
CMOS single-chip 8-bit MCU with EEPROM and 12-bit A/D converter



Main features

- **8-bit Microcontroller with high speed 8051 CPU**
- **Basic MCU Function**
 - 16Kbytes Flash Code Memory
 - 512bytes EEPROM Backup Memory
 - 1Kbytes SRAM Data Memory
- **Built-in Analog Function**
 - Power-On Reset and Low Voltage Reset
 - Internal 16MHz RC Oscillator ($\pm 3\%$, $T_A = -40 \sim +85^\circ\text{C}$)
 - Internal 1MHz RING Oscillator
- **Peripheral features**
 - 12-bit Analog to Digital Converter (15 inputs)
 - Serial Interface (2-ch USART + SPI + I2C)
 - 6-channel 10-bit PWM for Motor Control
- **I/O and packages**
 - Up to 30 programmable I/O lines with 32LQFP
 - 32LQFP/32QFN/28TSSOP/20TSSOP
- **Operating conditions**
 - 1.8V to 5.5V wide voltage range
 - -40°C to 85°C temperature range
- **Application**
 - Small Home Appliance
 - BLDC Motor Controller
 - High speed PWM Application (10-bit 125kHz ~ 7-bit 1MHz PWM)
LED Lighting Control
 - Step-up or Step-down Power Converter Control

MC97FG316

MC97FG216

User's manual

V 1.6

Revision history

[illegible]**Version 1.6**

Published by FAE team

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1 Overview

1.1. Description

The MC97FG316 is an advanced CMOS 8-bit microcontroller with 16Kbytes 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: 16Kbytes of FLASH, 256bytes of internal SRAM, 768bytes of external SRAM, 512bytes of Data EEPROM, general purpose I/O, 8/16-bit timer/counter, watchdog timer, watch timer, SPI, USART, I2C, on-chip POR, LVR, 12-bit A/D converter, analog comparator, buzzer driving port, 10-bit high speed PWM output, on-chip RC oscillator and clock circuitry. The MC97FG316 also supports power saving modes to reduce power consumption.

Device Name	FLASH	IRAM	XRAM	EEPROM	ADC	I/O PORT	Package
MC97FG316L	16Kbytes	256bytes	768bytes	512bytes	15inputs	30	32LQFP
MC97FG316U							32QFN
MC97FG316R					12inputs	26	28TSSOP
MC97FG216R					10inputs	18	20TSSOP

Table 1.1 Ordering Information of MC97FG316

1.2 Features

- **CPU**
 - 8-bit CISC core (8051 Compatible, 2 clock per cycle)
- **16Kbytes On-Chip FLASH**
 - Optional boot code section with protection
 - Endurance : 10,000 times at room temperature
 - Retention : 10 years
- **256bytes SRAM**
- **768bytes XRAM**
- **512bytes Data EEPROM**
 - Endurance : 300,000 times at room temperature
 - Retention : 10 years
- **General Purpose I/O (GPIO)**
 - 30Ports (P0[7:0], P1[6:0], P2[6:0], P3[7:0]): 32-Pin
 - 26Ports (P0[7:0], P1[6:0], P2[2:0], P3[7:0]): 28-Pin
 - 18Ports (P0[7:0], P1[6:0], P2[2:0]): 20-Pin
- **One Basic Interval Timer**
- **Timer/Counter**
 - 8-bit × 4-ch (16-bit × 2-ch) + 16-bit × 1-ch
- **3 High Frequency 10-bit PWM (Using Timer1)**
- **10-bit PWM (Using Timer3)**
- **Watch Dog Timer**
- **Watch Timer**
- **SPI**
- **USART (2-ch)**
- **I2C**
- **Buzzer Driving Port**
- **12-bit A/D Converter**
 - 15-Input channels : 32-Pin
- **Analog Comparator**
 - On Chip Analog Comparator
- **Interrupt Sources**
 - External Interrupts (7)
 - Pin Change Interrupt(P0) (1)
 - USART0,1 (4)
 - SPI (1)
 - Timer (5)
 - I2C (1)
 - ADC (1)
 - Analog Comparator (1)
 - WDT (1)
 - WT (1)
- BIT (1)
- **On-Chip RC-Oscillator**
 - 16MHz(±3% @-40 ~ +85°C)
- **Power On Reset**
- **Low Voltage Reset**
- **Minimum Instruction Execution Time**
 - 200ns (@10MHz, NOP Instruction)
- **Power Down Mode**
 - IDLE, STOP1, STOP2 mode
- **Sub-Active mode**
 - System used by external 32.768kHz crystal or internal 125kHz Ring oscillator
- **Operating Frequency**
 - 4MHz ~ 16MHz
- **Operating Voltage**
 - 1.8V ~ 5.5V
- **Operating Temperature : -40 ~ +85°C**
- **Package Type**
 - 32LQFP/QFN
 - 28TSSOP
 - 20TSSOP
 - Pb free package

1.3 Development tools

1.3.1 Compiler

ABOV Semiconductor does not provide compiler. It is recommended that you consult a compiler provider.

The MC97FG316 core is Mentor 8051, and the ROM size is smaller than 64Kbytes. Therefore, developer can use the standard 8051 compiler from other providers.

1.3.2 OCD2(On-chip debugger) emulator and debugger

The OCD2 (On Chip Debug) emulator supports ABOV Semiconductor's 8051 series MCU emulation. The OCD2 interface uses two-wire connection between PC and MCU which is attached to user's system. The OCD2 can read or change the value of MCU internal memory and I/O peripherals. And the OCD2 also controls MCU internal debugging logic, it means OCD2 controls emulation, step run, monitoring, etc.

The OCD2 debugger program works on Microsoft-Windows NT, 2000, XP, Vista (32-bit) operating system. If you want to see more details, please refer to OCD2 debugger manual. You can download debugger S/W and manual from our web-site (<http://www.abov.co.kr>).

Connection:

- DSCL (MC97FG316 P06 port)
- DSDA (MC97FG316 P07 port)

OCD2 connector diagram: Connect OCD2 with user system

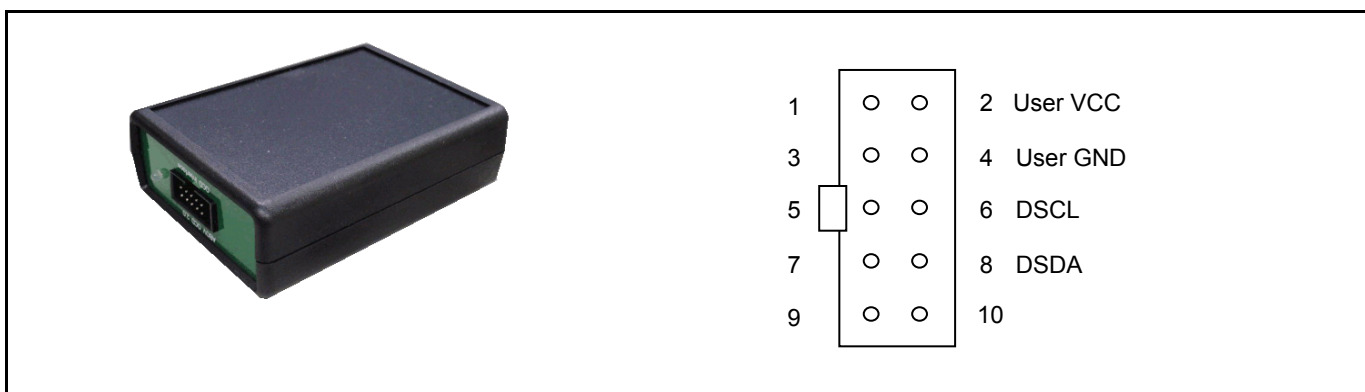


Figure 1.1 debugger and pin description

OCD2 emulator:

It can write code to MCU device too, because OCD2 debugger supports ISP (In System Programming). It does not require additional H/W, except developer's target system.

1.3.3 Programmer

PGMplusLC2 Writer:

It programs MCU device directly.

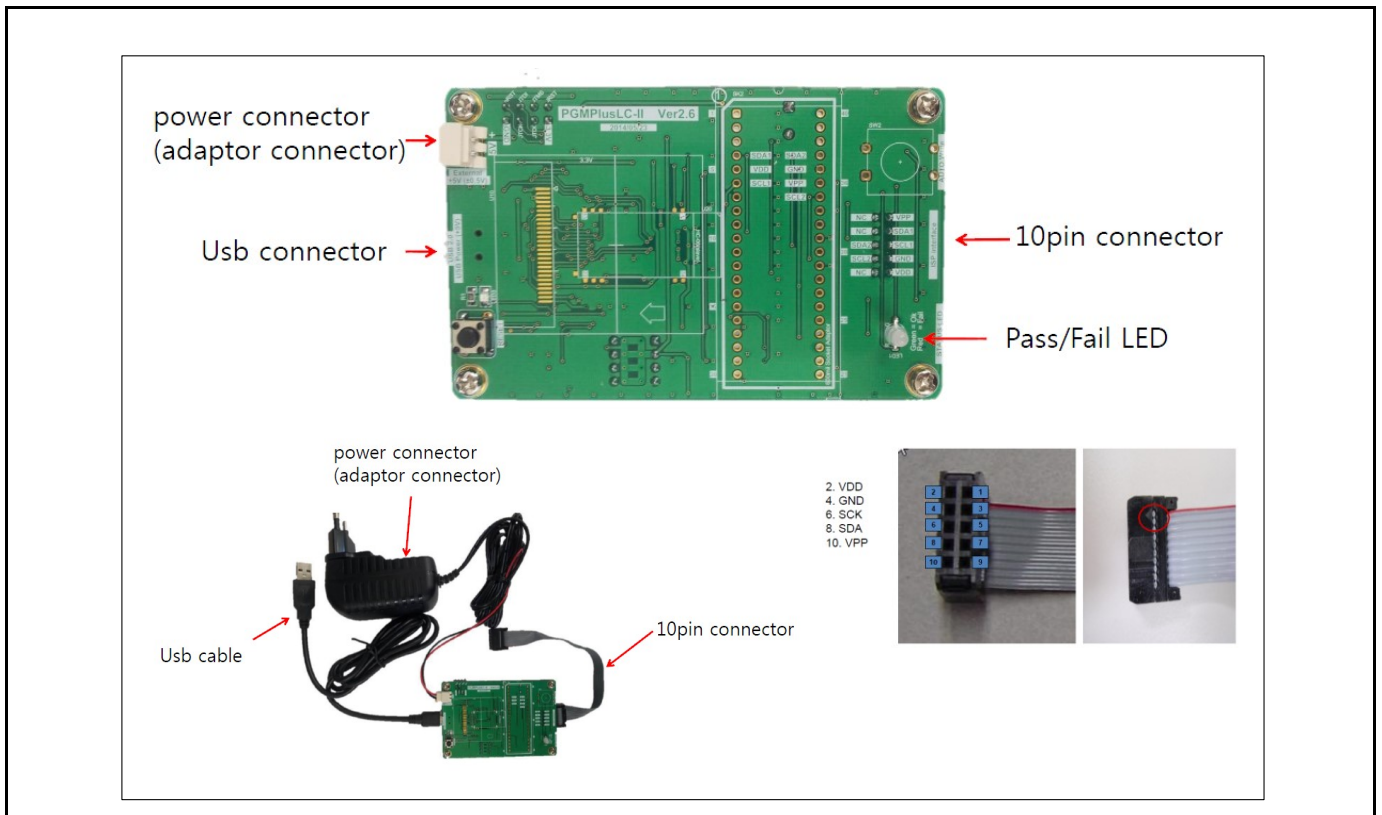


Figure 1.2 PGMplusLC2 Writer

E- PGM+ : It programs MCU device directly.

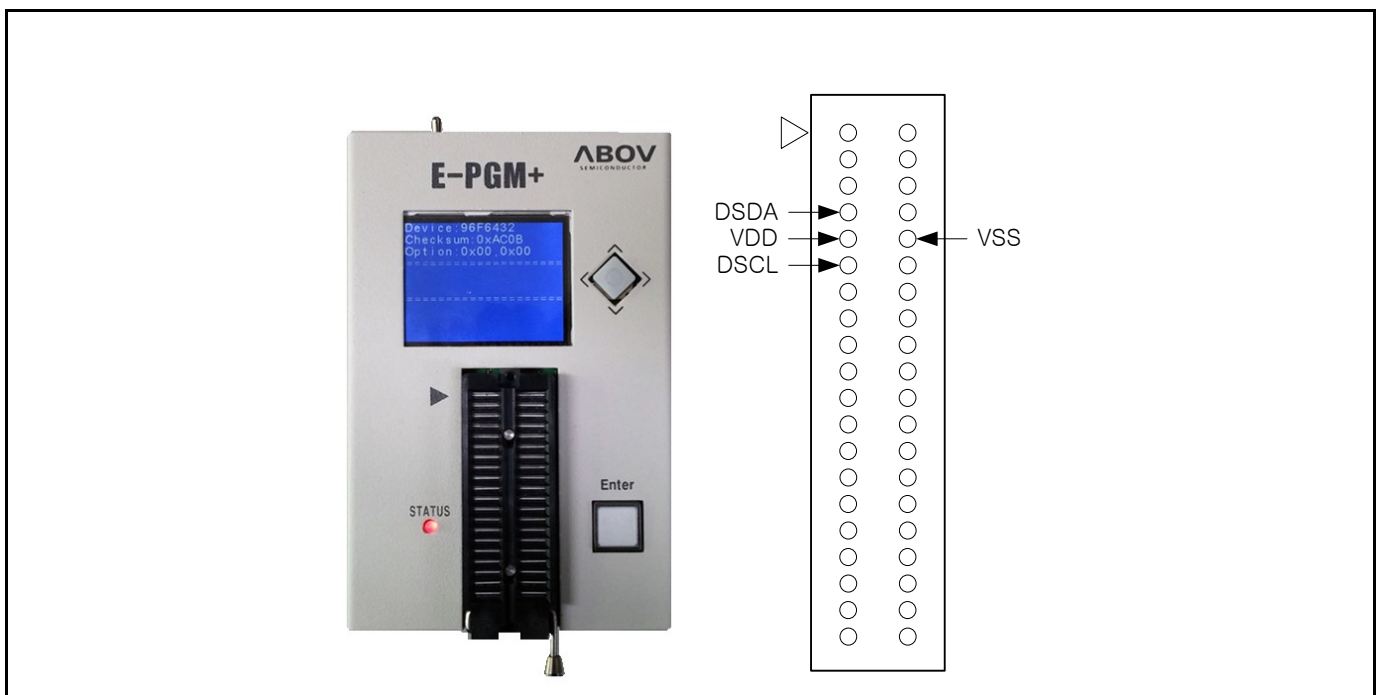


Figure 1.3 E-PGM+(Single writer)

Gang programmer:

It programs 6 MCU devices at once. So, it is mainly used in mass production factory.

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 E- Gang6 (for Mass Production)

On-Board programming :

The program memory of MC97FG316 is FLASH Memory Type. This flash is accessed by serial data format. There are four pins (DSCL, DSDA, VDD, and VSS) for programming/reading the flash. The MC97FG316 needs only four signal lines including VDD and VSS pins for programming FLASH with serial protocol. Therefore the on-board programming is possible if the programming signal lines are considered when the PCB of application board is designed.

Pin name	Main chip pin name	During programming	
		I/O	Description
DSCL	P06	I	Serial clock pin. Input only pin.
DSDA	P07	I/O	Serial data pin. Output port when reading and input port when programming. Can be assigned as input/push-pull output port.
VDD, VSS	VDD, VSS	-	Logic power supply pin.

Table 1.2 Descriptions of pins used to programming/reading the Flash

2 Block diagram

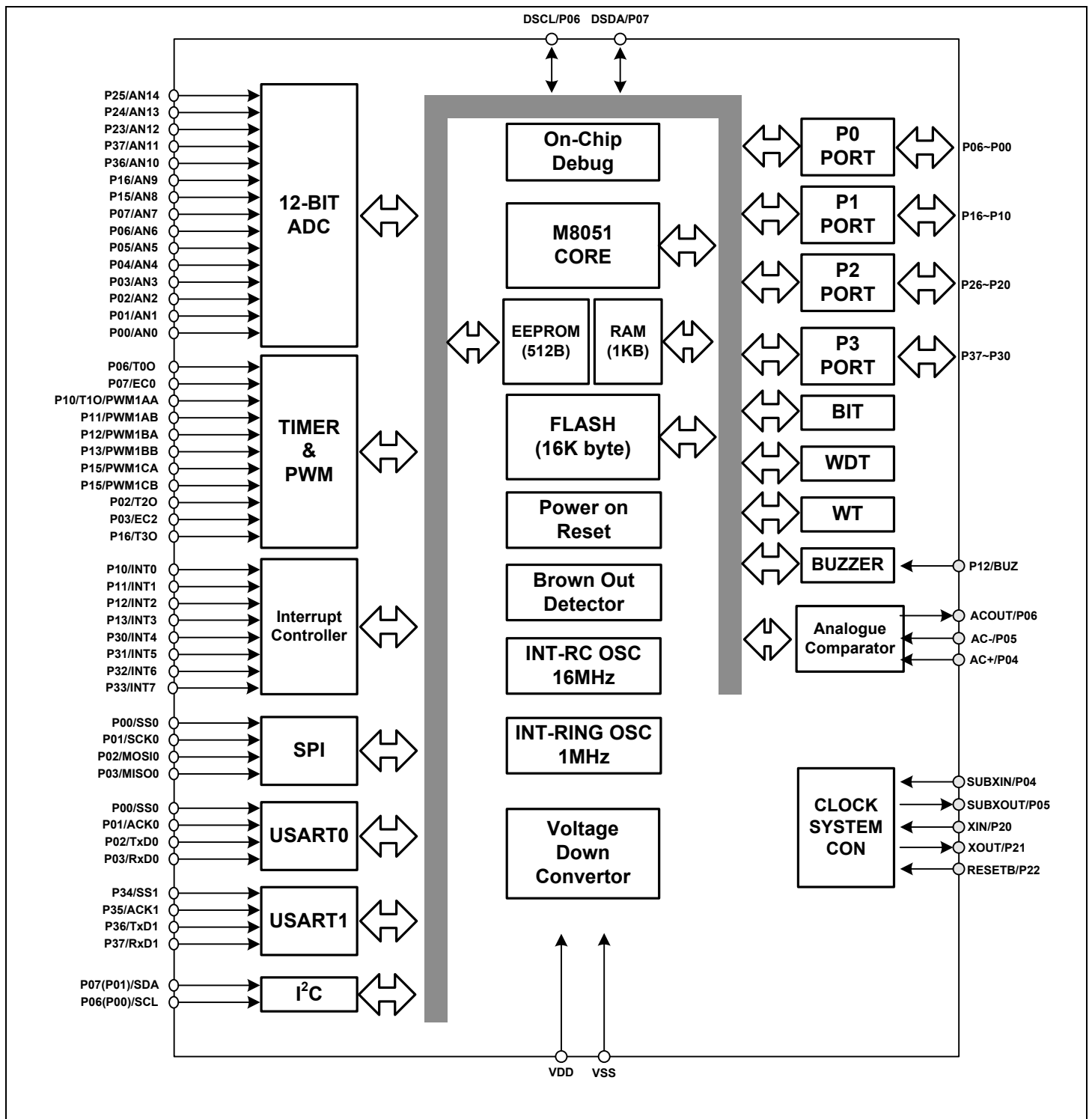


Figure 2.1 Block diagram of MC97FG316

3 Pin assignment

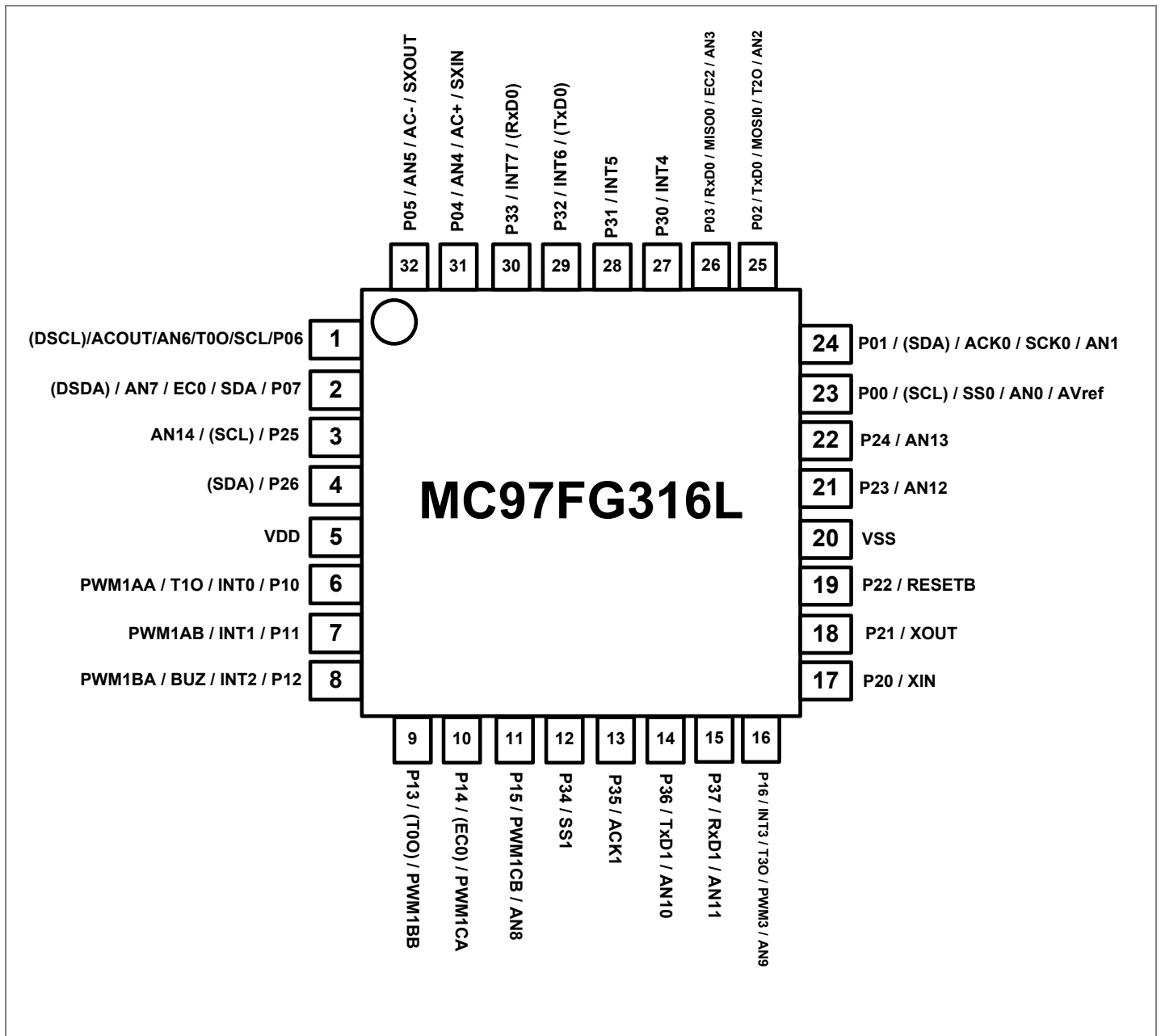


Figure 3.1 MC97FG316 32LQFP pin assignment

NOTE)

1. If 28PKG, P2[6:3] in 32-pin package are removed and their function can't operate.
2. If 20PKG, P2[6:3] and P3[7:0] in 32-pin package are removed and their function can't operate.
3. When On-Chip Debugging, ISP uses P0[7:6] pin as DSCL, DSDA.
4. The outside pin operation has higher priority than the inside pin operation. Ex) In pin26, if P03, RxD0, MISO0, EC2 and AN3 are set, AN3 will be operated.

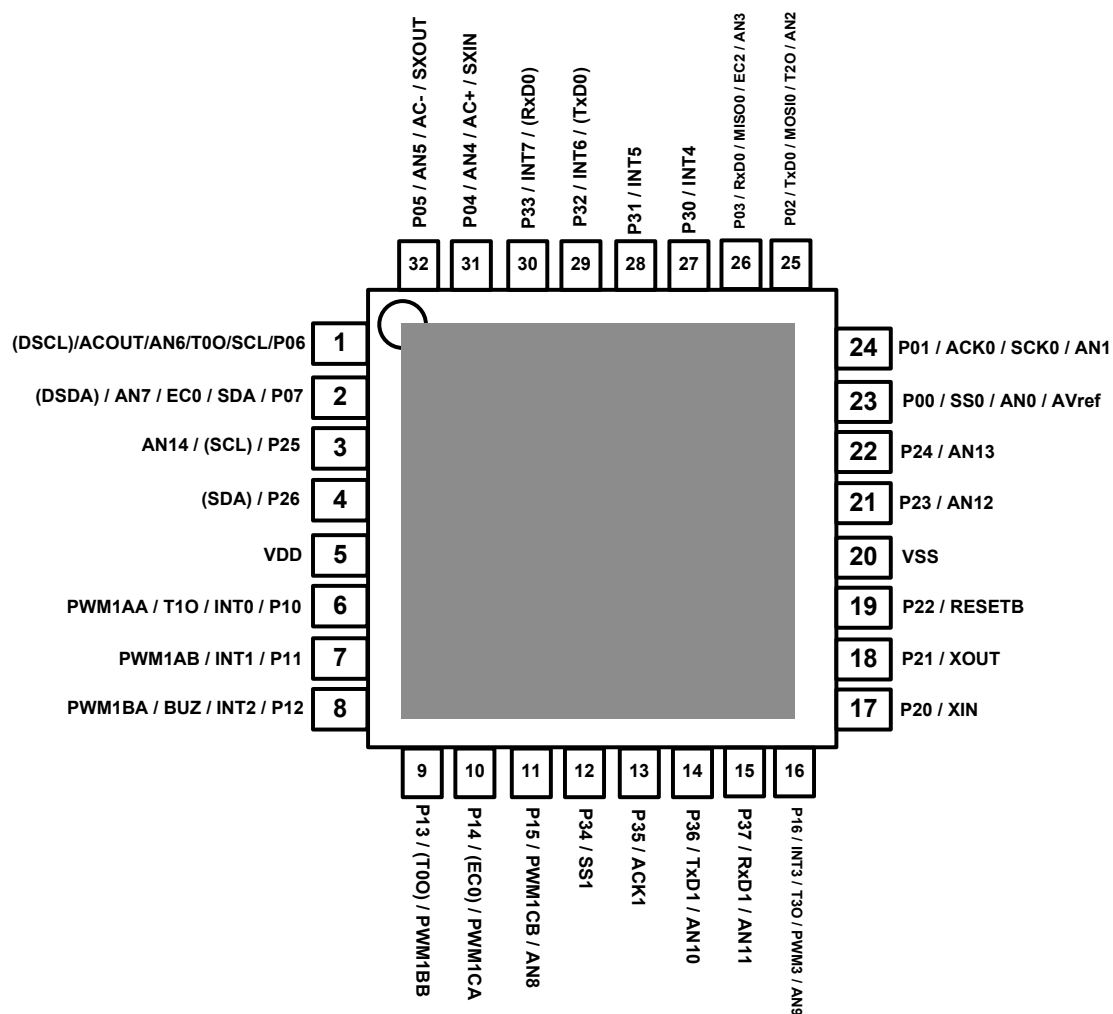


Figure 3.2 MC97FG316 32QFN pin assignment

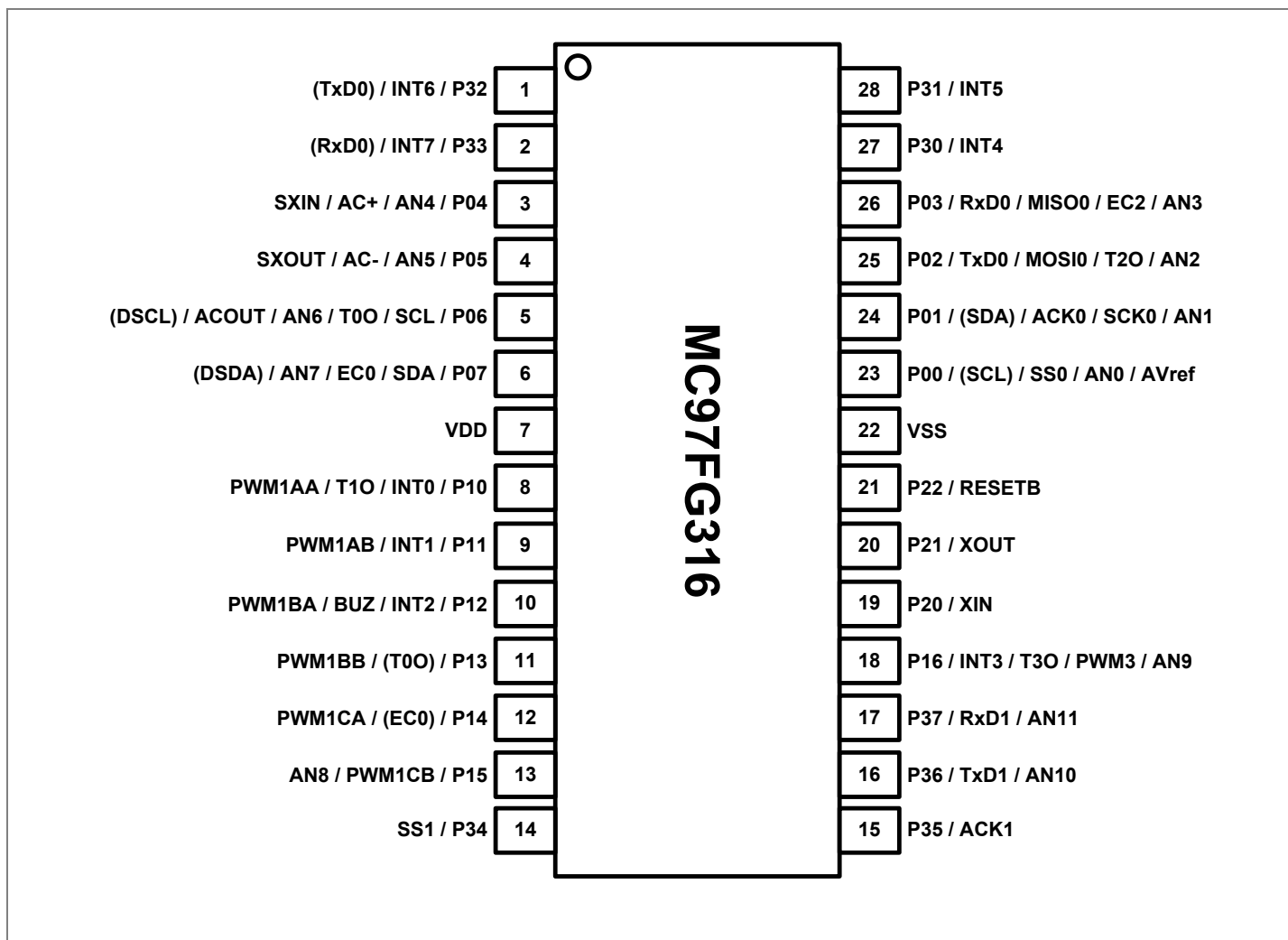


Figure 3.3 MC97FG316 28TSSOP pin assignment

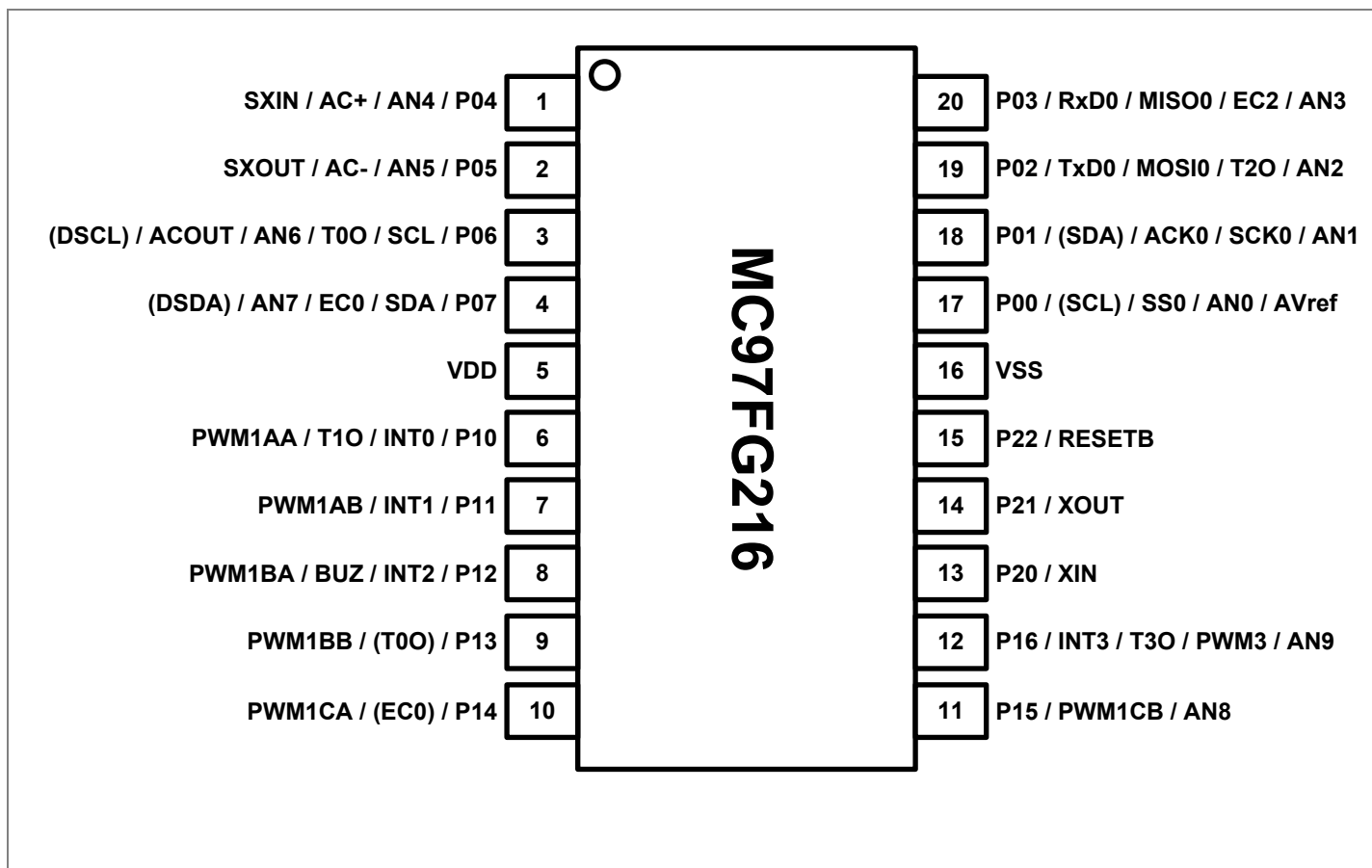


Figure 3.4 MC97FG216 20TSSOP pin assignment

4 Package Diagram

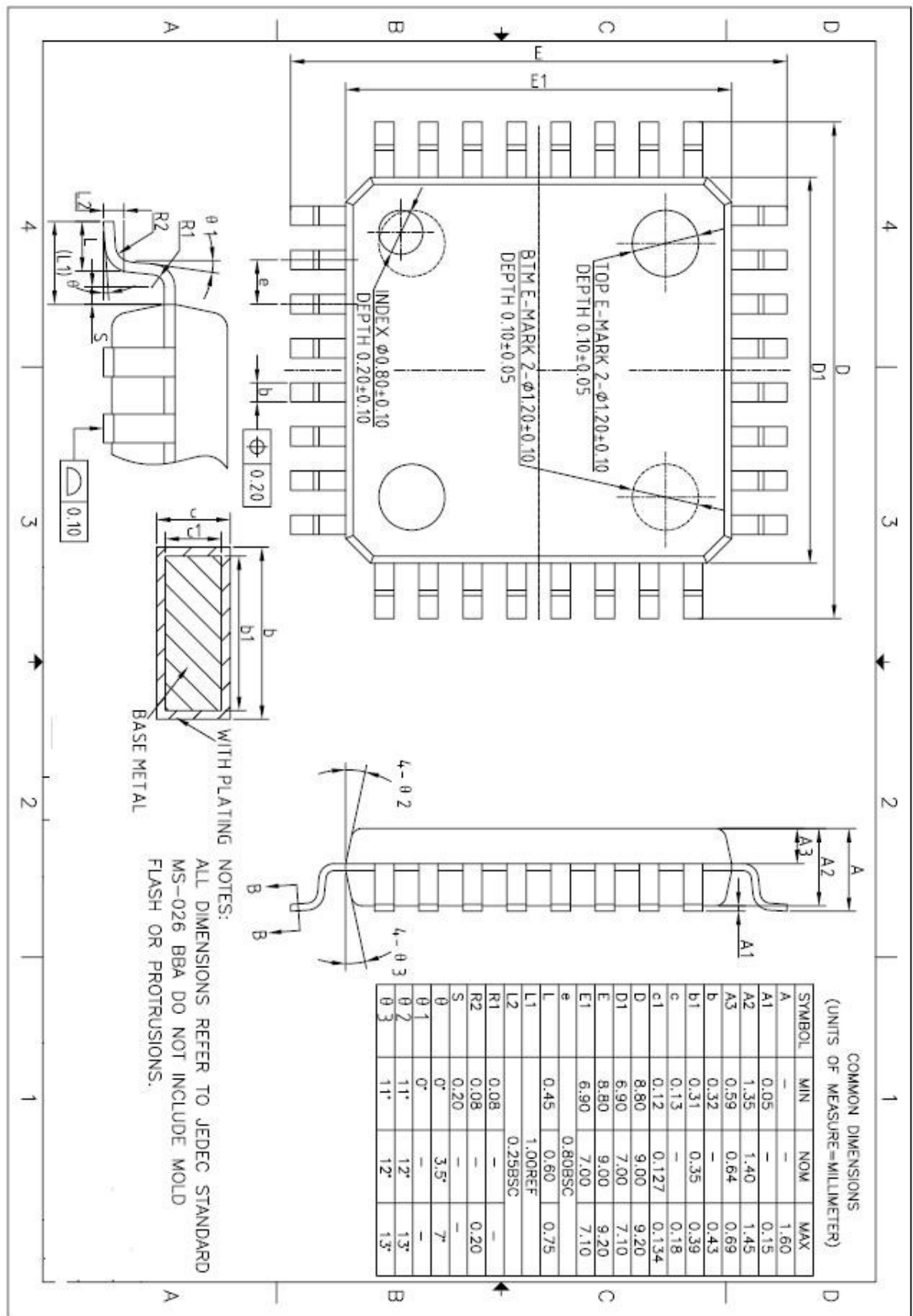


Figure 4.1 32-Pin LQFP Package

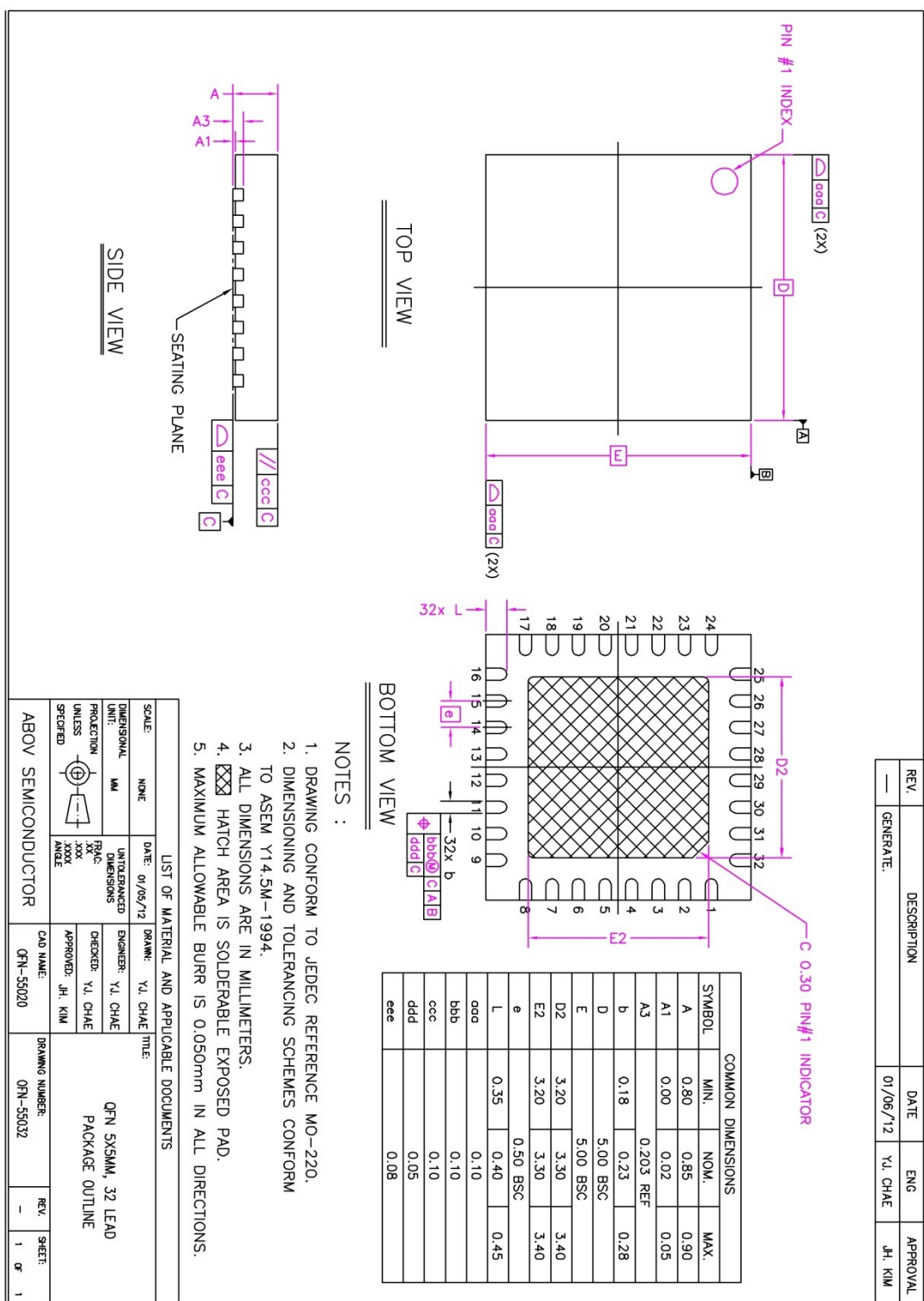


Figure 4.2 32-Pin QFN Package

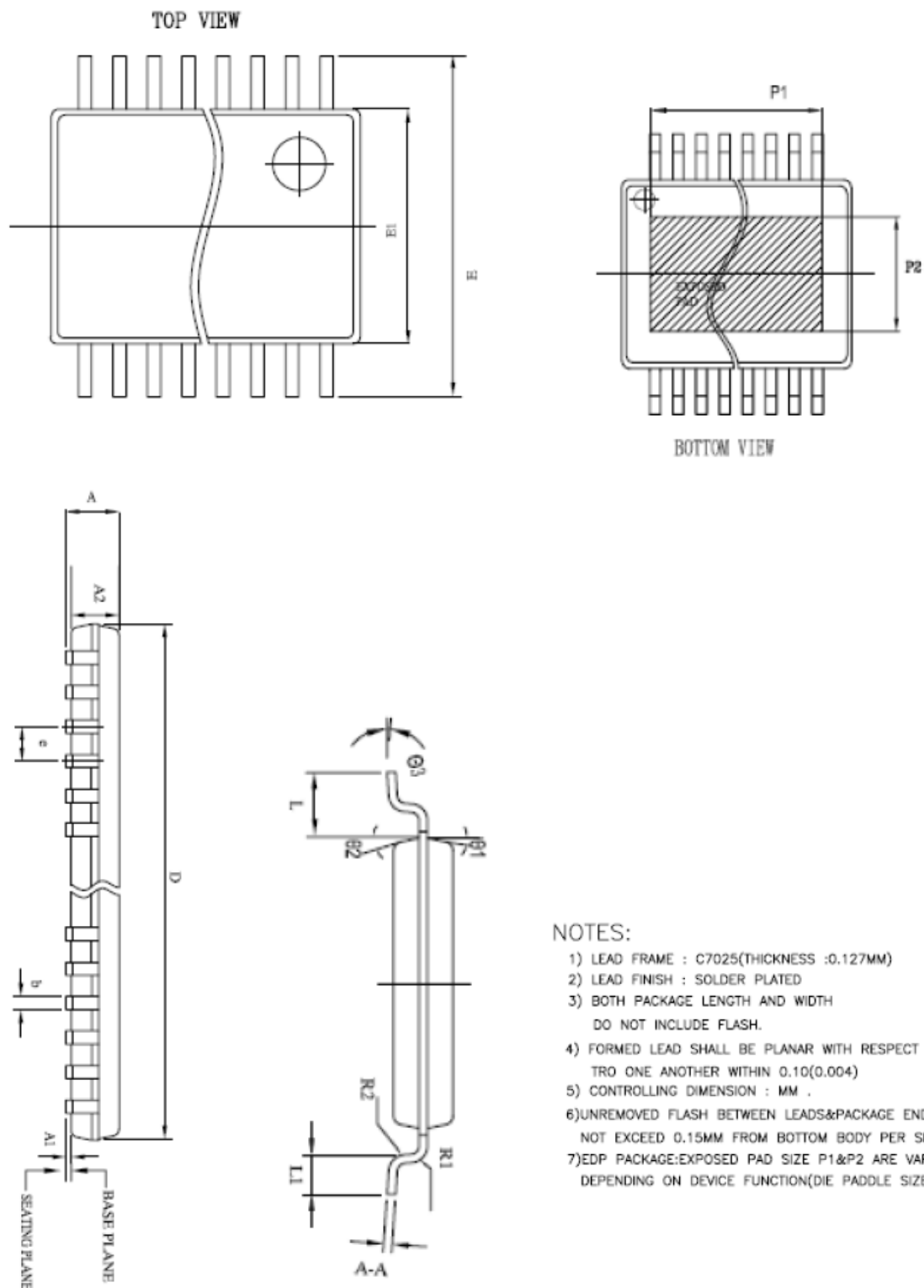


Figure 4.3 28/20-Pin TSSOP Package

Symbol	TSSOP8LD		TSSOP14/16LD		TSSOP20LD		TSSOP20		TSSOP24LD		TSSOP28LD	
	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min	Max
A		1.200		1.200		1.200		1.200		1.200		1.200
A1	0.050	0.150	0.050	0.150	0.050	0.150	0.050	0.150	0.050	0.150	0.050	0.150
A2	0.800	1.050	0.800	1.050	0.800	1.050	0.800	1.050	0.800	1.050	0.800	1.050
E	6.250	6.550	6.250	6.550	6.250	6.550	6.250	6.550	6.250	6.550	6.250	6.550
E1	4.300	4.500	4.300	4.500	4.300	4.500	4.300	4.500	4.300	4.500	4.300	4.500
D	2.900	3.100	4.900	5.100	6.400	6.600	6.400	6.600	7.700	7.900	9.600	9.800
L		1.000		1.000		1.000		1.000		1.000		1.000
L1	0.450	0.750	0.450	0.750	0.450	0.750	0.450	0.750	0.450	0.750	0.450	0.750
e	0.650		0.650		0.650		0.650		0.650		0.650	
b	0.190	0.300	0.190	0.300	0.190	0.300	0.190	0.300	0.190	0.300	0.190	0.300
R1	0.15TYP		0.15TYP		0.15TYP		0.15TYP		0.15TYP		0.15TYP	
R2	0.15TYP		0.15TYP		0.15TYP		0.15TYP		0.15TYP		0.15TYP	
A-A	0.090	0.200	0.090	0.200	0.090	0.200	0.090	0.200	0.090	0.200	0.090	0.200
01	12° TYP		12° TYP		12° TYP		12° TYP		12° TYP		12° TYP	
02	12° TYP		12° TYP		12° TYP		12° TYP		12° TYP		12° TYP	
03	0	8	0	8	0	8	0	8	0	8	0	8

Symbol	TSSOP-EP/16LD		TSSOP20-F		TSSOP-EP/28LD		TSSOP-EP/24LD	
	Min	Max	Min	Max	Min	Max	Min	Max
A		1.200		1.200		1.200		1.200
A1	0.050	0.150	0.050	0.150	0.050	0.150	0.050	0.150
A2	0.800	1.050	0.800	1.050	0.800	1.050	0.800	1.050
E	6.250	6.550	6.250	6.550	6.250	6.550	6.250	6.550
E1	4.300	4.500	4.300	4.500	4.300	4.500	4.300	4.500
D	4.852	4.952	6.400	6.600	10.262	10.414	10.262	10.414
P1	2.740	3.050	3.800	4.300	2.780	3.250	5.640	5.940
P2	2.740	3.050	2.600	3.100	1.710	2.210	2.740	3.050
Pad Siz	3.0*3.0		3.0*4.2		2.11*3.15		3.0*5.1	
L		1.000		1.000		1.000		1.000
L1	0.450	0.750	0.450	0.750	0.450	0.750	0.450	0.750
b	0.190	0.300	0.190	0.300	0.190	0.300	0.190	0.300
e	0.650		0.650		0.650		0.650	
R1	0.15TYP		0.15TYP		0.15TYP		0.15TYP	
R2	0.15TYP		0.15TYP		0.15TYP		0.15TYP	
A-A	0.090	0.200	0.090	0.200	0.090	0.200	0.090	0.200
01	12° TYP		12° TYP		12° TYP		12° TYP	
02	12° TYP		12° TYP		12° TYP		12° TYP	
03	0	8	0	8	0	8	0	8

Figure 4.4 28/20-Pin TSSOP Package (continue)

5 Pin Description

PIN Name	I/O	Function	@RESET	Shared with
P00	I/O	Port P0 8-bit I/O Port Can be set in input or output mode in 1-bit units Internal pull-up register can be selected by software when this port is used as input port Open Drain enable register can be selected by software when this port is used as output port AN0~AN7 can be selected by ADCM register	Input	Avref / AN0 / SS0/(SCL)
P01				AN1 / SCK0 / ACK0/(SDA)
P02				AN2 / T2O / MOSI0 / TxD0
P03				AN3 / EC2 / MISO0 / RxD0
P04				SXIN / AC+ / AN4
P05				SXOUT / AC- / AN5
P06				DSCL / ACOUT/ AN6/ T0O / SCL
P07				DSDA / AN7/ EC0 / SDA
P10	I/O	Port P1 7-bit I/O Port Can be set in input or output mode in 1-bit units Internal pull-up register can be selected by software when this port is used as input port Open Drain enable register can be selected by software when this port is used as output port AN8, AN9 can be selected by ADCM register	Input	PWM1AA / T1O / INT0
P11				PWM1AB / INT1
P12				PWM1BA / BUZ / INT2
P13				PWM1BB
P14				PWM1CA
P15				AN8 / PWM1CB
P16				AN9 / PWM3 / T3O / INT3
P20	I/O	Port P2 7-bit I/O Port Can be set in input or output mode in 1-bit units Internal pull-up register can be selected by software when this port is used as input port Open Drain enable register can be selected by software when this port is used as output port AN12, AN13, AN14 can be selected by ADCM register	Input	XIN
P21				XOUT
P22				RESETB
P23				AN12
P24				AN13
P25				AN14
P26				-
P30	I/O	Port P3 8-bit I/O Port Can be set in input or output mode in 1-bit units Internal pull-up register can be selected by software when this port is used as input port Open Drain enable register can be selected by software when this port is used as output port AN10, AN11 can be selected by ADCM register	Input	INT4
P31				INT5
P32				INT6
P33				INT7
P34				SS1
P35				ACK1
P36				AN10 / TxD1
P37				AN11 / RxD1

