTR	1	2	73
JZ rel	Jump on accumulator = 0	2	2	60
JNZ rel	Jump on accumulator ≠ 0	2	2	70
CJNE A,dir,rel	Compare A,direct jne relative	3	2	B5
CJNE A,#d,rel	Compare A,immediate jne relative	3	2	B4
CJNE Rn,#d,rel	Compare register, immediate jne relative	3	2	B8-BF
CJNE @Ri,#d,rel	Compare indirect, immediate jne relative	3	2	B6-B7
DJNZ Rn,rel	Decrement register, jnz relative	3	2	D8-DF
DJNZ dir,rel	Decrement direct byte, jnz relative	3	2	D5

MISCELLANEOUS				
Mnemonic	**Description**	**Bytes**	**Cycles**	**Hex code**
NOP	No operation	1	1	00

ADDITIONAL INSTRUCTIONS (selected through EO[7:4])				
Mnemonic	**Description**	**Bytes**	**Cycles**	**Hex code**
MOVC @(DPTR++),A	M8051W/M8051EW-specific instruction supporting software download into program memory	1	2	A5
TRAP	Software break command	1	1	A5

In the above table, an entry such as E8-EF indicates a continuous block of hex opcodes used for 8 different registers, the register numbers of which are defined by the lowest three bits of the corresponding code. Non-continuous blocks of codes, shown as 11→F1 (for example), are used for absolute jumps and calls, with the top 3 bits of the code being used to store the top three bits of the destination address.

The CJNE instructions use the abbreviation #d for immediate data; other instructions use #data.

B. Instructions on how to use the input port.

- Error occur status
  - Using compare jump instructions with input port, it could cause error due to the timing conflict inside the MCU.
  - Compare jump Instructions which cause potential error used with input port condition:

```
JB      bit, rel      ; jump on direct bit=1
JNB     bit, rel      ; jump on direct bit=0
JBC     bit, rel      ; jump on direct bit=1 and clear
CJNE    A, dir, rel ; compare A, direct jne relative
DJNZ    dir, rel      ; decrement direct byte, jnz relative
```

  - It is only related with Input port. Internal parameters, SFRs and output bit ports don't cause any error by using compare jump instructions.
  - If input signal is fixed, there is no error in using compare jump instructions.

- Error status example

```
while(1){
  if (P00==1){ P10=1; }
  else { P10=0; }
  P11^=1;
}
```

```
zzz:  JNB     080.0, xxx  ; it possible to be error
      SETB    088.0
      SJMP    yyy
xxx:  CLR     088.0
yyy:  MOV     C,088.1
      CPL     C
      MOV     088.1,C
      SJMP    zzz
```

```
unsigned char ret_bit_err(void)
{
  return !P00;
}
```

```
      MOV     R7, #000
      JB      080.0, xxx  ; it possible to be error
      MOV     R7, #001
xxx:  RET
```

- Preventative measures (2 cases)
  - Do not use input bit port for bit operation but for byte operation. Using byte operation instead of bit oper ation will not cause any error in using compare jump instructions for input port.

```
while(1){
 if ((P0&0x01)==0x01){ P10=1; }
  else { P10=0; }
  P11^=1;
}
```

```
zzz:  MOV     A, 080      ; read as byte
      JNB     0E0.0, xxx  ; compare
      SETB    088.0
      SJMP    yyy
xxx:  CLR     088.0
yyy:  MOV     C,088.1
      CPL     C
      MOV     088.1,C
      SJMP    zzz
```

- If you use input bit port for compare jump instruction, you have to copy the input port as internal paramet er or carry bit and then use compare jump instruction.

```
bit tt;
while(1){
  tt=P00;
  if (tt==0){ P10=1;}
  else {P10=0;}
  P11^=1;
}
```

```
zzz:  MOV   C,080.0     ; input port use internal parameter
      MOV   020.0, C    ; move
      JB    020.0, xxx  ; compare
      SETB  088.0
      SJMP  yyy
xxx:  CLR   088.0
yyy:  MOV   C,088.1
      CPL   C
      MOV   088.1,C
      SJMP  zzz
```