Table 5.1 Normal Pin Description

6 Port Structures

6.1 General Purpose I/O Port

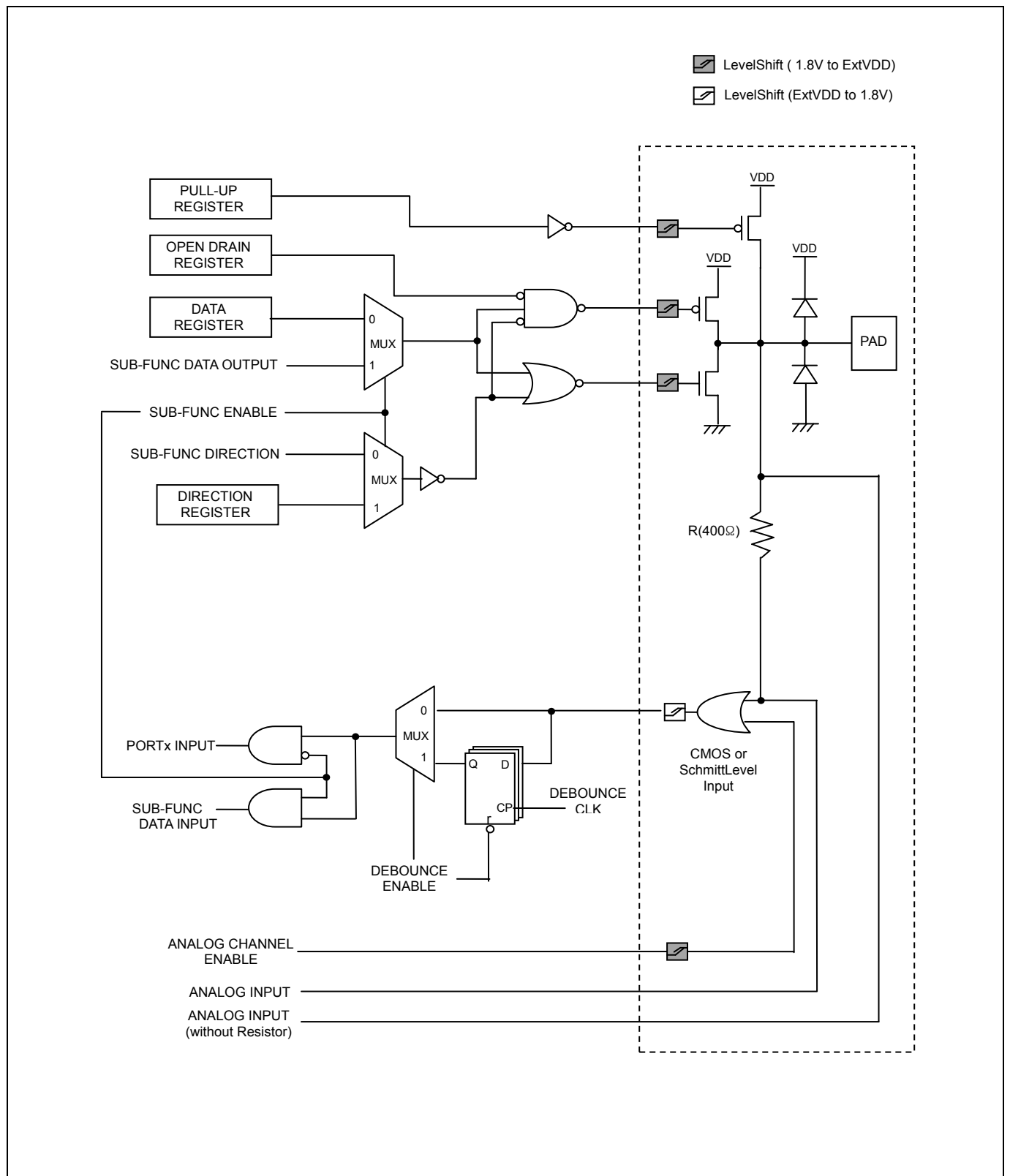


Figure 6.1 General Purpose I/O Port

6.2 External Interrupt I/O Port

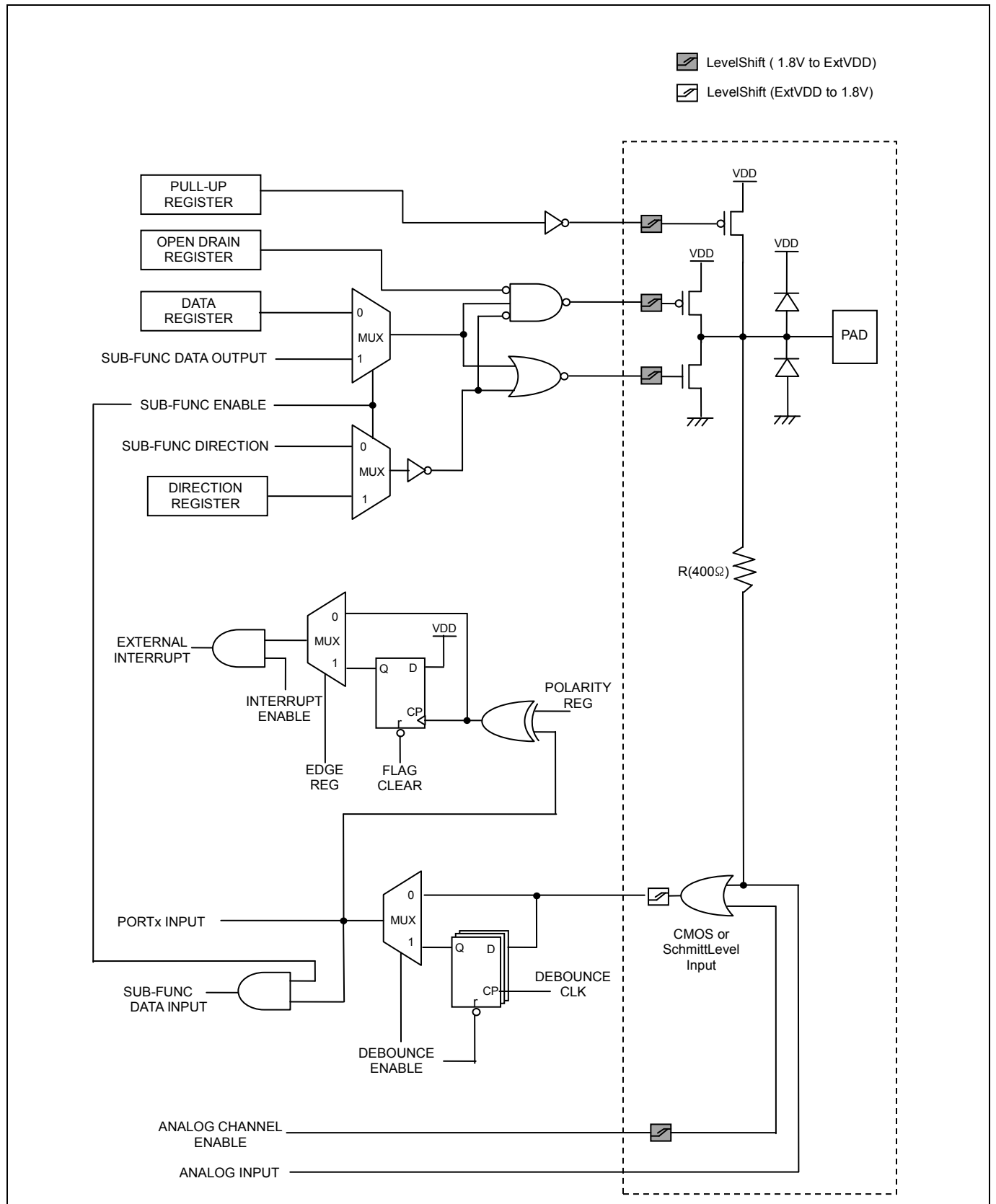


Figure 6.2 External Interrupt I/O Port

7 Electrical Characteristics

7.1 Absolute Maximum Ratings

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}	-15	mA	Maximum current output sourced by (I _{OH} per I/O pin)
	ΣI _{OH}	-80	mA	Maximum current (ΣI _{OH})
	I _{OL}	30	mA	Maximum current sunk by (I _{OL} per I/O pin)
	ΣI _{OL}	160	mA	Maximum current (ΣI _{OL})
Total Power Dissipation	P _T	400	mW	—
Storage Temperature	T _{STG}	-65~+150	°C	—

Table 7.1 Absolute Maximum Ratings

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

(T _A =-40°C ~ +85°C)							
Parameter	Symbol	Conditions		MIN	TYP	MAX	Unit
Operating Voltage	VDD	f _X = 1, 4, 8, 16MHz	Internal RC	1.8	—	5.5	V
		f _X = 4~ 16MHz	X-tal				
		f _X = 32.768kHz	Sub crystal				
		f _X = 1kHz	Internal Ring OSC				
Operating Temperature	T _{OPR}	VDD=1.8~5.5V		-40	—	85	°C

Table 7.2 Recommended Operating Conditions

7.3 A/D Converter Characteristics

(TA=-40℃ ~ +85℃, VDD=AVDD=2.7V ~ 5.5V, VSS=0V)

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
A/D converting Resolution	-	-	-	12	-	bits
Integral Non-Linearity	INL	Vref=5.12V, Vss=0V, TA=+25℃	-	-	±3	LSB
Differential Non-Linearity	DNL		-	-	±2	
Zero Offset Error	ZOE		-	±1	±3	
Overall Accuracy	OA		-	±3	-	
Conversion Time	t _{CONV}	-	-	60	-	Cycle
Analog Input Voltage	V _{AIN}	-	VSS	-	Vref	V
Analog Reference Voltage	AVREF	(note)	2.7	-	5.5	V
Analog Input Current	I _{AIN}	VDD=Vref=5V	-	-	10	uA
Analog Block Current	I _{AVDD}	VDD=Vref=5V	-	1	3	mA
		VDD=Vref=3V	-	0.5	1.5	mA
		VDD=Vref=5V Power down mode	-	100	500	nA

Table 7.3 A/D Converter Characteristics

NOTE) When Vref is less than 2.7V, the ADC resolution is worse.

Cycle = 2/fosc, ex) 0.5us@ 8Mhz

7.4 Analog Comparator Characteristics

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
Input Leakage Current	I _L	VDDEXT=5V, Vin=1/2VDDEXT	-50	-	50	nA
Input Offset Voltage	V _{offset}	VDDEXT=5V, Vin=1/2VDD	10	-	40	±mV
Operating Current	I _{OP}	COMP_EN=H	-	30	-	uA
Power Down Current	I _{PD}	COMP_EN=L	-	1	-	uA
Response Time	V _{RT}	CL= 50pF, VDDEXT=5V	-	-	1	us
BGR		VDD=4V, TA=+25℃	-	1.174	-	V

Table 7.4 Analog Comparator Characteristics

7.5 Power-On Reset Characteristics

($T_A = -40^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{DD} = 1.8 \sim 5.5\text{V}$, $V_{SS} = 0\text{V}$)

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
RESET Release Level	V_{POR}	-	1.3	1.4	1.5	V
RESET Release Level	t_R	-	0.05	-	5	V/ms
POR Current	I_{POR}	-	-	-	10	μA

Table 7.5 Power-On Reset Characteristics

7.6 Low Voltage Reset Characteristics

($T_A = -40^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{DD} = 1.8 \sim 5.5\text{V}$, $V_{SS} = 0\text{V}$)

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
Operating Voltage	V_{OP}	-	V_{SS}	-	5.5	V
Operating Temperature	T_{OP}	-	-40	-	+85	$^{\circ}\text{C}$
Detection Level	V_{LVR}	-	4.0	4.2V	4.4	V
		-	3.4	3.6V	3.8	V
		-	2.3	2.5V	2.7	V
		-	1.4	1.6V	1.8	V
Hysteresis	ΔV	-	-	20	-	mV
Operating Current	I_{LVR}	Enable	-	-	50	μA
		Disable	-	-	1	μA

Table 7.6 LVR Characteristics

7.7 Internal RC Oscillator Characteristics

($T_A = -40^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{DD} = 1.8 \sim 5.5\text{V}$, $V_{SS} = 0\text{V}$)

Parameter	Symbol	Conditions		MIN	TYP	MAX	Unit
Frequency	f_{IRC}	$V_{DD} = 1.8 \sim 5.5\text{V}$		15.52	16	16.48	MHz
Tolerance	-	$T_A = -40^{\circ}\text{C} \text{ to } +85^{\circ}\text{C}$	With 0.1 μF Bypass capacitor	-	-	± 3.0	%
Stabilization Time	T_{HFS}	-		-		10	ms
IRC Current	I_{IRC}	Enable		-	200	-	μA
		Disable		-	-	1	μA

Table 7.7 Internal RC Oscillator Characteristics

7.8 Ring-Oscillator Characteristics

($T_A = -40^{\circ}\text{C} \sim +85^{\circ}\text{C}$, $V_{DD} = 1.8 \sim 5.5\text{V}$, $V_{SS} = 0\text{V}$)

Parameter	Symbol	Conditions		MIN	TYP	MAX	Unit
Frequency	f_{IRC}	$V_{DD} = 1.8 \sim 5.5\text{V}$		0.8	1	1.2	MHz
Tolerance	-	$T_A = -40^{\circ}\text{C} \text{ to } +85^{\circ}\text{C}$	With 0.1uF Bypass capacitor	-	-	± 20	%
Stabilization Time	T_{HFS}	—		—		TBD	ms
IRC Current	I_{IRC}	Enable		—	10	—	μA
		Disable		-	-	1	μA

Table 7.8 Ring-Oscillator Characteristics

7.9 PLL Characteristics

($T_A = 0^{\circ}\text{C} \sim +70^{\circ}\text{C}$, $V_{DD18} = 1.6\text{V} \sim 2.0\text{V}$, $V_{SS} = 0\text{V}$)

Parameter	Symbol	Condition	Min.	Typ.	Max.	Unit
PLL current	I_{PLL}	-	-	1.2	-	mA
Input clock frequency	f_{xin}	-	2	4	16	MHz
Output clock frequency	f_{out}	-	6.25	64	128	MHz
Output clock duty	TOD	-	40	-	60	%
Setting time	t_D	-	-	-	0.5	ms
Accuracy (Jitter)	-	Peak to peak	-	-	500	ps

Table 7.9 PLL Characteristics

7.10 DC Characteristics

(VDD =2.7~5.5V, VSS =0V, fXIN=10.0MHz, TA=-40~+85℃)

Parameter	Symbol	Condition	MIN	TYP	MAX	Unit
Input Low Voltage	V _{IL1}	P2[2]	-0.5	-	0.2VDD	V
	V _{IL2}	All others PAD	-0.5	-	0.2VDD	V
Input High Voltage	V _{IH1}	P2[2]	0.8VDD	-	VDD	V
	V _{IH2}	All others PAD	0.7VDD	-	VDD	V
Output Low Voltage	V _{OL1}	ALL I/O (IOL=20mA, VDD=4.5V)	-	-	1	V
Output High Voltage	V _{OH1}	ALL I/O (IOH=-8.57mA, VDD=4.5V)	3.5	-	-	V
Input High Leakage Current	I _{IH}	ALL PAD	-	-	1	uA
Input Low Leakage Current	I _{IL}	ALL PAD	-1	-	-	uA
Pull-Up Resister	R _{PU}	ALL PAD	20	-	50	kΩ
Power Supply Current	I _{DD1}	Run Mode, fXIN=12MHz @5V	-	*2.6	10	mA
	I _{DD2}	Sleep Mode, fXIN=12MHz @5V	-	*1.5	5	mA
	I _{DD3}	Sub Active Mode, fSUBXIN=32.768kHz @5V	-	*270	500	uA
	I _{DD4}	STOP1 Mode, WDT Active @5V (LVR enable)	-	*50	200	uA
	I _{DD5}	STOP1 Mode, WDT Active @5V (LVR disable)	-	*25	100	uA
	I _{DD6}	STOP2 Mode, WDT Disable @5V (LVR enable)	-	*27	100	uA
	I _{DD7}	STOP2 Mode, WDT Disable @5V (LVR disable)	-	*1	7 (room temp)	uA

Table 7.10 DC Characteristics

NOTE)

1. STOP1: WDT running, STOP2: WDT disable.
2. (*) typical test condition : VDD=5V, Internal RC-OSC=8MHz, ROOM TEMP, all PORT output LOW, Timer0 Active, 1 PORT toggling

7.11 AC Characteristics

($T_A = -40^{\circ}\text{C} - +85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V} - 5.5\text{V}$)

Parameter	Symbol	Conditions	MIN	TYP	MAX	Unit
RESETB input low width	t_{RST}	Input, $V_{DD}=5\text{V}$	15	-	-	μs
Interrupt input high, low width	t_{IWH} , t_{IWL}	All interrupt, $V_{DD}=5\text{V}$	125	-	-	ns
External Counter Input High, Low Pulse Width	t_{ECWH} , t_{ECWL}	EC_n , $V_{DD}=5\text{V}$ ($n=0, 1, 2$)	125	-	-	ns
External Counter Transition Time	t_{REC} , t_{FEC}	EC_n , $V_{DD}=5\text{V}$ ($n=0, 1, 2$)	-	-	20	ns

Table 7.11 AC Characteristics

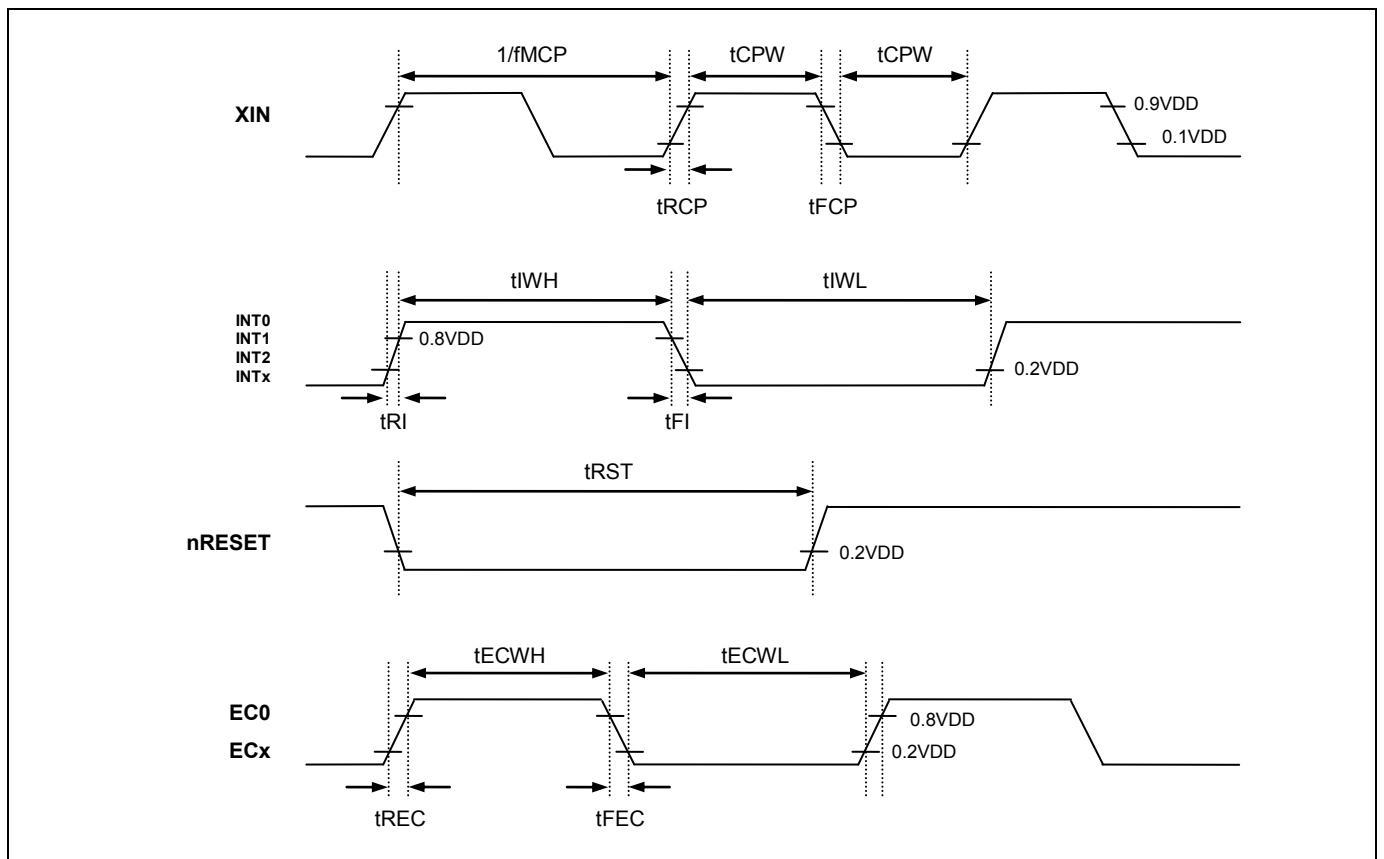


Figure 7.1 AC Timing

7.12 SPI Characteristics

($T_A = -40^{\circ}\text{C} - +85^{\circ}\text{C}$, $V_{DD} = 1.8\text{V} - 5.5\text{V}$)

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			

Table 7.12 SPI Characteristics

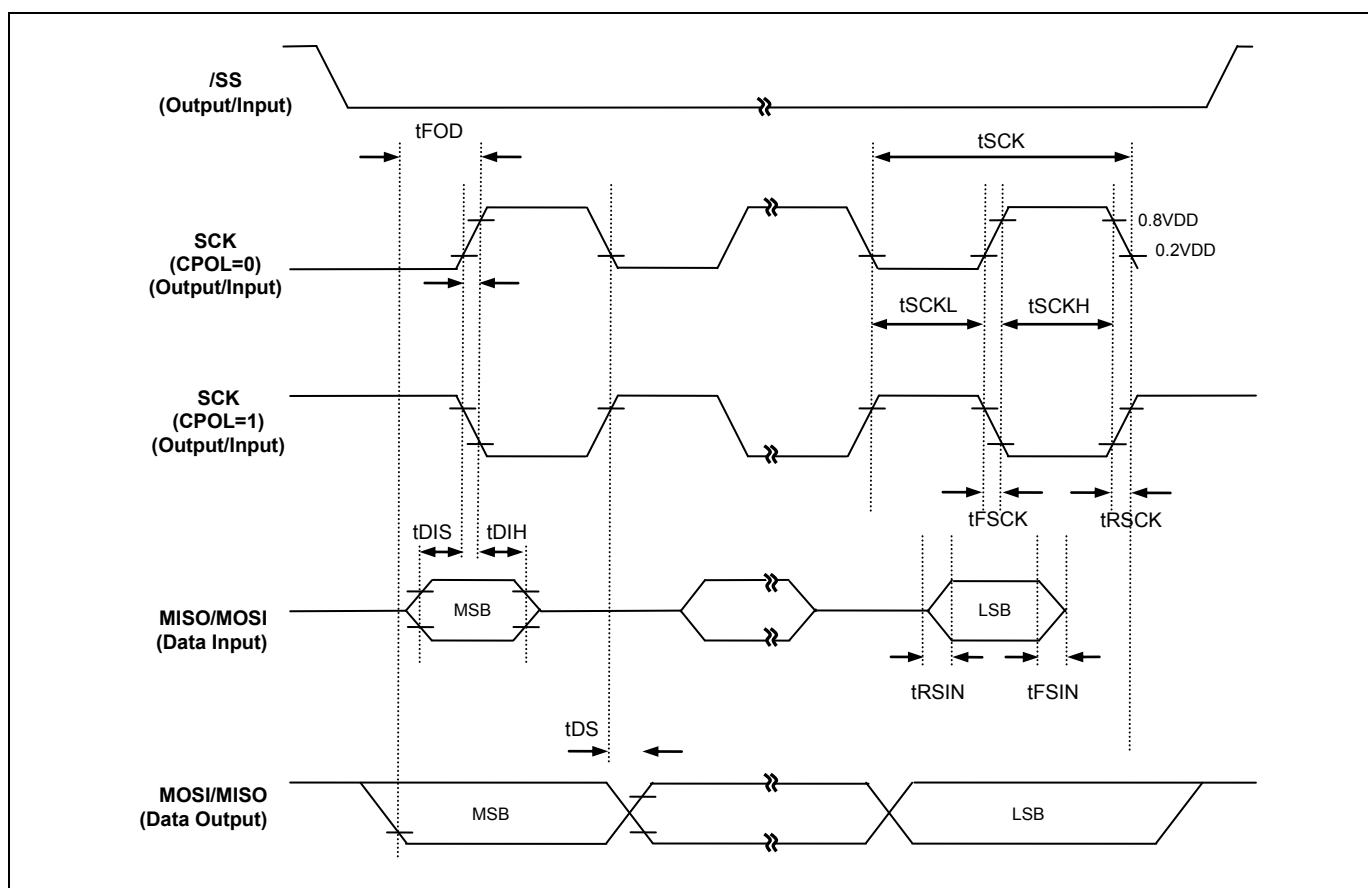


Figure 7.2 SPI Timing

7.13 I2C Characteristics

($T_A = -40^\circ\text{C} - +85^\circ\text{C}$, $V_{DD} = 1.8\text{V} - 5.5\text{V}$)

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	–	us
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

Table 7.13 SPI Characteristics

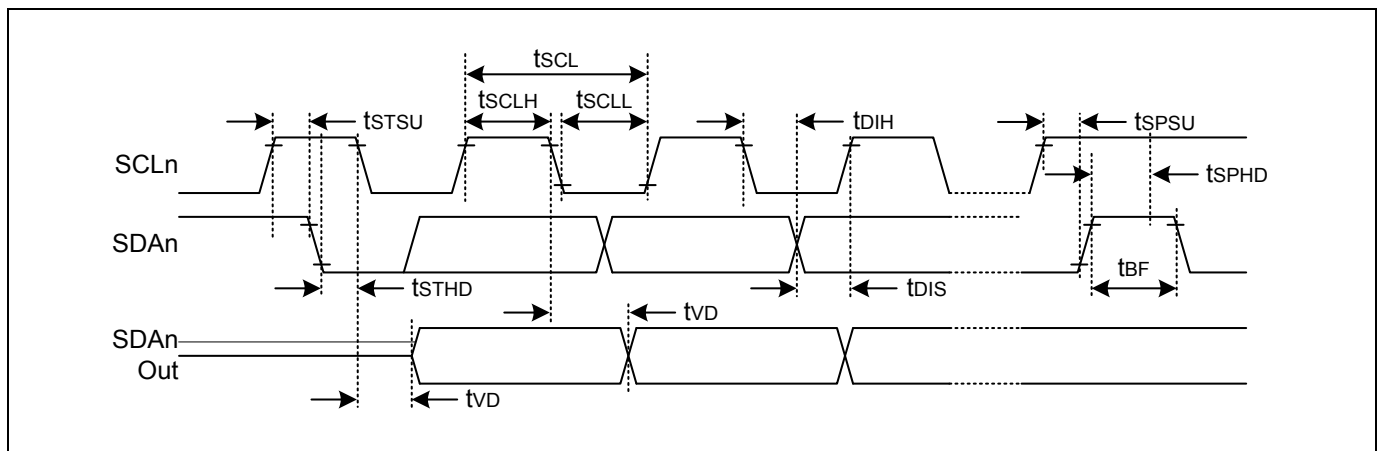


Figure 7.3 I2C Timing

7.14 Main Clock Oscillator Characteristics

(VDD=5.0V±10%, VSS=0V, TA=-40~+85℃)

Parameter	MIN	TYP	MAX	ETC
Operating Voltage (VDDEXT)	1.5V		5.5V	
TEMP	-40℃		85℃	
IDD	-	660uA	-	@4Mhz, VDDEXT(5V)
Operating Frequency	-		16Mhz	
Ext. Load Cap	5pF	22pF	35pF	C1,C2

Table 7.14 Main Clock Oscillator Characteristics

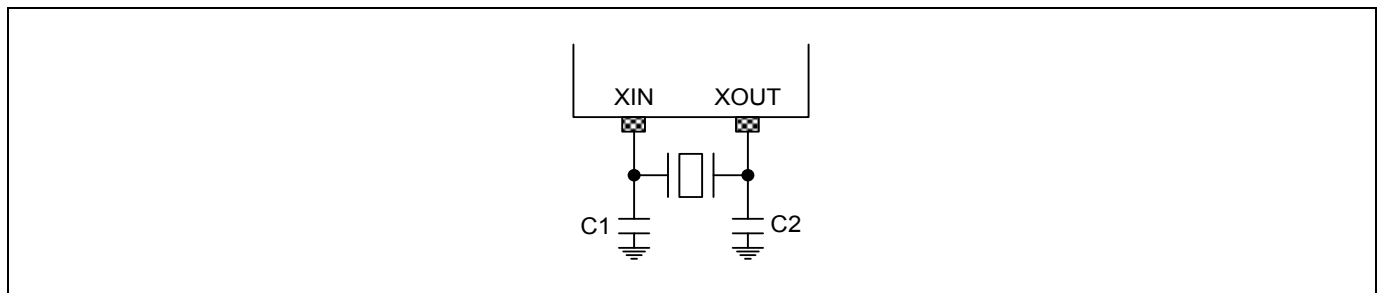


Figure 7.4 Crystal Oscillator

7.15 Sub Clock Oscillator Characteristics

(VDD=5.0V±10%, VSS=0V, TA=-40~+85℃)

Parameter	MIN	TYP	MAX	ETC
Operating Voltage	-	1.8V	-	
TEMP	-40℃	-	85℃	
IDD	-	3uA	-	
Operating Frequency	-	32.768kHz	-	
Ext. Load Cap	5pF	15pF	20pF	C1,C2

Table 7.15 Sub Clock Oscillator Characteristics

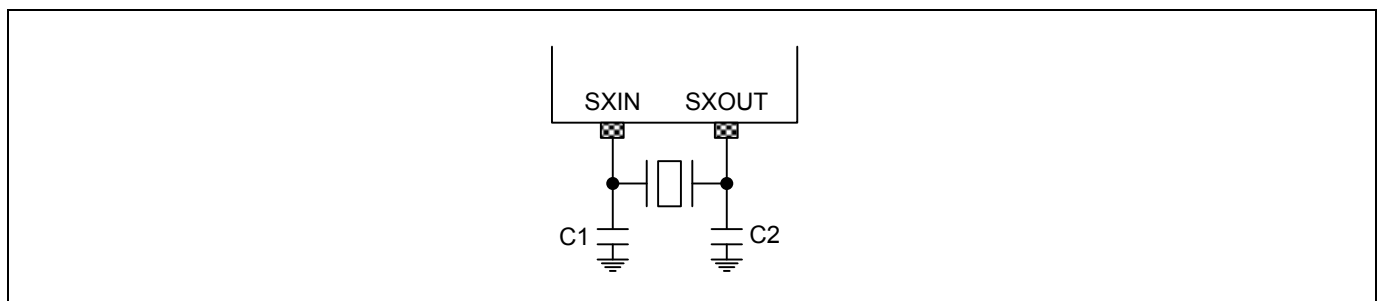


Figure 7.5 Sub-Crystal Oscillator

7.16 Operating Voltage Range

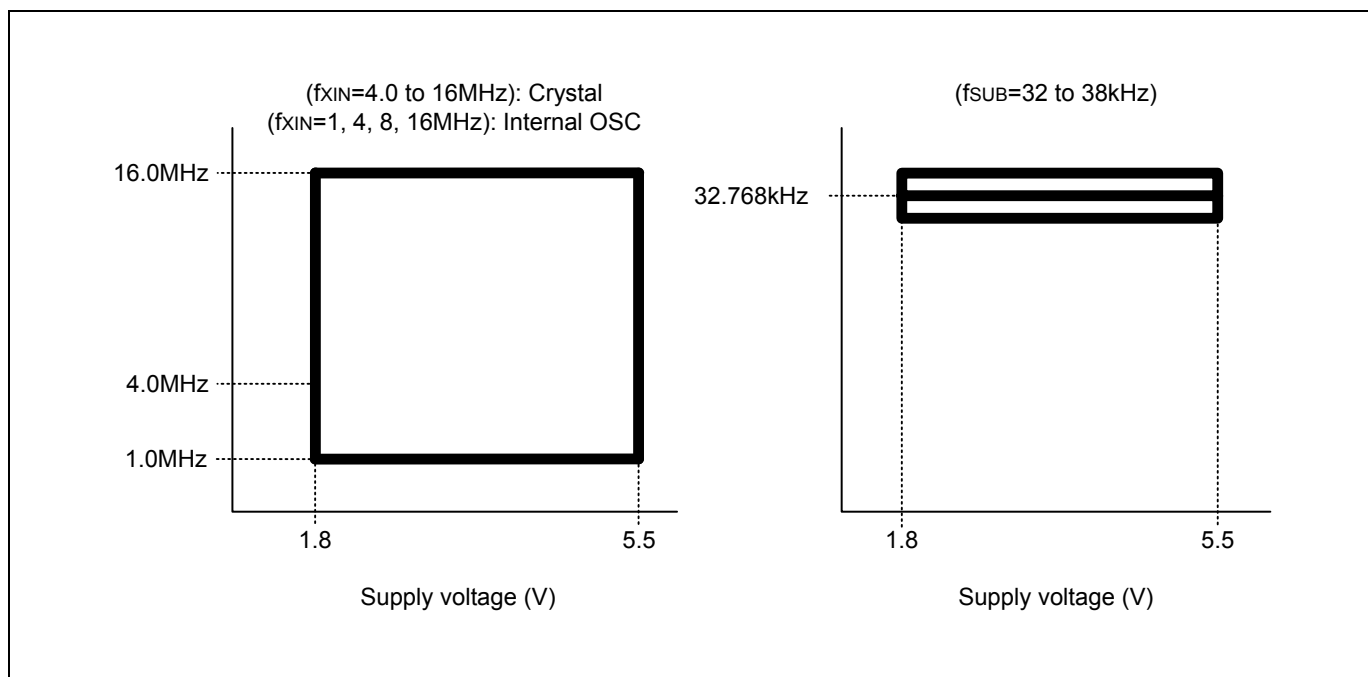


Figure 7.6 Operating Voltage Range

7.17 Operating Voltage Range

These graphs and tables provided in this section are for design guidance only and are not tested or guaranteed. In some graphs or tables the data presented are outside specified operating range (e.g. outside specified VDD range). This is for information only 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.

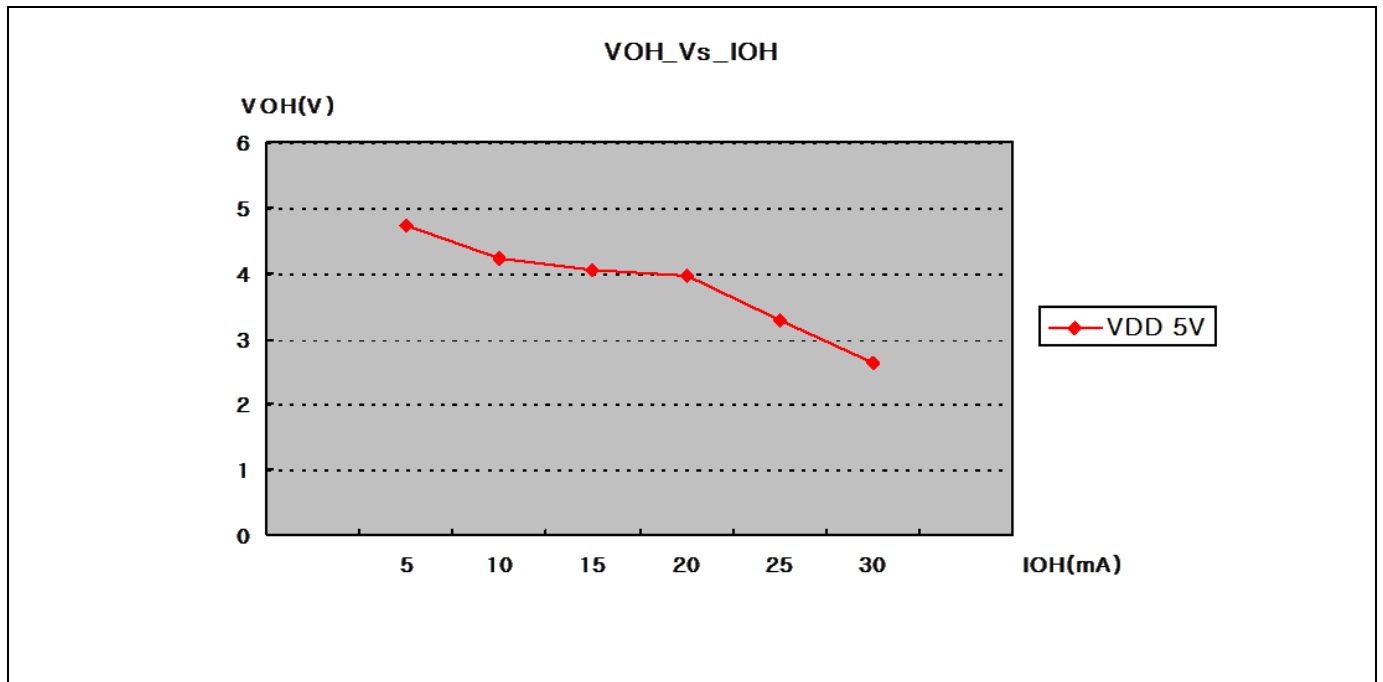


Figure 7.7 VOH_Vs_IOH

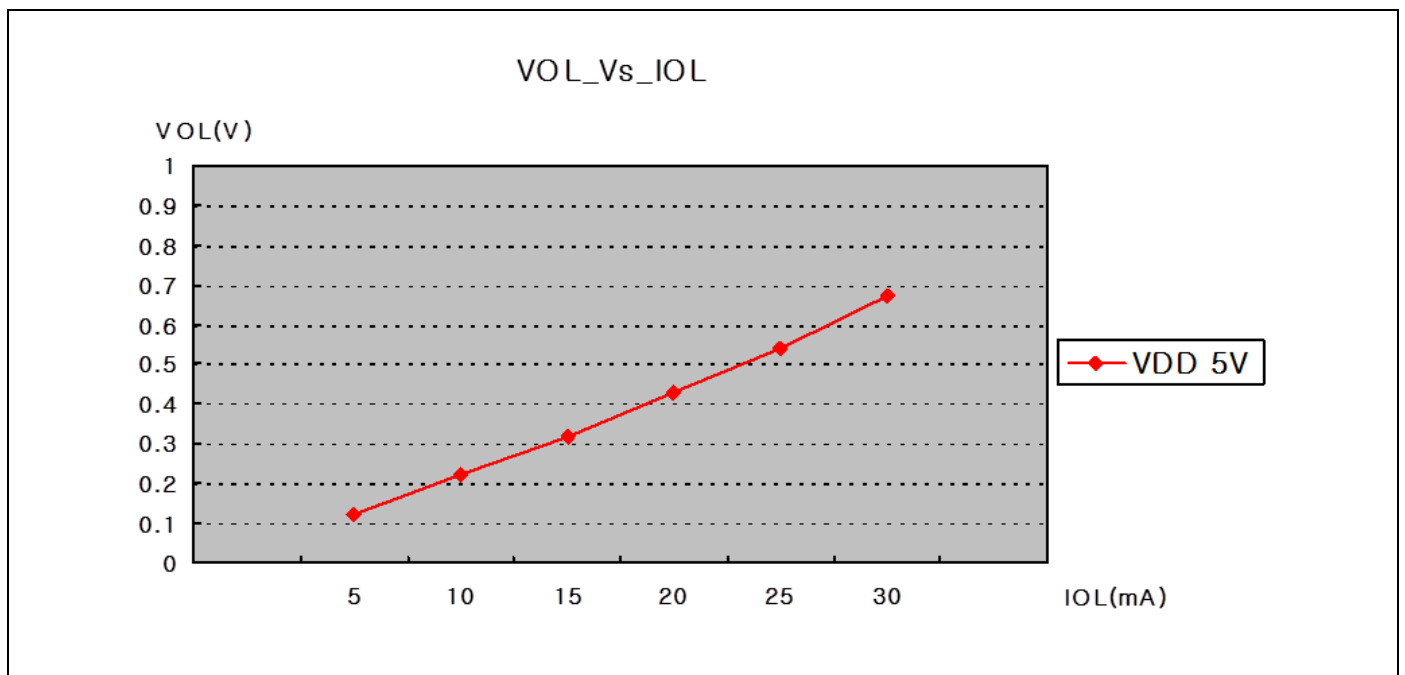


Figure 7.8 VOL vs IOL

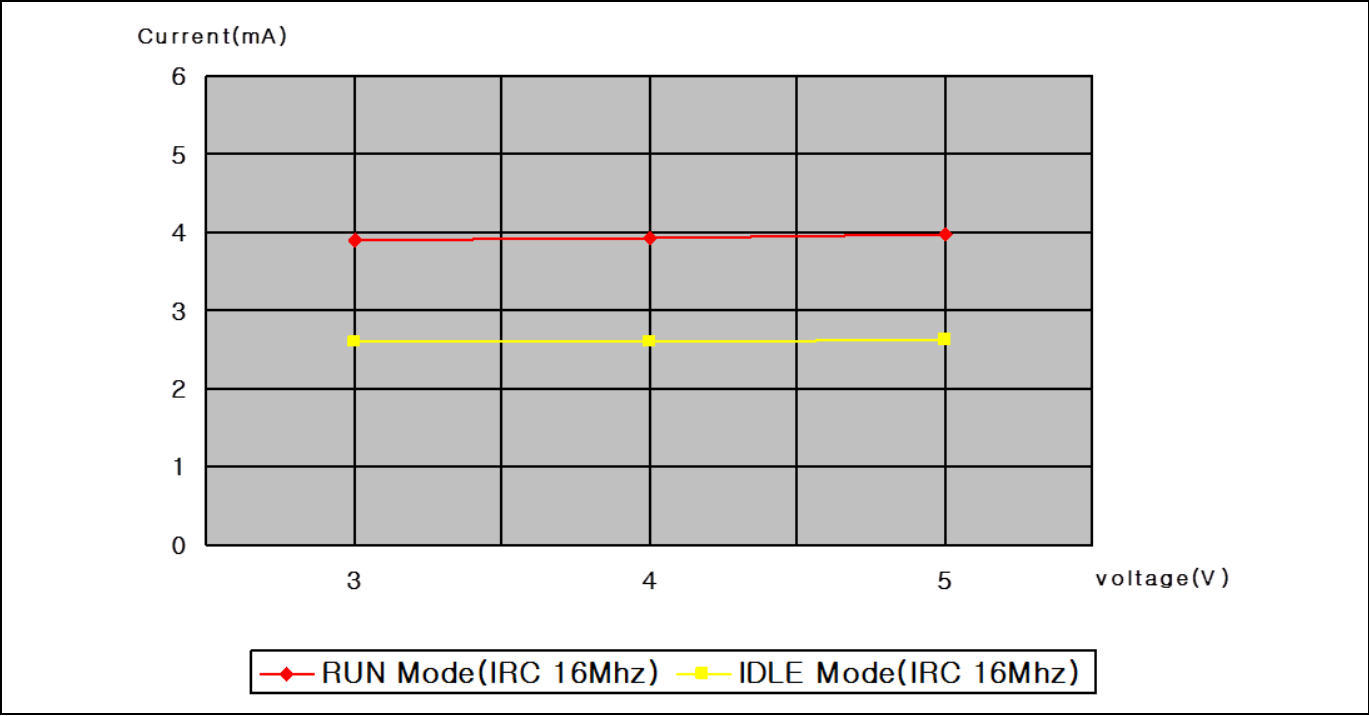


Figure 7.9 Power Supply Current (RUN, IDLE)

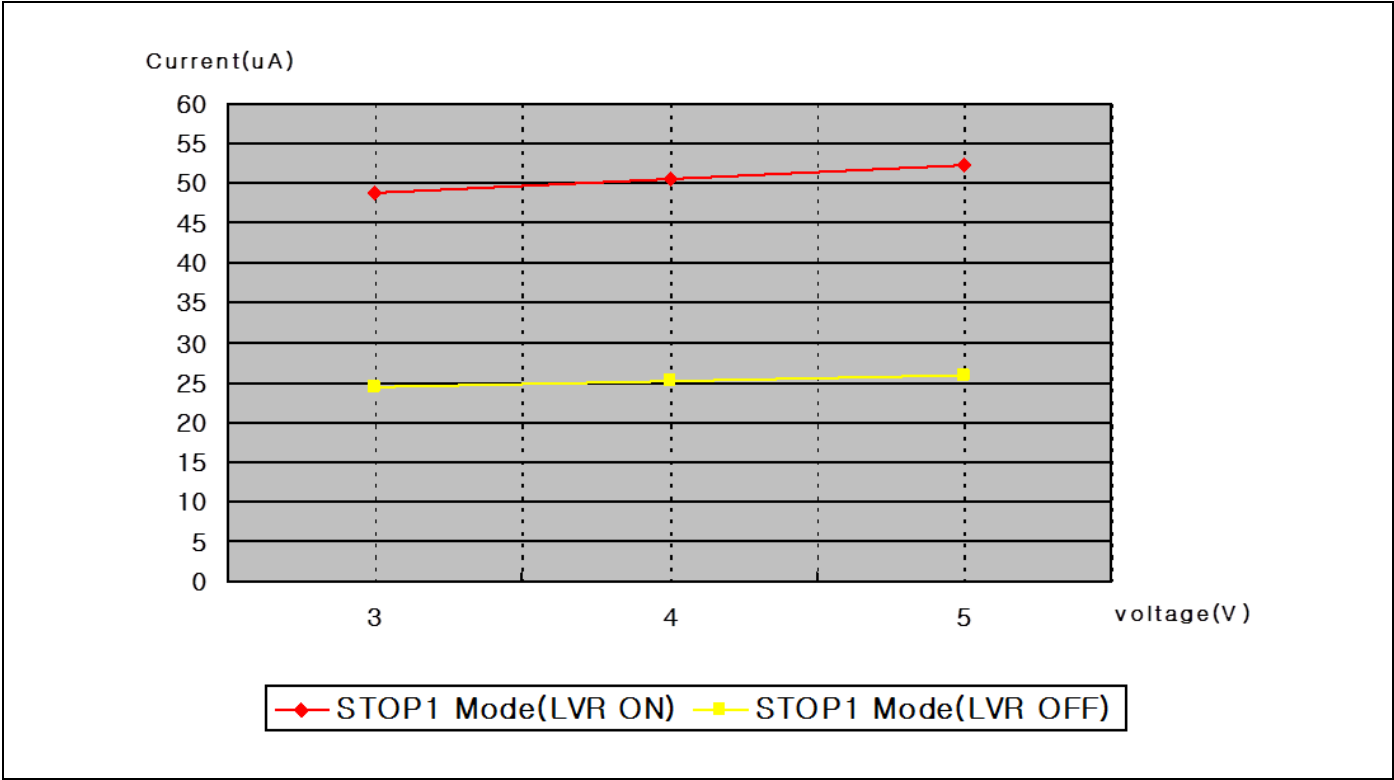


Figure 7.10 Stop1 current

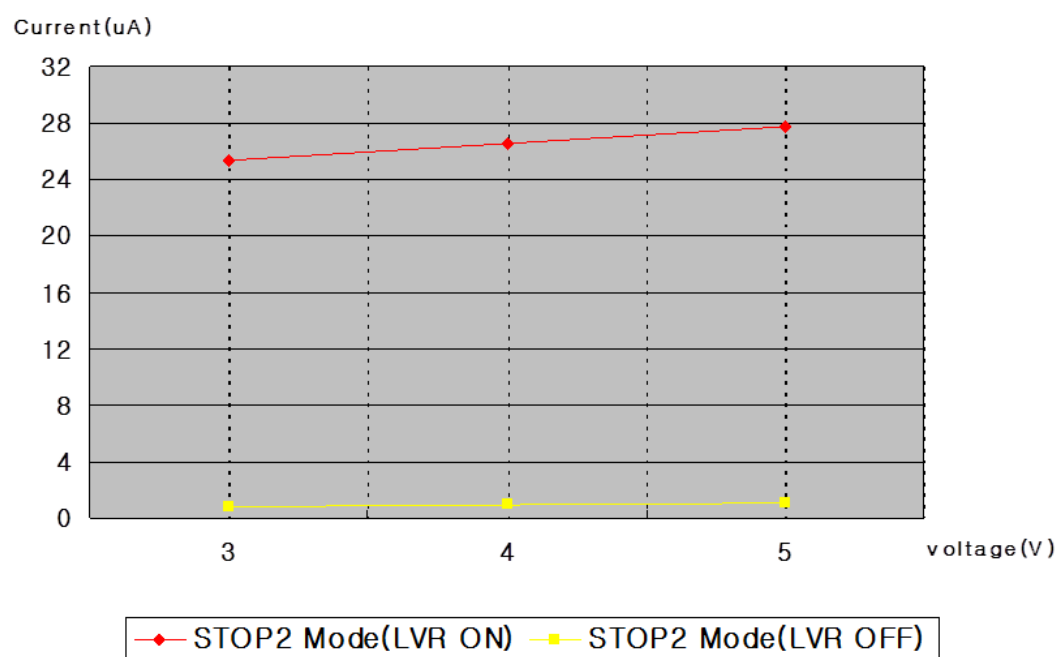


Figure 7.11 Stop2 current

7.18 Recommended Application Circuit

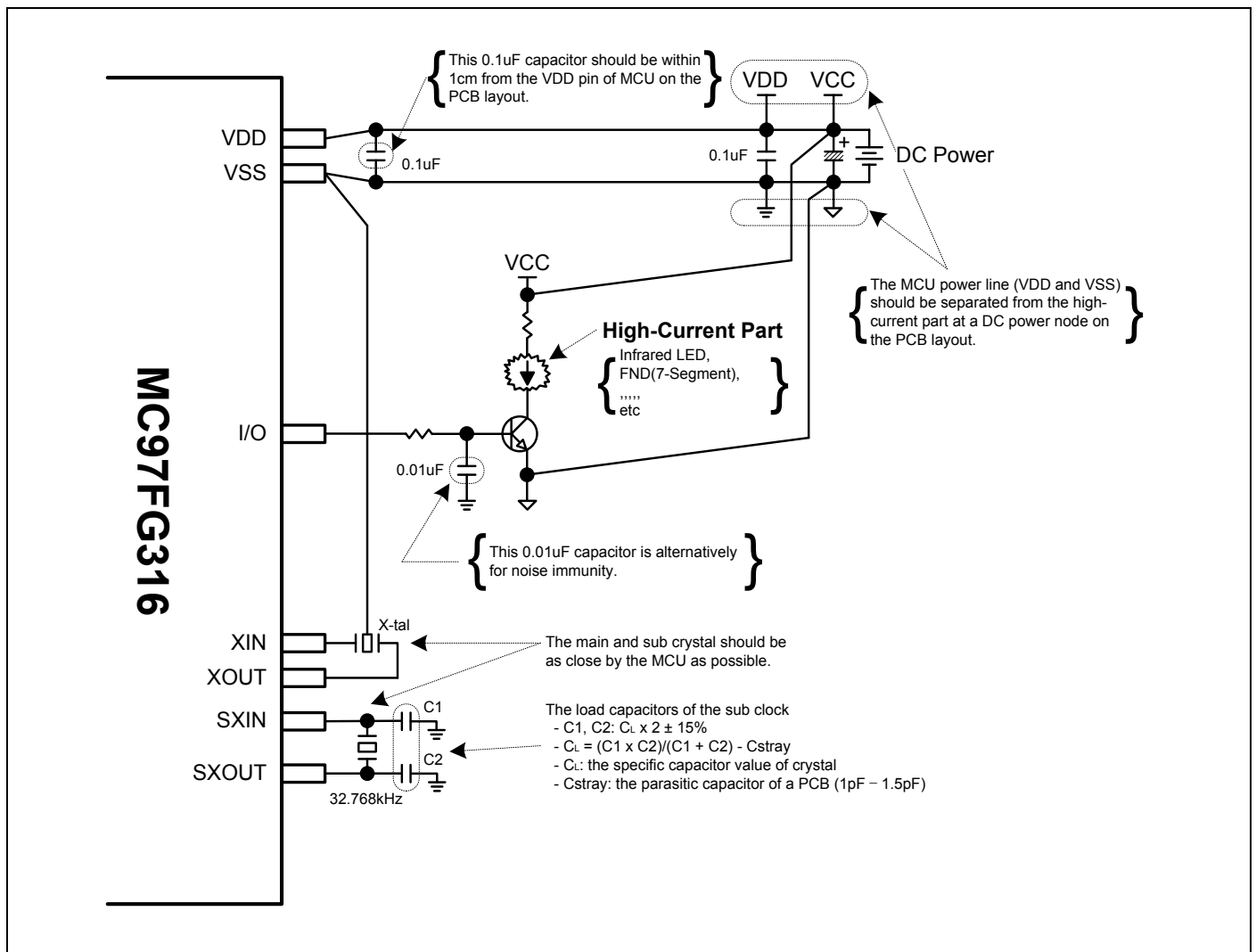


Figure 7.12 Recommended Circuit and Layout

8 Memory

The MC97FG316 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 can be more quickly stored and manipulated by 8-bit CPU. Nevertheless, 16-bit Data memory addresses can also be generated through the DPTR register.

Program memory can only be read, not written. There can be up to 64Kbytes of Program memory. In the MC97FG316 FLASH version, the 16Kbytes of Program memory are provided on-chip. Data memory can be read and written up to 256bytes internal memory (DATA) including the stack area.

8.1 Program Memory

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

Figure 8.1 shows a map of the lower part of the program memory. After reset, the CPU begins execution from address 0000H. Each interrupt is assigned to a fixed address in program memory. The interrupt causes the CPU to jump to that addressed, where it commences execution of the service routine. External interrupt 0, for example, is assigned to address 0003H. If external interrupt 0 would be requested, its service routine must begin at location 0003H. When the interrupt is not used, the Rom address is used as general purpose program memory. If an interrupt service routine is short enough (as is often case in S/W), 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.

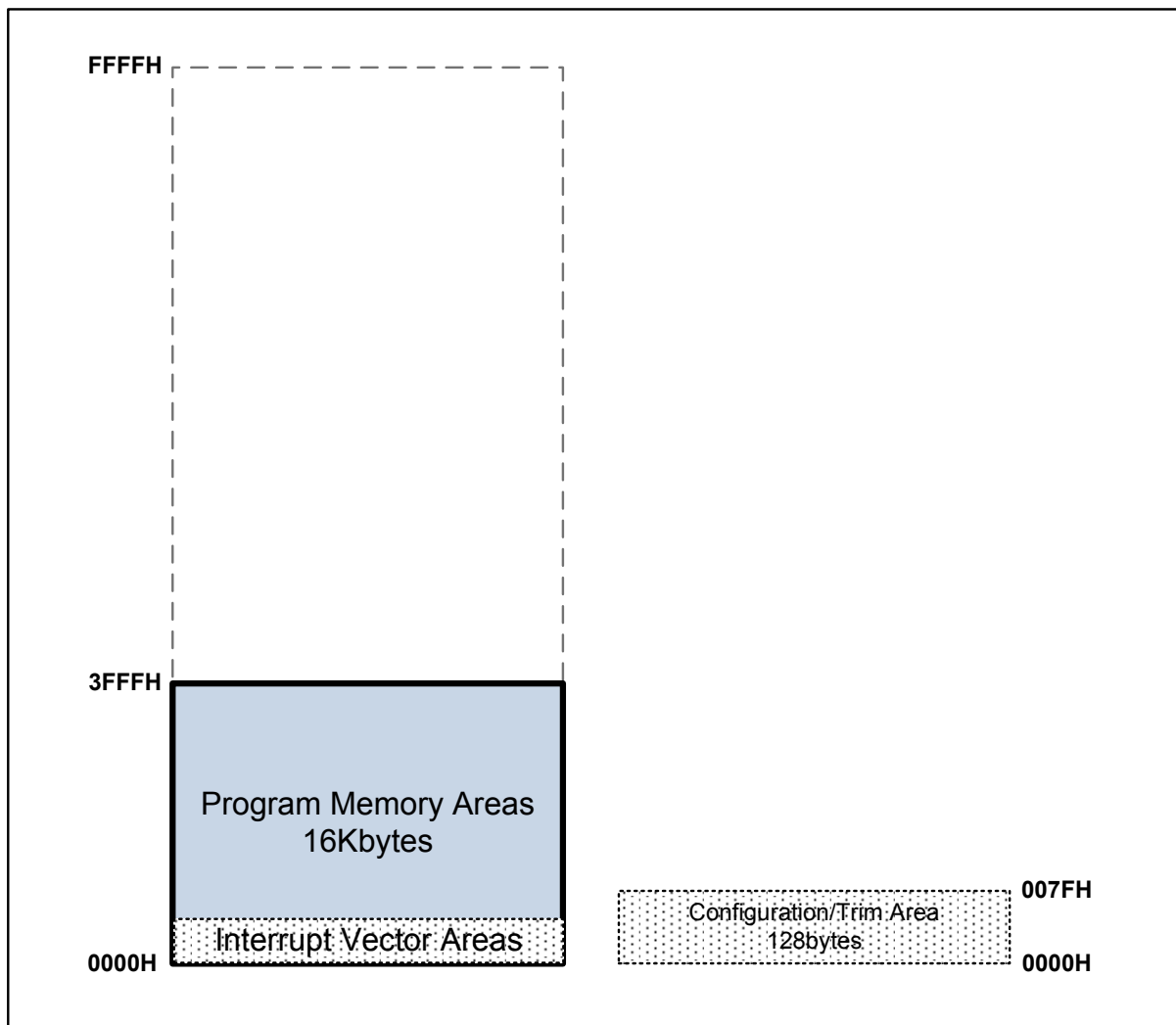


Figure 8.1 Program Memory

- User Function Mode: 16K Bytes Included Interrupt Vector address
- Non-volatile and reprogramming memory: Flash memory based on EEPROM cell

8.2 Data Memory

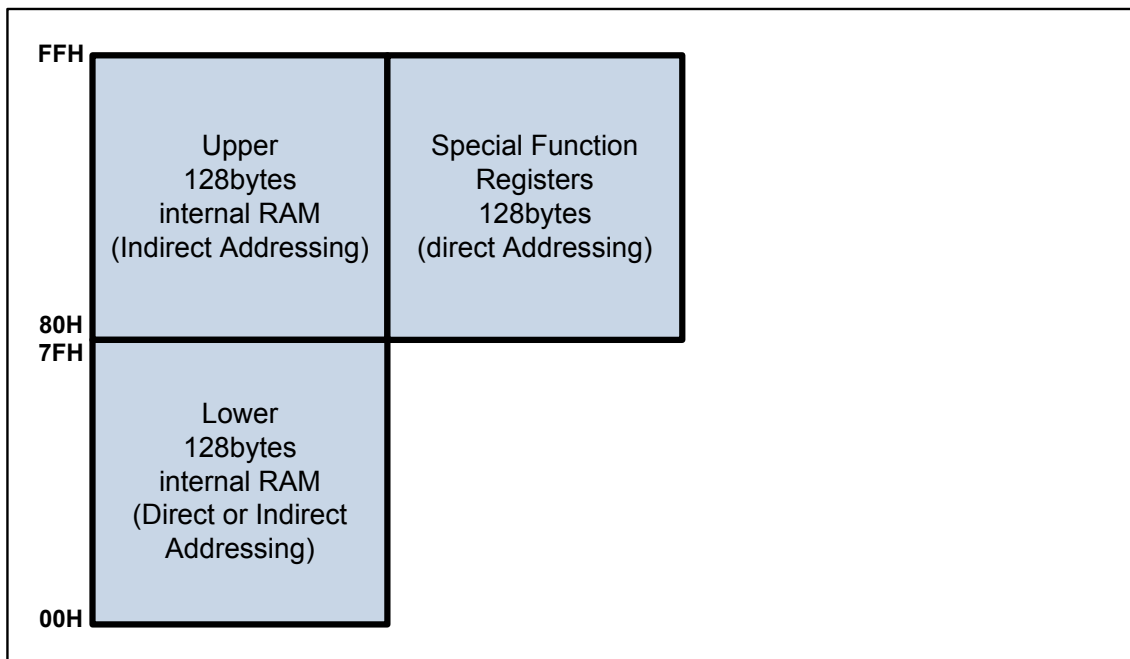


Figure 8.2 Data Memory Map

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

Internal Data memory address is one byte, which implies an address space of only 256 bytes. However, the addressing modes for internal RAM can in fact accommodate 384 bytes, 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 128bytes 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 usage of code space, since register instructions needs less bytes than direct addressing instructions.

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 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 user RAM and stack pointer.

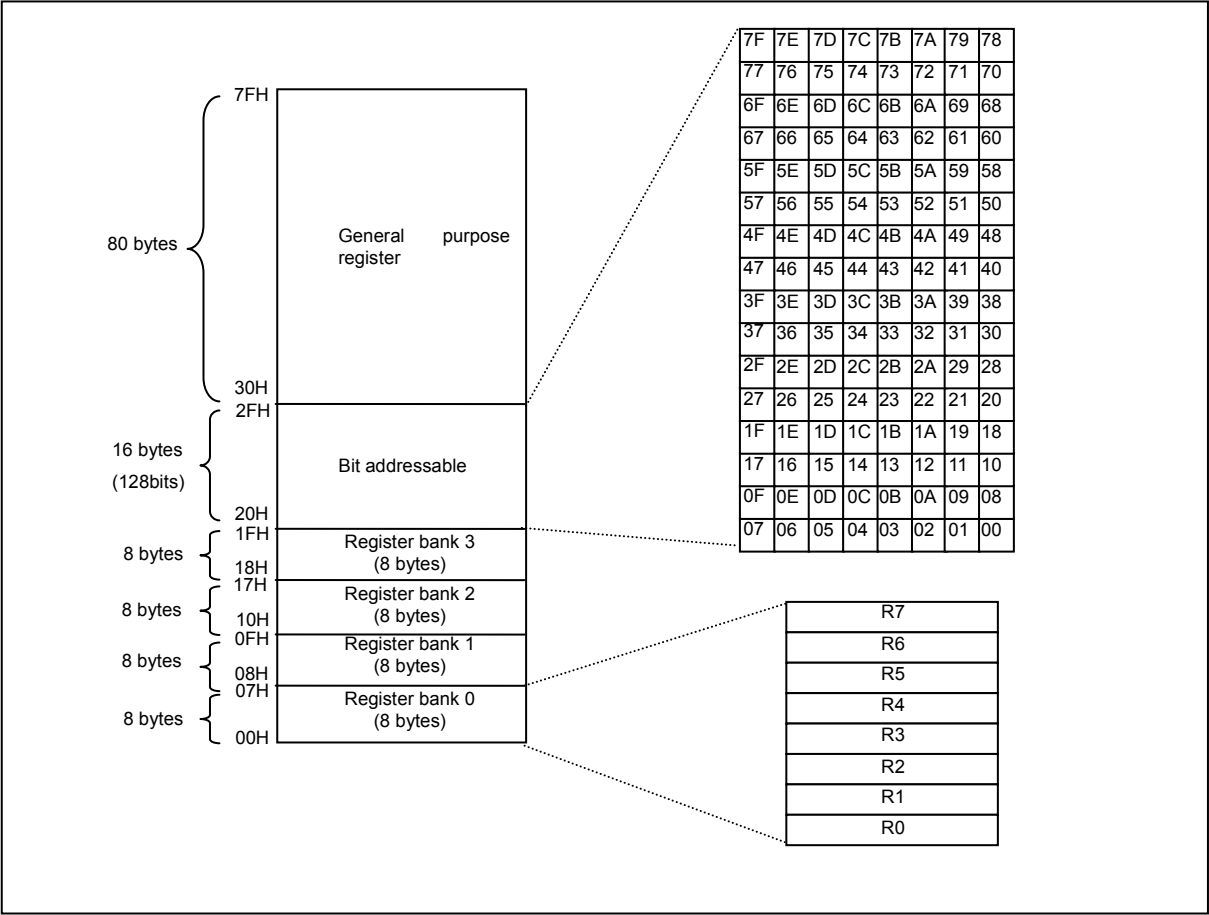


Figure 8.3 Low 128 Bytes

8.3 EEPROM Data Memory and XSRAM

MC97FG316 has 512bytes EEPROM Data memory. This area has no relation with RAM/FLASH. It can read and write through SFR with 8-bit unit.

For more information about EEPROM Data memory, see chapter 15.

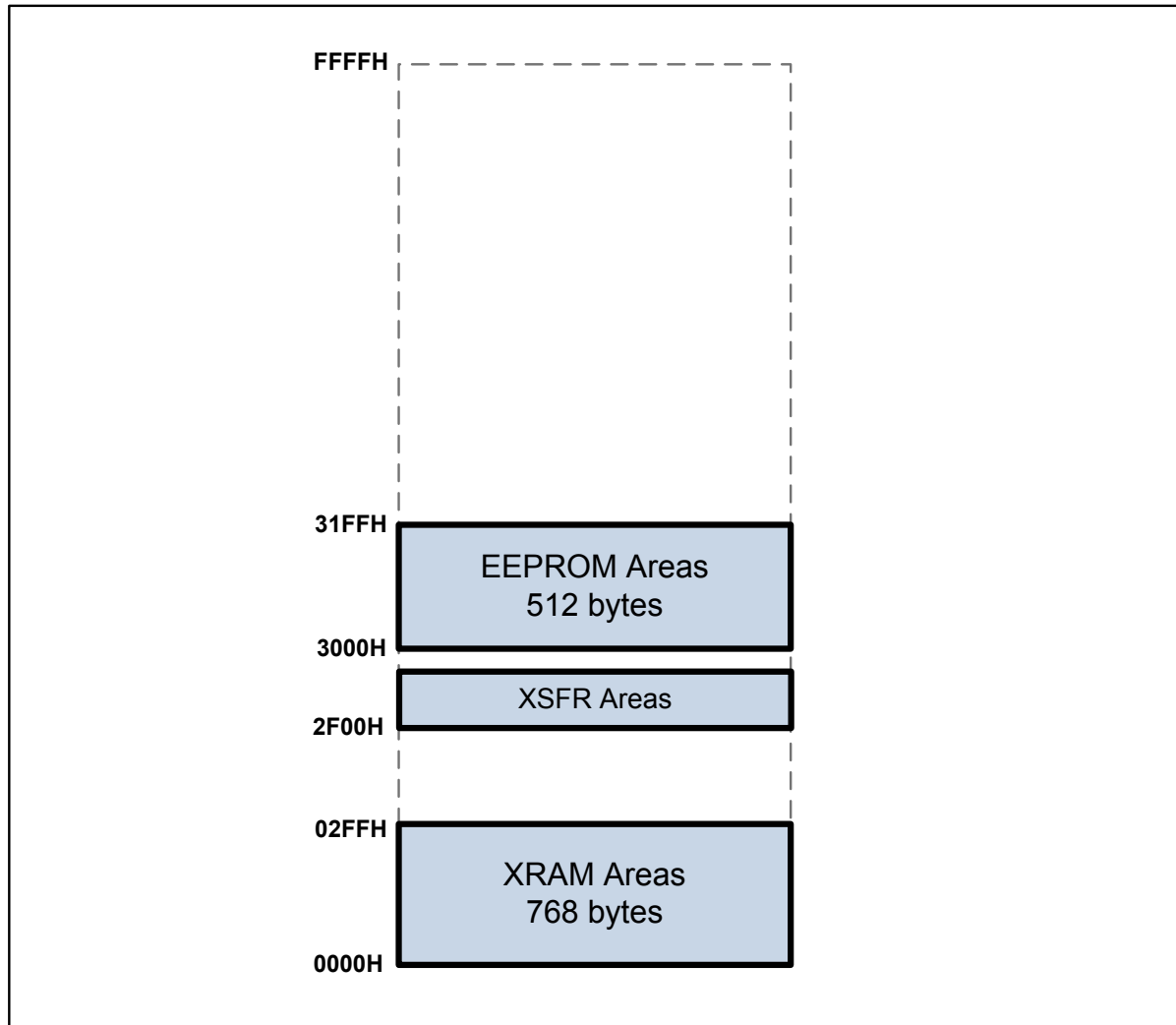


Figure 8.4 XDATA Memory Area

8.4 SFR Map

8.4.1 SFR Map Summary

	0H/8H ⁽¹⁾	1H/9H	2H/AH	3H/BH	4H/CH	5H/DH	6H/EH	7H/FH
2F58H	-	-	-	-	-	-	TEST_REGB	TEST_REGA
2F50H	FUSE_CONF	FUSE_TEMP	FUSE_FREQ	FUSE_RING	FUSE_BGR	FUSE_FLAS	FUSE_XTAL	-
2F48H	-	-	-	-	-	-	-	-
2F40H	-	-	-	-	-	-	-	-
2F38H	-	-	-	-	-	-	-	-
2F30H	-	-	-	-	-	-	-	-
2F28H	-	-	-	-	-	-	-	-
2F20H	-	-	-	-	-	-	-	-
2F18H	-	-	-	-	-	-	WDTTEST0	WDTTEST1
2F10H	PSR0	PSR1	PSR2	-	WDTC	WDTSR	WDTCNTH	WDTCNTH
2F08H	P0DB	P1DB	P2DB	P3DB	-	-	TESTTCRC0	TESTTCRC1
2F00H	P0PU	P1PU	P2PU	P3PU	P0OD	P1OD	P2OD	P3OD
F8H	UCRCC	ACCSR	UCTRL11	UCTRL12	UCTRL13	USTAT1	UBAUD1	UDATA1
F0H	B	UCRCDIN	FEARL	FEARM	FEARH	FEDR	FETR	-
E8H	UCRCL	UCRCH	FEMR	FECR	FESR	FETCR	FEARL1	FEARM1
E0H	ACC	TCRCC	UCTRL01	UCTRL02	UCTRL03	USTAT0	UBAUD0	UDATA0
D8H	TCRCL	TCRCH	I2CMR	I2CSR	I2CSCLLR	I2CSCLHR	I2CSDAHR	I2CDR
D0H	PSW	-	SPICR	SPIDR	SPISR	T4H	I2CSAR1	I2CSAR
C8H	ADCRL	ADCRH	T3CR	T3DR / T3PPR	T3 / T3PDR / CDR3	T3PWHR	T4CR	T4L
C0H	ADCM	ADCM2	T1DLYB	T1DLYC	T1ISR	T1IMSK	T2CR	T2 / T2DR / CDR2
B8H	-	T1BDRL	T1BDRH	T1CDRL	T1CDRH	T1PCR2	T1PCR3	T1DLYA
B0H	T1 / T1ADRL / CDR1	T1ADRH	T0CR	T0 / T0DR / CDR0	T1CR	T1DR / T1PPRL	T1PPRH	T1PCR
A8H	IE	IE1	IE2	IE3	-	-	PCI0	TMISR
A0H	XBANK	P3IO	EO	EIENAB	EIFLAG	EIEDGE	EIPOLA	EIBOTH
98H	P3	P2IO	IP1	IP1H	IP2	IP2H	IP3	IP3H
90H	P2	P1IO	IP	IPH	PLLCR	WTMR	WTR / WTCR	BUZCR
88H	P1	P0IO	SCCR	BCCR	BITR	WDTCR	WDTIDR	BUZDR
80H	P0	SP	DPL	DPH	DPL1	DPH1	LVRCCR	PCON

Table 8.1 SFR Map Summary

NOTE)

1. The registers are bit-addressable (except for XSFR)

8.4.2 8051 Compiler Compatible SFR

ACC (Accumulator) : E0H

7	6	5	4	3	2	1	0
ACC							
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

ACC

Accumulator

B (B Register) : F0H

7	6	5	4	3	2	1	0
B							
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

B

B Register

SP (Stack Pointer) : 81H

7	6	5	4	3	2	1	0
SP							
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 07H

SP

Stack Pointer

DPL (Data Pointer Low Byte) : 82H

7	6	5	4	3	2	1	0
DPL							
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

DPL

Data Pointer Low Byte

DPH (Data Pointer High Byte) : 83H

7	6	5	4	3	2	1	0
DPH							
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

DPH

Data Pointer High Byte

DPL1 (Data Pointer1 Low Byte) : 84H

7	6	5	4	3	2	1	0
DPL1							
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

DPL1

Data Pointer1 Low Byte

DPH1 (Data Pointer1 High Byte) : 85H

7	6	5	4	3	2	1	0
DPH1							

RW	RW	RW	RW	RW	RW	RW	RW
----	----	----	----	----	----	----	----

Initial value : 00H

DPH1 Data Pointer1 High Byte

PSW (Program Status Word) : D0H

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

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	-	-	-	DPSEL0
R	R	R	RW	R	R	R	RW

Initial value : 00H

TRAP_EN	Select the instruction
0	Select MOVX @(DPTR++), A
1	Select Software TRAP instruction
DPSEL	Select Banked Data Point Register
0	DPTR0
1	DPTR1

XBANK (XRAM Bank Pointer) : A0H

7	6	5	4	3	2	1	0
XBANK							
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

XBANK XRAM Bank Pointer

- Note)
1. This XBANK register holds the [15:8] part of memory address during access to data.
 2. Address[15:0] : "XBANK:Ri" (R1: R0 or R1)
 3. Ex) MOVX A, @Ri ; Move external data (XBANK:Ri[15:0]) to A
 MOVX @Ri, A ; Move A to external data (XBANK:Ri[15:0])

9 I/O Ports

9.1 I/O Ports

The MC97FG316 has four I/O ports (P0, P1, P2 and 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 includes 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 independently used as an input or an output through the PxIO register. Clearing bits in this read/write register will select the corresponding pins in Px as an input, setting a bit sets the pin to output. All bits are cleared by a system reset.

9.2.3 Pull-up Resistor Selection Register (PxPU)

The on-chip pull-up resistor can be connected to them in 1-bit units with a pull-up resistor selection register (PxPU). The pull-up register selection controls the pull-up resistor enable/disable of each port. When the corresponding bit is 1, the pull-up resistor of the pin is enabled. When 0, the pull-up resistor is disabled. All bits are cleared by a system reset. (Only port pull-up resistor selection have default ON state for unused pins in 32-pin package for 16, 20, 28-pin package).

9.2.4 Open-drain Selection Register (PxOD)

There is internally open-drain selection register (PxOD) in P0, P1, P2 and P3. The open-drain selection register controls the open-drain enable/disable of each port. Ports become push-pull by a system reset.

9.2.5 De-bounce Enable Register (PxDB)

P0, P1, P2 and P3 support debounce function. The De-bounce enable register controls the debounce function of each port..

9.2.6 Pin Change Interrupt Enable Register (PCI0)

The P0 can support Pin Change Interrupt function. Pin Change Interrupts PCI will trigger if any PCI enabled P0[7:0] pin toggles. The PCI0 Register control which pins contribute to the pin change interrupts.

9.2.7 Port Selection Register (PSRx)

PSRx registers prevent the input leakage current when ports are connected to analog inputs. If the bit of PSRx is '1', the dynamic current path from the schmitt OR gate of the port is cut off and the digital input of the corresponding port is always '1'.

9.2.8 Register Map

Name	Address	Dir	Default	Description
P0	80H	R/W	00H	P0 Data Register
P0IO	89H	R/W	00H	P0 Direction Register
P0PU	2F00H	R/W	00H	P0 Pull-up Resistor Selection Register
P0OD	2F04H	R/W	00H	P0 Open-drain Selection Register
P0DB	2F08H	R/W	00H	P0 Debounce Enable Register
PCI0	AEH	R/W	00H	P0 Pin Change Interrupt Enable Register
P1	88H	R/W	00H	P1 Data Register
P1IO	91H	R/W	00H	P1 Direction Register
P1PU	2F01H	R/W	00H	P1 Pull-up Resistor Selection Register
P1OD	2F05H	R/W	00H	P1 Open-drain Selection Register
P1DB	2F09H	R/W	00H	P1 Debounce Enable Register
P2	90H	R/W	00H	P2 Data Register
P2IO	99H	R/W	00H	P2 Direction Register
P2PU	2F02H	R/W	00H	P2 Pull-up Resistor Selection Register
P2OD	2F06H	R/W	00H	P2 Open-drain Selection Register
P2DB	2F0AH	R/W	00H	P2 Debounce Enable Register
P3	98H	R/W	00H	P3 Data Register
P3IO	A1H	R/W	00H	P3 Direction Register
P3PU	2F03H	R/W	00H	P3 Pull-up Resistor Selection Register
P3OD	2F07H	R/W	00H	P3 Open-drain Selection Register
P3DB	2F0BH	R/W	00H	P3 Debounce Enable Register
PSR0	2F10H	R/W	00H	Port Selection Register 0
PSR1	2F11H	R/W	00H	P1,P2,P3 Port Selection Register
PSR2	2F12H	R/W	00H	Special Port Selection Register

Table 9.1 Register Map

9.3 Px Port

9.3.1 Px Port Description

Px is 8-bit I/O port. Px control registers consist of Data register (Px), direction register (PxIO), debounce enable register (PxDB), pull-up register selection register (PxPU), open-drain selection register (PxOD), pin change interrupt register (PCI0).

9.3.2 Register description for Px

Px (Px Data Register) : 80H, 88H, 90H, 98H

7	6	5	4	3	2	1	0
Px7	Px6	Px5	Px4	Px3	Px2	Px1	Px0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

Px[7:0] I/O Data

PxIO (Px Direction Register) : 89H, 91H, 99H, A1H

7	6	5	4	3	2	1	0
Px7IO	Px6IO	Px5IO	Px4IO	Px3IO	Px2IO	Px1IO	Px0IO
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PxIO[7:0] Px data I/O direction.
0 Input
1 Output

PxPU (Px Pull-up Resistor Selection Register) : 2F00H ~ 2F03H

7	6	5	4	3	2	1	0
Px7PU	Px6PU	Px5PU	Px4PU	Px3PU	Px2PU	Px1PU	Px0PU
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PxPU[7:0] Configure pull-up resistor of Px port
0 Disable
1 Enable

PxOD (Px Open-drain Selection Register) : 2F04H ~ 2F07H

7	6	5	4	3	2	1	0
Px7OD	Px6OD	Px5OD	Px4OD	Px3OD	Px2OD	Px1OD	Px0OD
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PxOD[7:0] Configure open-drain of Px port
0 Disable
1 Enable

PxDB (Px Debounce Enable Register) : 2F08H ~ 2F0BH

7	6	5	4	3	2	1	0
Px7DB	Px6DB	Px5DB	Px4DB	Px3DB	Px2DB	Px1DB	Px0DB
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PxDB[7:0] Configure de-bounce of Px port

0 Disable

1 Enable

PCI0 (P0 Pin Change Interrupt Enable Register) : AEH

7	6	5	4	3	2	1	0
PCI07	PCI06	PCI05	PCI04	PCI03	PCI02	PCI01	PCI00
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PCI0[7:0] Configure Pin Change Interrupt of P0 port

0 Disable

1 Enable

PSR0 (Port Selection Register) : 2F10H

7	6	5	4	3	2	1	0
PSR07	PSR06	PSR05	PSR04	PSR03	PSR02	PSR01	PSR00
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PSR0[7:0] P07~P00 port selection register

0 Disable analog channel AN[7:0] (default)

1 Enable analog channel AN[7:0]

PSR1 (P1,2,3 Port Selection Register) : 2F11H

7	6	5	4	3	2	1	0
PSR17	PSR16	PSR15	PSR14	PSR13	PSR12	PSR11	PSR10
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PSR1[7] I2C ports selection register

0 When PSR2[1]="0", P0[7:6] for I2C (default)

1 When PSR2[1]="0", P2[6:5] for I2C

PSR1[6:0] P25,P24,P23,P37,P36,P16,P15 port selection register

0 Disable analog channel AN[14:8] (default)

1 Enable analog channel AN[14:8]

PSR2 (USART0, TIMER0 Port Selection Register) : 2F12H

7	6	5	4	3	2	1	0
-	-	-	-	-	-	PSR21	PSR20
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PSR2[1]	I2C ports selection register 2
0	I2C by PSR1[7] (default)
1	P0[1:0] for I2C
PSR2[0]	RxD0, TxD0, EC0, T0O ports selection register
0	P0[3:2] for RxD0, TxD0 (default) P0[7:6] for EC0, T0O
1	P3[3:2] for RxD0, TxD0 P1[4:3] for EC0, T0O

9.4 Port RESET Noise Canceller

The Figure 9.1 is the Noise canceller time diagram for Noise cancel of Port RESET. It has the Noise cancel value is about 5us (@VDD=5V) to Port Reset input.

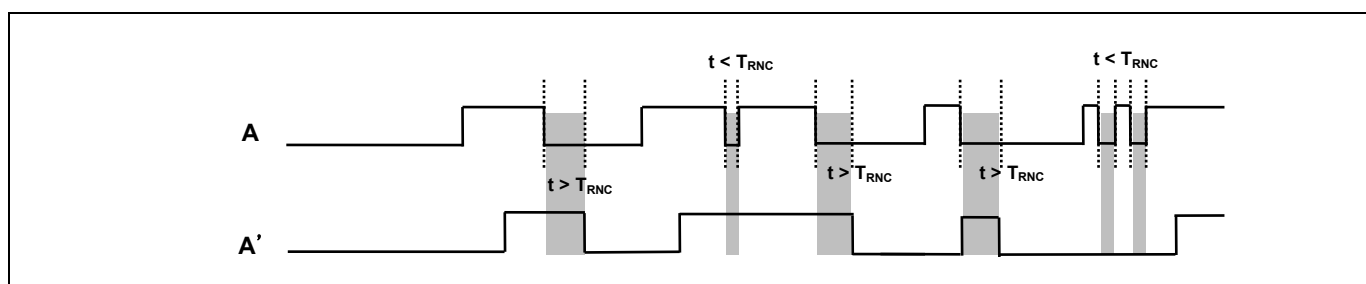


Figure 9.1 Port Reset noise canceller time diagram

10 Interrupt Controller

10.1 Overview

The MC97FG316 supports up to 24 interrupt sources. The interrupts have separate enable register bits and allows software control. They can also have four levels of priority assigned to them. The interrupt controller has following features:

- the request from 24 interrupt source
- 4 priority levels
- Multi Interrupt possibility
- If the requests of different priority are received simultaneously, the request of higher priority is serviced first and then lower priority is serviced.
- Each interrupt source can be controlled by EA bit and each IEx bit
- Interrupt latency: 5~8 machine cycles in single interrupt system

The maskable interrupts are enabled through four pair of interrupt enable registers (IE, IE1, IE2, IE3). Bits of IE, IE1, IE2, IE3 register individually enable/disable a particular interrupt source. Overall interrupts are controlled by EA (bit 7 of IE). 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 MC97FG316 supports a 4-level priority scheme. Each maskable interrupt is individually assigned to one of four priority levels by writing to [IP, IPH] or [IP1, IP1H] or [IP2, IP2H] or [IP3, IPH3].

Figure 10.1 shows the Interrupt Priority Level. Priority can be set by writing to two bits of IPx and IPxH register. Each bit of IPx , IPxH corresponds to each interrupt and decides one of 4 priority levels of each interrupt. High level interrupt priority always has higher priority than low level interrupt. And small number interrupt has higher priority than large number interrupt in the same level.

Figure 10.1 shows INT10 is higher priority small than any interrupt.

(priority order : INT10 > INT4 > INT19 > INT0 > INT1 > ~~ > INT23)

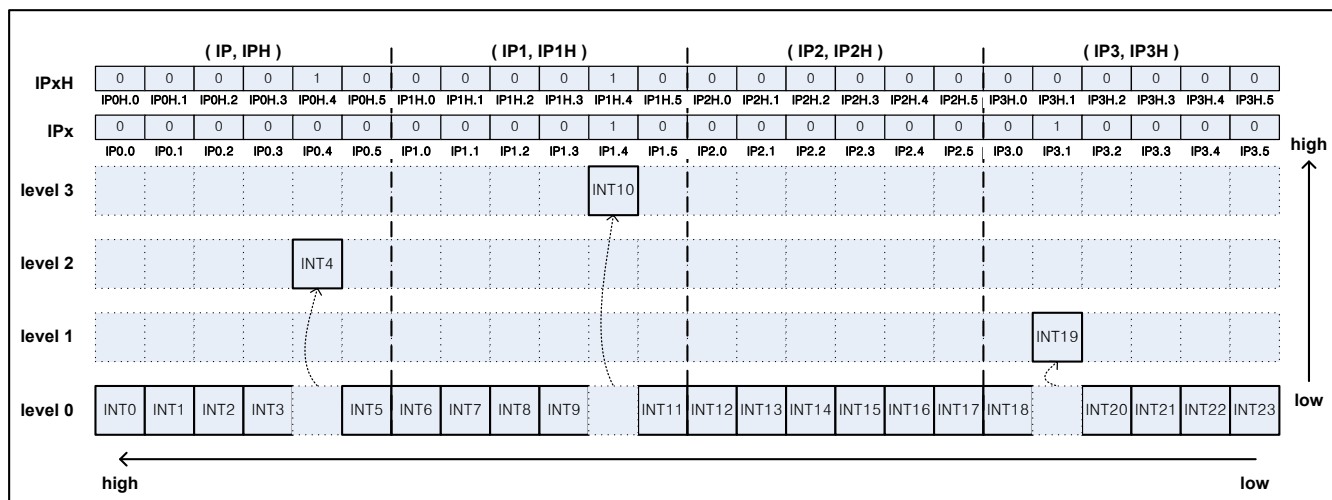


Figure 10.1 Interrupt Priority Level

10.2 External Interrupt

The external interrupt on INT0, INT1, INT2, INT3, INT4, INT5, INT6 and INT7 pins receive various interrupt request depending on the EIEDGE (External Interrupt Edge register) and EIPOLA (External Interrupt Polarity register) and EIBOTH (External Interrupt Both Edge register) as shown in Figure 10.1. Also each external interrupt source has control setting bits. The EIFLAG (External interrupt flag register) register provides the status of external interrupts.

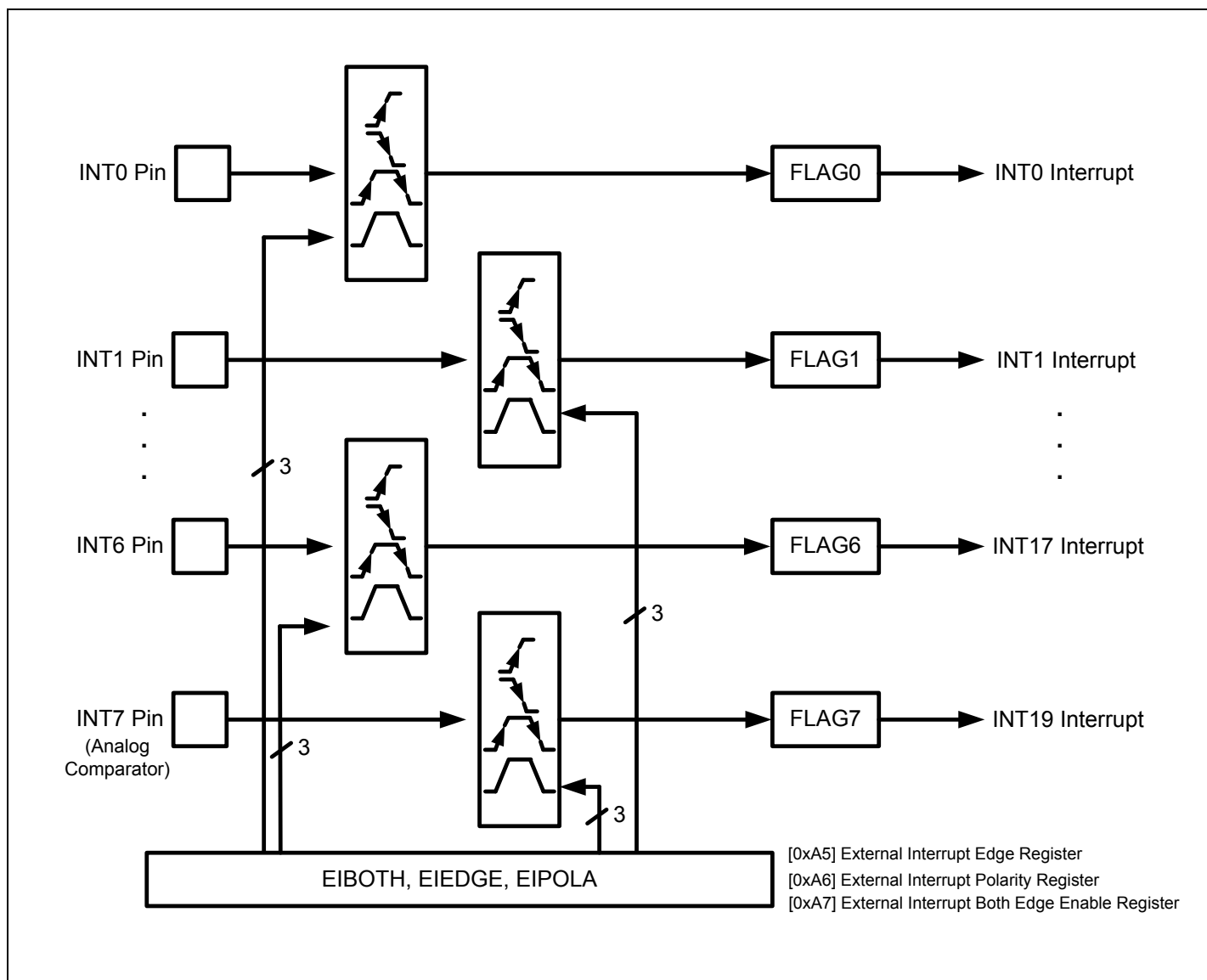


Figure 10.2 External Interrupt Description

10.3 Block Diagram

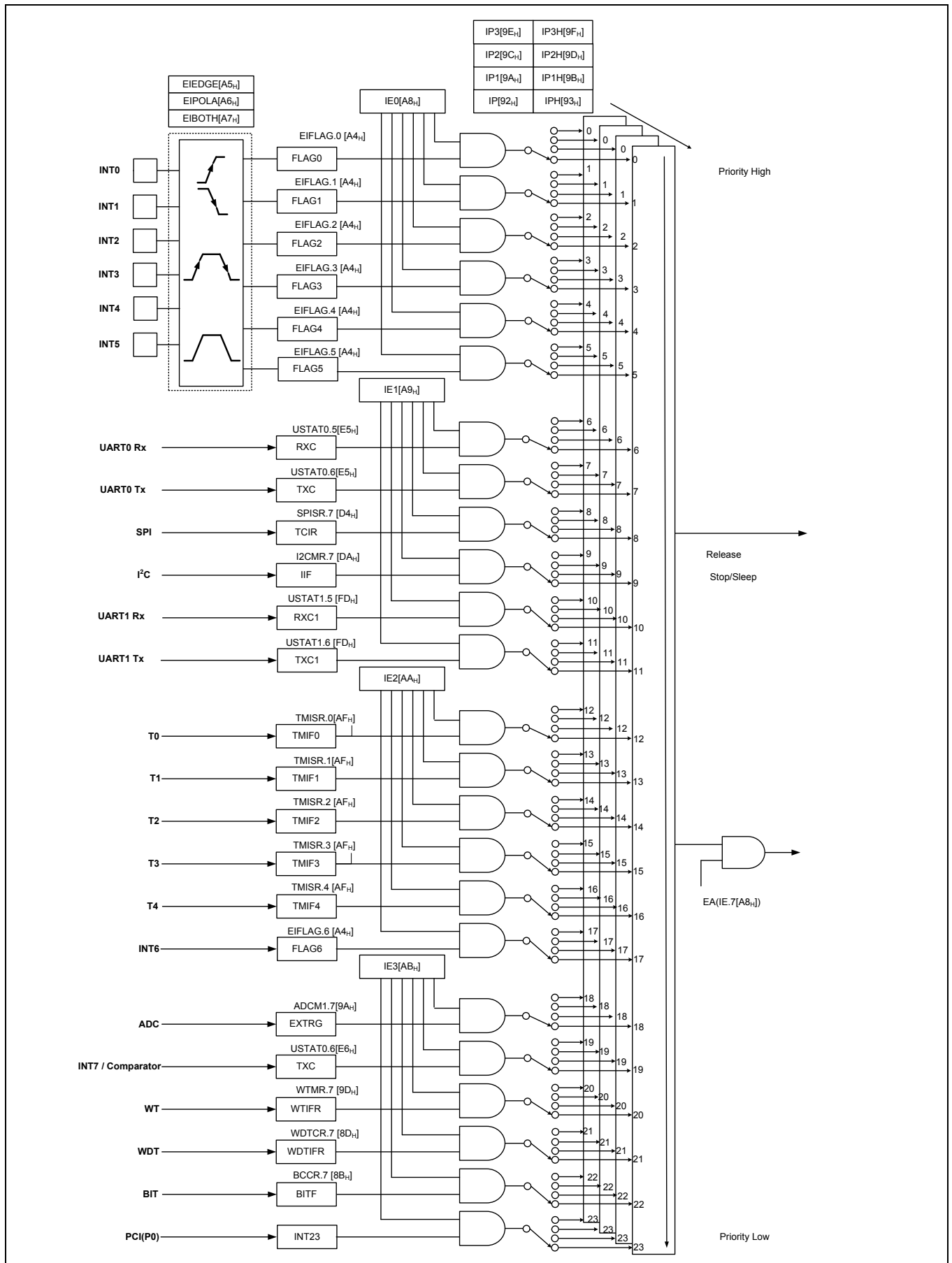


Figure 10.3 Block Diagram of Interrupt

10.4 Interrupt Vector Table

The interrupt controller supports 24 interrupt sources as shown in the Table 10.2 below. When interrupt becomes service, long call instruction (LCALL) is executed in the vector address. 24 Interrupt request have a decided priority order.

Interrupt Source	Symbol	Interrupt Enable bit	Priority	Mask	Vector Address
Hardware Reset	RESETB	0	0	Non-Maskable	0000H
External Interrupt 0	INT0	IE0.0	1	Maskable	0003H
External Interrupt 1	INT1	IE0.1	2	Maskable	000BH
External Interrupt 2	INT2	IE0.2	3	Maskable	0013H
External Interrupt 3	INT3	IE0.3	4	Maskable	001BH
External Interrupt4	INT4	IE0.4	5	Maskable	0023H
External Interrupt5	INT5	IE0.5	6	Maskable	002BH
USART0 Rx	INT6	IE1.0	7	Maskable	0033H
USART0Tx	INT7	IE1.1	8	Maskable	003BH
SPI0	INT8	IE1.2	9	Maskable	0043H
I2C	INT9	IE1.3	10	Maskable	004BH
USART1 Rx	INT10	IE1.4	11	Maskable	0053H
USART1 Tx	INT11	IE1.5	12	Maskable	005BH
T0	INT12	IE2.0	13	Maskable	0063H
T1	INT13	IE2.1	14	Maskable	006BH
T2	INT14	IE2.2	15	Maskable	0073H
T3	INT15	IE2.3	16	Maskable	007BH
T4	INT16	IE2.4	17	Maskable	0083H
External Interrupt6	INT17	IE2.5	18	Maskable	008BH
ADC	INT18	IE3.0	19	Maskable	0093H
External Interrupt7 / Comparator	INT19	IE3.1	20	Maskable	009BH
WT	INT20	IE3.2	21	Maskable	00A3H
WDT	INT21	IE3.3	22	Maskable	00ABH
BIT	INT22	IE3.4	23	Maskable	00B3H
Pin Change Interrupt(P0)	INT23	IE3.5	24	Maskable-	00BBH

Table 10.1 Interrupt Vector Address Table

For executing maskable interrupt, specific interrupt source must set '1' by writing a '1' to associated bit in the IEx and EA bit must set '1'. If interrupt request is received, specific interrupt request flag set '1'. And it remains '1' until CPU accepts interrupt. After then, 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 as '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 stack. For the interrupt service routine, the interrupt controller gives the address of LJMP instruction to CPU. After finishing the current instruction, interrupt service routine needs 5~8 machine cycle and the interrupt service task is terminated upon execution of an interrupt return instruction [RETI]. The following process is the flow of whole interrupt service routine.

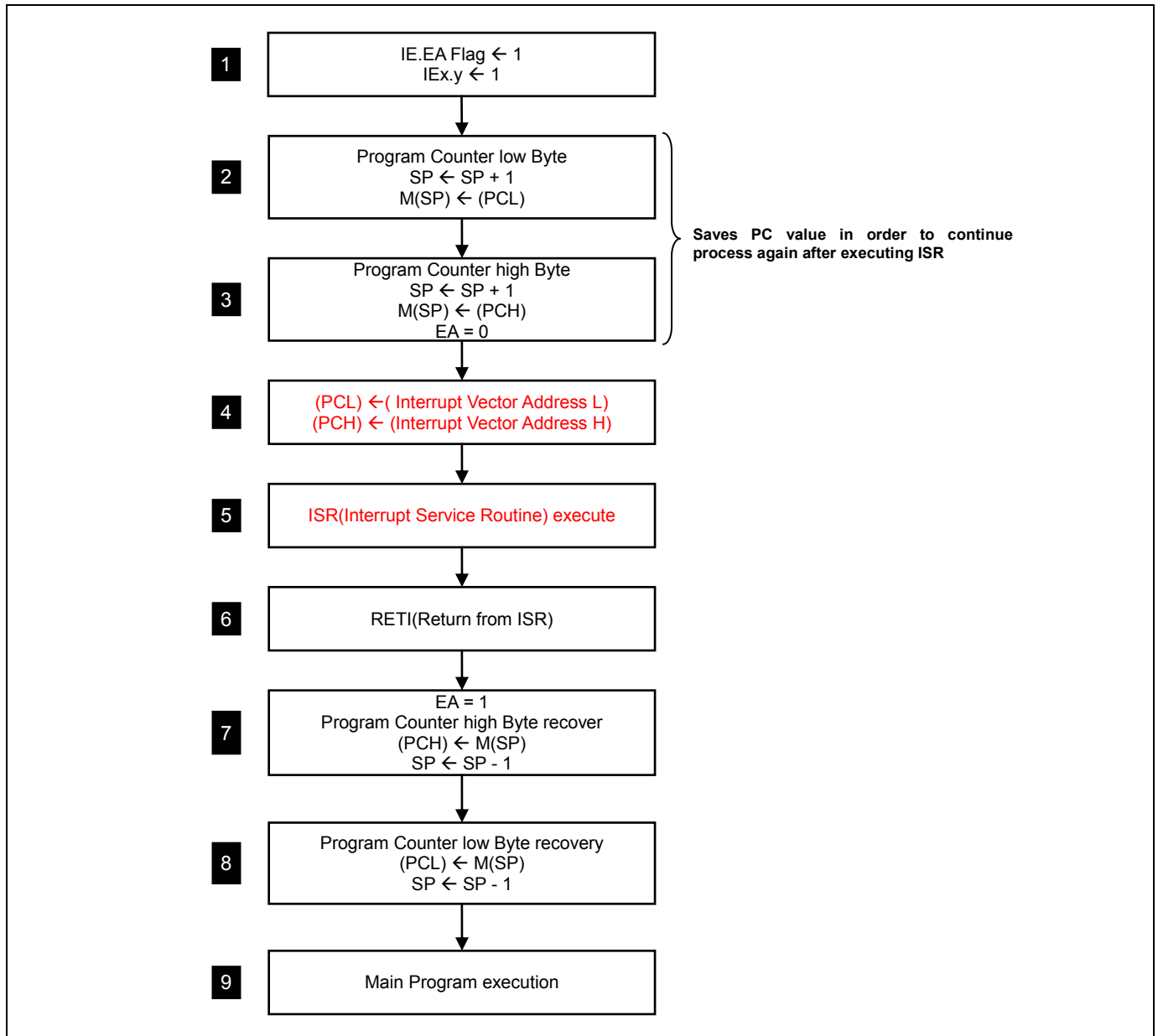


Figure 10.4 Interrupt Flow

10.6 Effective Timing after Controlling Interrupt bit

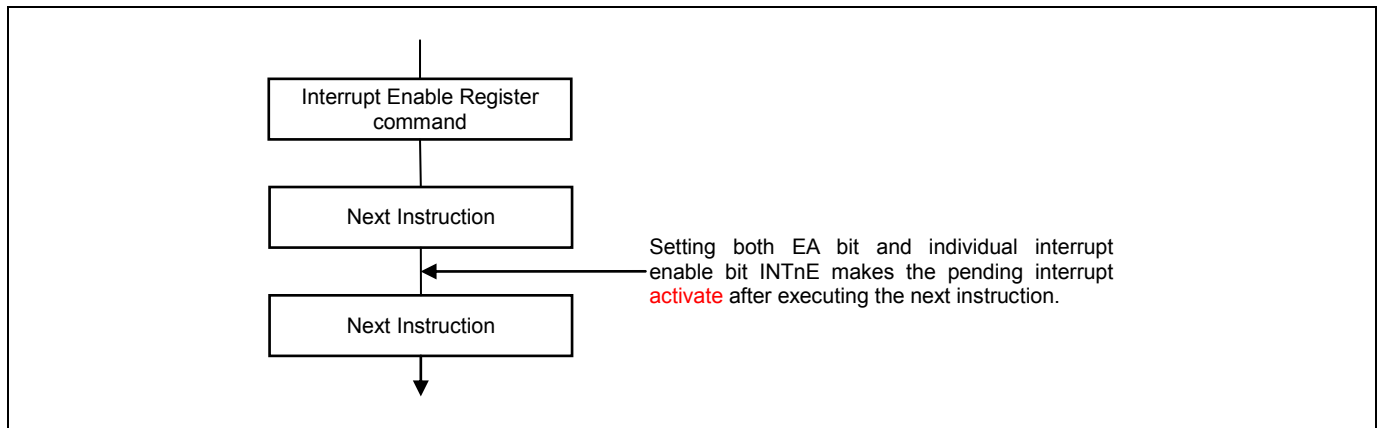


Figure 10.5 Interrupt Enable Register effective Timing

10.7 Multi Interrupt

If two different priority level requests are received simultaneously, the higher priority level request is serviced. If requests of the interrupt are received at the same time, an interrupt polling sequence determines by hardware which request is serviced. However, multiple processing is possible through software for special features.

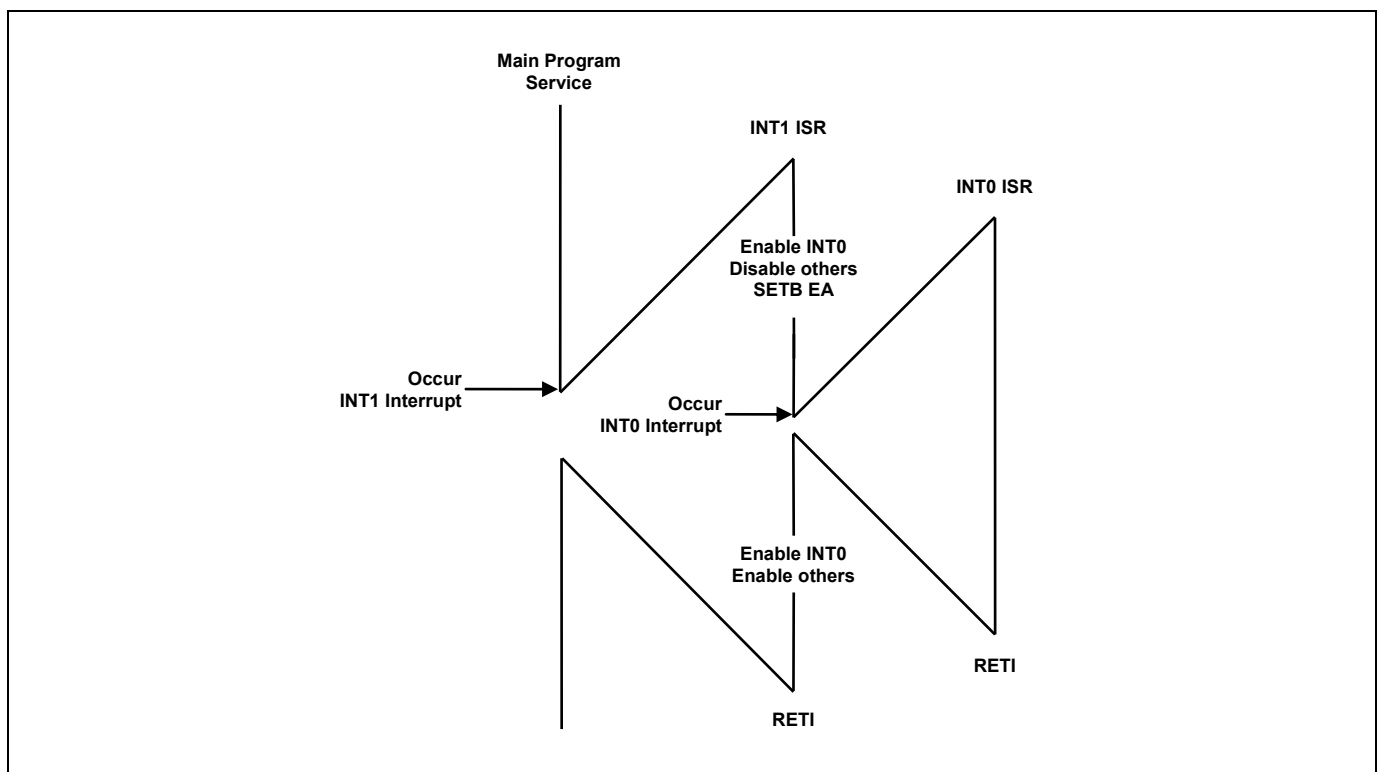


Figure 10.6 Execution of Multi Interrupt

Following example shows the service INT0 routine during INT1 routine in Figure 10 6. In this example.

Example) Software Multi Interrupt:

```

INT1:  MOV    IE, #01H    ; Enable INT0 only
        MOV    IE1, #00H  ; Disable others
        SETB   EA         ; Enable global interrupt (necessary for multi interrupt)
        :
        MOV    IE, #0FFH  ; Enable all Interrupts
        MOV    IE1, #0FFH
        RETI

```

10.8 Interrupt Enable Accept Timing

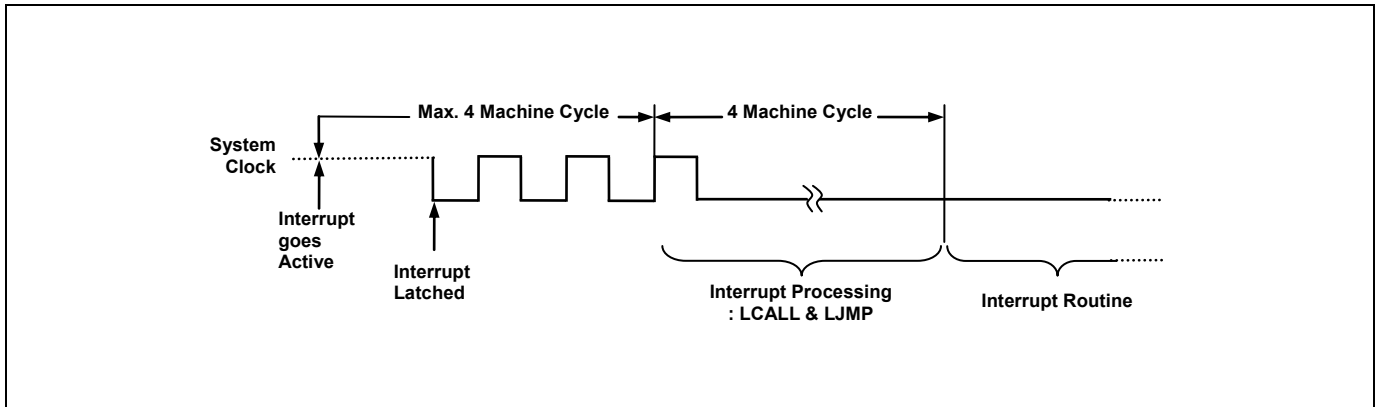


Figure 10.7 Interrupt Response Timing Diagram

NOTE)

1. Machine cycle = 2*system clock

10.9 Interrupt Service Routine Address

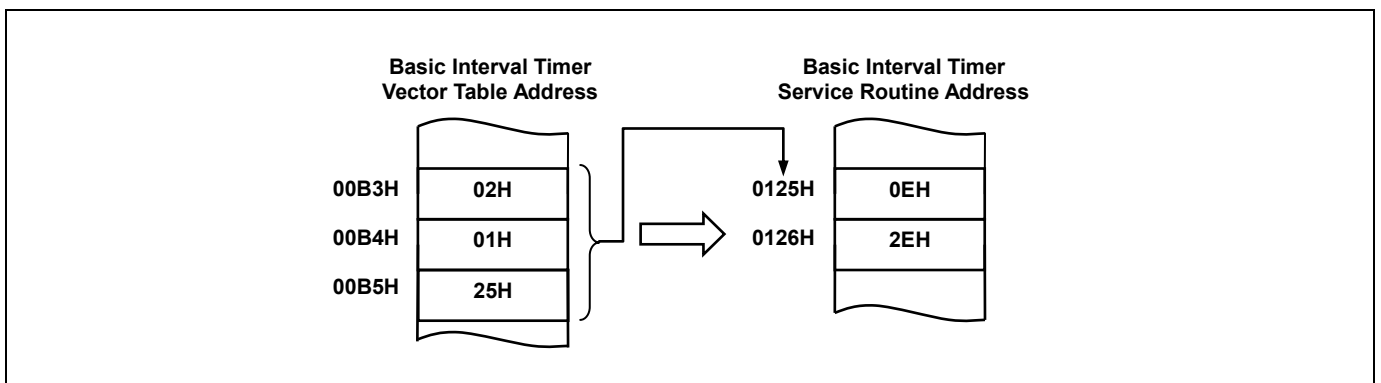
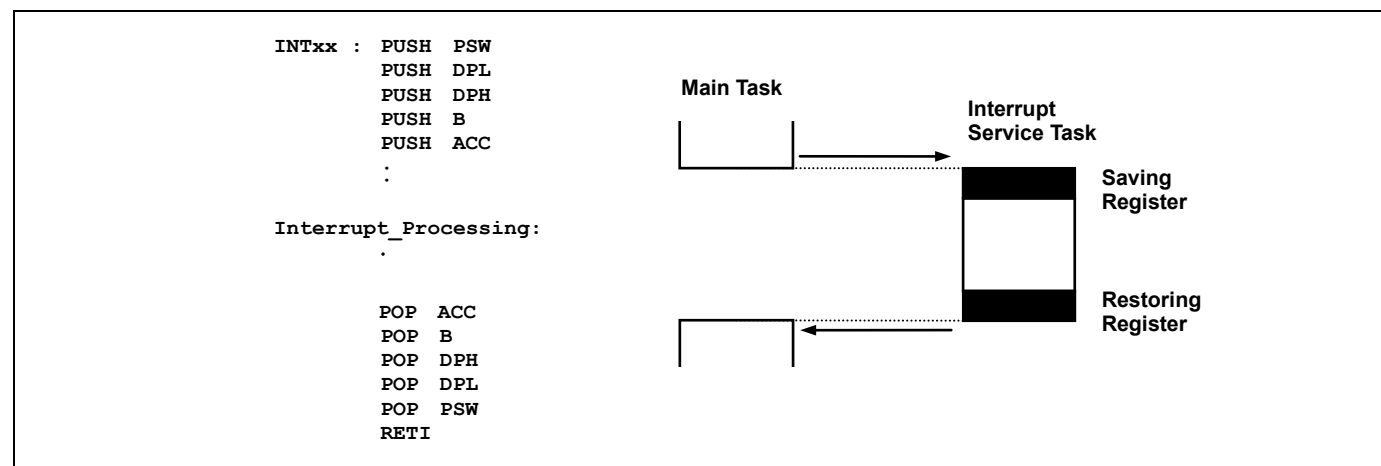


Figure 10.8 Correspondence between Vector Table Address and the Entry Address of ISR

10.10 Saving/Restore General-Purpose Registers



NOTE)

1. 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. Totally 24 peripheral are able to control interrupt.

10.12.2 Interrupt Priority Register (IP, IP1,IP2,IP3)

The 24 interrupt divides 8 groups which have each 3 interrupt sources. A group can decide 4 levels interrupt priority using interrupt priority register. Level 3 is the high priority, while level 0 is the low priority. Initially, IP, IP1,IP2,IP3 reset value is '0'. At that initialization, low interrupt number has a higher priority than high interrupt number. If decided the priority, low interrupt number has a higher priority than high interrupt number in that group.

10.12.3 External Interrupt Flag Register (EIFLAG)

The EIFLAG is set to '1' when the external interrupt generating condition is satisfied. The flag is cleared when the interrupt routine is executed. Alternatively, the flag can be cleared by writing a '0' to it.

10.12.4 External Interrupt Edge Register (EIEDGE)

The EIEDGE determines type of edge or level sensitive interrupt. Initially, default value is level. For level, write '0' to related bit. For edge, write '1' to related bit.

10.12.5 External Interrupt Edge Register (EIEDGE)

According to EIEDGE register, the external interrupt polarity (EIPOLA) register has a different meaning. If EIEDGE is level type, EIPOLA is able to have Low/High level value. If EIEGDE is edge type, EIPOLA is able to have rising/falling edge value.

10.12.6 External Interrupt Enable Register (EIENAB)

When EIENAB is written to '1', the corresponding external pin interrupt is enabled. The EIEDGE and EIPOLA register defines whether the external interrupt is activated on rising or falling edge or level sensed.

10.12.7 External Interrupt Both Edge Enable Register (EIBOTH)

When EIBOTH is written to '1', the corresponding external pin interrupt is enabled by both edges. Initially, default value is disabled.

10.12.8 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	92H	R/W	00H	Interrupt Priority Register
IPH	93H	R/W	00H	Interrupt Priority Register High
IP1	9AH	R/W	00H	Interrupt Priority Register 1
IP1H	9BH	R/W	00H	Interrupt Priority Register 1 High
IP2	9CH	R/W	00H	Interrupt Priority Register 2
IP2H	9DH	R/W	00H	Interrupt Priority Register 2 High
IP3	9EH	R/W	00H	Interrupt Priority Register 3
IP3H	9FH	R/W	00H	Interrupt Priority Register 3 High
EIENAB	A3H	R/W	00H	External Interrupt Enable Register
EIFLAG	A4H	R/W	00H	External Interrupt Flag Register
EIEDGE	A5H	R/W	00H	External Interrupt Edge Register
EIPOLA	A6H	R/W	00H	External Interrupt Polarity Register
EIBOTH	A7H	R/W	00H	External Interrupt Both Edge Enable Register

Table 10.2 Register Map

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 Register (EIFLAG), External Interrupt Edge Register (EIEDGE), External Interrupt Polarity Register (EIPOLA), External Interrupt Enable Register (EIENAB) and External Interrupt Both Edge Enable Register(EIBOTH).

10.13.1 Register Description for Interrupt

IE (Interrupt Enable Register) : A8H

7	6	5	4	3	2	1	0
EA	-	INT5E	INT4E	INT3E	INT2E	INT1E	INT0E
RW	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

EA	Enable or disable all interrupt bits
0	All Interrupt disable
1	All Interrupt enable
INT5E	Enable or disable External Interrupt5
0	Disable
1	Enable
INT4E	Enable or disable External Interrupt4
0	Disable
1	Enable
INT3E	Enable or disable External Interrupt 3
0	Disable
1	Enable
INT2E	Enable or disable External Interrupt 2
0	Disable
1	Enable
INT1E	Enable or disable External Interrupt 1
0	Disable
1	Enable
INT0E	Enable or disable External Interrupt 0
0	Disable
1	Enable

IE1 (Interrupt Enable Register 1) : A9H

7	6	5	4	3	2	1	0
-	-	INT11E	INT10E	INT9E	INT8E	INT7E	INT6E
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

INT11E	Enable or disable USART1 Tx Interrupt
0	Disable
1	Enable
INT10E	Enable or disable USART1 Rx Interrupt
0	Disable
1	Enable
INT9E	Enable or disable I2C Interrupt
0	Disable
1	Enable
INT8E	Enable or disable SPI0 Interrupt
0	Disable
1	Enable
INT7E	Enable or disable USART0 Tx Interrupt
0	Disable
1	Enable
INT6E	Enable or disable USART0 Rx Interrupt

0 Disable
1 Enable

IE2 (Interrupt Enable Register 2) : AAH

7	6	5	4	3	2	1	0
-	-	INT17E	INT16E	INT15E	INT14E	INT13E	INT12E
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

INT17E Enable or disable External Interrupt6
0 Disable
1 Enable

INT16E Enable or disable Timer 4 Interrupt
0 Disable
1 Enable

INT15E Enable or disable Timer 3 Interrupt
0 Disable
1 Enable

INT14E Enable or disable Timer 2 Interrupt
0 Disable
1 Enable

INT13E Enable or disable Timer 1 Interrupt
0 Disable
1 Enable

INT12E Enable or disable Timer 0 Interrupt
0 Disable
1 Enable

IE3 (Interrupt Enable Register 3) : ABH

7	6	5	4	3	2	1	0
-	-	INT23E	INT22E	INT21E	INT20E	INT19E	INT18E
R	R	RW	RW	RW	RW	RW	RW

Initial value : 00H

INT23E	Enable or disable Pin Change Interrupt 0 (Port 0)
0	Disable
1	Enable
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 Analog Comparator Interrupt
0	Disable
1	Enable
INT18E	Enable or disable ADC Interrupt
0	Disable
1	Enable

IP (Interrupt Priority Register) : 92H

7	6	5	4	3	2	1	0
-	-	IP5	IP4	IP3	IP2	IP1	IP0
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

IPH (Interrupt Priority Register High) : 93H

7	6	5	4	3	2	1	0
-	-	IPH5	IPH4	IPH3	IPH2	IPH1	IPH0
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

IP[5:0], IPH[5:0]		Select Interrupt Priority
		Each IPH and IP corresponds to INT5~INT0.
IPH	IP	Description
0	0	level 0 (lowest)
0	1	level 1
1	0	level 2
1	1	level 3 (highest)

IP1 (Interrupt Priority Register 1) : 9AH

7	6	5	4	3	2	1	0
-	-	IP15	IP14	IP13	IP12	IP11	IP10
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

IP1H (Interrupt Priority Register 1 High) : 9BH

7	6	5	4	3	2	1	0
-	-	IP1H5	IP1H4	IP1H3	IP1H2	IP1H1	IP1H0
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

IP1[5:0],
IP1H[5:0]Select Interrupt Group Priority
Each IP1H and IP1 corresponds to INT11~INT6.

IP1H	IP1	Description
0	0	level 0 (lowest)
0	1	level 1
1	0	level 2
1	1	level 3 (highest)

IP2 (Interrupt Priority Register 2) : 9CH

7	6	5	4	3	2	1	0
-	-	IP25	IP24	IP23	IP22	IP21	IP20
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

IP2H (Interrupt Priority Register 2 High) : 9DH

7	6	5	4	3	2	1	0
-	-	IP2H5	IP2H4	IP2H3	IP2H2	IP2H1	IP2H0
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

IP2[5:0],
IP2H[5:0]Select Interrupt Priority
Each IP2H and IP2 corresponds to INT17~INT12.

IP2H	IP2	Description
0	0	level 0 (lowest)
0	1	level 1
1	0	level 2
1	1	level 3 (highest)

IP3 (Interrupt Priority Register 3) : 9EH

7	6	5	4	3	2	1	0
-	-	IP35	IP34	IP33	IP32	IP31	IP30
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

IP3H (Interrupt Priority Register 3 High) : 9FH

7	6	5	4	3	2	1	0
-	-	IP3H5	IP3H4	IP3H3	IP3H2	IP3H1	IP3H0
-	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

IP3[5:0],
IP3H[5:0]Select Interrupt Group Priority
Each IP3H and IP3 corresponds to INT23~INT18.

IP1H	IP1	Description
0	0	level 0 (lowest)
0	1	level 1
1	0	level 2

1 1 level 3 (highest)

EIFLAG (External Interrupt Flag Register) : A4H

7	6	5	4	3	2	1	0
FLAG7	FLAG6	FLAG5	FLAG4	FLAG3	FLAG2	FLAG1	FLAG0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

FLAG[7:0] If External Interrupt is occurred, the flag becomes '1'. The flag can be cleared by writing a '0' to bit

0 External Interrupt not occurred

1 External Interrupt occurred

EIEDGE (External Interrupt Edge Register) : A5H

7	6	5	4	3	2	1	0
EDGE7	EDGE6	EDGE5	EDGE4	EDGE3	EDGE2	EDGE1	EDGE0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

EDGE[7:0] Determines which type of edge or level sensitive interrupt may occur.

0 Level (default)

1 Edge

EIPOLA (External Interrupt Polarity Register) : A6H

7	6	5	4	3	2	1	0
POLA7	POLA6	POLA5	POLA4	POLA3	POLA2	POLA1	POLA0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

POLA[7:0] According to EIEDGE, External interrupt polarity register has a different means. If EIEDGE is level type, external interrupt polarity is able to have Low/High level value. If EIEDGE is edge type, external interrupt polarity is able to have rising/ falling edge value.

Level case:

0 When High level, Interrupt occurred (default)

1 When Low level, Interrupt occurred

Edge case:

0 When Rising edge, Interrupt occurred (default)

1 When Falling edge, Interrupt occurred

EIENAB (External Interrupt Enable Register) : A3H

7	6	5	4	3	2	1	0
ENAB7	ENAB6	ENAB5	ENAB4	ENAB3	ENAB2	ENAB1	ENAB0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

ENAB[7:0] Control External Interrupt

0 Disable (default)

1 Enable

EIBOTH (External Interrupt Both Edge Enable Register) : A7H

7	6	5	4	3	2	1	0
BOTH7	BOTH6	BOTH5	BOTH4	BOTH3	BOTH2	BOTH1	BOTH0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

BOTH[7:0]

Determines which type of interrupt may occur, EIBOTH or EIEDGE+EIPOLA. if EIBOTH is enable, EIEDGE and EIPOLA register value don't matter.

- 0 Disable (default)
- 1 Enable

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-frequency clock oscillator. The system clock operation can be easily obtained by attaching a crystal between the XIN and XOUT pin, respectively. The system clock can also be obtained from the external oscillator. In this case, it is necessary to put the external clock signal into the XIN pin and open the XOUT pin. The default system clock is INT-RC Oscillator and the default division rate is one. In order to stabilize system internally, use 1MHz RING oscillator for BIT, WDT and ports de-bounce.

- Calibrated Internal RC Oscillator (16MHz)
 - . INT-RC OSC/1 (Default system clock)
 - . INT-RC OSC/2 (8MHz)
 - . INT-RC OSC/4 (4MHz)
 - . INT-RC OSC/8 (2MHz)
- Crystal Oscillator (4~16MHz)
- Sub-Clock Crystal Oscillator (32.768kHz)

11.1.2 Block Diagram

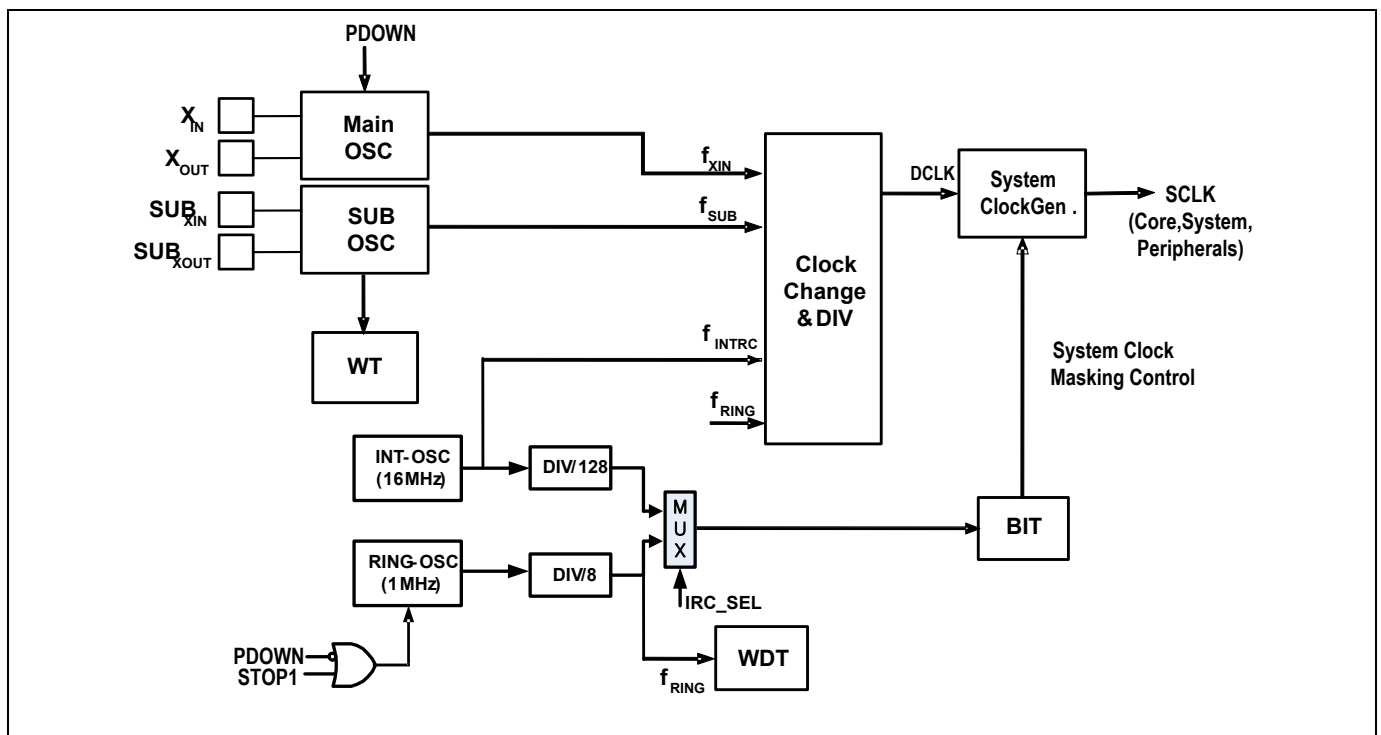


Figure 11.1 Clock Generator Block Diagram

11.1.3 Register Map

Name	Address	Dir	Default	Description
SCCR	8AH	R/W	04H	System and Clock Control Register

Table 11.1 Register Map

11.1.4 Clock Generator Register Description

The Clock Generation Register uses clock control for system operation. The clock generation consists of System and Clock register.

11.1.5 Register Description for Clock Generator

SCCR (System and Clock Control Register) : 8AH

7	6	5	4	3	2	1	0
STOP1	DIV1	DIV0	CBYS	ISTOP	XSTOP	CS1	CS0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 04H

STOP1	Control the STOP Mode NOTE) when PCON=0x03, It is applied. But when PCON=0x01, don't set this bit. 0 STOP2 Mode (at PCON=0x03) (default) 1 STOP1 Mode (at PCON=0x03)	
DIV[1:0]	When using fINTRC as system clock, determine division rate. NOTE) when using fINTRC as system clock, only division rate come into effect. NOTE) To change by software, CBYS set to '1' DIV1 DIV0 description 0 0 fINTRC/1 (16MHz) 0 1 fINTRC/2 (8MHz) 1 0 fINTRC/4 (4MHz) 1 1 fINTRC/8 (2MHz)	
CBYS	Control the scheme of clock change. If this bit set to '0', clock change is controlled by hardware. But if this set to '1', clock change is controlled by software. Ex) when setting CS[1:0], if CBYS bit set to '0', it is not changed right now, CPU goes to STOP mode and then when wake-up, it applies to clock change. NOTE) when clear this bit, keep other bits in SCCR. 0 Clock changed by hardware during stop mode (default) 1 Clock changed by software	
ISTOP	Control the operation of INT-RC Oscillation NOTE) when CBYS='1', It is applied 0 RC-Oscillation enable (default) 1 RC-Oscillation disable	
XSTOP	Control the operation of X-Tal Oscillation NOTE1) when CBYS='1', It is applied NOTE2) if XINENA bit in FUSE_CONF to '0', XSTOP is fixed to '1' 0 X-Tal Oscillation enable 1 X-Tal Oscillation disable (default)	
CS[1:0]	Determine System Clock NOTE) by CBYS bit, reflection point is decided CS1 CS0 Description 0 0 fINTRC INTRC (16MHz)	

0	1	fXIN Main Clock (4~16MHz)
1	0	fSUB (32.768kHz)
1	1	fRING (125kHz)

11.2 Basic Interval Timer

11.2.1 Overview

The MC97FG316 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 (BITF).

The MC97FG316 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 clock function, time interrupt occurrence

11.2.2 Block Diagram

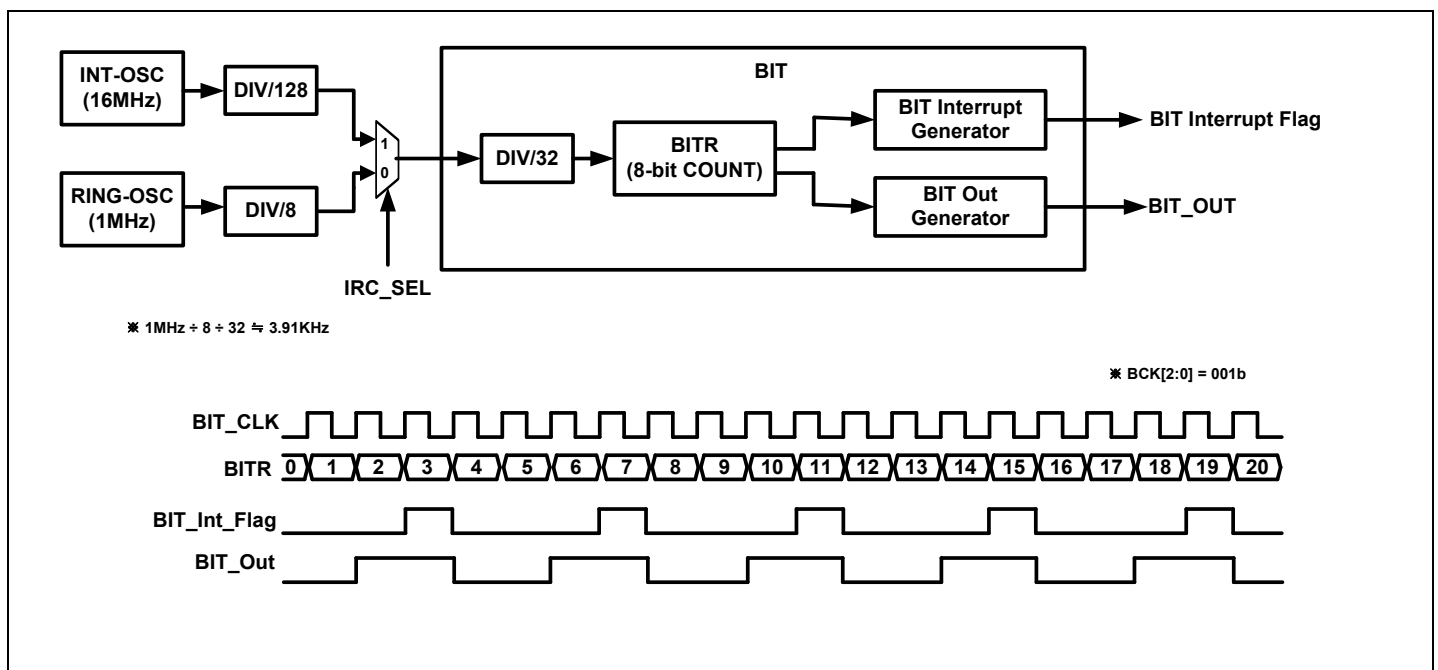


Figure 11.2 Basic Interval Timer Block Diagram

11.2.3 Register Map

Name	Address	Dir	Default	Description
BCCR	8BH	R/W	05H	BIT Clock Control Register
BITR	8CH	R	00H	Basic Interval Timer Register

Table 11.2 Register Map

11.2.4 Basic Interval Timer Register Description

The Basic Interval Timer Register consists of Basic Clock control register (BCCR) and Basic Interval Timer register (BITR). If BCLR bit set to '1', BITR becomes '0' and then counts up. After 1 machine cycle, BCLR bit is cleared as '0' automatically.

11.2.5 Register Description for Basic Interval Timer

BCCR (BIT Clock Control Register) : 8BH

7	6	5	4	3	2	1	0
BITF	-	NCen	IRC_SEL	BCLR	BCK2	BCK1	BCK0
RW	R	R	R	RW	RW	RW	RW

Initial value : 05H

BITF	When BIT Interrupt occurs, this bit becomes '1'. For clearing bit, write '0' to this bit.			
	0	no generation		
	1	generation		
NCen	Noise Cancel enable. (Test Only)			
	0	Disable (default)		
	1	Enable		
IRC_SEL	BIT Clock selection.			
	0	RING-OSC(1MHz) selection		
	1	INT-OSC(16MHz) selection		
BCLR	If BCLR bit is written to '1', BIT Counter is cleared as '0'			
	0	Free Running		
	1	Clear Counter		
BCK[2:0]	Select BIT overflow period (BIT Clock $\div$ 3.9kHz $\div$ 0.256msec)			
	BCK2	BCK1	BCK0	
	0	0	0	0.512msec (BIT Clock * 2)
	0	0	1	1.024msec (BIT Clock * 4)
	0	1	0	2.048msec (BIT Clock * 8)
	0	1	1	4.096msec (BIT Clock * 16)
	1	0	0	8.192msec (BIT Clock * 32)
	1	0	1	16.384msec (BIT Clock * 64 : default)
	1	1	0	32.768msec (BIT Clock * 128)
	1	1	1	65.536msec (BIT Clock * 256)

BITR (Basic Interval Timer Register) : 8CH

7	6	5	4	3	2	1	0
BIT7	BIT6	BIT5	BIT4	BIT3	BIT2	BIT1	BIT0
R	R	R	R	R	R	R	R

Initial value : 00H

BIT[7:0]	BIT Counter
----------	-------------

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. When 75% of the overflow time is reached, a watchdog interrupt can be generated. The overflow time of the watchdog timer can select by WDTOVF[2:0] of WDTCR. If an overflow occurs, an internal reset is generated. The WDTRC operation in the STOP/IDLE mode differs as follows depending on the setting value of WDTPDON. If WDTPDON = 0, the WDTRC operation stop in the STOP/IDLE mode and if WDTPDON = 1, the WDTRC operation in the STOP/IDLE mode. The watchdog timer operates on the 5kHz embedded 3.9Khz RC oscillator clock.

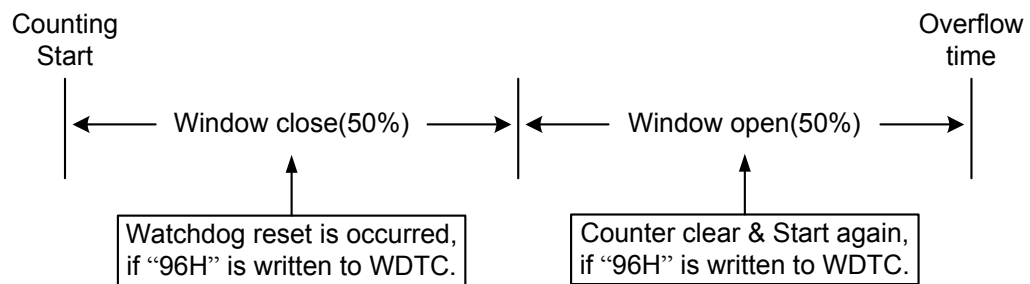
Watchdog reset is occurred in the following cases:

- When the watchdog timer counter overflows
- When the data except “96H” is written to the WDTC register
- When the data “96H” is written to the WDTC register during a window close period

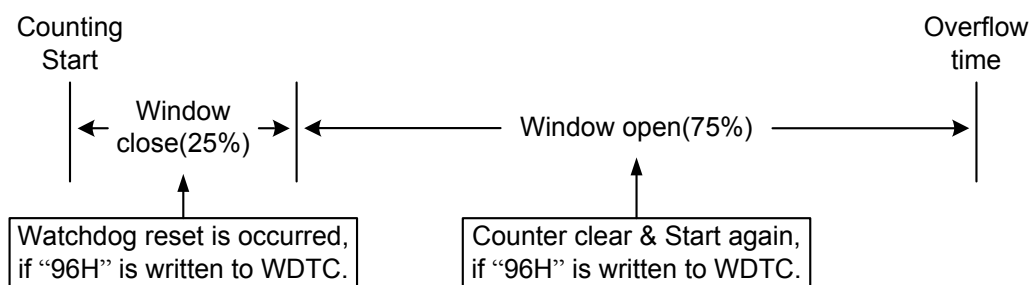
11.3.2 Setting window open period of watchdog timer

The window open period of the watchdog timer can select as 50%, 75%, and 100% by WINDOW[1:0] of WDTCR. If the data "96H" is written to the WDTC register during a window close period, watchdog reset is occurred. And if the data "96H" is written to the WDTC register during a window open period, watchdog timer counter is cleared and start counting again.

1. WDT window open period is selected as 50%.



2. WDT window open period is selected as 75%.



3. WDT window open period is selected as 100%.

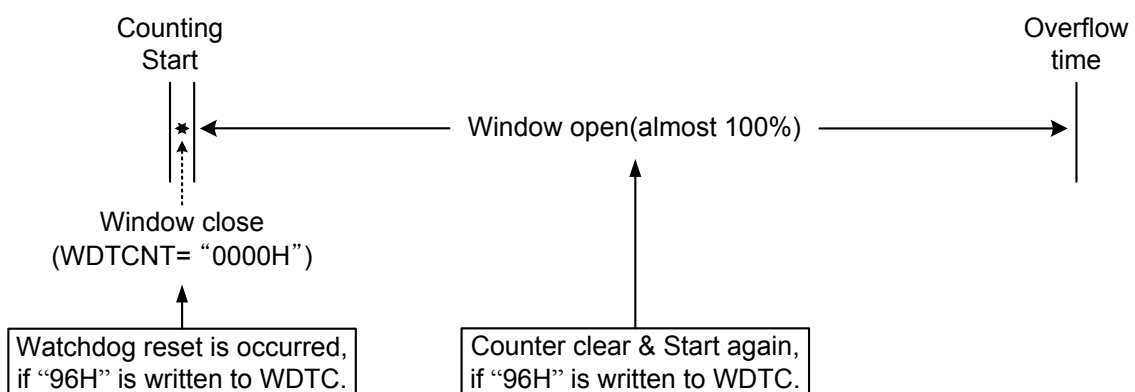


Figure 11.3 Window open period of watchdog timer

Setting of window open period	Window close period	Window open period
50%, WINDOW[1:0]=00b & WDTPDON = 1	50%	50%
75%, WINDOW[1:0]=01b & WDTPDON = 1	25%	75%
100%, WINDOW[1:0]=10b & WDTPDON = 1	WDTCNT = "0000H"	Almost 100%
100%, WDTPDON = 0	WDTCNT = "0000H"	Almost 100%

Table 11.3 Setting window open period of watchdog timer

NOTE)

The window open period is 100% when WDTPDON = 0, regardless the value of the WINDOW[1:0] of WDTCR.

11.3.3 Block Diagram

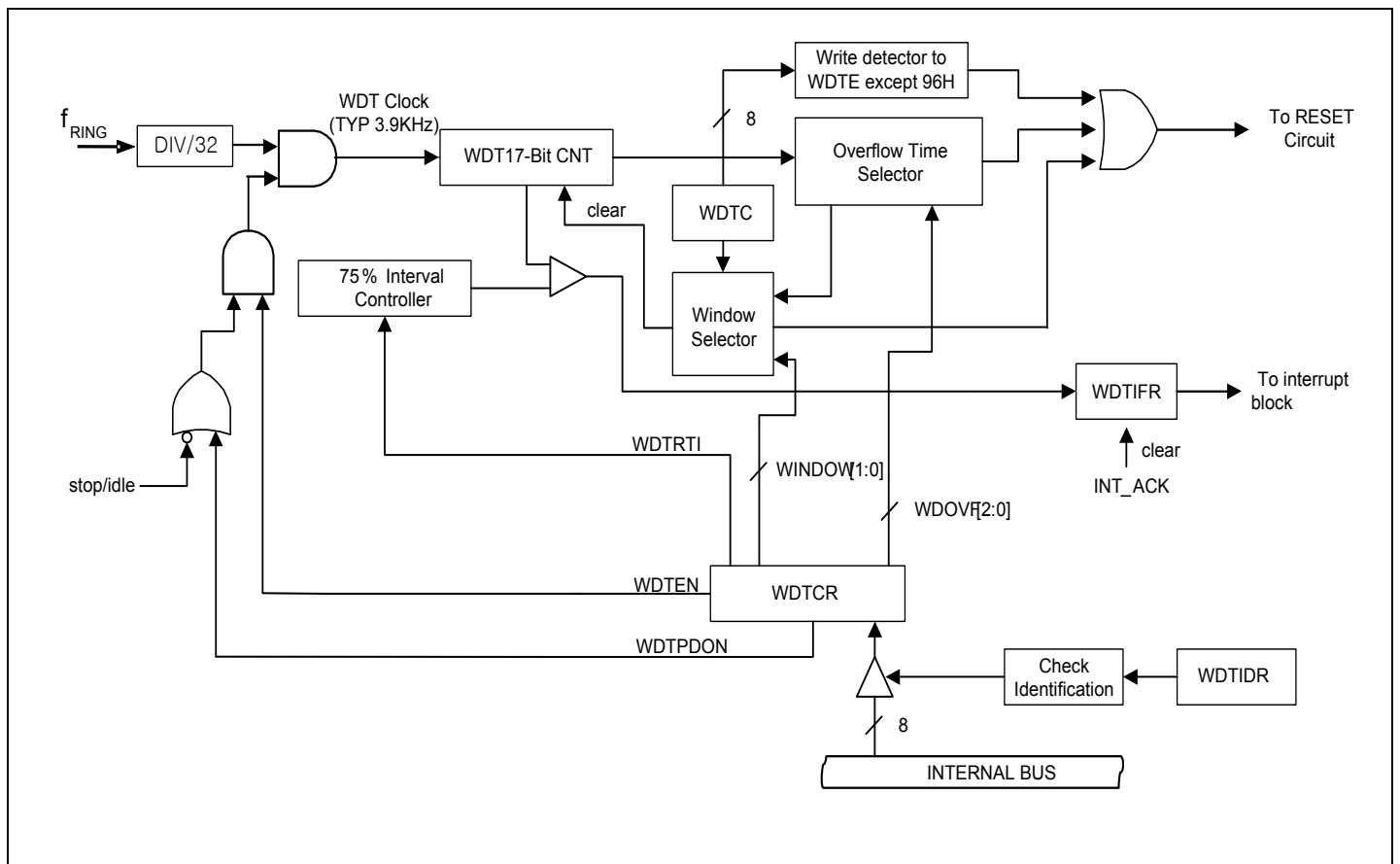


Figure 11.4 WDT Block Diagram

11.3.4 Register Map

Name	Address	Dir	Default	Description
WDTDC	2F14H	R/W	00H	Watch Dog Timer Clear Register
WDTSR	2F15H	R/W	00H	Watch Dog Timer Status Register
WDTIDR	8EH	R/W	00H	Watch Dog Timer Identification Register
WDTCR	8DH	R/W	07H	Watch Dog Timer Control Register
WDTCNTH	2F16H	R	00H	Watch Dog Timer Count H Register
WDTCNTH	2F17H	R	00H	Watch Dog Timer Count L Register

Table 11.4 Register Map

11.3.5 Watch Dog Timer Register Description

The Watch dog timer (WDT) Register consists of Watch Dog Timer Clear Register (WDTC), Watch Dog Timer Status Register (WDTSR), Watch Timer Identification Register(WDTIDR), Watch Timer Control Register(WDTCR) and Watch Dog Timer Count Register (WDTCNTH,WDTCNTL).

11.3.6 Register Description for Watch Dog Timer

WDTCNTH (Watch Dog Timer Counter High Register) : 2F16H

7	6	5	4	3	2	1	0
WDTCNT15	WDTCNT14	WDTCNT13	WDTCNT12	WDTCNT11	WDTCNT10	WDTCNT9	WDTCNT8
R	R	R	R	R	R	R	R

Initial value : 00H

WDTCNT[15:8] WDT Counter High

WDTCNTL (Watch Dog Timer Counter Low Register) : 2F17H

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[15:8] WDT Counter Low

WDTC (Watch Dog Timer Clear Register) : 2F14H

7	6	5	4	3	2	1	0
WDTC7	WDTC6	WDTC5	WDTC4	WDTC3	WDTC2	WDTC1	WDTC0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

WDTC[7:0] WDT Counter clear
Others Reset occurs.
10010110 WDT counter clear and start again.

WDTSR (Watch Dog Timer Status Register) : 2F15H

7	6	5	4	3	2	1	0
-	-	-	-	-	-	WSTATE	WDTIFR
-	-	-	-	-	-	R	RW

Initial value : 00H

WSTATE Window Status.
0 Close window.
1 Open window.

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.

WDTIDR (Watch Dog Timer Identification Register) : 8EH

7	6	5	4	3	2	1	0
WDTID7	WDTID6	WDTID5	WDTID4	WDTID3	WDTID2	WDTID1	WDTID0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

WDTIDR[7:0] WDT Identification for a WDTCR

Others No identification value.

01011001 Identification value for a WDTCR write.

(These bits are automatically cleared to logic '00H' immediately after WDTCR write.)

WDTCR (Watch Dog Timer Control Register) : 8DH

7	6	5	4	3	2	1	0
WDTEN	WDTRTI	WDTPDON	WINDOW1	WINDOW0	WDOVF2	WDOVF1	WDOVF0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 07H

WDTEN Control WDT operation

0 Disable (WDTRC Stop)

1 Enable

WDTRTI 3/4 Interval interrupt

0 Disable (WDT overflow reset used)

1 Enable

WDTPDON Operation on Stop/Idle Mode

0 WDTRC operation stop in Stop/Idle Mode

1 WDTRC operation in Stop/Idle Mode

WINDOW[1:0] Select WDT window open period

LOCKA1 LOCKA0 description

0 0 50%

0 1 75%

1 0 100%

1 1 not used

Note) The window open period is 100% when WDTPDON = 0, regardless the value of the WINDOW1 and WINDOW0 bits.

WDOVF[2:0] Select overflow time

WDOVF2 WDOVF1 WDOVF0 description

0 0 0 $2^6/f_{WDT}$ 0 0 1 $2^7/f_{WDT}$ 0 1 0 $2^8/f_{WDT}$ 0 1 1 $2^9/f_{WDT}$ 1 0 0 $2^{11}/f_{WDT}$ 1 0 1 $2^{13}/f_{WDT}$ 1 1 0 $2^{14}/f_{WDT}$ 1 1 1 $2^{16}/f_{WDT}$ **NOTE)**

When accessing WDTCR, '0x59' must be firstly written to WDTIDR.

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 mode register. To operate the watch timer, determine the input clock source, output interval and set WTEN as '1' in watch timer mode register (WTMR). It is able to execute simultaneously or individually. To stop or reset WT, clear the WTEN bit in WTMR register. Even if CPU is STOP mode, sub clock is able to be alive and so WT can continue the operation. The watch timer counter circuits is composed of 21-bit counter. Low 14-bit is binary counter and high 7-bit is auto reload counter in order to raise resolution. In WTR, 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

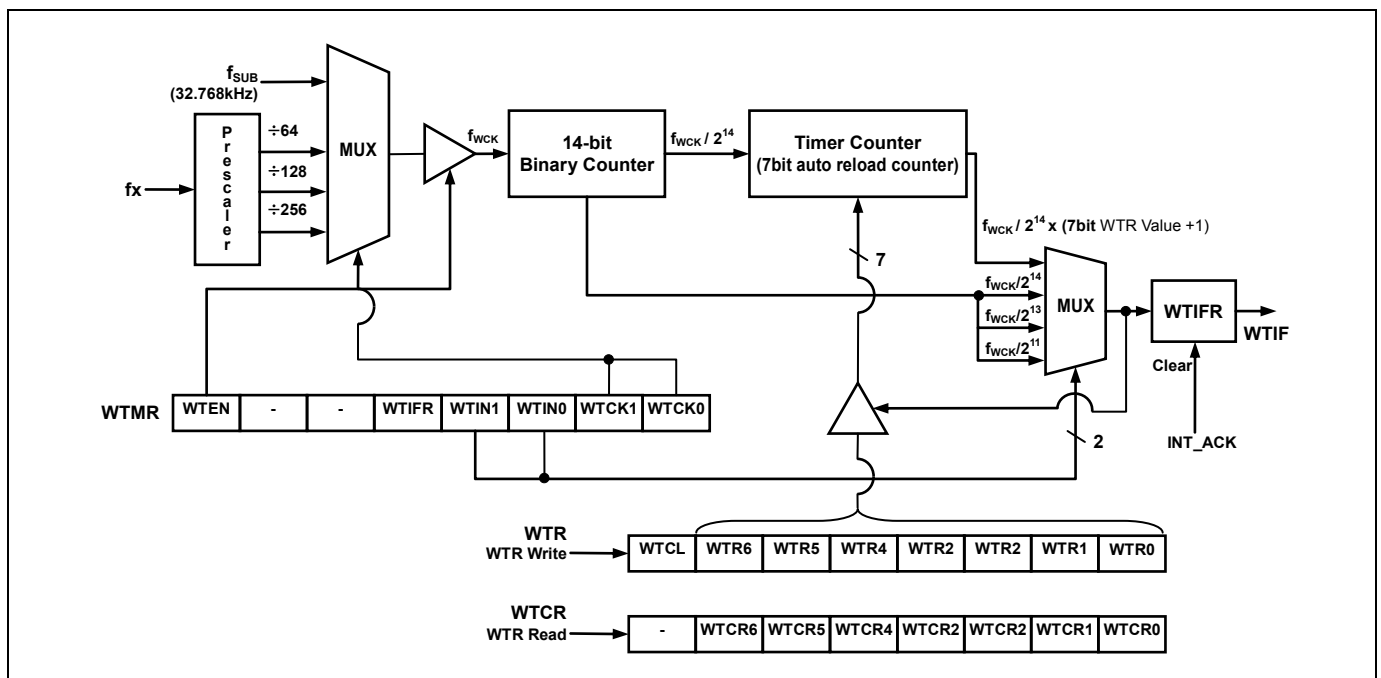


Figure 11.5 Watch Timer Block Diagram

11.4.3 Register Map

Name	Address	Dir	Default	Description
WTMR	95H	R/W	00H	Watch Timer Mode Register
WTR	96H	W	7FH	Watch Timer Register
WTCR	96H	R	00H	Watch Timer Counter Register

Table 11.5 Register Map

11.4.4 Watch Timer Register Description

The watch timer register (WT) consists of Watch Timer Mode Register (WTMR), Watch Timer Counter Register (WTCR) and Watch Timer Register (WTR). As WTMR is 6-bit writable/readable register, WTMR can control the clock source (WTCK), interrupt interval (WTIN) and function enable/disable (WTEN). Also there is WT interrupt flag bit (WTIFR).

11.4.5 Register Description for Watch Timer

WTMR (Watch Timer Mode Register) : 95H

7	6	5	4	3	2	1	0
WTEN	-	-	WTIFR	WTIN1	WTIN0	WTCK1	WTCK0
RW	-	-	RW	RW	RW	RW	RW

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 auto 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	fwck/2048
	0	1	fwck/8192
	1	0	fwck/16384
	1	1	fwck/16384 x (7bit WT Value)
WTCK[1:0]	Determine Source Clock		
	WTCK1	WTCK0	description
	0	0	fsub
	0	1	fx/256
	1	0	fx/128
	1	1	fx/64

NOTE)

1. Remark: fx– Main system clock oscillation frequency
2. fsub- Sub clock oscillation frequency
3. fwck- selected Watch Timer clock

WTR (Watch Timer Register: Write Case) : 96H

7	6	5	4	3	2	1	0
WTCL	WTR6	WTR5	WTR4	WTR3	WTR2	WTR1	WTR0
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)

WTR[6:0] Set WT period

WT Interrupt Interval=(fwck/2¹⁴) x(7bit WT Value+1)**NOTE)**

1. To guarantee proper operation, it is greater than 01H to write WTR.

WTCR (Watch Timer Counter Register: Read Case) : 96H

7	6	5	4	3	2	1	0
	WTCR6	WTCR5	WTCR4	WTCR3	WTCR2	WTCR1	WTCR0
-	R	R	R	R	R	R	R

Initial value : 00H

WTCR[6:0] WT Counter

11.5 Timer/PWM

11.5.1 8-bit Timer/Event Counter 0, 1

11.5.1.1 Overview

Timer 0 and timer 1 can be used as either two 8-bit timer/counter or one 16-bit timer/counter with combine them. Each 8-bit timer/event counter module has multiplexer, 8-bit timer data register, 8-bit counter register, mode register, input capture register, comparator. For PWM, it has PWM register (T1PPRH, T1PPRL, T1ADRH, T1ADRL, T1BDRH, T1BDRL, T1CDR, T1PCR, T1PCR2, T1PCR3, T1PHR, T1DLYA, T1DLYB, T1DLYC, T1ISR, T1IMSK).

It has seven operating modes:

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

NOTE)

1. TxDR must be set to higher than 0x03 for guaranteeing operation.

The timer/counter can be clocked by an internal or an external clock source (external EC0). The clock source is selected by clock select logic which is controlled by the clock select (T0CK[2:0], T1CK[3:0]). Also the timer/PWM/event counter 1 can use more clock sources than timer/event counter 0.

- TIMER0 clock source: $fX/(2, 4, 8, 32, 128, 512, 2048)$, EC0
- TIMER1 clock source: $fX/(1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048, 4096, 8192, 16384)$, T0CK

In the capture mode, by INT0, INT1, the data is captured into Input Capture Register. The timer 0 outputs the compare result to T0 port in 8/16-bit mode. Also the timer 1 outputs the result to T1 port in the timer mode and the PWM wave form to PWMA, PWMAB(bar), PWMB, PWMBB, PWMC, PWMCB Port(6-channel) in the PWM mode.

16BIT	CAP0	CAP1	PWM1E	T0CK[2:0]	T1CK[3:0]	T0/1_PE	Timer 0	Timer 1
0	0	0	0	XXX	XXXX	00	8-bit Timer	8-bit Timer
0	0	1	0	111	XXXX	00	8-bit Event Counter	8-bit Capture
0	1	0	0	XXX	XXXX	01	8-bit Capture	8-bit Compare Output
0	0	0	1	XXX	XXXX	11	8-bit Timer/Counter	10-bit PWM
1	0	0	0	XXX	1111	00	16-bit Timer	
1	0	0	0	111	1111	00	16-bit Event Counter	
1	1	1	0	XXX	1111	00	16-bit Capture	
1	0	0	0	XXX	1111	01	16-bit Compare Output	

Table 11.6 Timer 0,1 operating modes

11.5.1.2 8-bit Timer/Counter Mode

The 8-bit Timer/Counter Mode is selected by control registers as shown in Figure 11.6.

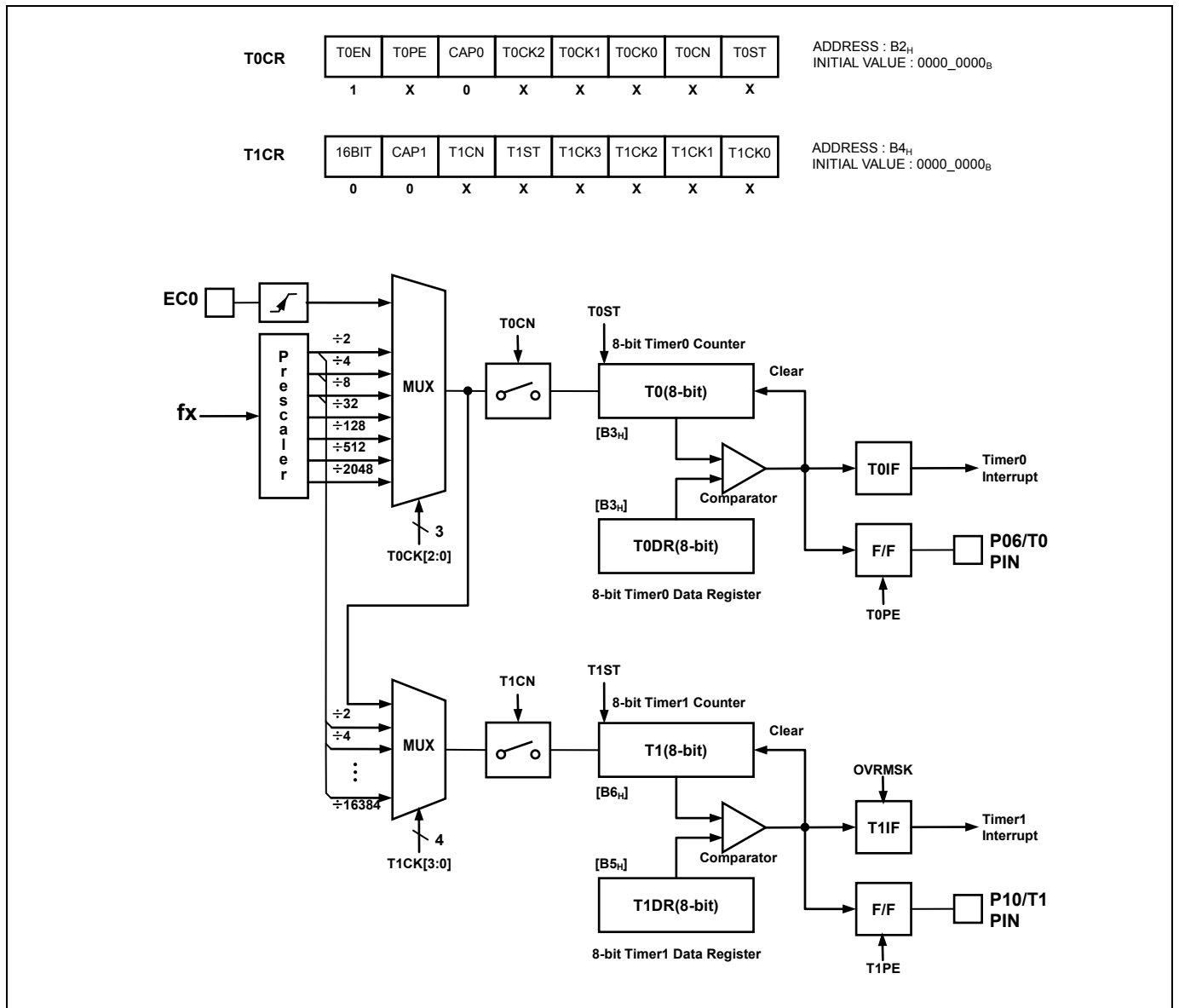


Figure 11.6 8-bit Timer/Event Counter 0, 1 Block Diagram

The two 8-bit timers have each counter and data register. The counter register is increased by internal or external clock input. The timer0 can use the input clock with one of 2, 4, 8, 32, 128, 512, 2048 prescaler division rates (T0CK[2:0]). The timer1 can use the input clock with one of 1, 2, 8 ~ 16384 and timer 0 overflow clock (T1CK[3:0]). When the value of T0/T1 value and the value of T0DR, T1DR are respectively identical in Timer0/Timer1, the interrupt of Timer0/Timer1 occurs. The external clock (EC0) counts up the timer at the rising edge. If EC0 is selected from T0CK[2:0], EC0 port becomes input port. The timer 1 can't use the external EC0 clock.

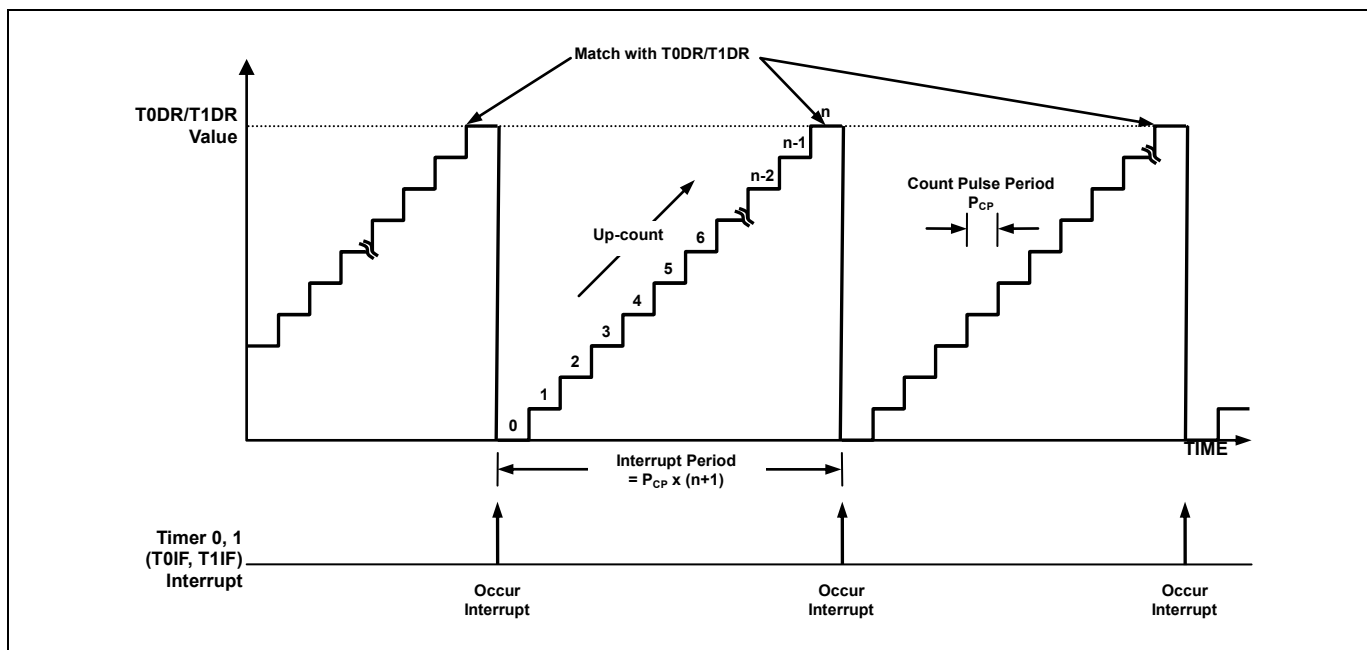


Figure 11.7 Timer/Event Counter 0, 1 Example

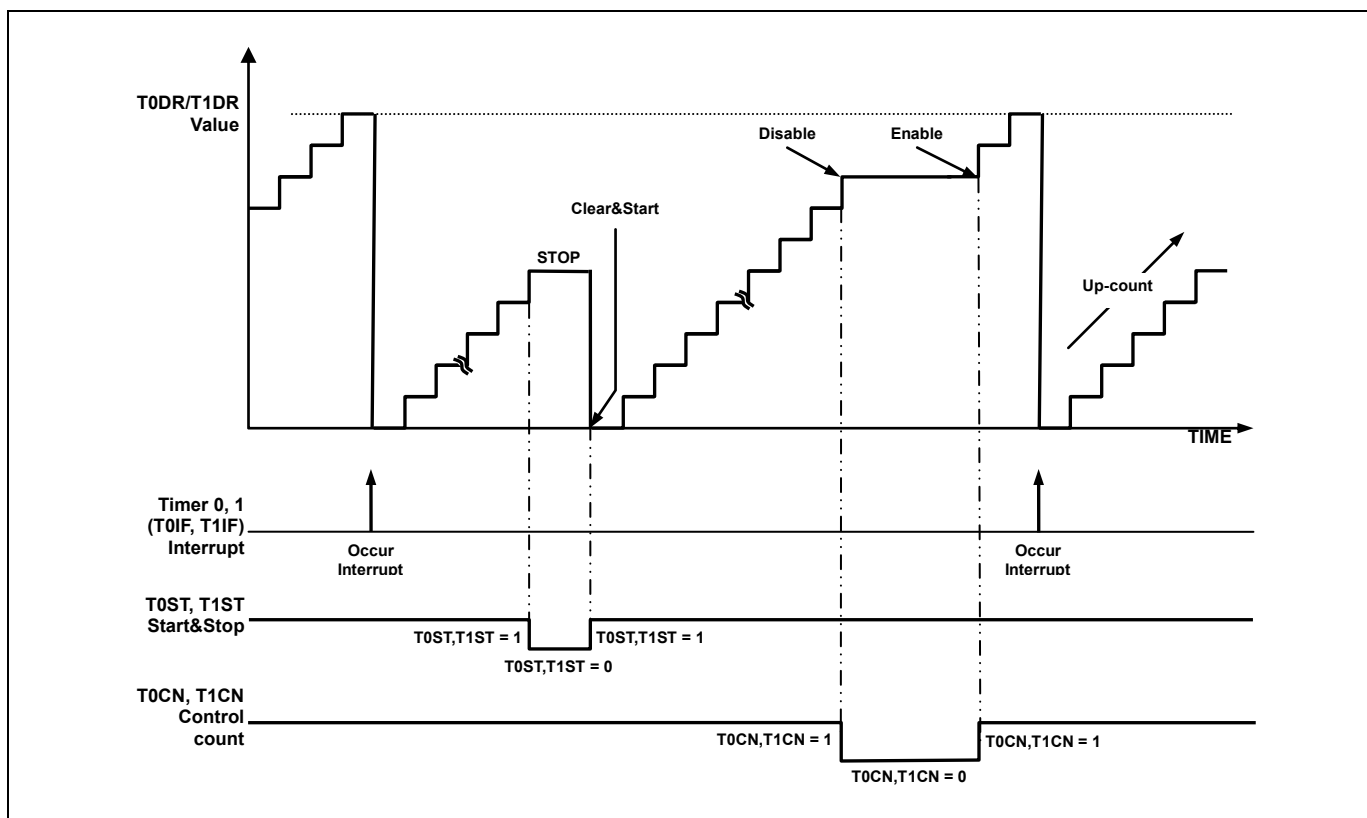


Figure 11.8 Timer/Event Counter0, 1 Count Operation

11.5.1.3 16-bit Timer/Counter Mode

The timer register runs with all 16 bits. A 16-bit timer/counter register T0, T1 are incremented from 0003H to FFFFH until it matches T0DR, T1DR to reset 0000H. The match output generates the Timer 0 interrupt (No timer 1 interrupt). The clock source is selected from T0CK[2:0] and T1CK[3:0] must set 1111b and 16BIT bit must set to '1'. The timer 0 is LSB 8-bit, the timer 1 is MSB 8-bit. T0DR must not be 0x00 (0x01~0xFF). The 16-bit mode selection is shown as Figure 11.9.

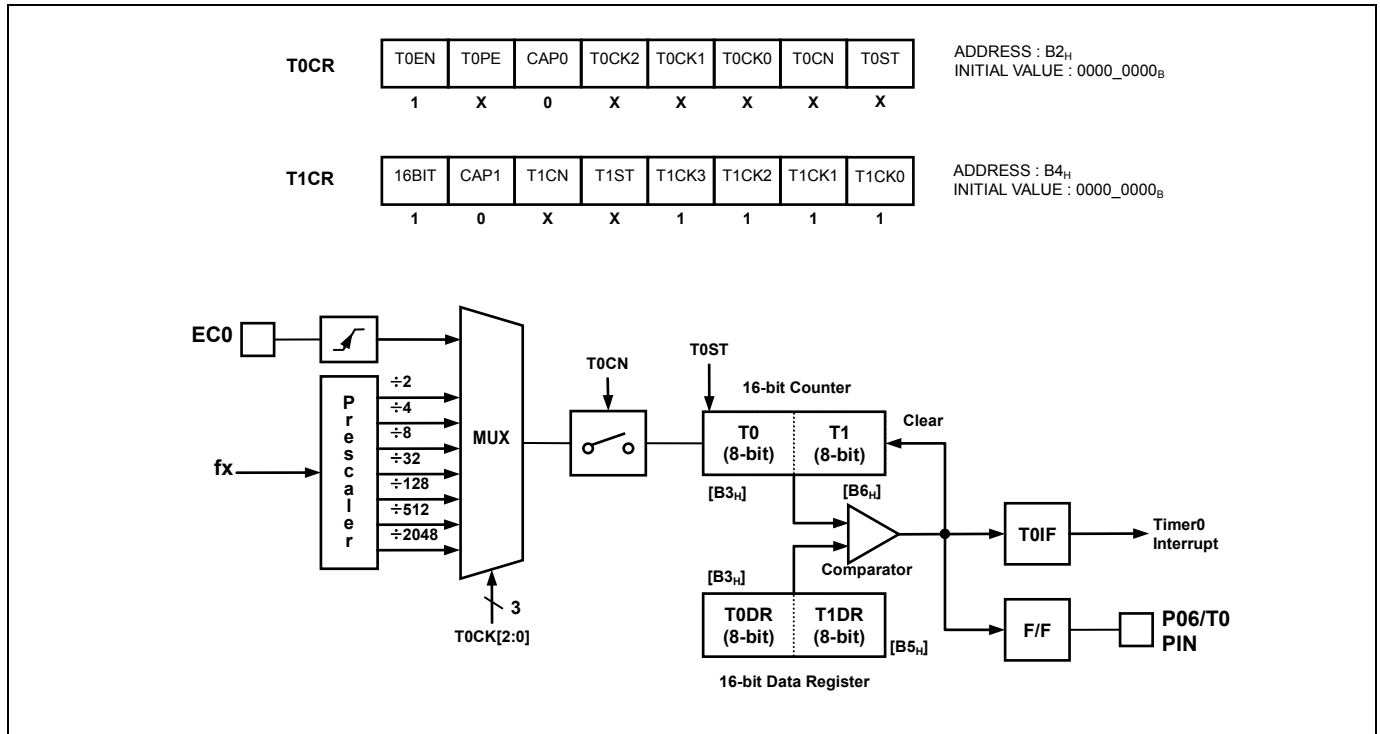


Figure 11.9 16-bit Timer/Counter for Time 0, 1

11.5.1.4 8-bit Capture Mode

The timer0/1 capture mode is evoked by setting CAP0/CAP1 as '1'. The clock source can use the internal/external clock. Basically, it has the same function of the 8-bit timer/counter mode and the interrupt occurs at T0, T1 and T0DR, T1DR matching time, respectively. The capture result is loaded into CDR0, CDR1. The T0, T1 value is automatically cleared by hardware and restarts counter.

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

As the EIEDGE and EIPOLA register setting, the external interrupt INT1, INT0 function is chosen.

The CDR0, T0 and T0DR are in same address. In the capture mode, reading operation reads the CDR0, not T0DR because path is opened to the CDR0. The CDR1 has the same function.

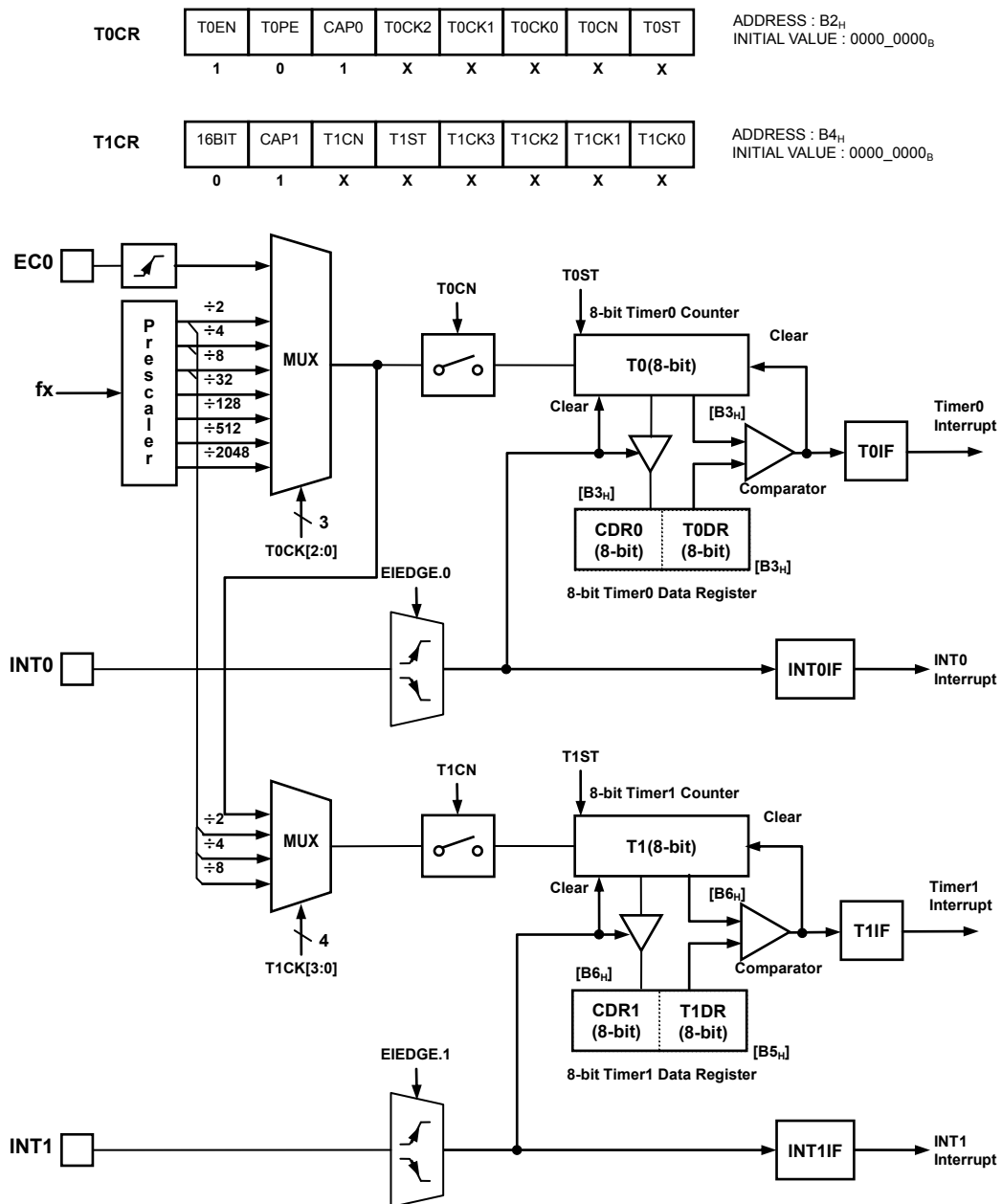


Figure 11.10 8-bit Capture Mode for Timer 0, 1

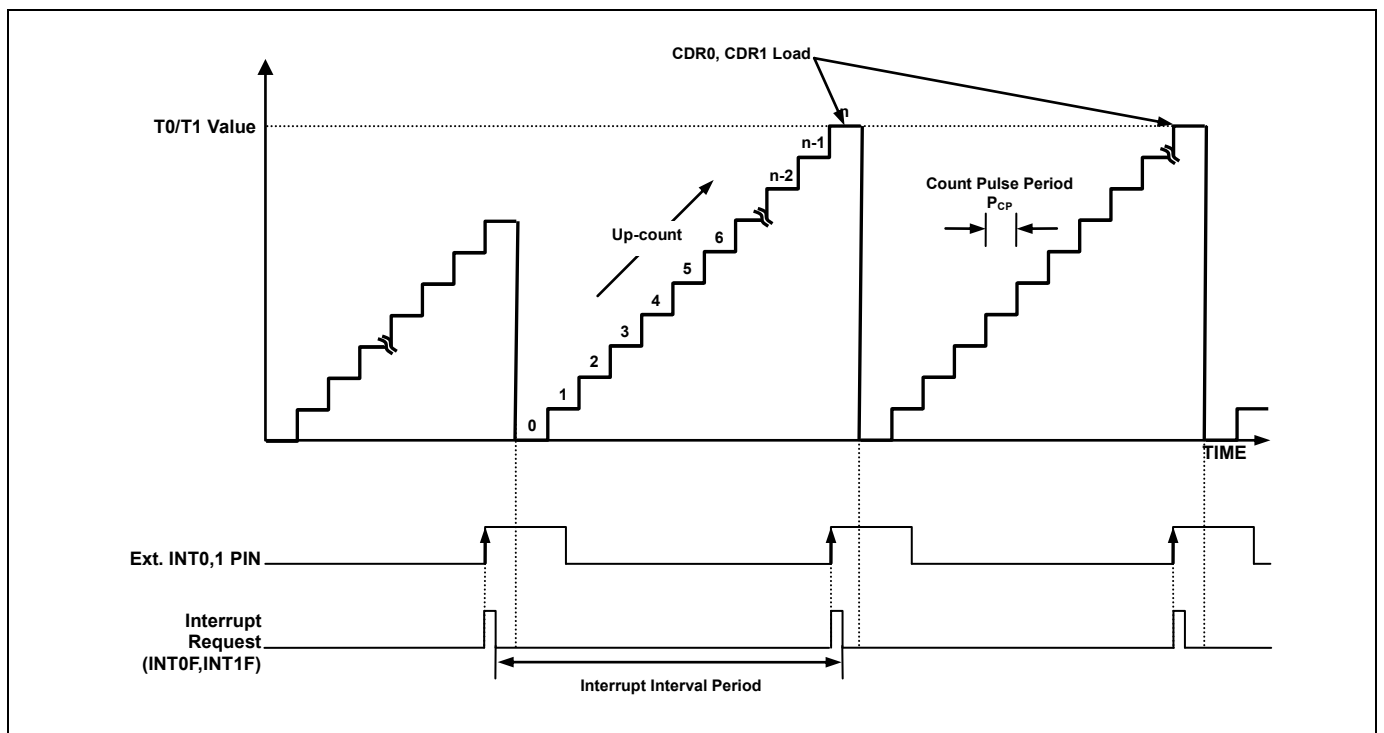


Figure 11.11 Input Capture Mode Operation of Timer 0, 1

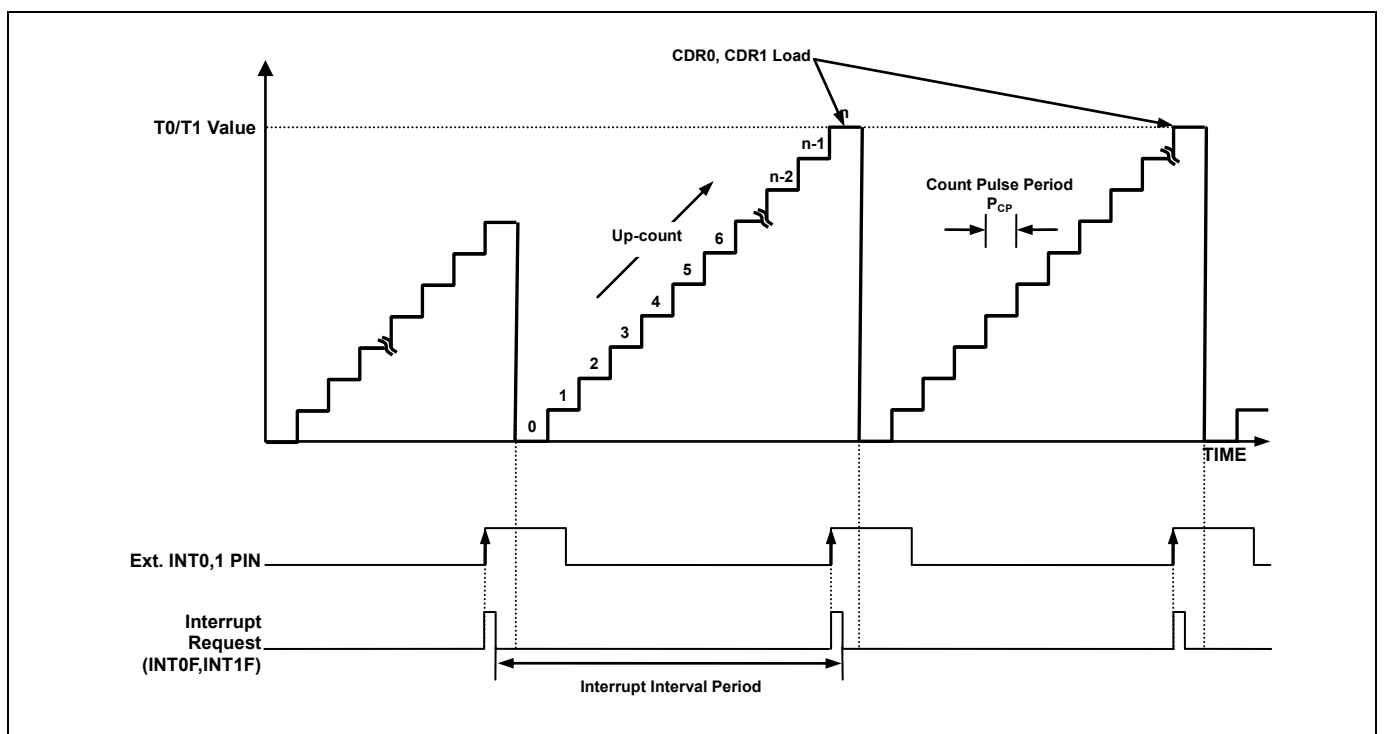


Figure 11.12 Express Timer Overflow in Capture Mode

11.5.1.5 16-bit Capture Mode

The 16-bit capture mode is the same operation as 8-bit capture mode, except that the timer register uses 16 bits. The clock source is selected from T0CK[2:0] and T1CK[3:0] must set 1111b and 16BIT bit must set to '1'. The 16-bit mode setting is shown as Figure 11.13.

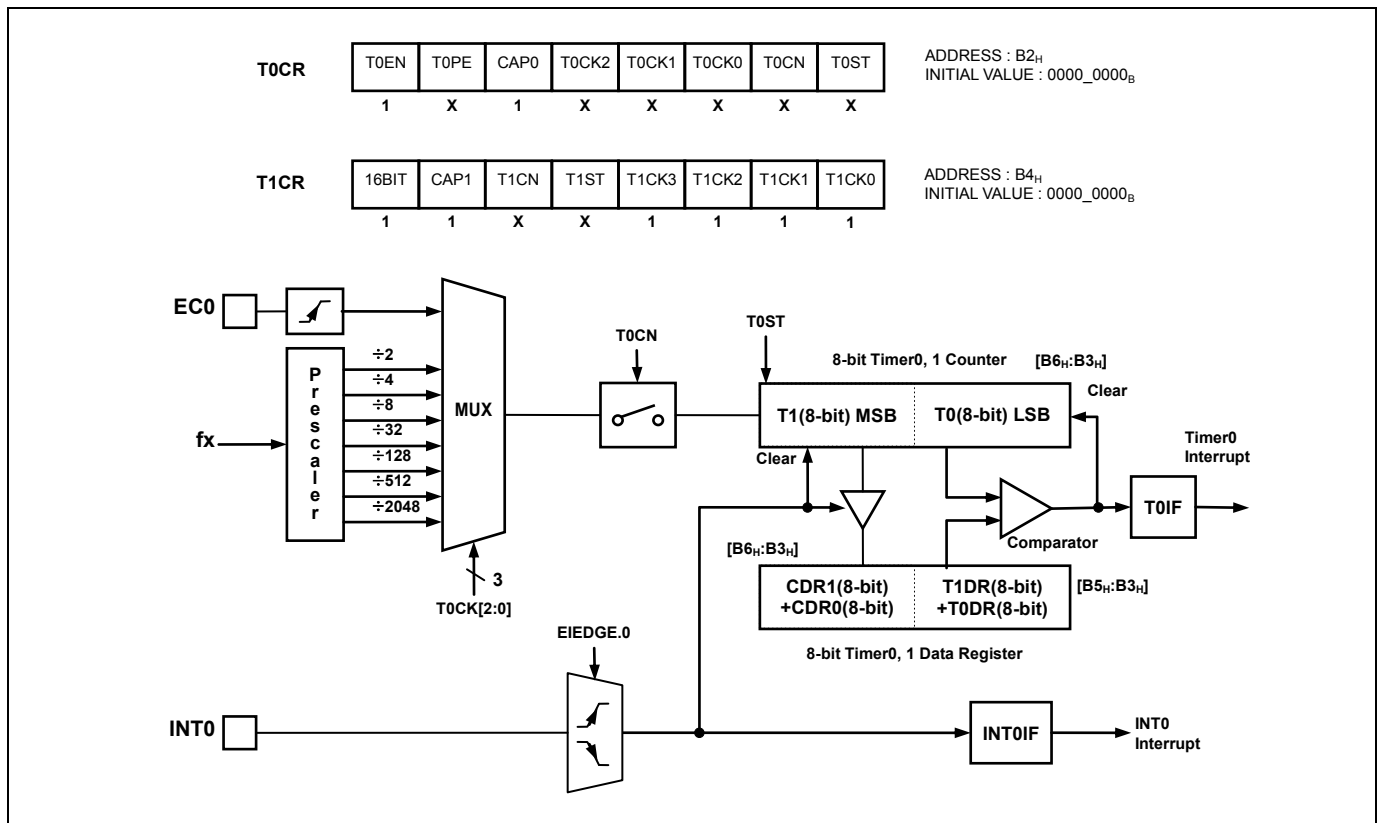


Figure 11.13 16-bit Capture Mode of Timer 0, 1

11.5.1.6 PWM Mode

The timer 1 has a high speed PWM (pulse Width Modulation) function. In PWM mode, the 6-channel pins output up to 10-bit resolution PWM output. This pin should be configured as a PWM output by set PWM1E to '1'. The period of the PWM output is determined by the T1PPRL (PWM period Low register) + T1PPRH[1:0], T1xDRL (each channel PWM duty Low register) + T1xDRH[1:0].

$$\text{PWM Period} = [T1PPRH[1:0]T1PPRL] \times \text{Source Clock}$$

$$\text{PWM Duty(A-ch)} = [T1ADRH[1:0] T1ADRL] \times \text{Source Clock}$$

NOTE)

1. T1PPRH/T1PPRL must be set to higher than T1PDR for guaranteeing operation.

Resolution	Frequency		
	T1CK[3:0]=0001 (250ns)	T1CK[3:0]=0010 (500ns)	T1CK[3:0]=0100 (2us)
10-bit	3.9kHz	1.95kHz	0.49kHz
9-bit	7.8kHz	3.9kHz	0.98kHz
8-bit	15.6kHz	7.8kHz	1.95kHz
7-bit	31.2kHz	15.6kHz	3.91kHz

Table 11.7 PWM Frequency vs. Resolution at 8MHz

The POLx bit of T1PCR3 register decides the polarity of duty cycle. If the duty value is set same to the period value, the PWM output is determined by the bit POLx (1: High, 0: Low). And if the duty value is set to "00H", the PWM output is determined by the bit POLx (1: Low, 0: High). PWM output is not retain high or low but toggle.

T1PCR	16BIT	CAP1	T1CN	T1ST	T1CK3	T1CK2	T1CK1	T1CK0
	0	0	X	X	X	X	X	X

ADDRESS : B4_H
INITIAL VALUE : 0000_0000_B

T1PCR	PWM1E	ESYNC	BMOD	PHLT	UPDT	UALL	NOPS1	NOPS0
	1	X	X	X	X	X	X	X

ADDRESS : B7_H
INITIAL VALUE : 0000_0000_B

T1PCR2	FORCA	FORCE6	PAOE	PABOE	PBOE	PBBOE	PCOE	PCOE
	X	1	X	X	X	X	X	X

ADDRESS : BD_H
INITIAL VALUE : 0000_0000_B

T1PCR3	T1_PE	POLA	POLB	POLC	POCO N	HCKE	-	PLLPD B
	X	X	X	X	X	X	X	X

ADDRESS : BE_H
INITIAL VALUE : 0000_00-0_B

T1xDRH						xDR9	xDR8
	X	X	X	X	X	X	X

ADDRESS : B1_H
INITIAL VALUE : 0000_0000_B

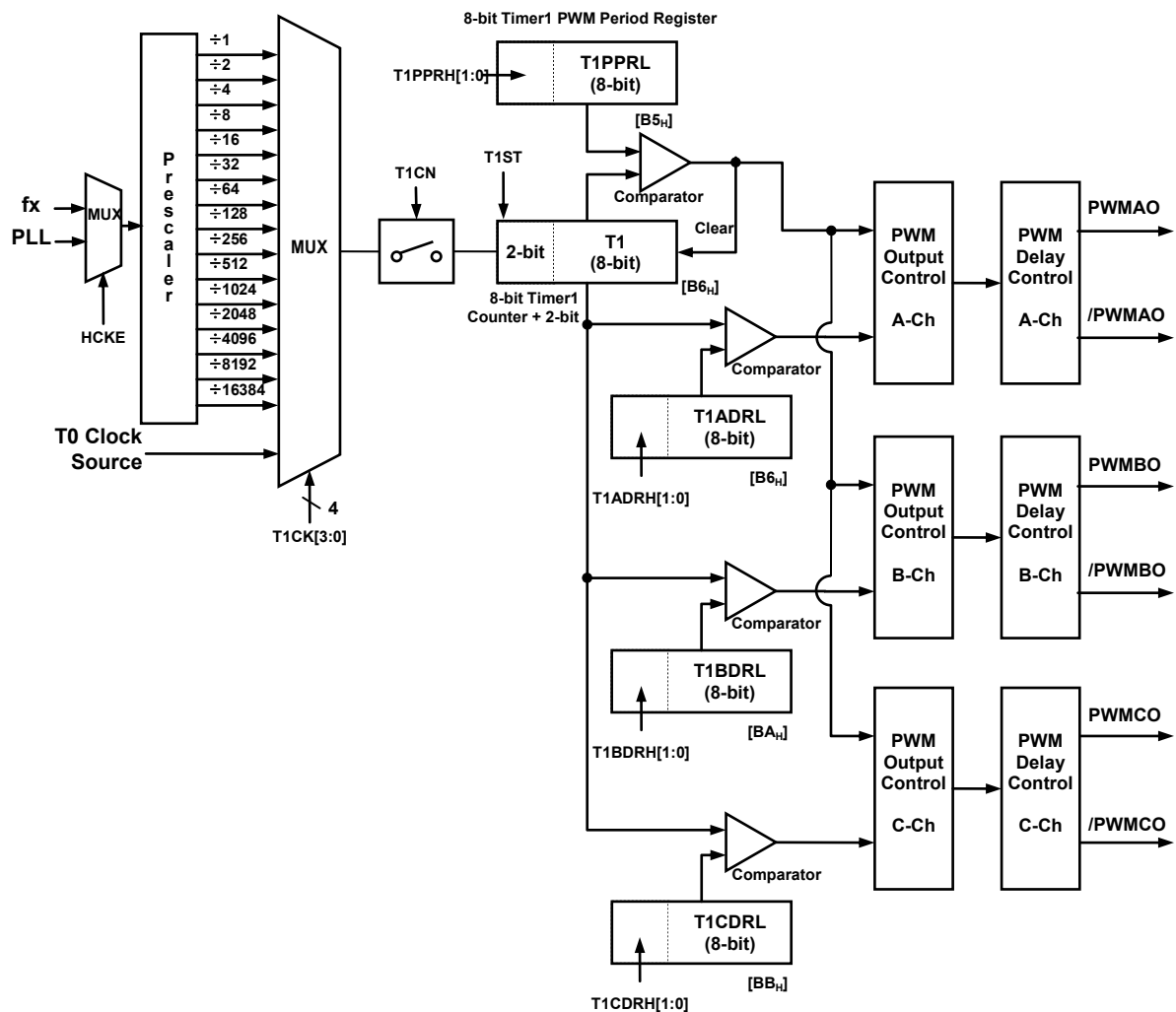


Figure 11.14 PWM Mode (Force 6-ch)

T1CR	16BIT	CAP1	T1CN	T1ST	T1CK3	T1CK2	T1CK1	T1CK0	ADDRESS : B4 _H INITIAL VALUE : 0000_0000 _B
	0	0	X	X	X	X	X	X	
T1PCR	PWM1E	ESYNC	BMOD	PHLT	UPDT	UALL	NOPS1	NOPS0	ADDRESS : B7 _H INITIAL VALUE : 0000_0000 _B
	1	X	X	X	X	X	X	X	
T1PCR2	FORCA	FORC6	PAOE	PABOE	PBOE	PBBOE	PCOE	PCOE	ADDRESS : BD _H INITIAL VALUE : 0000_0000 _B
	1	X	X	X	X	X	X	X	
T1PCR3	T1_PE	POLA	POLB	POLC	POCO N	HCKE	-	PLLPD B	ADDRESS : BE _H INITIAL VALUE : 0000_00-0 _B
	X	X	X	X	X	X	X	X	
T1xDRH							xDR9	xDR8	ADDRESS : B1 _H INITIAL VALUE : 0000_0000 _B
	X	X	X	X	X	X	X	X	

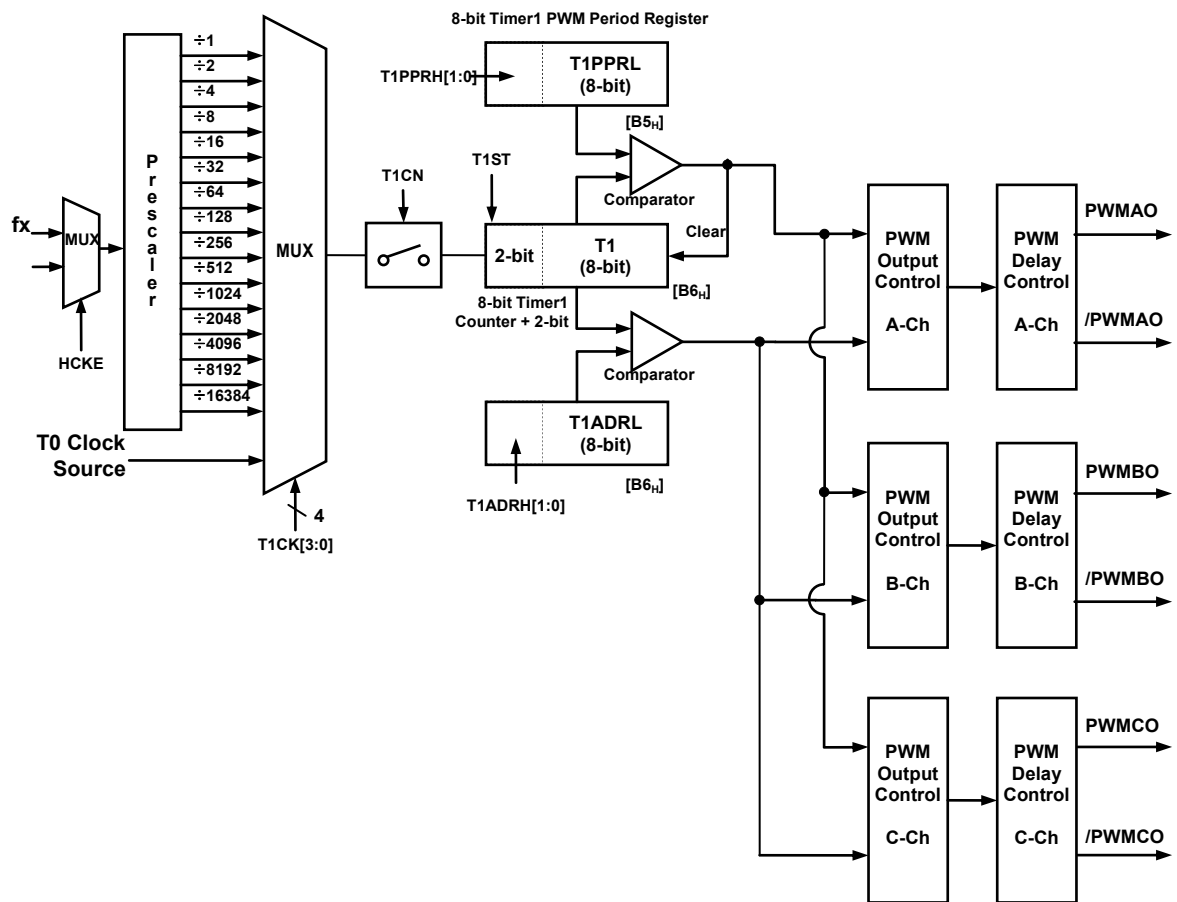


Figure 11.15 PWM Mode (Force All-ch)

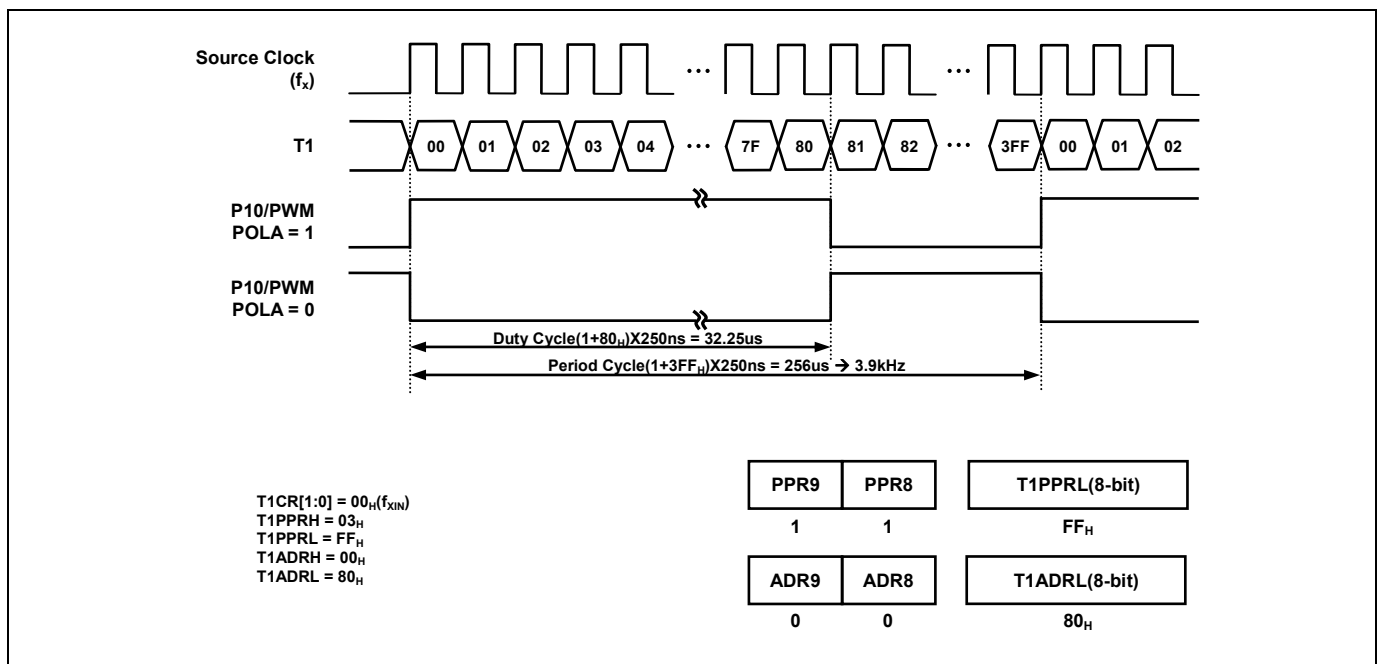


Figure 11.16 Example of PWM at 4MHz

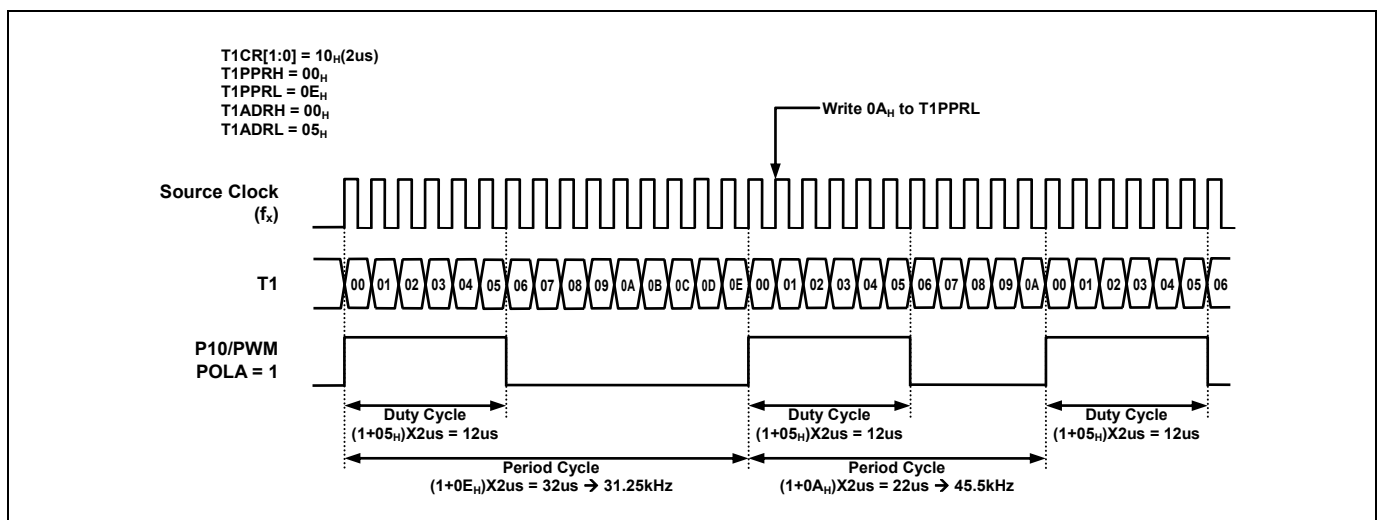


Figure 11.17 Example of Changing the Period in Absolute Duty Cycle at 4MHz

Update period & duty register value at once

The period and duty of PWM comes to move from temporary registers to PPRH/L (PWM Period High/Low Register) and PDR (PWM Duty Register) when always period match occurs. If you want that the period and duty is immediately changed, the UPDT bit in the T1PCR register must set to '1'. It should be noted that it needs the 3 cycle of timer clock for data transfer in the internal clock synchronization circuit. So the update data is written before 3 cycle of timer clock to get the right output waveform.

Phase correction & Frequency correction

On operating PWM, the phase and the frequency can be changed by using BMOD bit (back-to-back mode) in T1PCR register. (Figure 11.18, Figure 11.19, Figure 11.20 referred)

In the back-to-back mode, the counter of PWM repeats up/down count. In fact, the effective duty and period becomes twofold of the register set values. (Figure 11.18, Figure 11.19 referred)

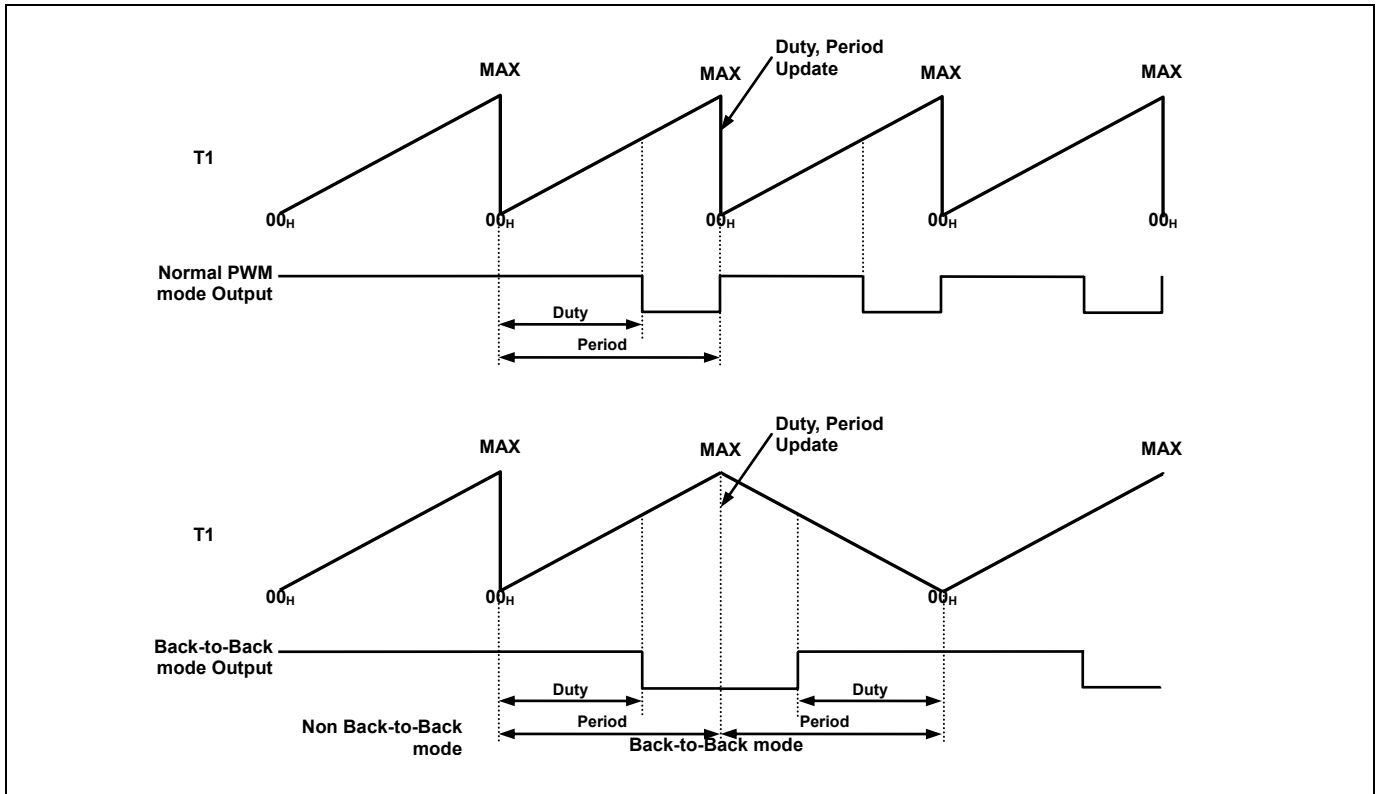


Figure 11.18 Example of PWM Output Waveform

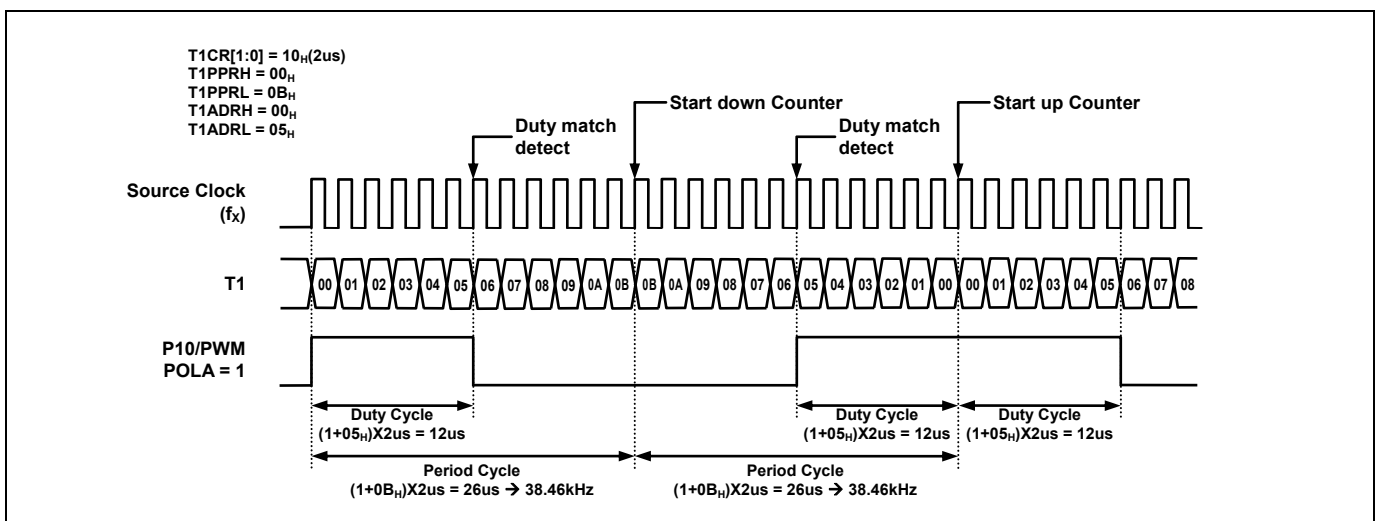


Figure 11.19 Example of PWM waveform in Back-to-Back mode at 4Mhz

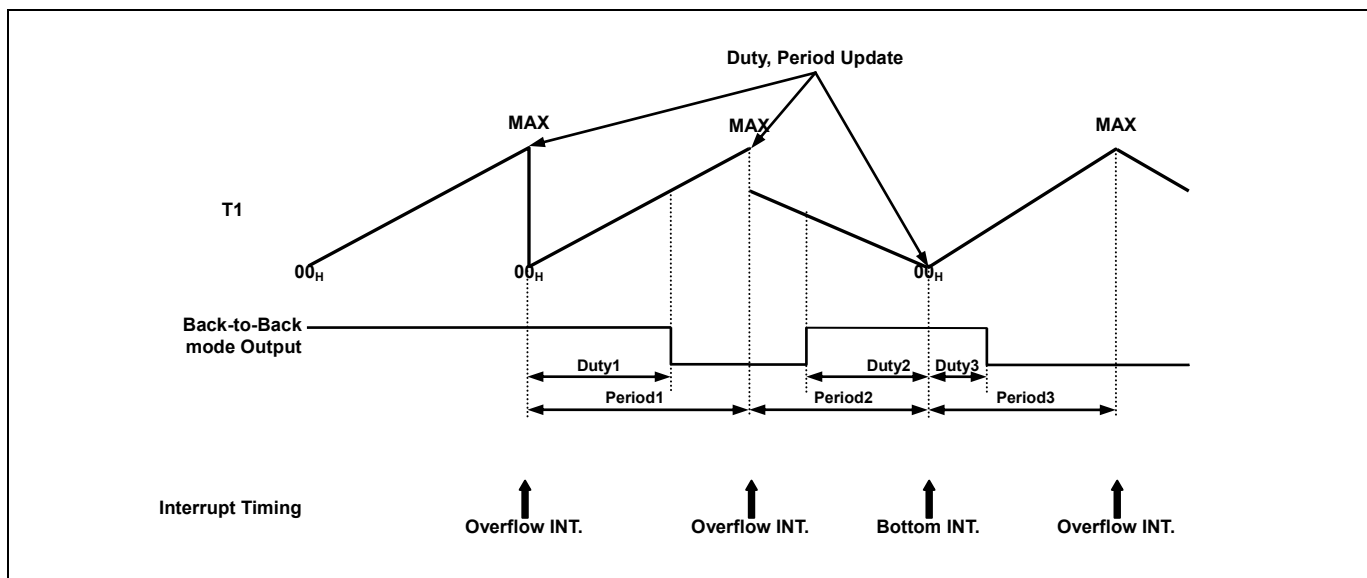


Figure 11.20 Example of Phase Correction and Frequency correction of PWM

External Sync

If using ESYNC bit of T1PCR register, it is possible to synchronize the output of PWM from external signal.

If ESYNC bit sets to '1', the external signal moves to PWM module through the BLNKB pin (P16). If BLNKB signal is low, immediately PWM output becomes a reset value, and internal counter becomes reset. If BLNKB signal returns to '1', the counter is started again and PWM output is normally generated. (Figure 11.21 referred)

PWM Halt

If using PHLT bit of T1PCR register, it is possible to stop PWM operation by the software. During PHLT bit being '1', PWM output becomes a reset value, and internal counter becomes reset as 0. Without changing PWM setting, it can temporarily stop PWM. In case of T1CN, when stopping counter, PWM output pin remains before states. But if PHLT bit sets to '1', PWM output pin has reset value.

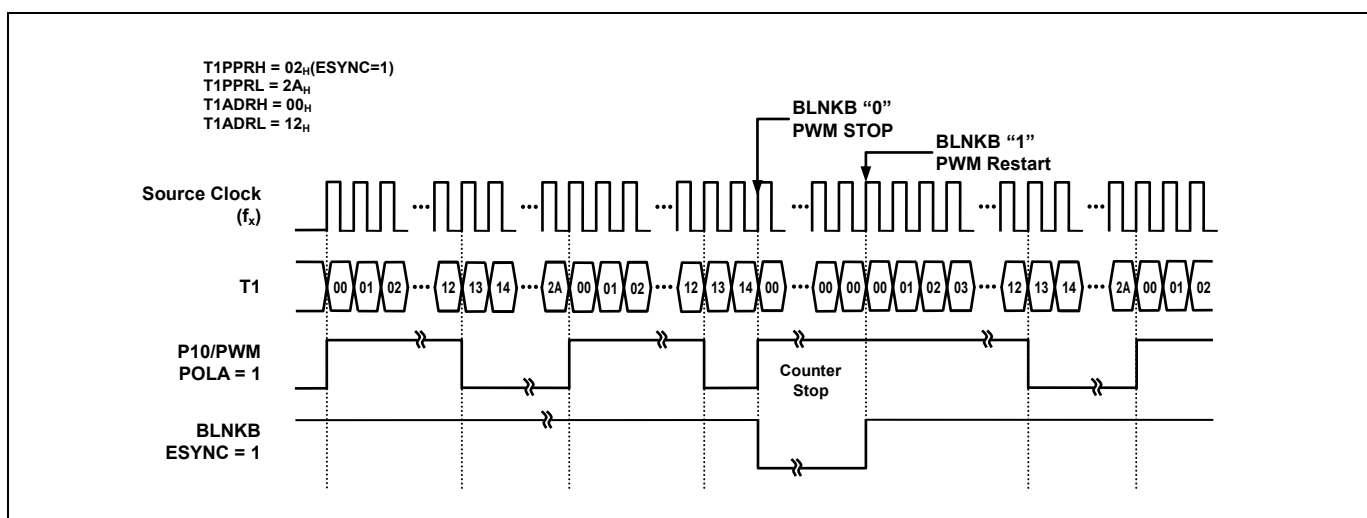


Figure 11.21 Example of PWM External Synchronization with BLNKB Input

FORCE Drive ALL ch with A-ch mode

If FORCA bit sets to '1', it is possible to enable or disable all PWM output pins through PWM outputs which occur from A-ch duty counter. It is noted that the inversion outputs of A, B, C channel have the same A-ch output waveform. According to POLA/B/C, it is able to control the inversion of outputs.

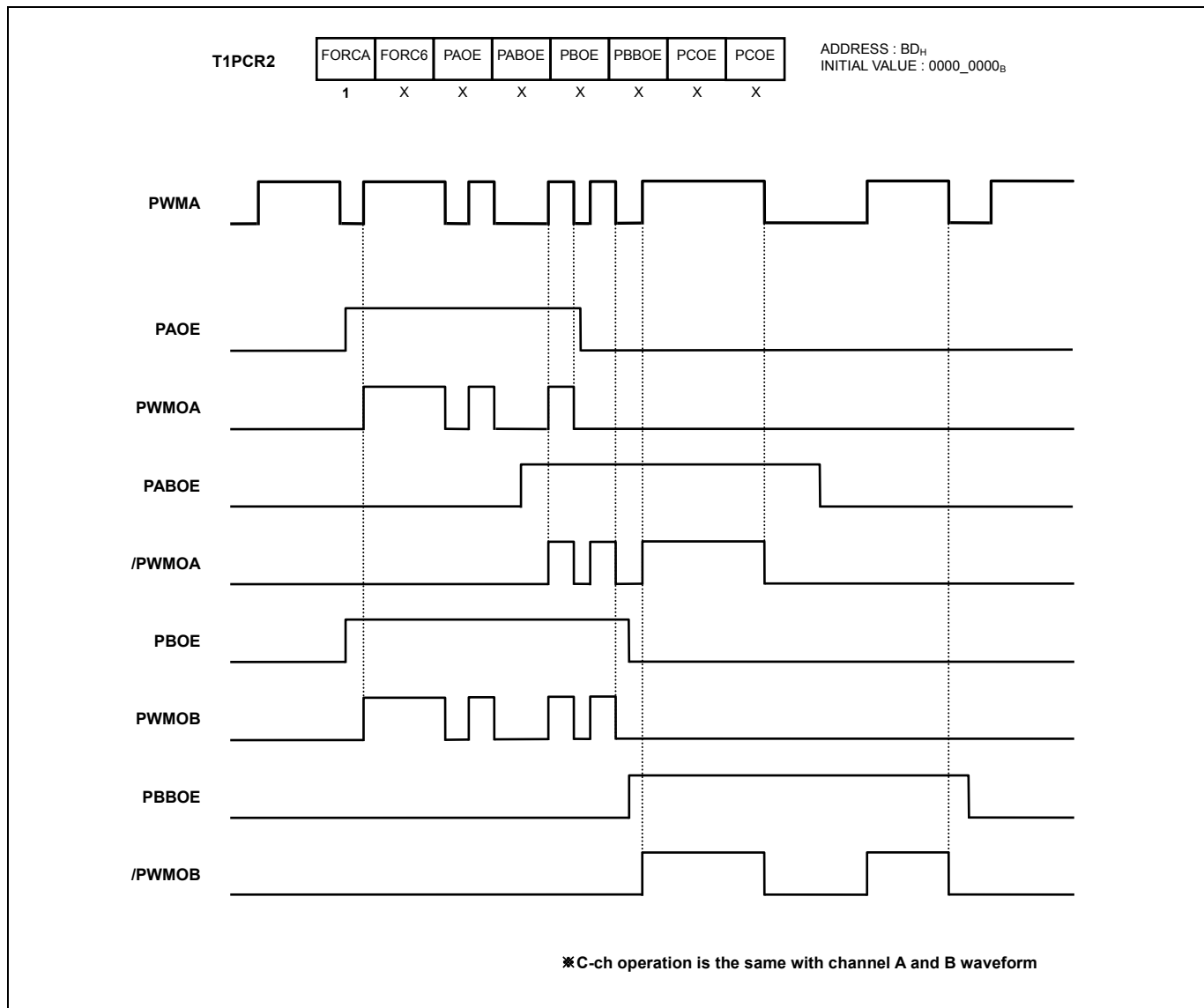


Figure 11.22 Example of Force Drive All-ch with A-ch

FORCE 6-ch Drive

If FORC6 bit sets to '1', it is possible to enable or disable PWM output pin and inversion output pin generated through the duty counter of each channel. The inversion output is the reverse phase of the PWM output. A A/AB output of the A-channel duty register, a B/BB output of the B-channel duty register, a C/CB output of the C-channel duty register are controlled respectively. If the UALL bit is set to '1', it is updated B/C channel duty at the same time, when it is written by a A-channel duty register.

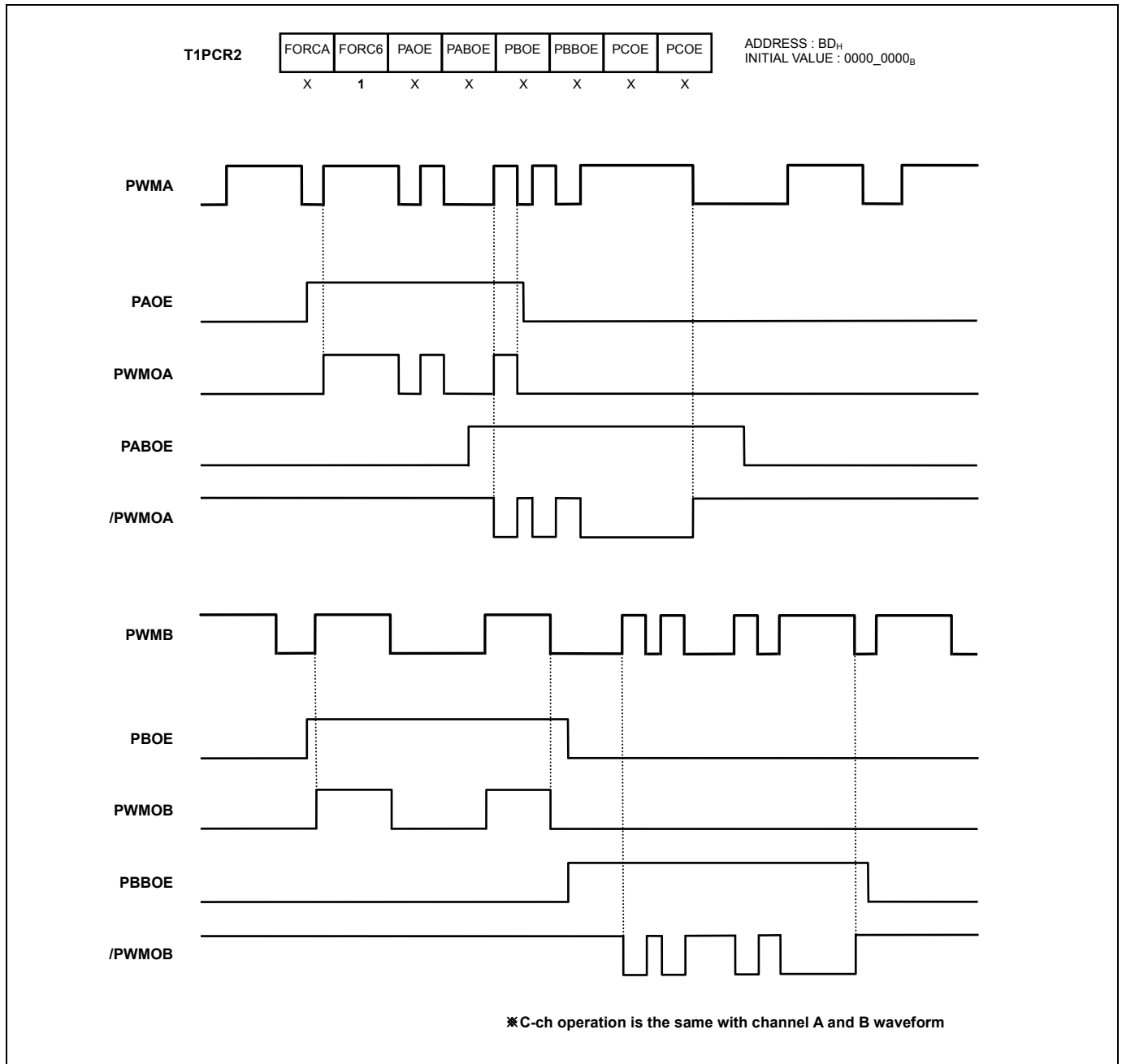


Figure 11.23 Example of Force Drive 6-ch Mode

T1CR	16BIT	CAP1	T1CN	T1ST	T1CK3	T1CK2	T1CK1	T1CK0	ADDRESS : B4 _H INITIAL VALUE : 0000_0000 _B
	0	0	X	X	X	X	X	X	
T1PCR	PWM1E	ESYNC	BMOD	PHLT	UPDT	UALL	NOPS1	NOPS0	ADDRESS : B7 _H INITIAL VALUE : 0000_0000 _B
	X	X	X	X	X	X	X	X	
T1PCR2	FORCA	FORC6	PAOE	PABOE	PBOE	PBBOE	PCOE	PCOE	ADDRESS : BD _H INITIAL VALUE : 0000_0000 _B
	X	X	X	X	X	X	X	X	
T1PCR3	T1_PE	POLA	POLB	POLC	POCON	HCKE	-	PLLPD B	ADDRESS : BE _H INITIAL VALUE : 0000_00-0 _B
	X	X	X	X	X	X	X	X	

PWM1E	T1_PE	FORCA FORC6	POCON	P1xE P1xBE	Port Control
0	1	X	X	X	T1 (timer1) output enable
1	1	0	0	X	All 6 PWM outputs enable
1	1	0	1	X	GPIO get control, when PWM stop*
1	X	1	0	0	Corresponding PWM output "0"
1	X	1	0	1	Corresponding PWM outputs enable
1	X	1	1	0	GPIO get control for disabled channels
1	X	1	1	1	Corresponding PWM outputs enable

* PWM stop condition : when ESYNC = "1", BLANKB can stop PWM1 or PHLT bit was set("1")
When POCON is set "1", ports direction of the disabled PWM channels would be controlled by GPIO registers. So if user set GPIO direction register as input mode for corresponding pins, disabled PWM pins would be input mode.

The port is fixed as the output at the Timer mode. But at the PWM mode, using POCON bit , when PWM output port does not work, it can change the state of output port to input (high-Z) state. It is determined from the port control register to select in/out signal. If using FORCE mode, it can only change the wanted channel direction of the 6-channel outputs. In the FORCE mode, the channel direction of the disabled output is determined by each port control register bit, regardless of the PWM stop.

Figure 11.24 PWM Port control

PWM output Delay

If using the PDLYA, PDLYB, PDLYC register, it can delay PWM output based on the rising edge. At that time, it does not change the falling edge, so the duty is reduced as the time delay. In POLA/B/C setting to '0', the delay is applied to the falling edge. In POLA/B/C setting to '1', the delay is applied to the rising edge. It can produce a pair of Non-overlapping clock. The each channel is able to have 4-bit delay. As it can select the clock up to 1/8 divided clock using NOPS1, NOPS0, the delay of its maximum 128 timer clock cycle is produced.

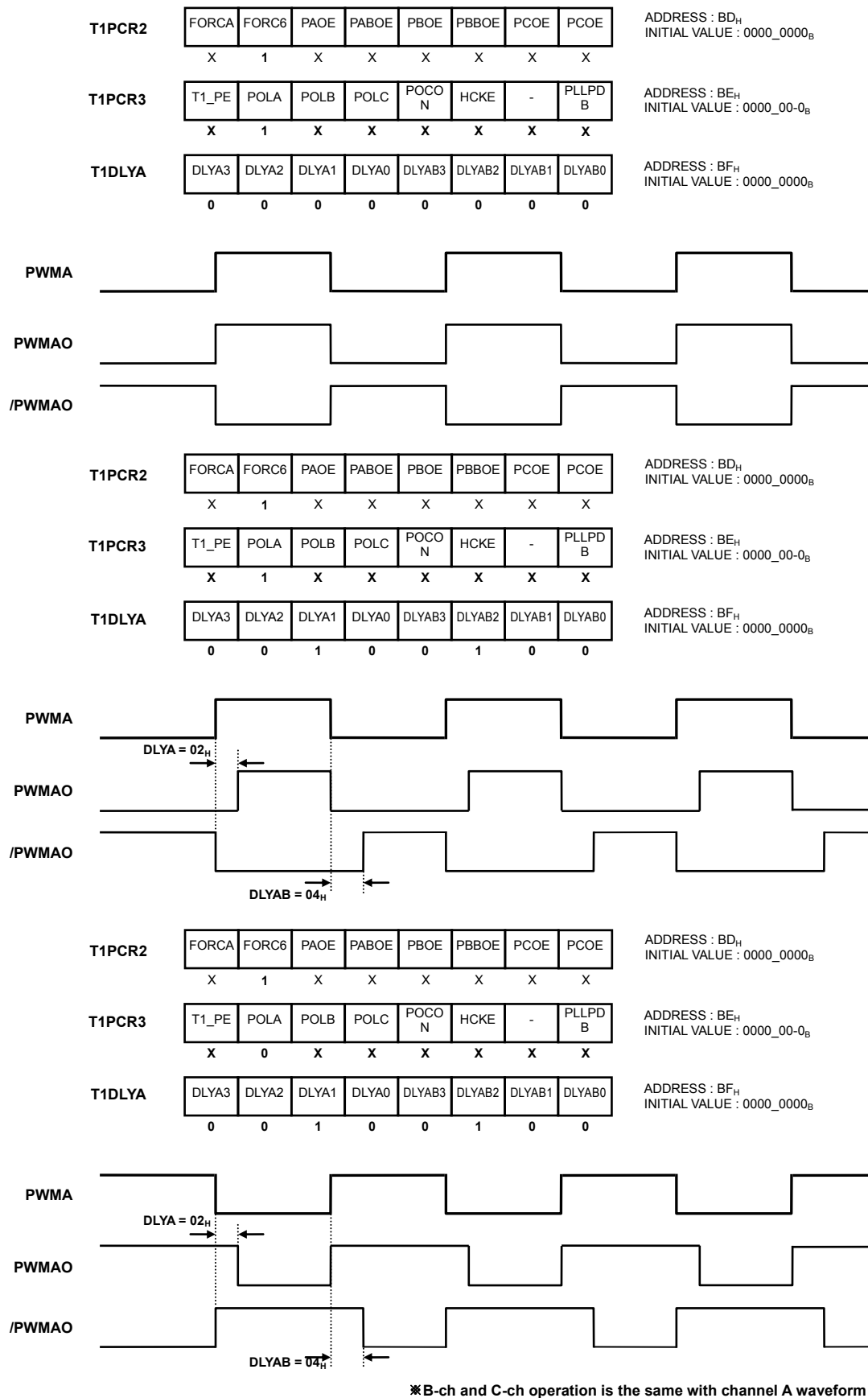


Figure 11.25 Example of PWM Delay

11.5.1.7 8-bit (16-bit) Compare Output Mode

If the T1 (T0+T1) value and the T1DR (T0DR+T1DR) value are matched, T1/PWM1A port outputs. The output is 50:50 of duty square wave, the frequency is following.

$$f_{COMP} = \frac{\text{Oscillator Frequency}}{2 \times \text{Prescaler Value} \times (TDR + 1)}$$

To export the compare output as T1/PWM1A, the T1_PE bit in the T1PCR3 register must set to '1'.

11.5.1.8 Register Map

Name	Address	Dir	Default	Description
T0CR	B2H	R/W	00H	Timer 0 Mode Control Register
T0	B3H	R	00H	Timer 0 Register
T0DR	B3H	W	FFH	Timer 0 Data Register
CDR0	B3H	R	00H	Capture 0 Data Register
T1CR	B4H	R/W	00H	Timer 1 Mode Control Register
T1DR	B5H	W	FFH	Timer 1 Data Register
T1PPRH	B6H	W	FFH	Timer 1 PWM Period Register High
T1PPRL	B5H	W	FFH	Timer 1 PWM Period Register Low
T1	B0H	R	00H	Timer 1 Register
T1ADRH	B1H	R/W	00H	Timer 1 PWM 1A Duty Register High
T1ADRL	B0H	R/W	7FH	Timer 1 PWM 1A Duty Register
CDR1	B0H	R	00H	Capture 1 Data Register
T1PCR	B7H	R/W	00H	Timer 1 PWM Control Register
T1BDRH	BAH	R/W	00H	Timer 1 PWM 1B Duty Register High
T1BDRL	B9H	R/W	7FH	Timer 1 PWM 1B Duty Register Low
T1CDRH	BCH	R/W	00H	Timer 1 PWM 1C Duty Register High
T1CDRL	BBH	R/W	7FH	Timer 1 PWM 1C Duty Register Low
T1PCR2	BDH	R/W	00H	Timer 1 PWM Control Register 2
T1PCR3	BEH	R/W	00H	Timer 1 PWM Control Register 3
T1DLYA	BFH	R/W	00H	PWM1 Non-Overlap Delay Register ch. A/AB
T1DLYB	C2H	R/W	00H	PWM1 Non-Overlap Delay Register ch. B/BB
T1DLYC	C3H	R/W	00H	PWM1 Non-Overlap Delay Register ch. C/CB
T1ISR	C4H	R/W	00H	Timer 1 Interrupt Status Register
T1IMSK	C5H	R/W	00H	Timer 1 Interrupt Mask Register
PLLCR	94H	R/W	42H	Timer1 PLL Control Register

Table 11.8 Register Map

11.5.1.9 Timer/Counter 0 Register Description

The Timer/Counter 0,1 register consists of Timer 0 Mode Control Register (T0CR), Timer 0 Register (T0), Timer 0 Data Register (T0DR), Capture 0 Data Register (CDR0), Timer 1 Mode Control Register (T1CR), Timer 1 Data Register (T1DR), Timer 1 PWM Period Register High/Low (T1PPRH/L), Timer 1 Register (T1), Timer 1 PWM 1A Duty Register High/Low (T1ADRH/L), Capture 1 Data Register (CDR1), Timer 1 PWM Control Register (T1PCR), Timer 1 PWM 1B Duty Register High/Low (T1BDRH/L), Timer 1 PWM 1C Duty Register High/Low (T1CDRH/L), Timer 1 PWM Control Register 2 (T1PCR2), Timer 1 PWM Control Register 3 (T1PCR3), PWM1 Non-Overlap Delay Register ch. A/AB (T1DLYA), PWM1 Non-Overlap Delay Register ch. B/BB (T1DLYB), PWM1 Non-Overlap Delay Register ch. C/CB (T1DLYC), Timer 1 Interrupt Status Register (T1ISR), Timer 1 Interrupt Mask Register (T1IMSK) and PLL Control Register (PLLCR)

11.5.1.10 Register description for Timer/Counter 0, 1

T0CR (Timer 0 Mode Control Register) : B2H

7	6	5	4	3	2	1	0
T0EN	T0_PE	CAP0	T0CK2	T0CK1	T0CK0	T0CN	T0ST
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

T0EN	Control Timer 0			
	0	Timer 0 disable		
	1	Timer 0 enable		
T0_PE	Control Timer 0 Output port			
	0	Timer 0 Output disable		
	1	Timer 0 Output enable		
CAP0	Control Timer 0 operation mode			
	0	Timer/Counter mode		
	1	Capture mode		
T0CK[2:0]	Select Timer 0 clock source. Fx is main 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)
T0CN	Control Timer 0 Count pause/continue			
	0	Temporary count stop		
	1	Continue count		
T0ST	Control Timer 0 start/stop			
	0	Counter stop		
	1	Clear counter and start		

T0 (Timer 0 Register: Read Case) : B3H

7	6	5	4	3	2	1	0
T07	T06	T05	T04	T03	T02	T01	T00
R	R	R	R	R	R	R	R

Initial value : 00H

T0[7:0] T0 Counter

T0DR (Timer 0 Data Register: Write Case) : B3H

7	6	5	4	3	2	1	0
T0D7	T0D6	T0D5	T0D4	T0D3	T0D2	T0D1	T0D0
W	W	W	W	W	W	W	W

Initial value : FFH

T0D[7:0] T0 Compare

CDR0 (Capture 0 Data Register: Read Case, Capture mode only) : B3H

7	6	5	4	3	2	1	0
CDR07	CDR06	CDR05	CDR04	CDR03	CDR02	CDR01	CDR00
R	R	R	R	R	R	R	R

Initial value : 00H

CDR0[7:0] T0 Capture

T1CR (Timer 1 Mode Count Register) : B4H

7	6	5	4	3	2	1	0
16BIT	CAP1	T1CN	T1ST	T1CK3	T1CK2	T1CK1	T1CK0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

16BIT	Select Timer 1 8/16-bit				
	0	8-bit			
	1	16-bit			
CAP1	Control Timer 1 operation mode				
	0	Timer/Counter mode			
	1	Capture mode			
T1CN	Control Timer 1 Count pause/continue				
	0	Temporary count stop			
	1	Continue count			
T1ST	Control Timer 1 start/stop				
	0	Counter stop			
	1	Clear counter and start			
T1CK[3:0]	Select Timer 1 clock source. Fx is main system clock frequency				
	T1CK3	T1CK2	T1CK1	T1CK0	description
	0	0	0	0	fx
	0	0	0	1	fx/2
	0	0	1	0	fx/4
	0	0	1	1	fx/8
	0	1	0	0	fx/16
	0	1	0	1	fx/32
	0	1	1	0	fx/64
	0	1	1	1	fx/128
	1	0	0	0	fx/256

1	0	0	1	fx/512
1	0	1	0	fx/1024
1	0	1	1	fx/2048
1	1	0	0	fx/4096
1	1	0	1	fx/8192
1	1	1	0	fx/16384
1	1	1	1	Using Timer 0 Clock

NOTE)

1. If you want to use “Using Timer 0 Clock”, you can set T0EN bit in T0CR

T1DR (Timer 1 Data Register: Write Case) : B5H

7	6	5	4	3	2	1	0
T1D7	T1D6	T1D5	T1D4	T1D3	T1D2	T1D1	T1D0
W	W	W	W	W	W	W	W

Initial value : FFH

T1D[7:0] T1 Compare

T1PPRH (Timer 1 PWM Period High Register: Write Case PWM mode only) : B6H

7	6	5	4	3	2	1	0
-	-	-	-	-	-	T1PP9	T1PP8
W	W	W	W	W	W	W	W

Initial value : 00H

T1PP[9:8] T1 PWM high period

T1PPRL (Timer 1 PWM Period Low Register: Write Case PWM mode only) : B5H

7	6	5	4	3	2	1	0
T1PP7	T1PP6	T1PP5	T1PP4	T1PP3	T1PP2	T1PP1	T1PP0
W	W	W	W	W	W	W	W

Initial value : FFH

T1PP[7:0] T1 PWM period

T1 (Timer 1 Register: Read Case) : B0H

7	6	5	4	3	2	1	0
T17	T16	T15	T14	T13	T12	T11	T10
R	R	R	R	R	R	R	R

Initial value : 00H

T1[7:0] T1 Counter period

T1ADRH (Timer 1 PWM 1A Duty High Register PWM mode only) : B1H

7	6	5	4	3	2	1	0
-	-	-	-	-	-	PAD9	PAD8
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

T1ADR[9:8] T1 PWM Duty
NOTE) only write, when PWM1E ‘1’

T1ADRL (Timer 1 PWM 1A Duty Low Register PWM mode only) : B0H

7	6	5	4	3	2	1	0
PAD7	PAD6	PAD5	PAD4	PAD3	PAD2	PAD1	PAD0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 7FH

T1ADR[7:0]

T1 PWM Duty

NOTE) only write, when PWM1E '1'**CDR1 (Capture 1 Data Register: Read Case, Capture mode only) : B0H**

7	6	5	4	3	2	1	0
CDR17	CDR16	CDR15	CDR14	CDR13	CDR12	CDR11	CDR10
R	R	R	R	R	R	R	R

Initial value : 00H

CDR1[7:0]

T1 Capture

T1PCR (Timer 1 PWM Control Register) : B7H

7	6	5	4	3	2	1	0
PWM1E	ESYNC	BMOD	PHLT	UPDT	UALL	NOPS1	NOPS0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

PWM1E	Control PWM
0	PWM disable
1	PWM enable
ESYNC	Select the operation of External Sync Mode
0	External Sync Mode disable
1	External Sync Mode enable (using with BLNKB(P16))
BMOD	Control Back-To-Back Mode operation
0	BtB mode disable (only up count)
1	BtB mode enable (Up/Down count)
PHLT	Control PWM
0	PWM running
1	PWM stop
UPDT	Determine the update time of PPR, PDR
0	Update at period match
1	Update at any time (after 3 timer clock, update)
UALL	Control update all duty register
0	Write duty register separately
1	Write all duty registers (via A duty)
NOPS1[1:0]	Select on-Overlap prescaler
NOTE) fpwm: PWM operation clock frequency	
NOPS1	NOPS0
0	0
0	1
1	0
1	1
	description
	fpwm
	fpwm/2
	fpwm/4
	fpwm/8

T1BDRH (Timer 1 PWM 1B Duty High Register) : BAH

7	6	5	4	3	2	1	0
-	-	-	-	-	-	PBD9	PBD8
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

T1BDR[9:8]

PWM 1B ch Duty

NOTE) only write, when PWM1E '1'**T1BDRL (Timer 1 PWM 1B Duty Low Register) : B9H**

7	6	5	4	3	2	1	0
PBD7	PBD6	PBD5	PBD4	PBD3	PBD2	PBD1	PBD0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 7FH

T1BDR[7:0]

PWM 1B ch Duty

NOTE) only write, when PWM1E '1'**T1CDRH (Timer 1 PWM 1C Duty High Register) : BCH**

7	6	5	4	3	2	1	0
-	-	-	-	-	-	PCD9	PCD8
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

T1CDR[9:8]

PWM 1C ch Duty

NOTE) only write, when PWM1E '1'**T1CDRL (Timer 1 PWM 1C Duty Low Register) : BBH**

7	6	5	4	3	2	1	0
PCD7	PCD6	PCD5	PCD4	PCD3	PCD2	PCD1	PCD0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 7FH

T1CDR[7:0]

PWM 1C ch Duty

NOTE) only write, when PWM1E '1'

T1PCR2 (Timer 1 PWM Control Register 2) : BDH

7	6	5	4	3	2	1	0
FORCA	FORC6	PAOE	PABOE	PBOE	PBBOE	PCOE	PCBOE
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

FORCA	Control Force Drive A Channel mode
0	Force Drive A Channel mode disable
1	Force Drive A Channel mode enable
FORC6	Control Force 6 Channel mode
Note) PAOE~PCBOE is effective when FORC6 sets to '1'	
0	Force 6 Channel mode disable
1	Force 6 Channel mode enable
PAOE/ PABOE	Select Channel A/AB operation
0	P1A (or P1AB) output disable
1	P1A (or P1AB) output enable
PBOE/ PBBOE	Select Channel B/BB operation
0	P1B (or P1BB) output disable
1	P1B (or P1BB) output enable
PCOE/ PCBOE	Select Channel C/CB operation
0	P1C (or P1CB) output disable
1	P1C (or P1CB) output enable

T1PCR3 (Timer 1 PWM Control Register 3) : BEH

7	6	5	4	3	2	1	0
T1_PE	POLA	POLB	POLC	POCON	HCKE	-	PLLPDB
RW	RW	RW	RW	RW	RW	-	RW

Initial value : 00H

T1_PE	Control Timer1/PWM1 Output port
0	T1, PWM1 Output operation disable
1	T1, PWM1 Output operation enable
POLA	Configure PWM A-ch polarity
0	Negative (Duty Match time, Clear)
1	Positive (Duty Match time, Set)
POLB	Configure PWM B-ch polarity
0	Negative (Duty Match time, Clear)
1	Positive (Duty Match time, Set)
POLC	Configure PWM C-ch polarity
0	Negative (Duty Match time, Clear)
1	Positive (Duty Match time, Set)
POCON	Control PWM output operation
0	PWM output control disable
1	PWM output control enable
HCKE	Select High frequency
Note) fCK is system frequency, Fout is PLL output frequency	
0	High frequency disable
1	High frequency enable (Fout > 3* fCK)
PLLPDB	Control PLL power Down mode
0	PLL disable (power down mode)
1	PLL enable (for stable, needs 1ms wait)

T1DLYA (PWM1 Non-Overlap Delay Register for channel A/AB) : BFH

7	6	5	4	3	2	1	0
DLYA3	DLYA2	DLYA1	DLYA0	DLYAB3	DLYAB2	DLYAB1	DLYAB0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

DLYA[3:0] PWM A channel Output Delay (Rising edge only)

DLYAB[3:0] PWM AB channel Output Delay (Rising edge only)

T1DLYB (PWM1 Non-Overlap Delay Register for channel B/BB) : C2H

7	6	5	4	3	2	1	0
DLYB3	DLYB2	DLYB1	DLYB0	DLYBB3	DLYBB2	DLYBB1	DLYBB0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

DLYB[3:0] PWM B channel Output Delay (Rising edge only)

DLYBB[3:0] PWM BB channel Output Delay (Rising edge only)

T1DLYC (PWM1 Non-Overlap Delay Register for channel C/CB) : C3H

7	6	5	4	3	2	1	0
DLYC3	DLYC2	DLYC1	DLYC0	DLYCB3	DLYCB2	DLYCB1	DLYCB0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

DLYC[3:0] PWM C channel Output Delay (Rising edge only)

DLYCB[3:0] PWM CB channel Output Delay (Rising edge only)

T1ISR (Timer 1 Interrupt Status Register) : C4H

7	6	5	4	3	2	1	0
IOVR	IBTM	ICMA	ICMB	ICMC	ICAP	-	-
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

IOVR	Overflow (match with T1DR in Timer mode or T1PPR in PWM mode) interrupt status Note) for clear, write '1' to this bit 0 Overflow no occurrence 1 Overflow occurrence
IBTM	Timer Bottom (goto zero) interrupt status in PWM Back-to-Back mode) Note) for clear, write '1' to this bit 0 Timer Bottom no occurrence 1 Timer Bottom occurrence
ICMA	PWM A-ch Duty Match interrupt status Note) for clear, write '1' to this bit 0 PWM A-ch Duty Match no occurrence 1 PWM A-ch Duty Match occurrence
ICMB	PWM B-ch Duty Match interrupt status Note) for clear, write '1' to this bit 0 PWM B-ch Duty Match no occurrence 1 PWM B-ch Duty Match occurrence
ICMC	PWM C-ch Duty Match interrupt status Note) for clear, write '1' to this bit 0 PWM C-ch Duty Match no occurrence 1 PWM C-ch Duty Match occurrence
ICAP	Timer Capture event interrupt status Note) for clear, write '1' to this bit 0 Timer Capture event no occurrence 1 Timer Capture event occurrence

T1MSK (Timer 1 Interrupt Mask Register) : C5H

7	6	5	4	3	2	1	0
OVRMSK	BTMMSK	CMAMSK	CMBMSK	CMCMSK	CAPMSK	-	-
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

OVRMSK	Control Overflow interrupt
0	Overflow interrupt disable
1	Overflow interrupt enable
BTMMSK	Control Timer Bottom interrupt
0	Timer Bottom interrupt disable
1	Timer Bottom interrupt enable
CMAMSK	Control Timer Compare Match (or PWM A-ch Match) interrupt
0	Timer Compare Match (or PWM A-ch Match) interrupt disable
1	Timer Compare Match (or PWM A-ch Match) interrupt enable
CMBMSK	Control PWM B-ch Match interrupt
0	PWM B-ch Match interrupt disable
1	PWM B-ch Match interrupt enable
CMCMSK	Control PWM C-ch Match interrupt
0	PWM C-ch Match interrupt disable
1	PWM C-ch Match interrupt enable
CAPMSK	Control Timer Capture event interrupt
0	Timer Capture event interrupt disable
1	Timer Capture event interrupt enable

PLLCR (PLL Control Register) : 94H

7	6	5	4	3	2	1	0
PLLCT7	PLLCT6	PLLCT5	PLLCT4	PLLCT3	PLLCT2	PLLCT1	PLLCT0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 42H

PLLCT[7:6] Pre Scaler (divider) Control

PLLCT7	PLLCT6	description
0	0	Div 1
0	1	Div 2
1	0	Div 4
1	1	Div 8

PLLCT5:[4] Feedback Control

PLLCT5	PLLCT4	description
0	0	Div 26
0	1	Div 32
1	0	Div 52
1	1	Div 64

PLLCT[3:1] Post Scaler (divider) Control (FOUT=fvco/M)

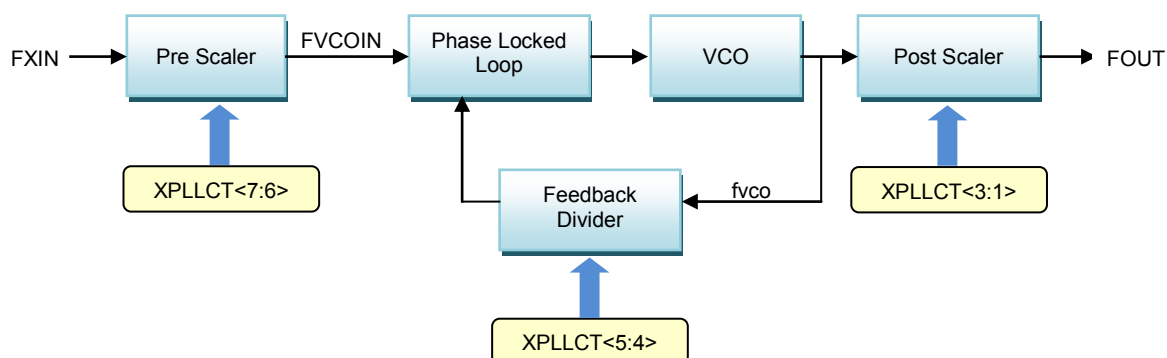
PLLCT3	PLLCT2	PLLCT1	description
0	0	0	M=1
0	0	1	M=2
0	1	0	M=4
0	1	1	M=5
1	0	0	M=6
1	0	1	M=8
1	1	0	M=10
1	1	1	M=16

PLLCT[0] PLL enable (this bit should enable before 1ms for using PLL)

0	PLL disable
1	PLL enable

Note)

1. FVCOIN value must be 2MHz or 4MHz for desire FOUT.
2. To change PLL frequency during the operation, PLL must be disabled before XPLLCT change



$$FVCOIN = 2\text{MHz or } 4\text{MHz} = FXIN / \text{Pre-Divide}$$

$$FVCO = FVCOIN * \text{Feedback-Divider} = 104\text{MHz or } 128\text{MHz}$$

$$FOUT = FVCO / \text{Post-Divider}$$

11.5.2 8-bit Timer/Event Counter 2, 3

11.5.2.1 Overview

Timer 2 and timer 3 can be used as either two 8-bit timer/counter or one 16-bit timer/counter. Each 8-bit timer/event counter module has multiplexer, 8-bit timer data register, 8-bit counter register, mode register, input capture register, comparator. For PWM, it has PWM register (T3PPR, T3PDR, T3PWHR).

It has seven operating modes:

- 8-bit Timer/Counter Mode
- 8-bit Capture Mode
- 8-bit Compare Output Mode
- 16-bit Timer/Counter Mode
- 16-bit Capture Mode
- 16-bit Compare Output Mode
- PWM Mode

The timer/counter can be clocked by an internal or external clock source (external EC2). The clock source is selected by clock select logic which is controlled by the clock select (T2CK[2:0], T3CK[1:0]).

- TIMER2 clock source : $fX/(1, 2, 4, 64, 256, 1024, 4096)$, EC2

- TIMER3 clock source : $fX/(1, 2, 16)$, T2CK

In the capture mode, by INT2, INT3, the data is captured into Input Capture Register. The Timer 2 outputs the compare result to T2 port in 8/16-bit mode. Also the timer 3 outputs the result T3 port in the timer mode and the PWM waveform to PWM3 in the PWM mode.

16BIT	CAP2	CAP3	PWM3E	T2CK[2:0]	T3CK[1:0]	T2/3_PE	Timer 2	Timer 3
0	0	0	0	XXX	XX	00	8-bit Timer	8-bit Timer
0	0	1	0	111	XX	00	8-bit Event Counter	8-bit Capture
0	1	0	0	XXX	XX	01	8-bit Capture	8-bit Compare Output
0	0	0	1	XXX	XX	11	8-bit Timer/Counter	10-bit PWM
1	0	0	0	XXX	11	00	16-bit Timer	
1	0	0	0	111	11	00	16-bit Event Counter	
1	1	1	0	XXX	11	00	16-bit Capture	
1	0	0	0	XXX	11	01	16-bit Compare Output	

Table 11.9 Operating Modes of Timer

11.5.2.2 8-bit Timer/Counter Mode

The 8-bit Timer/Counter Mode is selected by control registers as shown in Figure 11.26.

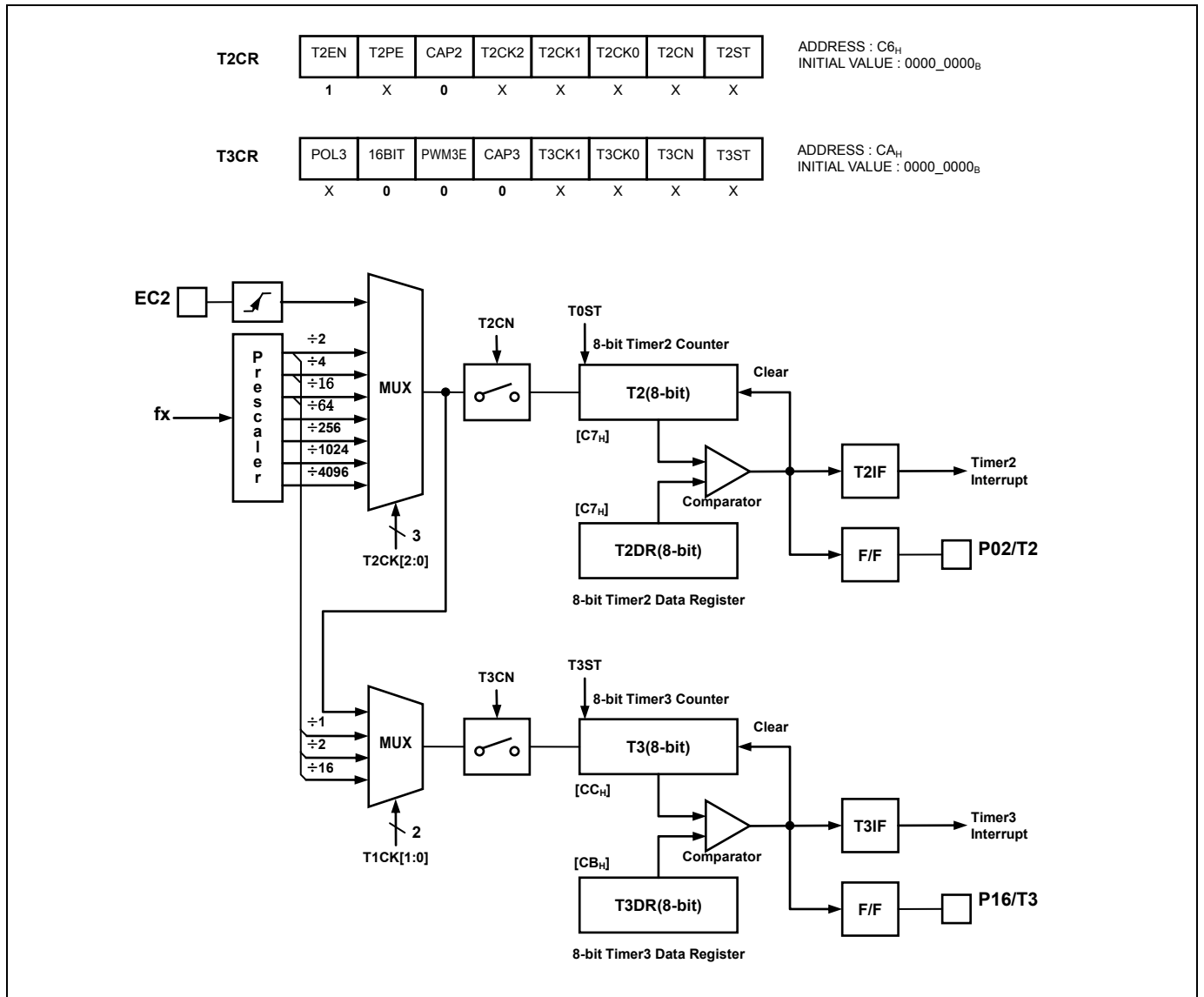


Figure 11.26 8-bit Timer/Event Counter2, 3 Block Diagram

The two 8-bit timers have each counter and data register. The counter register is increased by internal or external clock input. The timer2 can use the input clock with 2, 4, 16, 64, 256, 1024, 4096 prescaler division rates (T2CK[2:0]). The timer 3 can use the input clock with 1, 2, 16 and timer2 overflow clock (T3CK[1:0]). When the value of T2/T3 and the value of T2DR/T3DR are respectively identical in Timer2/Timer3, the interrupt of timer T2/T3 occurs. The external clock (EC2) counts up the timer at the rising edge. If EC2 is selected from T2CK[2:0], EC2 port becomes input port. The timer 3 can't use the external EC clock.

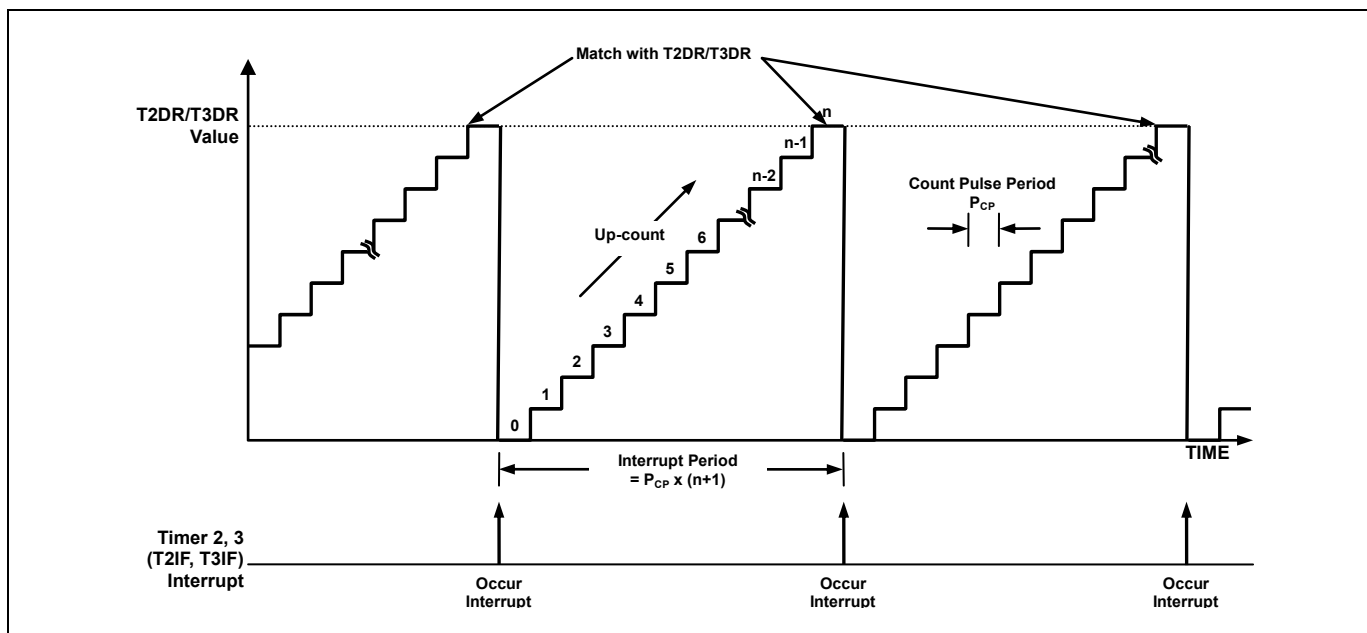


Figure 11.27 Timer/Event Counter2, 3 Example

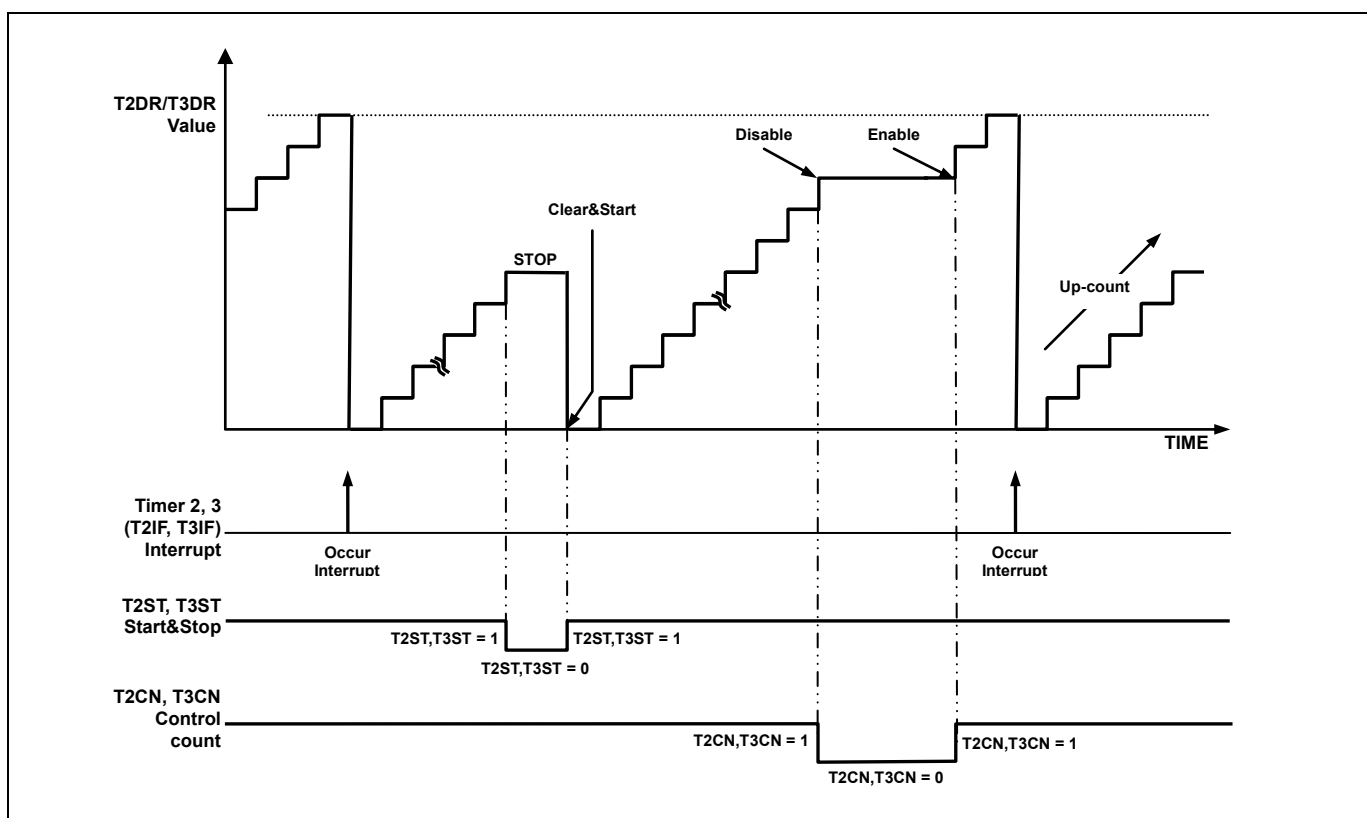


Figure 11.28 Operation Example of Timer/Event Counter2, 3

11.5.2.3 16-bit Timer/Counter Mode

The timer register is being run with all 16 bits. A 16-bit timer/counter register T2, T3 are incremented from 0003H to FFFFH until it matches T2DR, T3DR and then resets to 0000H. the match output generates the Timer 2 interrupt (no timer 3 interrupt). The clock source is selected from T2CK[2:0] and T3CK[1:0] must set 11b and 16BIT bit must set to '1'. The timer 2 is LSB 8-bit, the timer 3 is MSB 8-bit. T2DR must not be 0x00(0x01~0xFF). The 16-bit mode setting is shown as Figure 11.29.

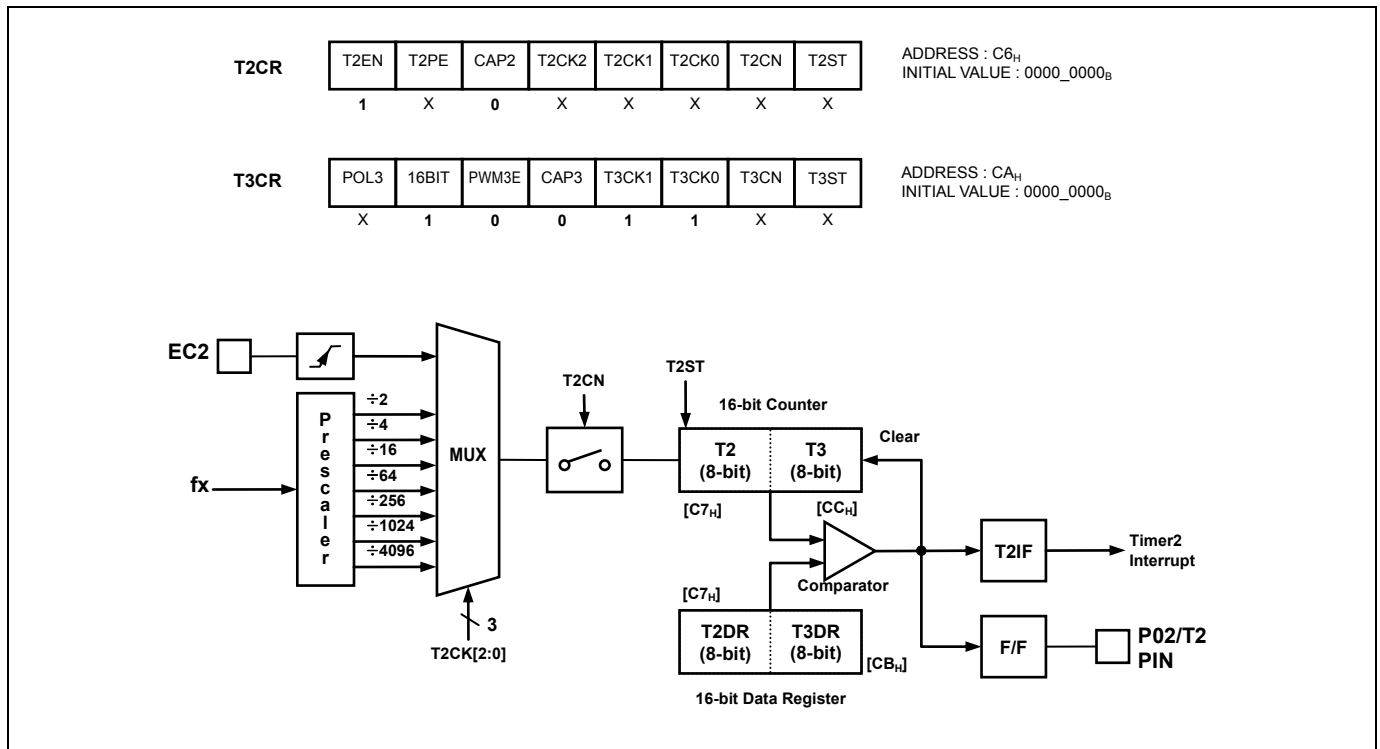


Figure 11.29 16-bit Timer/Event Counter2, 3 Block Diagram

11.5.2.4 8-bit Capture Mode

The timer 2, 3 capture mode is by evoked setting CAP2/CAP3 as '1'. The clock source can use the internal/external clock. Basically, it has the same function of the 8-bit timer/counter mode and the interrupt occurs at T2, T3 and T2DR, T3DR matching time, respectively. The capture result is loaded into CDR2, CDR3. The T2, T3 value is automatically cleared by hardware and restarts counter.

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

As the EIEDGE and EIPOLA register setting, the external interrupt INT2, INT3 function is chosen.

The CDR2, T2 and T2DR are in same address. In the capture mode, reading operation is read the CDR2, not T2DR because path is opened to the CDR2. The CDR3 has the same function.

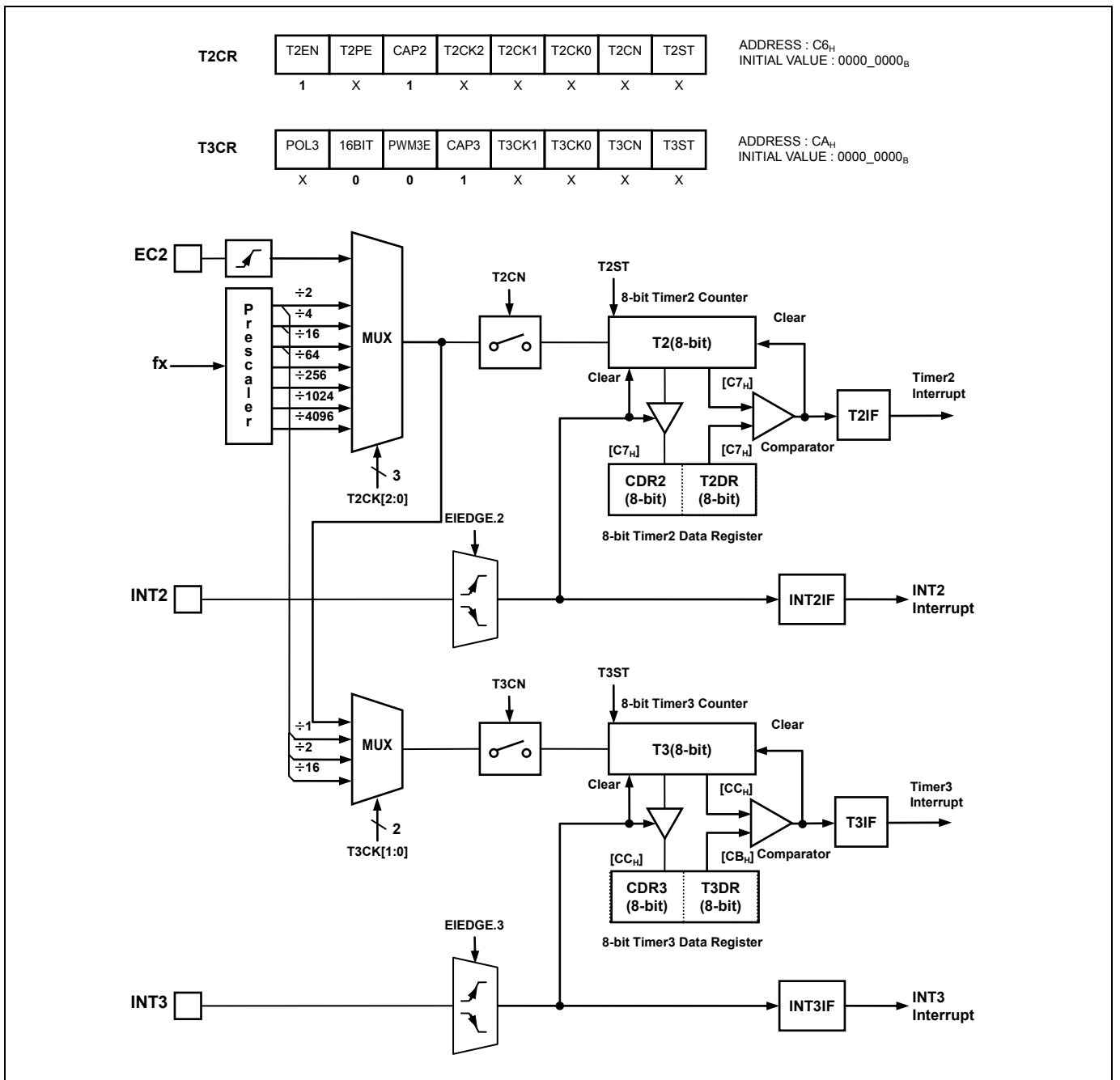


Figure 11.30 8-bit Capture Mode for Timer2, 3

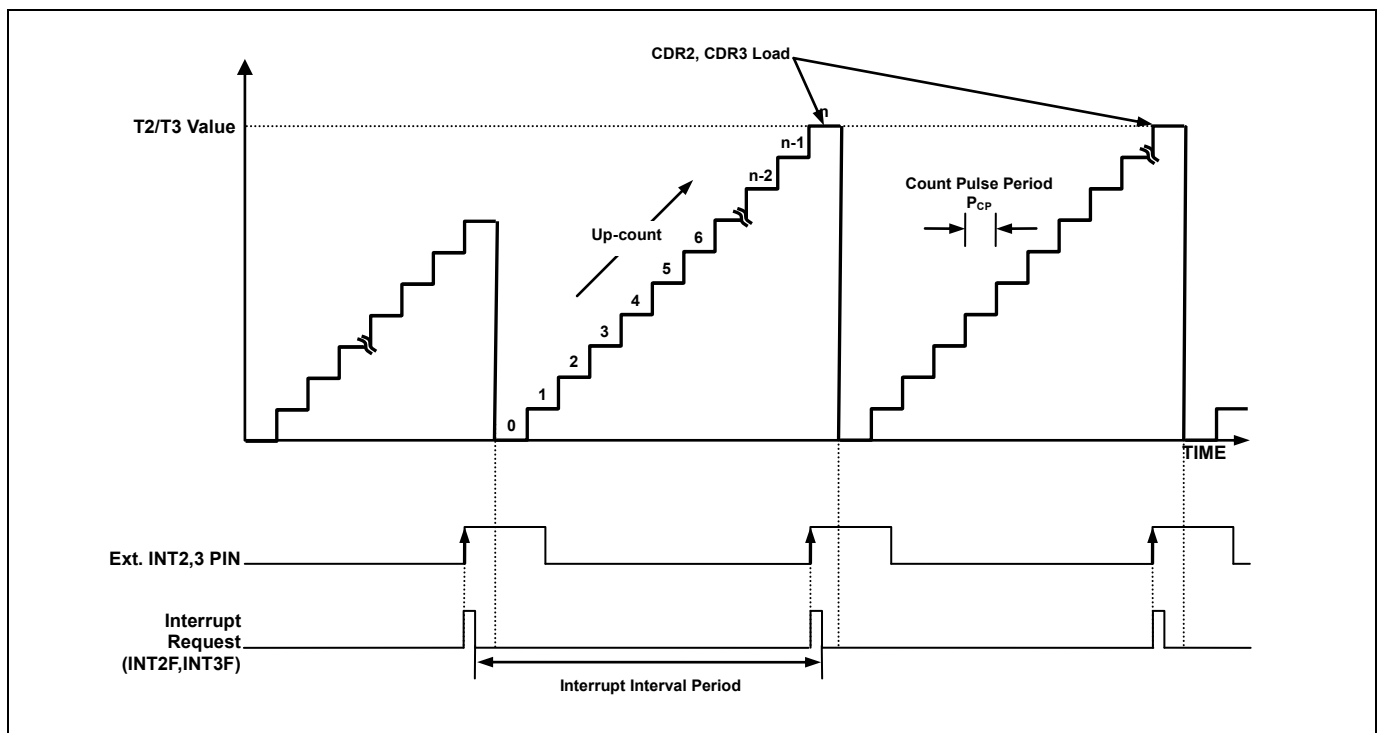


Figure 11.31 Input Capture Mode Operation of Timer 2, 3

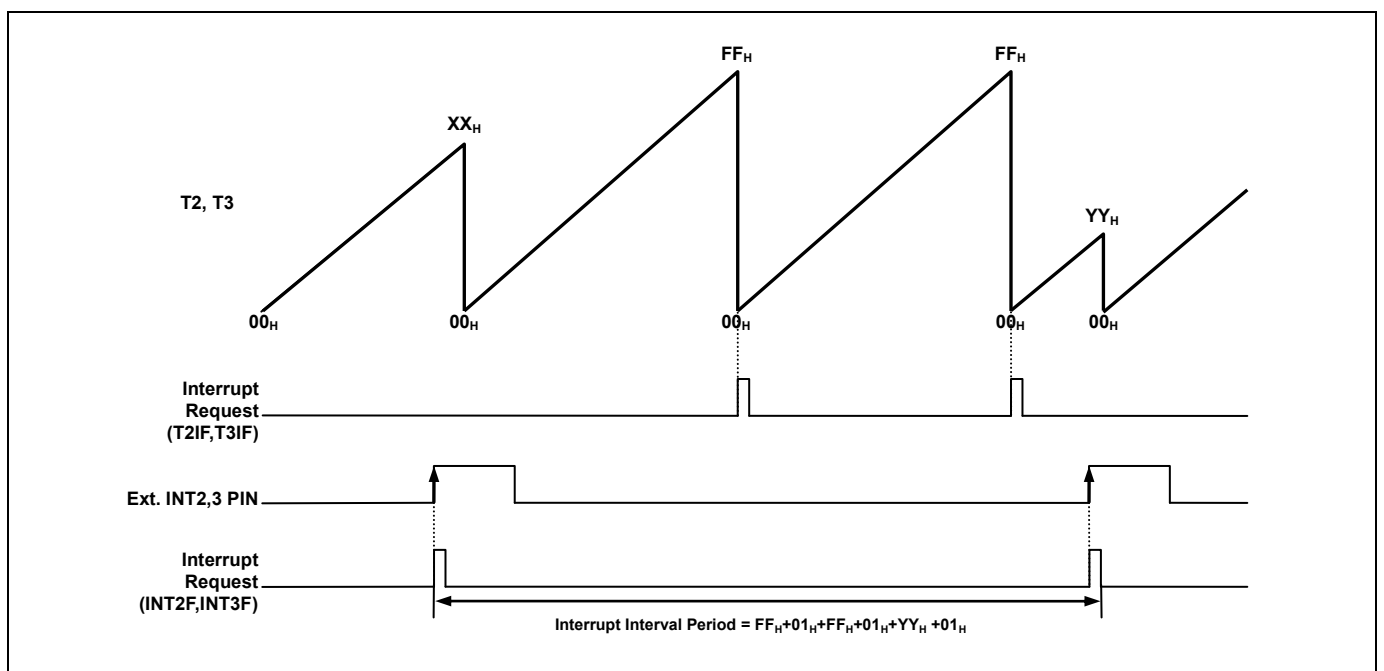


Figure 11.32 Express Timer Overflow in Capture Mode

11.5.2.5 16-bit Capture Mode

The 16-bit capture mode is the same operation as 8-bit capture mode, except that the timer register uses 16 bits. The clock source is selected from T2CK[2:0] and T3CK[1:0] must set 11b and 16BIT bit must set to '1'. The 16-bit mode setting is shown as Figure 11.33.

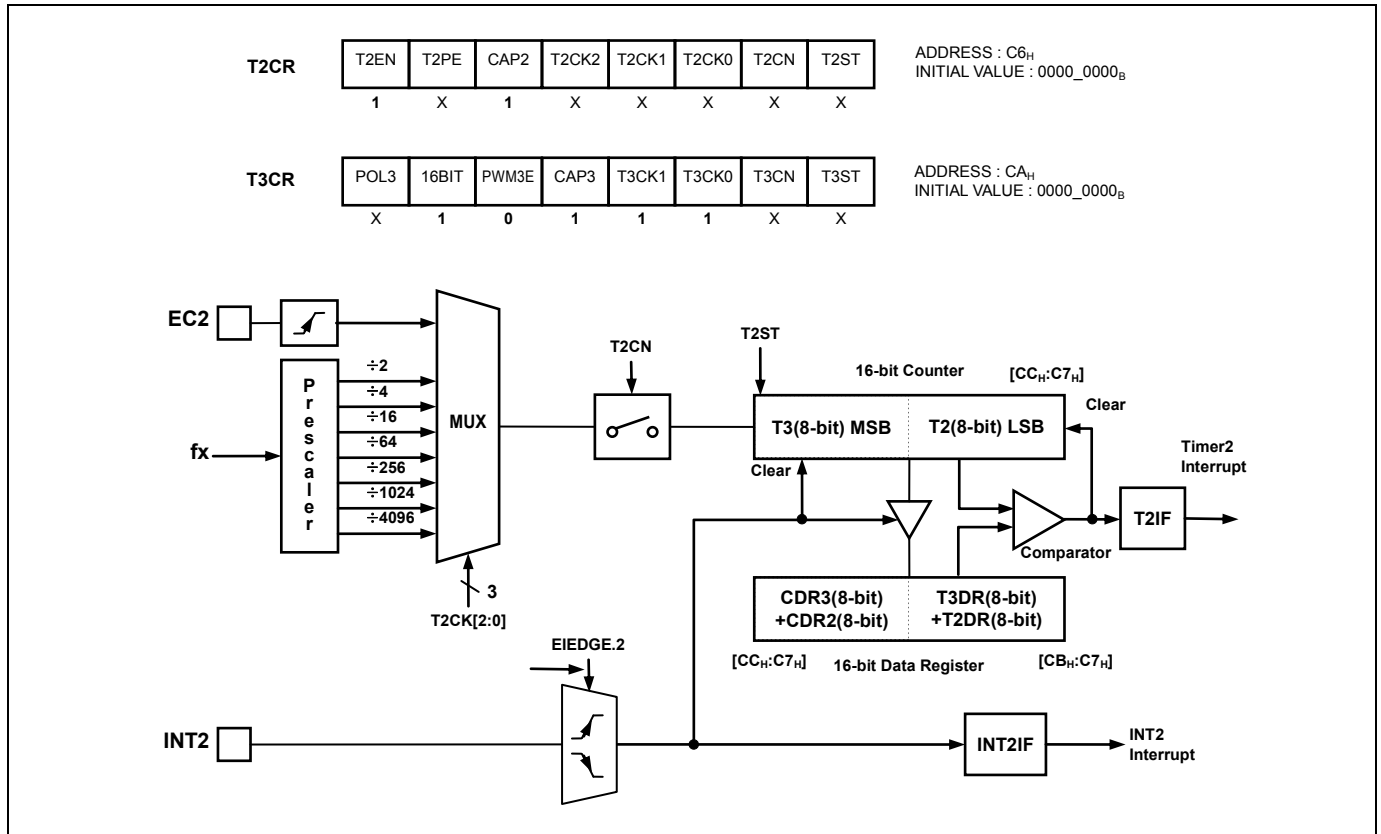


Figure 11.33 16-bit Capture Mode of Timer 2, 3

11.5.2.6 PWM Mode

The timer 3 has a PWM (pulse Width Modulation) function. In PWM mode, the T3/PWM3 output pin outputs up to 10-bit resolution PWM output. This pin should be configured as a PWM output by set T3_PE to '1'. The period of the PWM output is determined by the T3PPR (PWM period register) + T3PWHR[3:2] + T3PWHR[1:0]

$$\text{PWM Period} = [T3PWHR[3:2]T3PPR] \times \text{Source Clock}$$

$$\text{PWM Duty} = [T3PWHR[1:0] T3PDR] \times \text{Source Clock}$$

Resolution	Frequency		
	T3CK[1:0]=00 (125ns)	T3CK[1:0]=01 (250ns)	T3CK[1:0]=10 (2us)
10-bit	7.8kHz	3.9kHz	0.49kHz
9-bit	15.6kHz	7.8kHz	0.98kHz
8-bit	31.2kHz	15.6kHz	1.95kHz
7-bit	62.4kHz	31.2kHz	3.91kHz

Table 11.10 PWM Frequency vs. Resolution at 8MHz

The POL bit of T3CR register decides the polarity of duty cycle. If the duty value is set same to the period value, the PWM output is determined by the bit POL (1: High, 0: Low). And if the duty value is set to "00H", the PWM output is determined by the bit POL (1: Low, 0: High). If duty value and period value are equal, PWM output is not retain high or low but toggle.

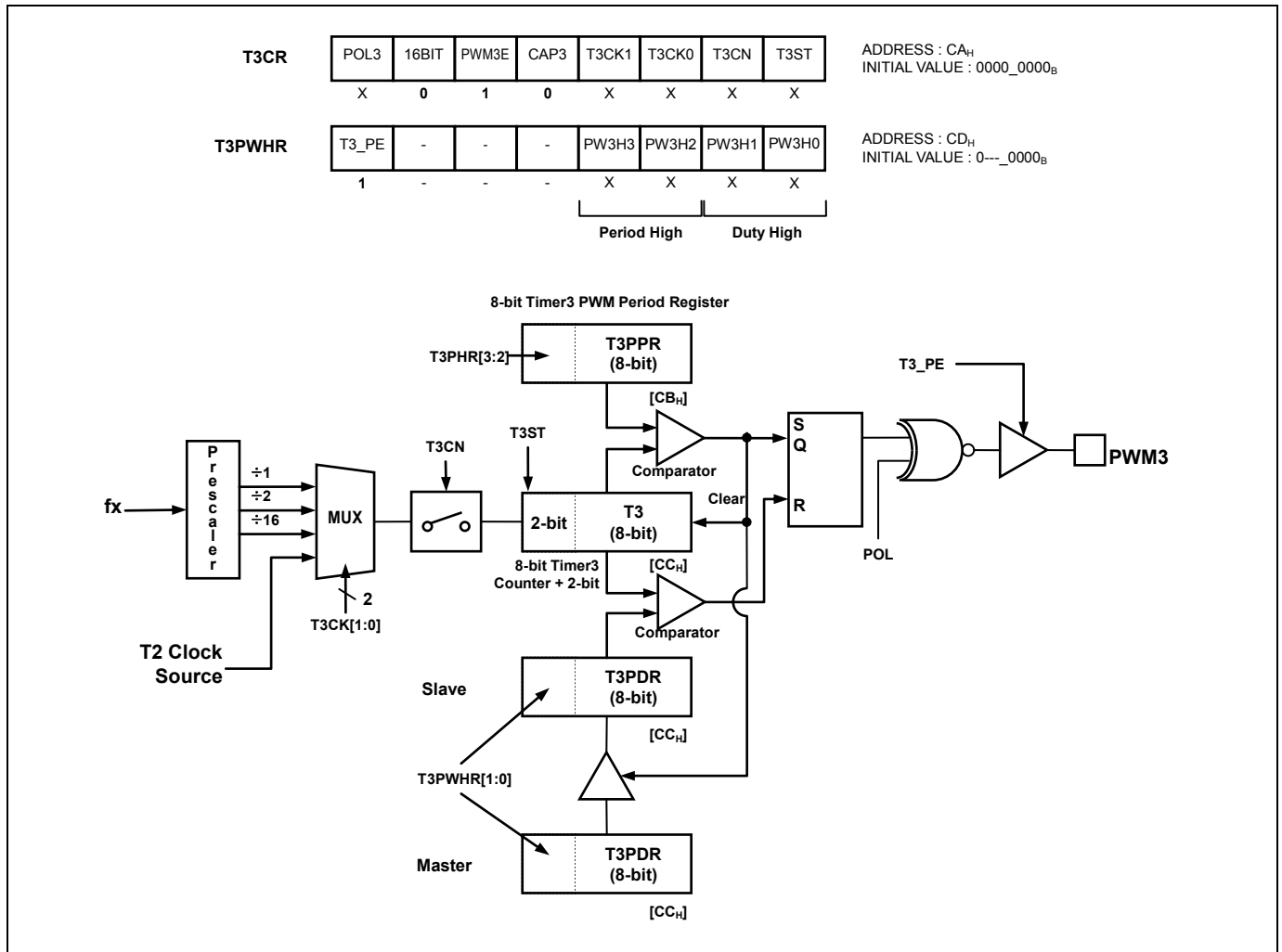


Figure 11.34 PWM Mode

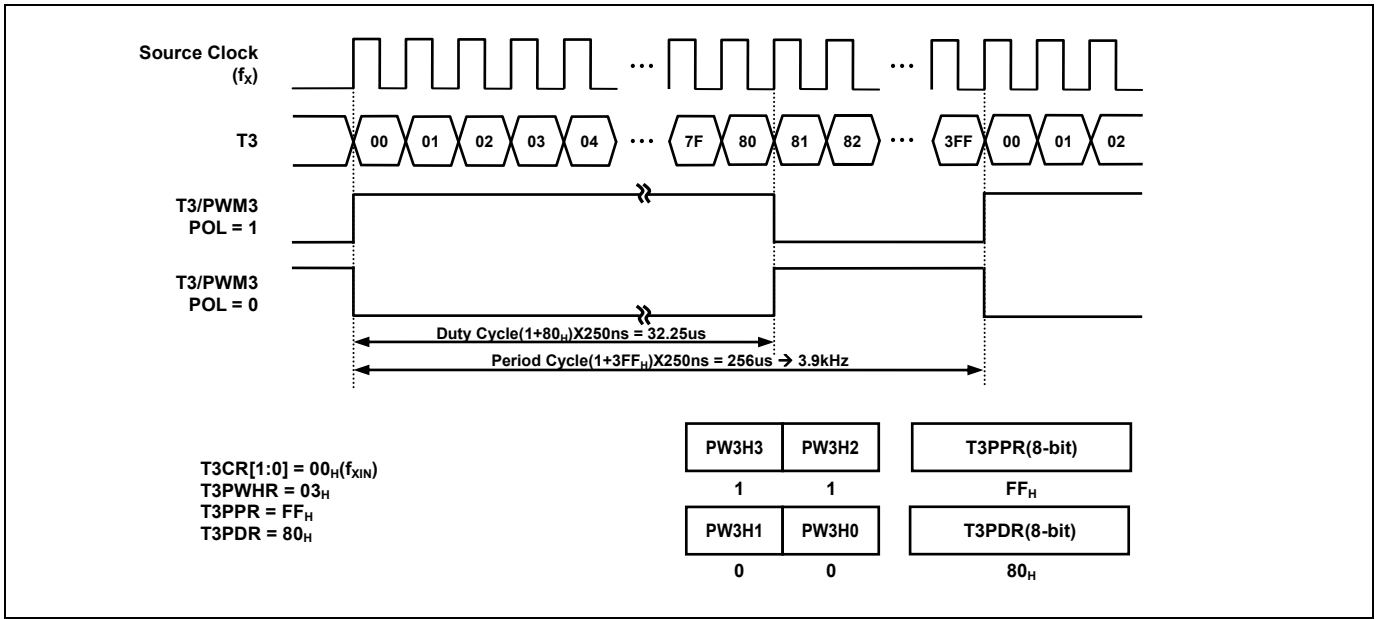


Figure 11.35 Example of PWM at 4MHz

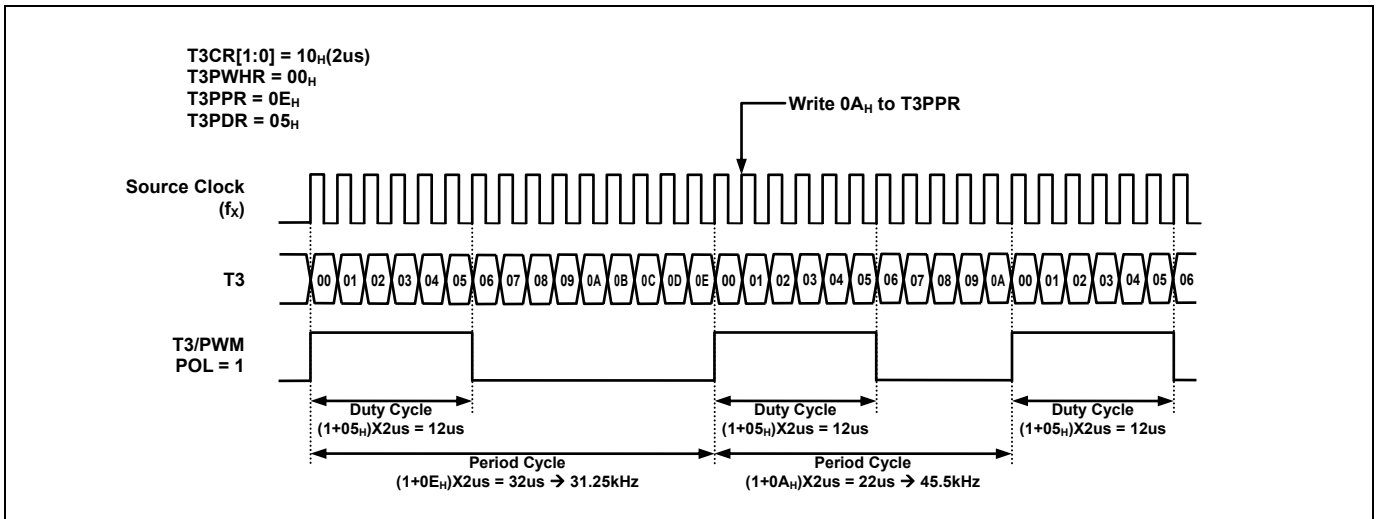


Figure 11.36 Example of Changing the Period in Absolute Duty Cycle at 4Mhz

11.5.2.7 8-bit (16-bit) Compare Output Mode

If the T3 (T2+T3) value and the T3DR (T2DR+T3DR) value are matched, T3/PWM3 port outputs. The output is 50:50 of duty square wave, the frequency is following

$$f_{COMP} = \frac{\text{Oscillator Frequency}}{2 \times \text{Prescaler Value} \times (TDR + 1)}$$

To export the compare output as T3/PWM3, the T3_PE bit in the T3PWHR register must set to '1'.

11.5.2.8 Register Map

Name	Address	Dir	Default	Description
T2CR	C6H	R/W	00H	Timer 2 Mode Control Register
T2	C7H	R	00H	Timer 2 Register
T2DR	C7H	W	FFH	Timer 2 Data Register
CDR2	C7H	R	00H	Capture 2 Data Register
T3CR	CAH	R/W	00H	Timer 3 Mode Control Register
T3DR	CBH	W	FFH	Timer 3 Data Register
T3PPR	CBH	W	FFH	Timer 3 PWM Period Register
T3	CCH	R	00H	Timer 3 Register
T3PDR	CCH	R/W	00H	Timer 3 PWM Duty Register
CDR3	CCH	R	00H	Capture 3 Data Register
T3PWHR	CDH	W	00H	Timer 3 PWM High Register

Table 11.11 Register Map

11.5.2.9 Timer/Counter 2, 3 Register description

The Timer/Counter 2, 3 Register consists of Timer 2 Mode Control Register (T2CR), Timer 2 Register (T2), Timer 2 Data Register (T2DR), Capture 2 Data Register (CDR2), Timer 3 Mode Control Register (T3CR), Timer 3 Data Register (T3DR), Timer 3 PWM Period Register (T3PPR), Timer 3 Register (T3), Timer 3 PWM Duty Register (T3PDR), Capture 3 Data Register (CDR3) and Timer 3 PWM High Register (T3PWHR).

11.5.2.10 Register description for Timer/Counter 2, 3

T2CR (Timer 2 Mode Control Register) : C6H

7	6	5	4	3	2	1	0
T2EN	T2_PE	CAP2	T2CK2	T2CK1	T2CK0	T2CN	T2ST
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

T2EN	Control Timer 2			
	0	Timer 2 disable		
	1	Timer 2 enable		
T2_PE	Control Timer 2 Output port			
	0	Timer 2 Output disable		
	1	Timer 2 Output enable		
CAP2	Control Timer 2 operation mode			
	0	Timer/Counter mode		
	1	Capture mode		
T2CK[2:0]	Select Timer 2 clock source. Fx is main system clock frequency			
	T2CK2	T2CK1	T2CK0	Description
	0	0	0	fx/2
	0	0	1	fx/4
	0	1	0	fx/16
	0	1	1	fx/64
	1	0	0	fx/256
	1	0	1	fx/1024
	1	1	0	fx/4096
	1	1	1	External Clock (EC2)
T2CN	Control Timer 2 Count pause/continue			
	0	Temporary count stop		
	1	Continue count		
T2ST	Control Timer 2 start/stop			
	0	Counter stop		
	1	Clear counter and start		

T2 (Timer 2 Register: Read Case) : C7H

7	6	5	4	3	2	1	0
T27	T26	T25	T24	T23	T22	T21	T20
R	R	R	R	R	R	R	R

Initial value : 00H

T2[7:0] T2 Counter data

T2DR (Timer 2 Data Register: Write Case) : C7H

7	6	5	4	3	2	1	0
T2D7	T2D6	T2D5	T2D4	T2D3	T2D2	T2D1	T2D0
W	W	W	W	W	W	W	W

Initial value : FFH

T2D[7:0] T2 Compare data

CDR2 (Capture 2 Data Register: Read Case) : C7H

7	6	5	4	3	2	1	0
CDR27	CDR26	CDR25	CDR24	CDR23	CDR22	CDR21	CDR20
R	R	R	R	R	R	R	R

Initial value : 00H

CDR2[7:0] T2 Capture data

T3CR (Timer 3 Mode Count Register) : CAH

7	6	5	4	3	2	1	0
POL	16BIT	PWM3E	CAP3	T3CK1	T3CK0	T3CN	T3ST
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

POL Configure PWM polarity
0 Negative (Duty Match: Clear)
1 Positive (Duty Match: Set)

16BIT Select Timer 1 8/16-bit
0 8-bit
1 16-bit

PWM3E Control PWM enable
0 PWM disable
1 PWM enable

CAP3 Control Timer 3 mode
0 Timer/Counter mode
1 Capture mode

T3CK[1:0] Select clock source of Timer 3. Fx is the frequency of main system.

T3CK1	T3CK0	Description
0	0	fx
0	1	fx/2
1	0	fx/16
1	1	Use Timer 2 Clock

NOTE) If you want to use “Using Timer 2 Clock”, you can set T2EN bit in T2CR

T3CN Control Timer 3 Count pause/continue
0 Temporary count stop
1 Continue count

T3ST Control Timer 3 start/stop
0 Counter stop
1 Clear counter and start

T3DR (Timer 3 Data Register: Write Case) : CBH

7	6	5	4	3	2	1	0
T3D7	T3D6	T3D5	T3D4	T3D3	T3D2	T3D1	T3D0
W	W	W	W	W	W	W	W

Initial value : FFH

T3D[7:0] T3 Compare data

T3PPR (Timer 3 PWM Period Register: Write Case PWM mode only) : CBH

7	6	5	4	3	2	1	0
T3PP7	T3PP6	T3PP5	T3PP4	T3PP3	T3PP2	T3PP1	T3PP0
W	W	W	W	W	W	W	W

Initial value : FFH

T3PP[7:0] T3 PWM Period data

T3 (Timer 3 Register: Read Case) : CCH

7	6	5	4	3	2	1	0
T37	T36	T35	T34	T33	T32	T31	T30
R	R	R	R	R	R	R	R

Initial value : 00H

T3[7:0] T3 Counter Period data

T3PDR (Timer 3 PWM Duty Register) : CCH

7	6	5	4	3	2	1	0
T3PD7	T3PD6	T3PD5	T3PD4	T3PD3	T3PD2	T3PD1	T3PD0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

T3PD[7:0] T3 PWM Duty data
NOTE) only write, when PWM3E '1'

CDR3 (Capture 3 Data Register: Read Case) : CCH

7	6	5	4	3	2	1	0
CDR37	CDR36	CDR35	CDR34	CDR33	CDR32	CDR31	CDR30
R	R	R	R	R	R	R	R

Initial value : 00H

CDR3[7:0] T3 Capture data

T3PWHR (Timer 3 PWM High Register) : CDH

7	6	5	4	3	2	1	0
T3_PE	-	-	-	PW3H3	PW3H2	PW3H1	PW3H0
W	-	-	-	W	W	W	W

Initial value : 00H

T3_PE Control Timer 3 Output port operation
NOTE) only writable bit. Be careful
 0 Timer 3 Output disable
 1 Timer 3 Output enable
 PW3H[3:2] PWM period High value (bit [9:8])
 PW3H[1:0] PWM duty High value (bit [9:8])

PERIOD:

PW3H3	PW3H2
-------	-------

T3PPR[7:0]

 DUTY:

PW3H1	PW3H0
-------	-------

T3PDR[7:0]

11.5.3 16-bit Timer 4

11.5.3.1 Overview

The 16-bit timer 4 consists of Multiplexer, Timer Data Register High/Low, Timer Register High/Low, Timer Mode Control Register. It is able to use internal 16-bit timer/ counter without a port output function.

The 16-bit timer 4 is able to use the divided clock of the main clock selected from pre-scalar output.

11.5.3.2 16-bit Timer/Counter Mode

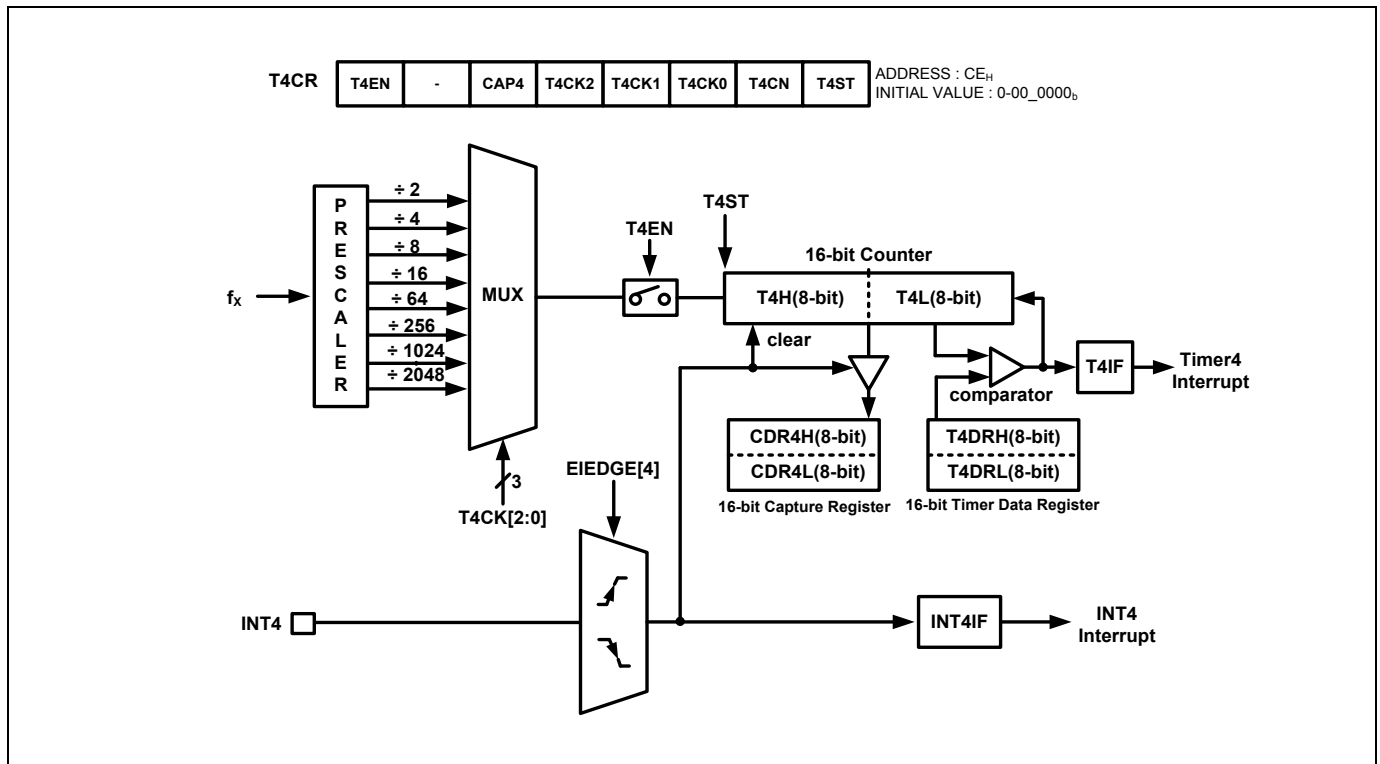


Figure 11.37 Timer4 16-bit Mode Block Diagram

11.5.3.3 Register Map

Name	Address	Dir	Default	Description
T4CR	CEH	R/W	00H	Timer 4 Mode Control Register
T4L	CFH	R	00H	Timer 4 Low Register
T4LDR	CFH	W	FFH	Timer 4 Low Data Register
LCDR4	CFH	R	00H	Low Capture 4 Data Register
T4H	D5H	R	00H	Timer 4 High Register
T4HDR	D5H	R/W	00H	Timer 4 High Data Register
HCDR4	D5H	R	00H	High Capture 4 Data Register

Table 11.12 Register Map

11.5.3.4 Timer 4 Register description

The timer 4 register consists of Timer 4 Mode Control Register (T4CR), Timer 4 Low Register (T4L), Timer 4 Low Data Register (T4LDR), Low Capture 4 Data Register (LCDR4), Timer 4 High Register (T4H), Timer 4 High Data Register (T4HDR), High Capture 4 Data Register (HCDR4).

11.5.3.5 Register description for Timer 4

T4CR (Timer 4 Mode Control Register) : CEH

7	6	5	4	3	2	1	0
T4EN	-	CAP4	T4CK2	T4CK1	T4CK0	T4CN	T4ST
RW	-	RW	RW	RW	RW	RW	RW

Initial value : 00H

T4EN	Control Timer 4 operation			
	0	Timer 4 disable		
	1	Timer 4 enable		
CAP4	Control Timer 4 mode			
	0	Timer/Counter mode		
	1	Capture mode		
T4CK[2:0]	Select Timer 4 clock source. fx is main system clock frequency			
	T4CK2	T4CK1	T4CK0	Description
	0	0	0	fx/2
	0	0	1	fx/4
	0	1	0	fx/8
	0	1	1	fx/16
	1	0	0	fx/64
	1	0	1	fx/256
	1	1	0	fx/1024
	1	1	1	fx/2048
T4CN	Control Timer 4 Count pause/continue			
	0	Temporary count stop		
	1	Continue count		
T4ST	Control Timer 4 start/stop			
	0	Counter stop		
	1	Clear Counter and start		

T4L (Timer 4 Low Register: Read Case) : CFH

7	6	5	4	3	2	1	0
T4L7	T4L6	T4L5	T4L4	T4L3	T4L2	T4L1	T4L0
R	R	R	R	R	R	R	R

Initial value : 00H

T4L[7:0]	T4L Counter
----------	-------------

T4LDR (Timer 4 Low Data Register: Write Case) : CFH

7	6	5	4	3	2	1	0
T4LD7	T4LD6	T4LD5	T4LD4	T4LD3	T4LD2	T4LD1	T4LD0
W	W	W	W	W	W	W	W

Initial value : FFH

T4LD[7:0] T4L Compare

LCDR4 (Low Capture 4 Data Register: Read Case) : CFH

7	6	5	4	3	2	1	0
LCDR47	LCDR46	LCDR45	LCDR44	LCDR43	LCDR42	LCDR41	LCDR40
R	R	R	R	R	R	R	R

Initial value : 00H

LCDR4[7:0] T4L Capture data

T4H (Timer 4 High Register: Read Case) : D5H

7	6	5	4	3	2	1	0
T4H7	T4H6	T4H5	T4H4	T4H3	T4H2	T4H1	T4H0
R	R	R	R	R	R	R	R

Initial value : 00H

T4H[7:0] T4H Counter Period

T4HDR (Timer 4 High Data Register: Write Case) : D5H

7	6	5	4	3	2	1	0
T4HD7	T4HD6	T4HD5	T4HD4	T4HD3	T4HD2	T4HD1	T4HD0
W	W	W	W	W	W	W	W

Initial value : FFH

T4HD[7:0] T4H Compare

HCDR4 (High Capture 4 Data Register: Read Case) : D5H

7	6	5	4	3	2	1	0
HCDR47	HCDR46	HCDR45	HCDR44	HCDR43	HCDR42	HCDR41	HCDR40
R	R	R	R	R	R	R	R

Initial value : 00H

HCDR4[7:0] T4H Capture data

11.5.4 Timer Interrupt Status Register (TMISR)

11.5.4.1 Register description for TMISR

TMISR (Timer Interrupt Status Register) : AFH

7	6	5	4	3	2	1	0
-	-	TMIF5	TMIF4	TMIF3	TMIF2	TMIF1	TMIF0
-	-	R	R	R	R	R	R

Initial value : 00H

TMIF5	Timer 5 Interrupt Flag
0	No Timer 5 interrupt
1	Timer 5 interrupt occurred, write "1" to clear interrupt flag
TMIF4	Timer 4 Interrupt Flag
0	No Timer 4 interrupt
1	Timer 4 interrupt occurred, write "1" to clear interrupt flag
TMIF3	Timer 3 Interrupt Flag
0	No Timer 3 interrupt
1	Timer 3 interrupt occurred, write "1" to clear interrupt flag
TMIF2	Timer 2 Interrupt Flag
0	No Timer 2 interrupt
1	Timer 2 interrupt occurred, write "1" to clear interrupt flag
TMIF1	Timer 1 Interrupt Flag
0	No Timer 1 interrupt
1	Timer 1 interrupt occurred, write "1" to clear interrupt flag
TMIF0	Timer 0 Interrupt Flag
0	No Timer 0 interrupt
1	Timer 0 interrupt occurred, write "1" to clear interrupt flag

NOTE)

1. The Timer Interrupt Status Register contains interrupt information of each timers. Even if user disabled timer interrupt at IE2, user could check timer interrupt condition from this register.

11.6 Buzzer Driver

11.6.1 Overview

The Buzzer consists of 6 bit counter, buzzer data register (BUZDR), and buzzer control register (BUZCR). The Square Wave is outputted through P12/BUZO pin. In buzzer data register BUZDR[5:0] controls the buzzer frequency and BUZDIV[1:0] selects fBUZ divided by DIV block . In buzzer control register (BUZCR), BUCK[2:0] selects source clock divided by prescaler

$$f_{\text{BUZO}} = \frac{f_{\text{BUZ}}}{2 \times \text{BUZDIV} \times (\text{BUZDATA} + 1)} (\text{Hz})$$

BUZDATA [5:0]	BUZDIV[1:0]			
	00 (fbuz/8)	01 (fbuz/16)	10 (fbuz/32)	11 (fbuz/64)
0	62.500	31.250	15.625	7.813
1	31.250	15.625	7.813	3.906
2	20.833	10.417	5.208	2.604
3	15.625	7.813	3.906	1.953
4	12.500	6.250	3.125	1.563
5	10.417	5.208	2.604	1.302
6	8.929	4.464	2.232	1.116
7	7.813	3.906	1.953	0.977
8	6.944	3.472	1.736	0.868
9	6.250	3.125	1.563	0.781
10	5.682	2.841	1.420	0.710
11	5.208	2.604	1.302	0.651
12	4.808	2.404	1.202	0.601
13	4.464	2.232	1.116	0.558
14	4.167	2.083	1.042	0.521
15	3.906	1.953	0.977	0.488
16	3.676	1.838	0.919	0.460
17	3.472	1.736	0.868	0.434
18	3.289	1.645	0.822	0.411
19	3.125	1.563	0.781	0.391
20	2.976	1.488	0.744	0.372
21	2.841	1.420	0.710	0.355
22	2.717	1.359	0.679	0.340
23	2.604	1.302	0.651	0.326
24	2.500	1.250	0.625	0.313
25	2.404	1.202	0.601	0.300
26	2.315	1.157	0.579	0.289
27	2.232	1.116	0.558	0.279
28	2.155	1.078	0.539	0.269
29	2.083	1.042	0.521	0.260
30	2.016	1.008	0.504	0.252
31	1.953	0.977	0.488	0.244

BUZDATA [5:0]	BUZDIV[1:0]			
	00 (fbuz/8)	01 (fbuz/16)	10 (fbuz/32)	11 (fbuz/64)
32	1.894	0.947	0.473	0.237
33	1.838	0.919	0.460	0.230
34	1.786	0.893	0.446	0.223
35	1.736	0.868	0.434	0.217
36	1.689	0.845	0.422	0.211
37	1.645	0.822	0.411	0.206
38	1.603	0.801	0.401	0.200
39	1.563	0.781	0.391	0.195
40	1.524	0.762	0.381	0.191
41	1.488	0.744	0.372	0.186
42	1.453	0.727	0.363	0.182
43	1.420	0.710	0.355	0.178
44	1.389	0.694	0.347	0.174
45	1.359	0.679	0.340	0.170
46	1.330	0.665	0.332	0.166
47	1.302	0.651	0.326	0.163
48	1.276	0.638	0.319	0.159
49	1.250	0.625	0.313	0.156
50	1.225	0.613	0.306	0.153
51	1.202	0.601	0.300	0.150
52	1.179	0.590	0.295	0.147
53	1.157	0.579	0.289	0.145
54	1.136	0.568	0.284	0.142
55	1.116	0.558	0.279	0.140
56	1.096	0.548	0.274	0.137
57	1.078	0.539	0.269	0.135
58	1.059	0.530	0.265	0.132
59	1.042	0.521	0.260	0.130
60	1.025	0.512	0.256	0.128
61	1.008	0.504	0.252	0.126
62	0.992	0.496	0.248	0.124
63	0.977	0.488	0.244	0.122

Table 11.13 Buzzer Frequency at 1MHz

11.6.2 Block Diagram

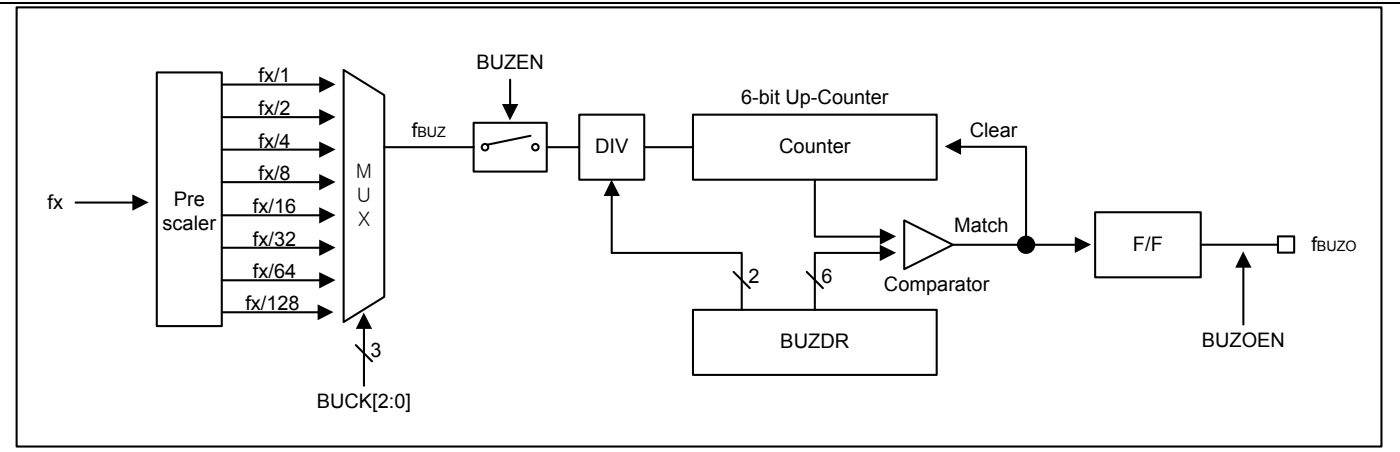


Figure 11.38 Buzzer Driver Block Diagram

11.6.3 Register Map

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

Table 11.14 Register Map

11.6.4 Buzzer Driver Register Description

Buzzer Driver consists of Buzzer Data Register (BUZDR), Buzzer Control Register (BUZCR).

11.6.5 Register Description for Buzzer Driver

BUZDR (Buzzer Data Register) : 8FH

7	6	5	4	3	2	1	0
BUZDIV1	BUZDIV2	BUZDR5	BUZDR4	BUZDR3	BUZDR2	BUZDR1	BUZDR0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : FFH

BUZDIV[1:0]		Buzzer Clock Divider	
BZDIV1	BUZDIV2	description	
0	0	$f_{BUZ}/8$	
0	1	$f_{BUZ}/16$	
1	0	$f_{BUZ}/32$	
1	1	$f_{BUZ}/64$	
BUZDATA[5:0]		These bits control the BUZZER frequency	
		Its resolution is 00H to 3FH	

BUZCR (Buzzer Control Register) : 97H

7	6	5	4	3	2	1	0
BUZOEN	-	-	-	BUCK2	BUCK1	BUCK0	BUZEN
-	-	-	-	RW	RW	RW	RW

Initial value : 00H

BUZOEN Control Buzzer output port

0 Buzzer Output disable

1 Buzzer Output enable

BUCK[2:0] Buzzer driver source clock selection

BUCK2 BUCK1 BUCK0 description

0 0 0 fx/1

0 0 1 fx/2

0 1 0 fx/4

0 1 1 fx/8

1 0 0 fx/16

1 0 1 fx/32

1 1 0 fx/64

1 1 1 fx/128

BUZEN Buzzer driver operation control

0 Buzzer driver disable

1 Buzzer driver enable

NOTE)

1. fx: System clock oscillation frequency.

11.7 USART

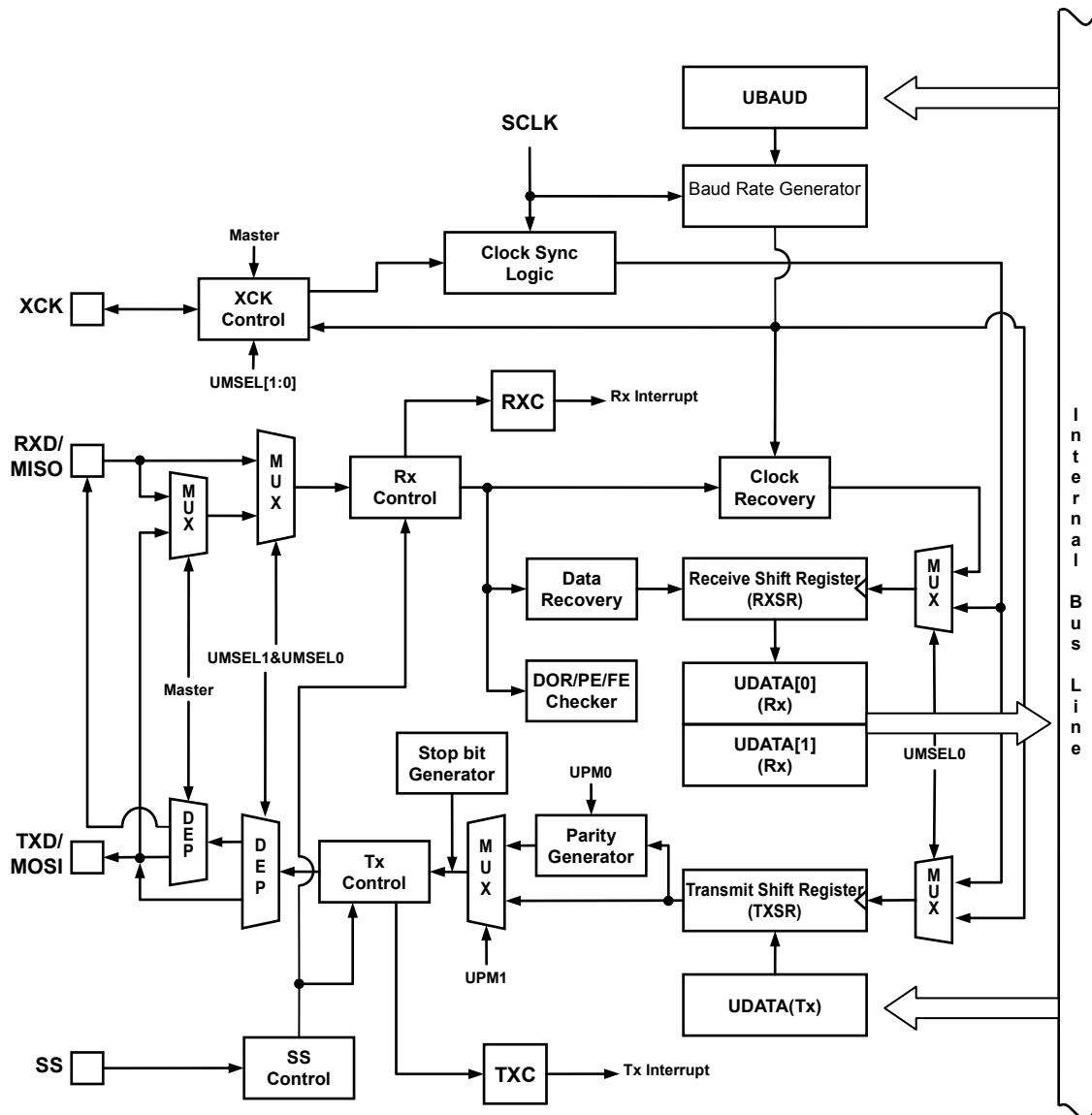
11.7.1 Overview

The Universal Synchronous and Asynchronous serial Receiver and Transmitter (USART) is a highly flexible serial communication device. The main features are listed below.

- Full Duplex Operation (Independent Serial Receive and Transmit Registers)
- Asynchronous or Synchronous Operation
- Master or Slave Clocked Synchronous and SPI Operation
- Supports all four SPI Modes of Operation (Mode 0, 1, 2, 3)
- LSB First or MSB First Data Transfer @SPI mode
- High Resolution 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
- Digital Low Pass Filter
- Three Separate Interrupts on TX Complete, TX Data Register Empty and RX Complete
- Double Speed Asynchronous Communication Mode

USART has three main parts of Clock Generator, Transmitter and Receiver. The Clock Generation logic consists of synchronization logic for external clock input used by synchronous or SPI slave operation, and the baud rate generator for asynchronous or master (synchronous or SPI) 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 a continuous transfer of data without any delay between frames. The receiver is the most complex part of the USART 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 (UDATAx) and control logic. The Receiver supports the same frame formats as the Transmitter and can detect Frame Error, Data OverRun and Parity Errors.

11.7.2 Block Diagram



UCTRLx1	UMSEL1	UMSEL0	UPM1	UPM0	USIZE2	USIZE1	USIZE0	UCPOL	ADDRESS : E2 _H , FA _H INITIAL VALUE : 0000_0000 _B
UCTRLx2	UDRIE	TXCIE	RXCIE	WAKEIE	TXE	RXE	USARTEN	U2X	ADDRESS : E3 _H , FB _H INITIAL VALUE : 0000_0000 _B
UCTRLx3	MASTER	LOOPS	DISXCK	SPISS	-	USBS	TX8	RX8	ADDRESS : E4 _H , FC _H INITIAL VALUE : 0000_-000 _B
USTATx	UDRE	TXC	RXC	WAKE	SOFTTRST	DOR	FE	PE	ADDRESS : E5 _H , FD _H INITIAL VALUE : 1000_0000 _B

Figure 11.39 USART Block Diagram

11.7.3 Clock Generation

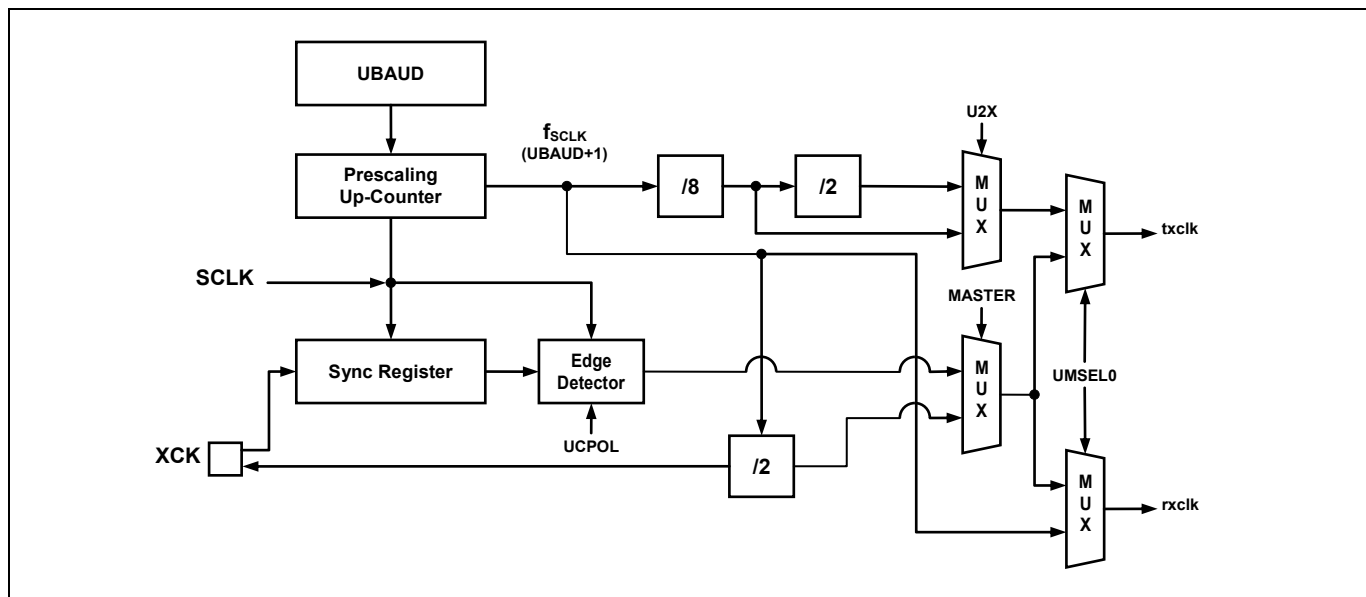


Figure 11.40 Clock Generation Block Diagram

The Clock generation logic generates the base clock for the Transmitter and Receiver. The USART supports four modes of clock operation and those are Normal Asynchronous, Double Speed Asynchronous, Master Synchronous and Slave Synchronous. The clock generation scheme for Master SPI and Slave SPI mode is the same as Master Synchronous and Slave Synchronous operation mode. The UMSELn bit in UCTRLx1 register selects between asynchronous and synchronous operation. Asynchronous Double Speed mode is controlled by the U2X bit in the UCTRLx2 register. The MASTER bit in UCTRLx2 register controls whether the clock source is internal (Master mode, output port) or external (Slave mode, input port). The XCK pin is only active when the USART operates in Synchronous or SPI mode.

Table below contains equations for calculating the baud rate (in bps).

Operating Mode	Equation for Calculating Baud Rate
Asynchronous Normal Mode (U2X=0)	$\text{Baud Rate} = \frac{f_{\text{SCLK}}}{16(\text{UBAUD}_x + 1)}$
Asynchronous Double Speed Mode (U2X=1)	$\text{Baud Rate} = \frac{f_{\text{SCLK}}}{8(\text{UBAUD}_x + 1)}$
Synchronous or SPI Master Mode	$\text{Baud Rate} = \frac{f_{\text{SCLK}}}{2(\text{UBAUD}_x + 1)}$

Table 11.15 Equations for Calculating Baud Rate Register Setting

11.7.4 External Clock (XCK)

External clocking is used by the synchronous or SPI slave modes of operation.

External clock input from the XCK pin is sampled by a synchronization logic to remove meta-stability. The output from the synchronization logic must then pass through an edge detector before it can be used by the Transmitter and Receiver. This process introduces a two CPU clock period delay and the maximum frequency of the external XCK pin is limited by the following equation.

$$f_{XCK} = \frac{f_{SCLK}}{4}$$

Where f_{XCK} is the frequency of XCK and f_{SCLK} is the frequency of main system clock (SCLK).

11.7.5 Synchronous mode Operation

When synchronous or SPI mode is used, the XCK pin will be used as either clock input (slave) or clock output (master). The dependency between the clock edges and data sampling or data change is the same. The basic principle is that data input on RXD (MISO in SPI mode) pin is sampled at the opposite XCK clock edge of the edge in the data output on TXD (MOSI in SPI mode) pin is changed.

The UCPOL bit in UCTRLx1 register selects which XCK clock edge is used for data sampling and which is used for data change. As shown in the figure below, when UCPOL is zero the data will be changed at XCK rising edge and sampled at XCK falling edge.

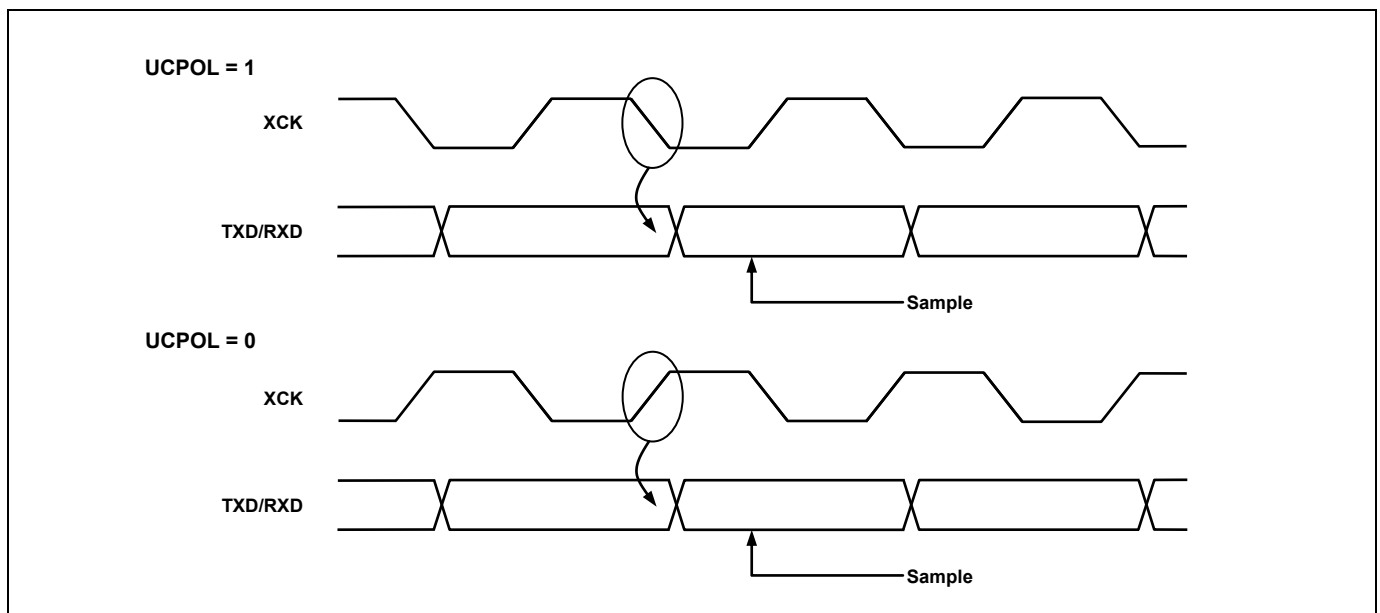


Figure 11.41 Synchronous Mode XCKn Timing

11.7.6 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 checking.

The USART 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 a total of nine, are succeeding, ending with the most significant bit (MSB). If enabled the parity bit is inserted after the data bits, before the stop bits. 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 next figure shows the possible combinations of the frame formats. Bits inside brackets are optional.

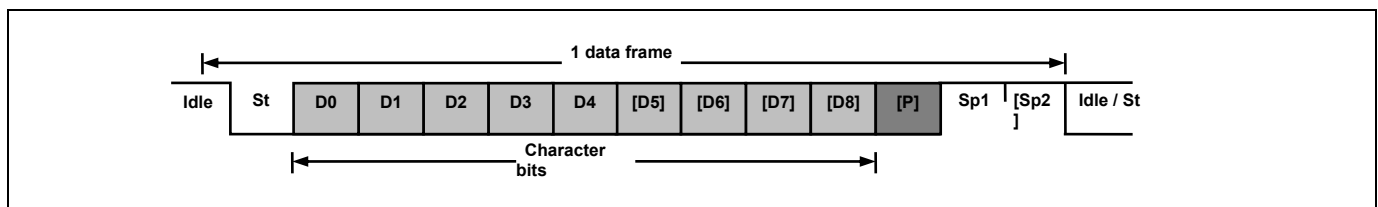


Figure 11.42 frame format

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 USART is set by the USIZE[2:0], UPM[1:0] and USBS bits in UCTRLx1 register. The Transmitter and Receiver use the same setting.

11.7.7 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 St + bits and first stop bit of a serial frame.

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

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

P_{even} : Parity bit using even parity

P_{odd} : Parity bit using odd parity

D_n : Data bit n of the character

11.7.8 USART Transmitter

The USART Transmitter is enabled by setting the TXE bit in UCTRLx1 register. When the Transmitter is enabled, the normal port operation of the TXD pin is overridden by the serial output pin of USART. The baud-rate, operation mode and frame format must be setup once before doing any transmissions. If synchronous or SPI operation is used, the clock on the XCK pin will be overridden and used as transmission clock. If USART operates in SPI mode, SS pin is used as SS input pin in slave mode or can be configured as SS output pin in master mode. This can be done by setting SPISS bit in UCTRLx3 register.

11.7.8.1 Sending Tx data

A data transmission is initiated by loading the transmit buffer (UDATAx 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 at the settings of control registers. If the 9-bit characters are used in asynchronous or synchronous operation mode (USIZE[2:0]=7), the ninth bit must be written to the TX8 bit in UCTRLx3 register before loading transmit buffer (UDATA register).

11.7.8.2 Transmitter flag and interrupt

The USART Transmitter has 2 flags which indicate its state. One is USART Data Register Empty (UDRE) and the other is Transmit Complete (TXC). Both flags can be used as interrupt sources.

UDRE flag indicates whether the transmit buffer is ready to be loaded with new data. This bit is set when the transmit buffer is empty and cleared when the transmit buffer contains transmission data which 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 not valid.

When the Data Register Empty Interrupt Enable (UDRIE) bit in UCTRL2 register is set and the Global Interrupt is enabled, USART 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 are 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 USTAT register.

When the Transmit Complete Interrupt Enable (TXCIE) bit in UCTRL2 register is set and the Global Interrupt is enabled, USART Transmit Complete Interrupt is generated while TXC flag is set.

11.7.8.3 Parity Generator

The Parity Generator calculates the parity bit for the sending serial frame data. When parity bit is enabled (UPM[1]=1), the transmitter control logic inserts the parity bit between the bits and the first stop bit of the sending frame.

11.7.8.4 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 is used as normal General Purpose I/O (GPIO) or primary function pin.

11.7.9 USART Receiver

The USART Receiver is enabled by setting the RXE bit in the UCTRLx1 register. When the Receiver is enabled, the normal pin operation of the RXD pin is overridden by the USART as the serial input pin of the Receiver. The baud-rate, mode of operation and frame format must be set before serial reception. If synchronous or SPI operation is used, the clock on the XCK pin will be used as transfer clock. If USART operates in SPI mode, SS pin is used as SS input pin in slave mode or can be configured as SS output pin in master mode. This can be done by setting SPISS bit in UCTRLx3 register.

11.7.9.1 Receiving Rx data

When USART is in synchronous or asynchronous operation mode, 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) or sampling edge of XCK (synchronous), and shifted into the receive shift register until the first stop bit of a frame is received. Even if there's 2nd stop bit in the frame, the 2nd 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 UDATAx register.

If 9-bit characters are used (USIZE[2:0] = 7), the ninth bit is stored in the RX8 bit position in the UCTRLx3 register. The 9th bit must be read from the RX8 bit before reading the low 8 bits from the UDATAx register. Likewise, the error flags FE, DOR, PE must be read before reading the data from UDATAx register. This is because the error flags are stored in the same FIFO position of the receive buffer.

11.7.9.2 Receiver flag and interrupt

The USART Receiver has one flag that indicates the Receiver state.

The Receive Complete (RXC) flag indicates whether there are unread data present 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 UCTRLx2 register is set and Global Interrupt is enabled, the USART Receiver Complete Interrupt is generated while RXC flag is set.

The USART 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 USTATx register. As data received 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 UDATAx register, read the USTATx register first which contains error flags.

The Frame Error (FE) flag indicates the state of the first stop bit. The FE flag is set when the stop bit was correctly detected as “1”, and the FE flag is cleared when the stop bit was incorrect, ie 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. A 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”.

Note) The error flags related to receive operation are not used when USART is in SPI mode.

11.7.9.3 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.

11.7.9.4 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 and the remaining data in the buffer is all reset. The RXD pin is not overridden the function of USART, so RXD pin becomes normal GPIO or primary function pin.

11.7.9.5 Asynchronous Data Reception

To receive asynchronous data frame, the USART 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 incoming bits and low pass filters them, 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, 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.

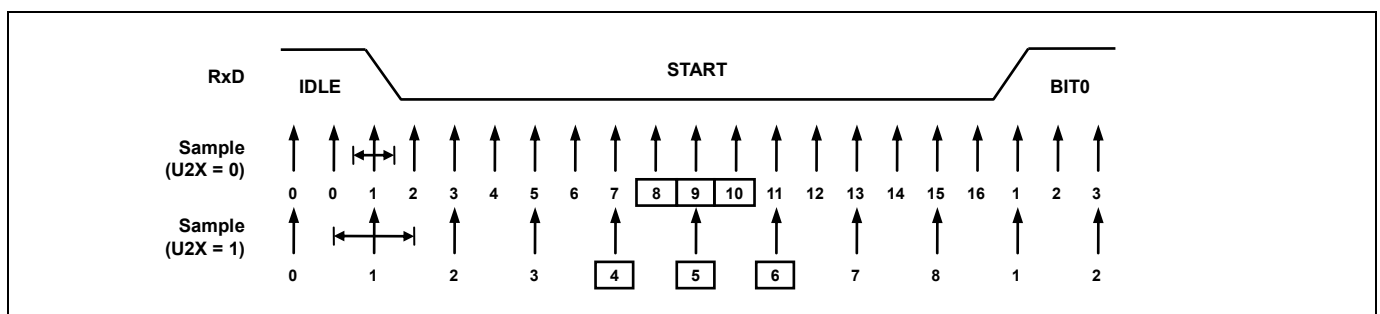


Figure 11.43 Start bit Sampling

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, 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 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.

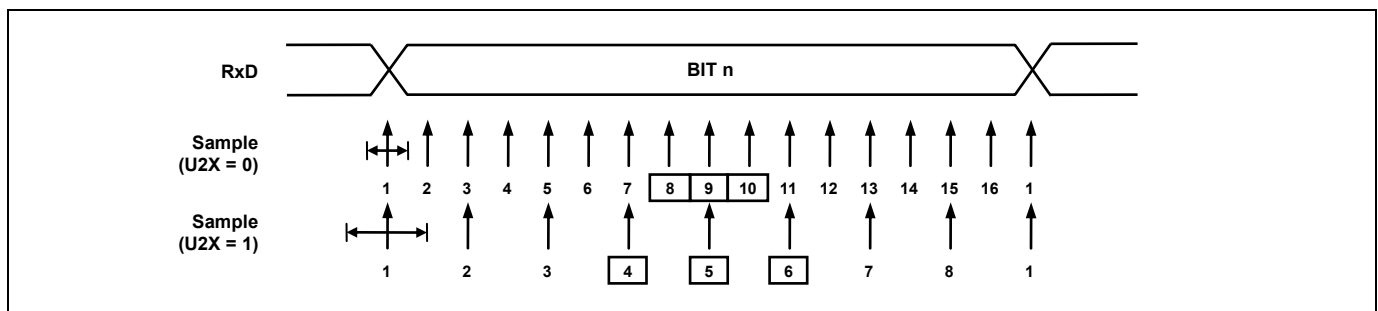


Figure 11.44 Sampling of Data and Parity bit

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 flag is set. After deciding first stop bit whether a valid stop bit is received or not, the Receiver enters into idle state and monitors the RXD line to check a valid high to low transition is detected (start bit detection).

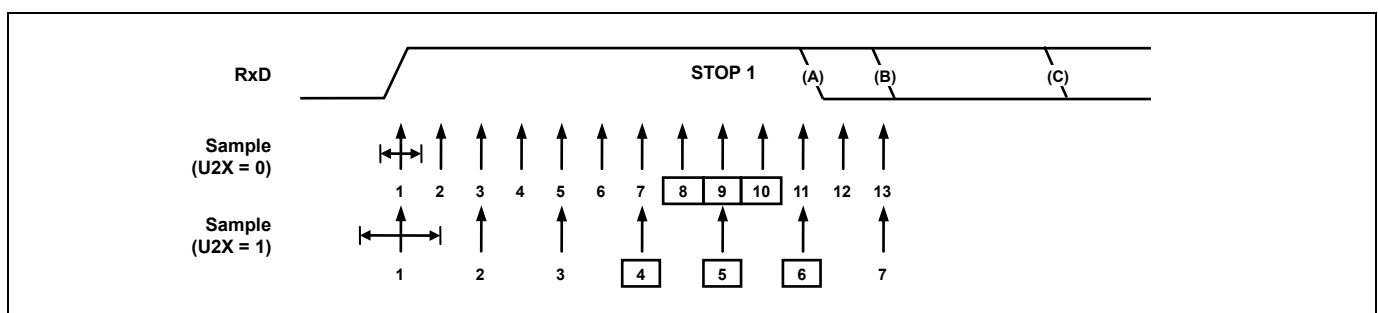


Figure 11.45 Stop bit Sampling and Next Start bit Sampling

11.7.10 SPI Mode

The USART can be set to operate in industrial standard SPI compliant mode. The SPI mode has the following features.

- Full duplex, three-wire synchronous data transfer
- Master or Slave operation
- Supports all four SPI modes of operation (mode0, 1, 2, and 3)
- Selectable LSB first or MSB first data transfer
- Double buffered transmit and receive
- Programmable transmit bit rate

When SPI mode is enabled (UMSEL[1:0]=3), the Slave Select (SS) pin becomes active low input in slave mode operation, or can be output in master mode operation if SPISS bit is set.

Note that during SPI mode of operation, the pin RXD is renamed as MISO and TXD is renamed as MOSI for compatibility to other SPI devices.

11.7.10.1 SPI Clock formats and timing

To accommodate a wide variety of synchronous serial peripherals from different manufacturers, the USART has a clock polarity bit (UCPOL) and a clock phase control bit (UCPHA) to select one of four clock formats for data transfers. UCPOL selectively insert an inverter in series with the clock. UCPHA selects one of two different clock phase relationships between the clock and data. Note that UCPHA and UCPOL bits in UCTRLx1 register have different meanings according to the UMSEL[1:0] bits which decides the operating mode of USART.

Table below shows four combinations of UCPOL and UCPHA for SPI mode 0, 1, 2, and 3.

SPI Mode	UCPOL	UCPHA	Leading Edge	Trailing Edge
0	0	0	Sample (Rising)	Setup (Falling)
1	0	1	Setup (Rising)	Sample (Falling)
2	1	0	Sample (Falling)	Setup (Rising)
3	1	1	Setup (Falling)	Sample (Rising)

Table 11.16 CPOL Functionality

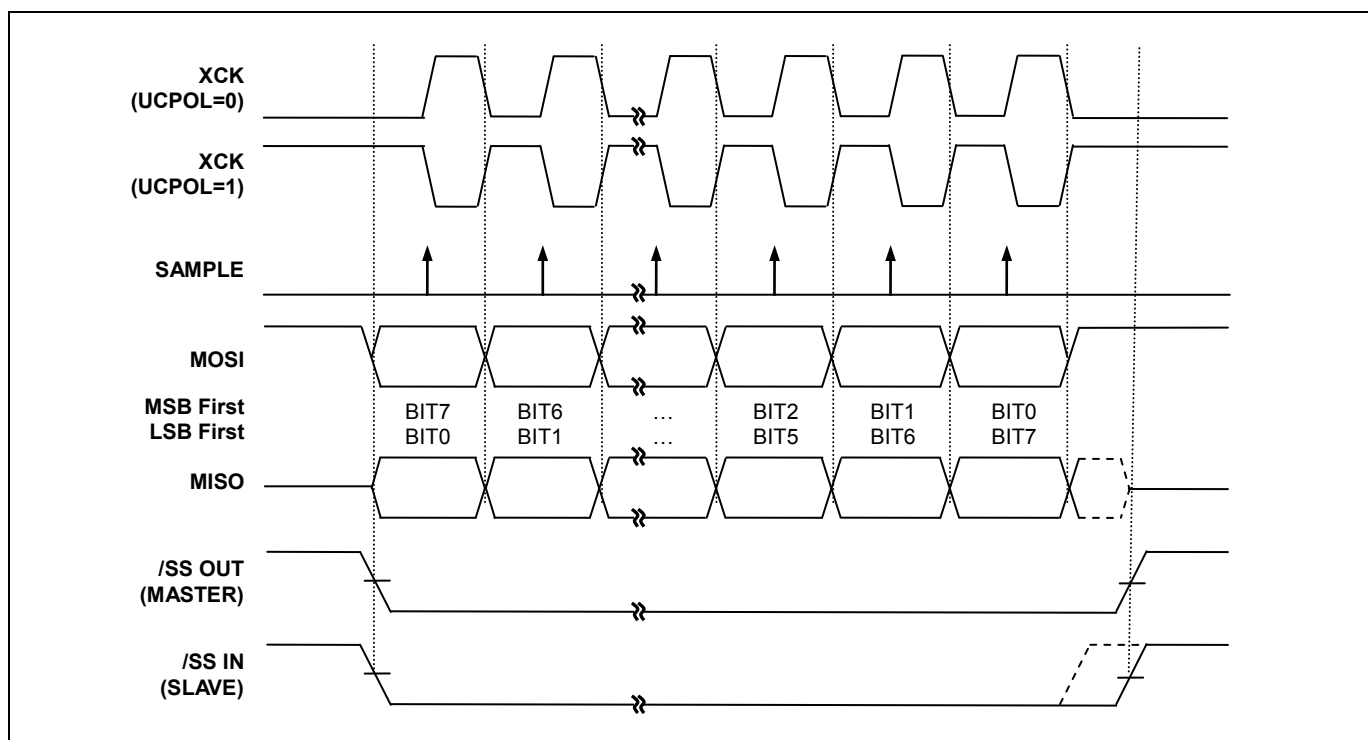


Figure 11.46 SPI Clock Formats when UCPHA=0

When UCPHA=0, the slave begins to drive its MISO output with the first data bit value when SS goes to active low. The first XCK edge causes both the master and the slave to sample the data bit value on their MISO and MOSI inputs, respectively. At the second XCK edge, the USART shifts the second data bit value out to the MOSI and MISO outputs of the master and slave, respectively. Unlike the case of UCPHA=1, when UCPHA=0, the slave's SS input must go to its inactive high level between transfers. This is because the slave can prepare the first data bit when it detects falling edge of SS input.

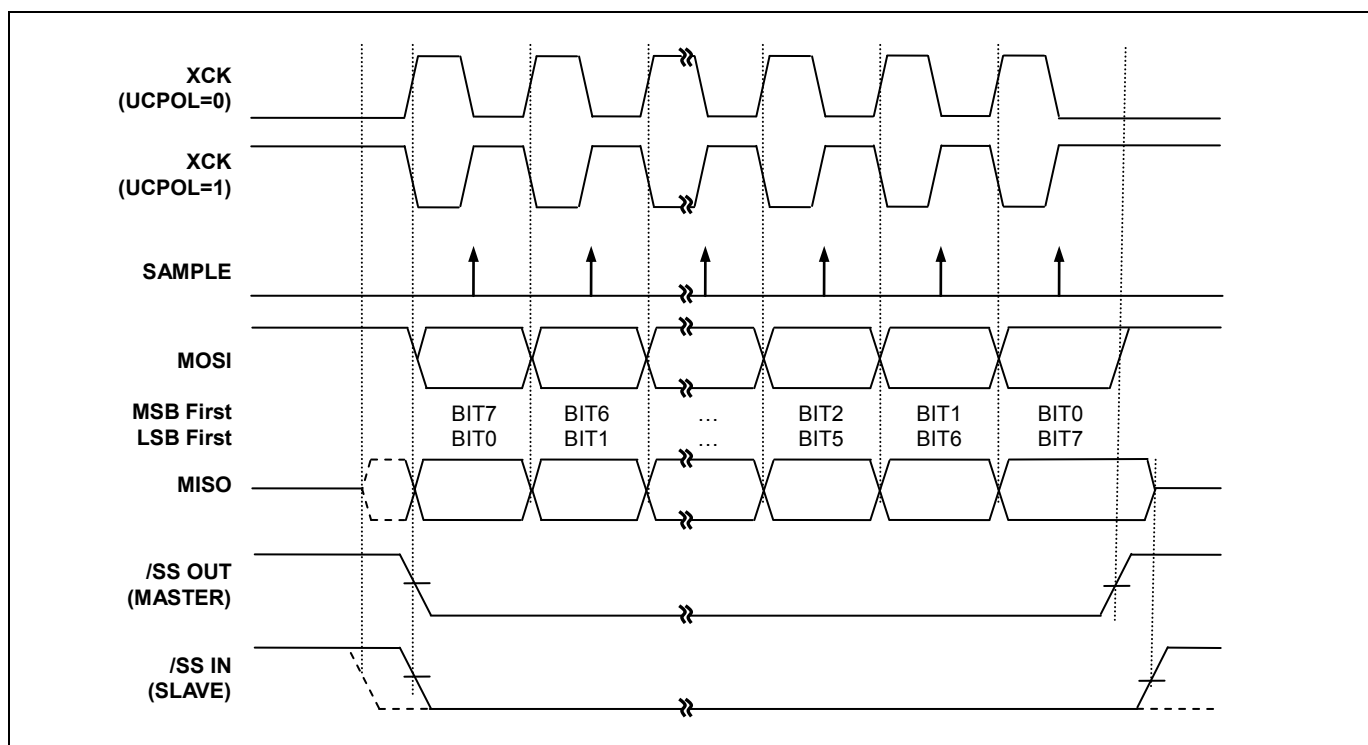


Figure 11.47 SPI Clock Formats when UCPHA=1

When UCPHA=1, the slave begins to drive its MISO output when SS goes active low, but the data is not defined until the first XCK edge. The first XCK edge shifts the first bit of data from the shifter onto the MOSI output of the master and the MISO output of the slave. The next XCK edge causes both the master and slave to sample the data bit value on their MISO and MOSI inputs, respectively. At the third XCK edge, the USART shifts the second data bit value out to the MOSI and MISO output of the master and slave respectively. When UCPHA=1, the slave's SS input is not required to go to its inactive high level between transfers.

Because the SPI logic reuses the USART resources, SPI mode of operation is similar to that of synchronous or asynchronous operation. An SPI transfer is initiated by checking for the USART Data Register Empty flag (UDRE=1) and then writing a byte of data to the UDATA Register. In master mode of operation, even if transmission is not enabled (TXE=0), writing data to the UDATA register is necessary because the clock XCK is generated from transmitter block.

11.7.11 Register Map

Name	Address	Dir	Default	Description
UCTRL01	E2H	R/W	00H	USART Control 1 Register 0
UCTRL02	E3H	R/W	00H	USART Control 2 Register 0
UCTRL03	E4H	R/W	00H	USART Control 3 Register 0
USTAT0	E5H	R	80H	USART Status Register 0
UBAUD0	E6H	R/W	FFH	USART Baud Rate Generation Register 0
UDATA0	E7H	R/W	FFH	USART Data Register 0
UCTRL11	FAH	R/W	00H	USART Control 1 Register 1
UCTRL12	FBH	R/W	00H	USART Control 2 Register 1
UCTRL13	FCH	R/W	00H	USART Control 3 Register 1
USTAT1	FDH	R	80H	USART Status Register 1
UBAUD1	FEH	R/W	FFH	USART Baud Rate Generation Register 1
UDATA1	FFH	R/W	FFH	USART Data Register 1

Table 11.17 Register Map

11.7.12 USART Register Description

USART module consists of USART Control 1 Register (UCTRLx1), USART Control 2 Register (UCTRLx2), USART Control 3 Register (UCTRLx3), USART Status Register (USTATx), USART Data Register (UDATAx), and USART Baud Rate Generation Register (UBAUDx).

11.7.13 Register Description for USART

UCTRLx1 (USART Control 1 Register) E2H, FAH

7	6	5	4	3	2	1	0
UMSEL1	UMSEL0	UPM1	UPM0	USIZE2	USIZE1 UDORD	USIZE0 UCPHA	UCPOL
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00_H

UMSEL[1:0]	Selects operation mode of USART			
	UMSEL1	UMSEL0	Operating Mode	
	0	0	Asynchronous Mode (Normal Uart)	
	0	1	Synchronous Mode (Synchronous Uart)	
	1	0	Reserved	
	1	1	SPI Mode	
UPM[1:0]	Selects Parity Generation and Check methods			
	UPM1	UPM0	Parity mode	
	0	0	No Parity	
	0	1	Reserved	
	1	0	Even Parity	
	1	1	Odd Parity	
USIZE[2:0]	When in asynchronous or synchronous mode of operation, 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	0	0	Reserved
	1	0	1	Reserved
	1	1	0	Reserved
	1	1	1	9-bit
UDORD	This bit is in the same bit position with USIZE1. In SPI mode, when set to one the MSB of the data byte is transmitted first. When set to zero the LSB of the data byte is transmitted first.			
	0	LSB First		
	1	MSB First		
UCPOL	Selects polarity of XCK in synchronous or SPI mode			
	0	TXD change @Rising Edge, RXD change @Falling Edge		
	1	TXD change @ Falling Edge, RXD change @ Rising Edge		
UCPHA	This bit is in the same bit position with USIZE0. In SPI mode, along with UCPOL bit, selects one of two clock formats for different kinds of synchronous serial peripherals. Leading edge means first XCK edge and trailing edge means 2 nd or last clock edge of XCK in one XCK pulse. And Sample means detecting of incoming receive bit, Setup means preparing transmit data.			
	UCPOL	UCPHA	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)

UCTRLx2 (USART Control 2 Register) E3H, FBH

7	6	5	4	3	2	1	0
UDRIE	TXCIE	RXCIE	WAKEIE	TXE	RXE	USARTEN	U2X
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00_H

UDRIE	Interrupt enable bit for USART 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 Asynchronous 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. 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
USARTEN	Activate USART module by supplying clock. 0 USART is disabled (clock is halted) 1 USART is enabled
U2X	This bit only has effect for the asynchronous operation and selects receiver sampling rate. 0 Normal asynchronous operation 1 Double Speed asynchronous operation

UCTRLx3 (USART Control 3 Register) E4H, FCH

7	6	5	4	3	2	1	0
MASTER	LOOPS	DISXCK	SPISS	-	USBS	TX8	RX8
RW	RW	RW	RW	-	RW	RW	RW

Initial value : 00_H

MASTER	Selects master or slave in SPI or Synchronous mode operation and controls the direction of XCK pin. 0 Slave mode operation and XCK is input pin. 1 Master mode operation and XCK is output pin
LOOPS	Controls the Loop Back mode of USART, for test mode 0 Normal operation 1 Loop Back mode
DISXCK	In Synchronous mode of operation, selects the waveform of XCK output. 0 XCK is free-running while USART is enabled in synchronous master mode. 1 XCK is active while any frame is on transferring.
SPISS	Controls the functionality of SS pin in master SPI mode. 0 SS pin is normal GPIO or other primary function 1 SS output to other slave device
USBS	Selects the length of stop bit in Asynchronous or Synchronous mode of operation. 0 1 Stop bit 1 2 Stop bit
TX8	The ninth bit of data frame in Asynchronous or Synchronous mode of operation. Write this bit first before loading the UDATA register. 0 MSB (9th bit) to be transmitted is '0' 1 MSB (9th bit) to be transmitted is '1'
RX8	The ninth bit of data frame in Asynchronous or Synchronous mode of operation. Read this bit first before reading the receive buffer. 0 MSB (9th bit) received is '0' 1 MSB (9th bit) received is '1'

USTATx (USART Status Register) E5H

7	6	5	4	3	2	1	0
UDRE	TXC	RXC	WAKE	SOFTTRST	DOR	FE	PE
RW	RW	RW	RW	RW	R	R	R

Initial value : 80_H

UDRE	The UDRE flag indicates if the transmit buffer (UDATA) is ready to be loaded with new data. If UDRE is '1', it means the transmit buffer is empty and can hold one or two new data. This flag can generate an UDRE interrupt. Writing '0' to this bit position will clear UDRE flag.
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. It is also cleared by writing '0' to this bit position. 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 RX pin is detected low while the CPU is in stop mode. This flag can be used to generate a WAKE interrupt. This bit is set only when in asynchronous mode of operation. ^{NOTE}
0	No WAKE interrupt is generated.
1	WAKE interrupt is generated.
SOFTTRST	This is an internal reset and only has effect on USART. Writing '1' to this bit initializes the internal logic of USART and is auto cleared.
0	No operation
1	Reset USART
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 when received while Parity Checking is enabled. This bit is valid until the receive buffer is read.
0	No Parity Error
1	Parity Error detected

NOTE)

1. When the WAKE function of USART is used as a release source from STOP mode, it is required to clear this bit in the RX interrupt service routine. Else the device will not wake-up from STOP mode again by the change of RX pin.

UBAUDx (USART Baud-Rate Generation Register) E6H, FEH

7	6	5	4	3	2	1	0
UBAUD7	UBAUD6	UBAUD5	UBAUD4	UBAUD3	UBAUD2	UBAUD1	UBAUD0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : FF_H

UBAUD [7:0] The value in this register is used to generate internal baud rate in asynchronous mode or to generate XCK clock in synchronous or SPI mode. To prevent malfunction, do not write '0' in asynchronous mode, and do not write '0' or '1' in synchronous or SPI mode.

UDATAx (USART Data Register) E7H, FFH

7	6	5	4	3	2	1	0
UDATA7	UDATA6	UDATA5	UDATA4	UDATA3	UDATA2	UDATA1	UDATA0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : FF_H

UDATA [7:0] The USART 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 UDATA register. Reading the UDATA register returns the contents of the Receive Buffer.
Write this register only when the UDRE flag is set. In SPI or synchronous master mode, write this register even if TX is not enabled to generate clock, XCK.

11.7.14 Baud Rate setting (example)

Baud Rate	fOSC=1.00MHz				fOSC=1.8432MHz				fOSC=2.00MHz			
	U2X=0		U2X=1		U2X=0		U2X=1		U2X=0		U2X=1	
	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR
2400	25	0.2%	51	0.2%	47	0.0%	95	0.0%	51	0.2%	103	0.2%
4800	12	0.2%	25	0.2%	23	0.0%	47	0.0%	25	0.2%	51	0.2%
9600	6	-7.0%	12	0.2%	11	0.0%	23	0.0%	12	0.2%	25	0.2%
14.4K	3	8.5%	8	-3.5%	7	0.0%	15	0.0%	8	-3.5%	16	2.1%
19.2K	2	8.5%	6	-7.0%	5	0.0%	11	0.0%	6	-7.0%	12	0.2%
28.8K	1	8.5%	3	8.5%	3	0.0%	7	0.0%	3	8.5%	8	-3.5%
38.4K	1	-18.6%	2	8.5%	2	0.0%	5	0.0%	2	8.5%	6	-7.0%
57.6K	-	-	1	8.5%	1	-25.0%	3	0.0%	1	8.5%	3	8.5%
76.8K	-	-	1	-18.6%	1	0.0%	2	0.0%	1	-18.6%	2	8.5%
115.2K	-	-	-	-	-	-	1	0.0%	-	-	1	8.5%
230.4K	-	-	-	-	-	-	-	-	-	-	-	-
Baud Rate	fOSC=3.6864MHz				fOSC=4.00MHz				fOSC=7.3728MHz			
	U2X=0		U2X=1		U2X=0		U2X=1		U2X=0		U2X=1	
	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR
2400	95	0.0%	191	0.0%	103	0.2%	207	0.2%	191	0.0%	-	-
4800	47	0.0%	95	0.0%	51	0.2%	103	0.2%	95	0.0%	191	0.0%
9600	23	0.0%	47	0.0%	25	0.2%	51	0.2%	47	0.0%	95	0.0%
14.4K	15	0.0%	31	0.0%	16	2.1%	34	-0.8%	31	0.0%	63	0.0%
19.2K	11	0.0%	23	0.0%	12	0.2%	25	0.2%	23	0.0%	47	0.0%
28.8K	7	0.0%	15	0.0%	8	-3.5%	16	2.1%	15	0.0%	31	0.0%
38.4K	5	0.0%	11	0.0%	6	-7.0%	12	0.2%	11	0.0%	23	0.0%
57.6K	3	0.0%	7	0.0%	3	8.5%	8	-3.5%	7	0.0%	15	0.0%
76.8K	2	0.0%	5	0.0%	2	8.5%	6	-7.0%	5	0.0%	11	0.0%
115.2K	1	0.0%	3	0.0%	1	8.5%	3	8.5%	3	0.0%	7	0.0%
230.4K	-	-	1	0.0%	-	-	1	8.5%	1	0.0%	3	0.0%
250K	-	-	1	-7.8%	-	-	1	0.0%	1	-7.8%	3	-7.8%
0.5M	-	-	-	-	-	-	-	-	-	-	1	-7.8%
Baud Rate	fOSC=8.00MHz				fOSC=11.0592MHz				fOSC=14.7456MHz			
	U2X=0		U2X=1		U2X=0		U2X=1		U2X=0		U2X=1	
	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR	UBAUD	ERROR
2400	207	0.2%	-	-	-	-	-	-	-	-	-	-
4800	103	0.2%	207	0.2%	143	0.0%	-	-	191	0.0%	-	-
9600	51	0.2%	103	0.2%	71	0.0%	143	0.0%	95	0.0%	191	0.0%
14.4K	34	-0.8%	68	0.6%	47	0.0%	95	0.0%	63	0.0%	127	0.0%
19.2K	25	0.2%	51	0.2%	35	0.0%	71	0.0%	47	0.0%	95	0.0%
28.8K	16	2.1%	34	-0.8%	23	0.0%	47	0.0%	31	0.0%	63	0.0%
38.4K	12	0.2%	25	0.2%	17	0.0%	35	0.0%	23	0.0%	47	0.0%
57.6K	8	-3.5%	16	2.1%	11	0.0%	23	0.0%	15	0.0%	31	0.0%
76.8K	6	-7.0%	12	0.2%	8	0.0%	17	0.0%	11	0.0%	23	0.0%
115.2K	3	8.5%	8	-3.5%	5	0.0%	11	0.0%	7	0.0%	15	0.0%
230.4K	1	8.5%	3	8.5%	2	0.0%	5	0.0%	3	0.0%	7	0.0%
250K	1	0.0%	3	0.0%	2	-7.8%	5	-7.8%	3	-7.8%	6	5.3%
0.5M	-	-	1	0.0%	-	-	2	-7.8%	1	-7.8%	3	-7.8%
1M	-	-	-	-	-	-	-	-	-	-	1	-7.8%

Table 11.18 Examples of UBAUD Settings for Commonly Used Oscillator Frequencies

11.8 SPI

11.8.1 Overview

There is Serial Peripheral Interface (SPI) one channel in MC97FG316. 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.

11.8.2 Block Diagram

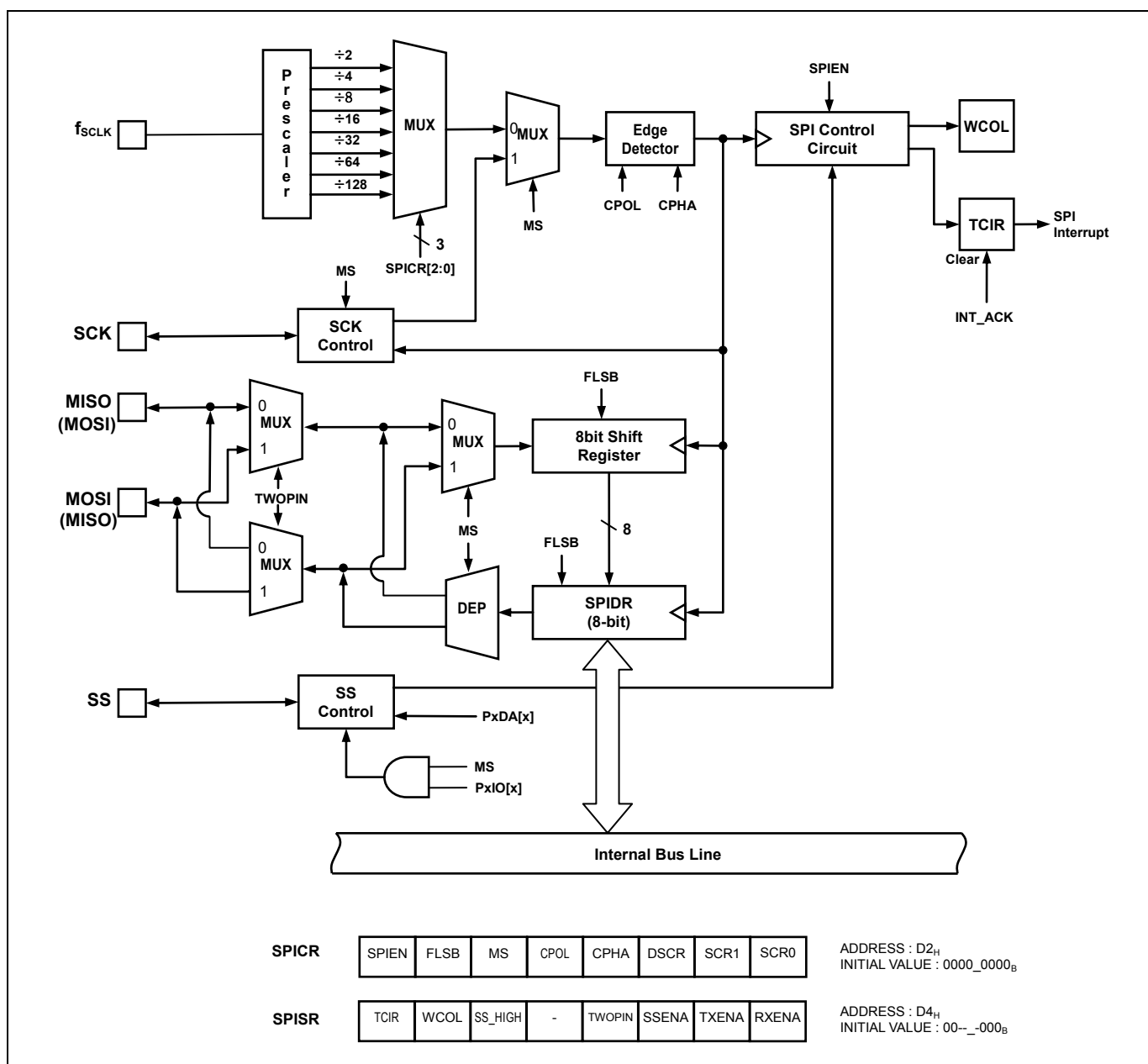


Figure 11.48 SPI Block Diagram

11.8.3 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, TCIR (Transmit Complete or Interrupt Request) bit will be set. If the SPI interrupt is enabled, an interrupt is requested. And TCIR bit is cleared by hardware when executing the corresponding interrupt. If SPI interrupt is disable, TCIR bit is cleared when user read the status register SPISR, and then access (read/write) the data register SPIDR.

NOTE)

1. If you want to use both transmit and receive, set the TXENA, RXENA bit of SPISR, and if user want to use only either transmit or receive, clear the TXENA or RXENA. In this case, user can use disabled pin by GPIO freely.

11.8.4 SS pin function

1. When the SPI is configured as a Slave, the SS pin is always input. If LOW signal comes into SS pin, the SPI logic is active. And if 'HIGH' signal comes 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 (PxIO[x]). If the SS pin is configured as an output, user can use general GPIO 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 comes 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, MS bit of SPICR will be cleared and the SPI becomes a Slave and then, TCIR bit of SPISR will be set, and if the SPI interrupt is enabled, an interrupt is requested.

NOTE)

1. - When the SS pin is configured as an output at Master mode, SS pin's output value is defined by user's software (PxDA[x]). Before SPICR setting, the direction of SS pin must be defined
2. - If you don't need to use SS pin, clear the SENA bit of SPISR. So, you can use disabled pin by GPIO freely. In this case, SS signal is driven by 'HIGH' or 'LOW' internally. In other words, master is 'HIGH', slave is 'LOW'
3. - When SS pin is configured as input(master or slave), if 'HIGH' signal come into SS pin, this flag bit will be set at the SS rising time. And you can clear it by writing '0'.

11.8.5 Timing Waveform

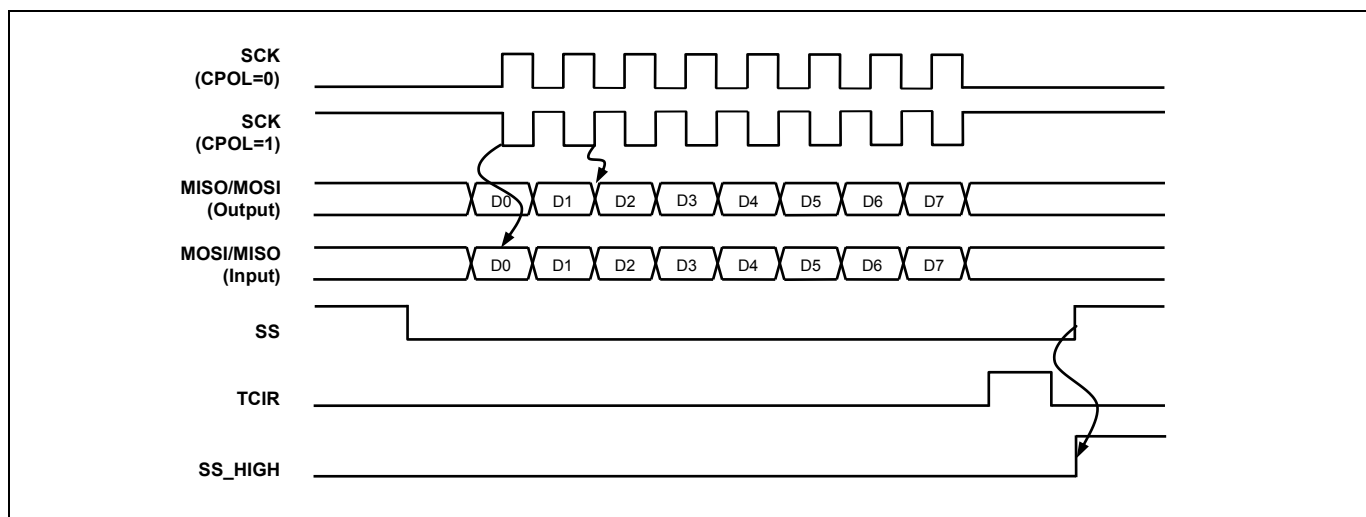


Figure 11.49 SPI Transmit/Receive Timing Diagram at CPHA = 0

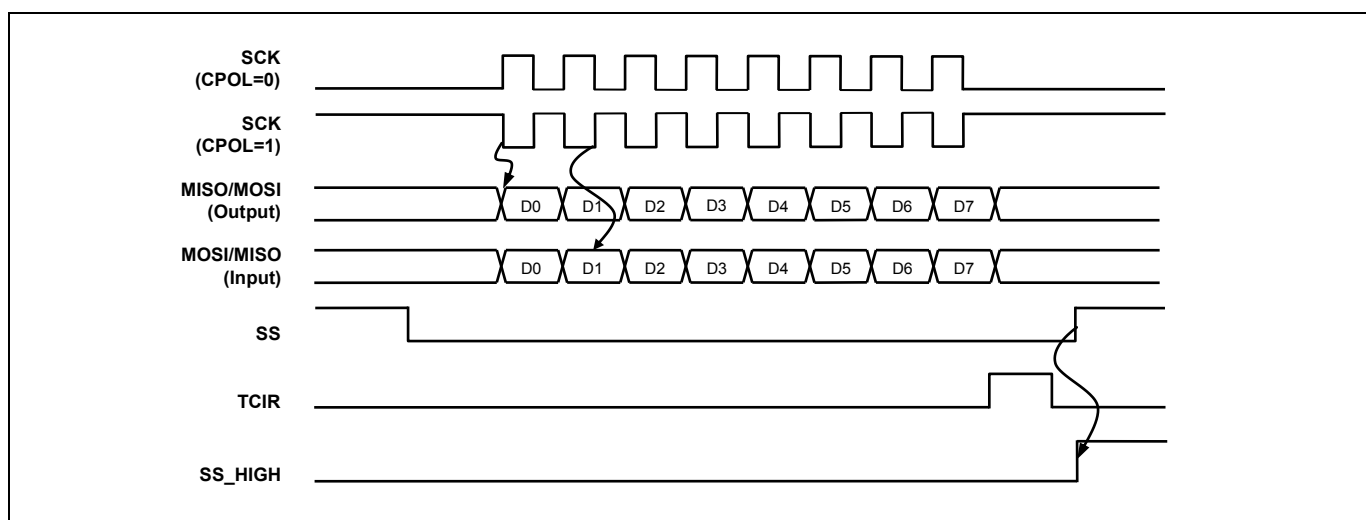


Figure 11.50 SPI Transmit/Receive Timing Diagram at CPHA = 1

11.8.6 Register Map

Name	Address	Dir	Default	Description
SPICR	D2H	R/W	0H	SPI Control Register
SPIDR	D3H	R/W	0H	SPI Data Register
SPISR	D4H	R/W	0H	SPI Status Register

Table 11.19 Register Map

11.8.7 SPI Register description

The SPI Register consists of SPI Control Register (SPICR), SPI Status Register (SPISR) and SPI Data Register (SPIDR)

11.8.8 Register Description for SPI

SPICR (SPI Control Register) : D2H

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

Initial value : 00H

SPIEN This bit controls the SPI operation

0 SPI Disable

1 SPI Enable

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 These two bits control the serial clock (SCK) mode

CPHA Clock Polarity (CPOL) bit determine SCK's value at idle mode

Clock Phase (CPHA) bit determine if data is sampled on the leading or trailing edge of SCK. Refer to Figure 11.49, Figure 11.50

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 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.

SCR[2:0]

fx– Main system clock oscillation frequency.

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

SPIDR (SPI Data Register) : D3H

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

Initial value : 00H

SPIDR [7:0]

SPI data register.

Although you only use reception, user must write any data in here to start the SPI operation.

SPISR (SPI Status Register) : D4H

7	6	5	4	3	2	1	0
TCIR	WCOL	SS_HIGH	-	TWOPIN	SSENA	TXENA	RXENA
R	R	RW	-	RW	RW	RW	RW

Initial value : 00H

TCIR	When a serial data transmission is complete, the TCIR bit is set. If the SPI interrupt is enabled, an interrupt is requested. And TCIR bit is cleared by hardware when executing the corresponding interrupt. If SPI interrupt is disable, TCIR bit is cleared when user read the status register SPISR, and then access (read/write) the data register SPIDR.
0	Interrupt cleared
1	Transmission Complete and Interrupt Requested
WCOL	This bit is set if the data register SPIDR is written during a data transfer. This bit is cleared when user read the status register SPISR, and then access (read/write) the data register SPIDR.
0	No collision
1	Write Collision
SS_HIGH	When SS pin is configured as input(master or slave), if 'HIGH' signal come into SS pin, this flag bit will be set at the SS rising time. And you can clear it by writing '0'. You can write only zero.
0	Flag is cleared
1	Flag is set
TWOPIN	This bit controls the 2 pin operation. In master mode,
0	Disable
1	Enable
SSENA	This bit controls the SS pin operation
0	Disable
1	Enable
TXENA	This bit controls a data transfer operation
0	Disable
1	Enable
RXENA	This bit controls a data reception operation
0	Disable
1	Enable

Note that if the MS is set to '0', when TWOPIN is set to '0', port 03 is set to MISO and if the MS is set to '0', when TWOPIN is set to '1', port 02 is set to MOSI. But if the MS is set to '1', when TWOPIN is set to '0', port 03 is set to MOSI and if the MS is set to '1', when TWOPIN is set to '1', port 02 is set to MISO.

11.9 I2C

11.9.1 Overview

The I2C is one of industrial standard serial communication 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 speed
- 7-bit address
- Support two slave addresses
- Both master and slave operation
- Bus busy detection

11.9.2 Block Diagram

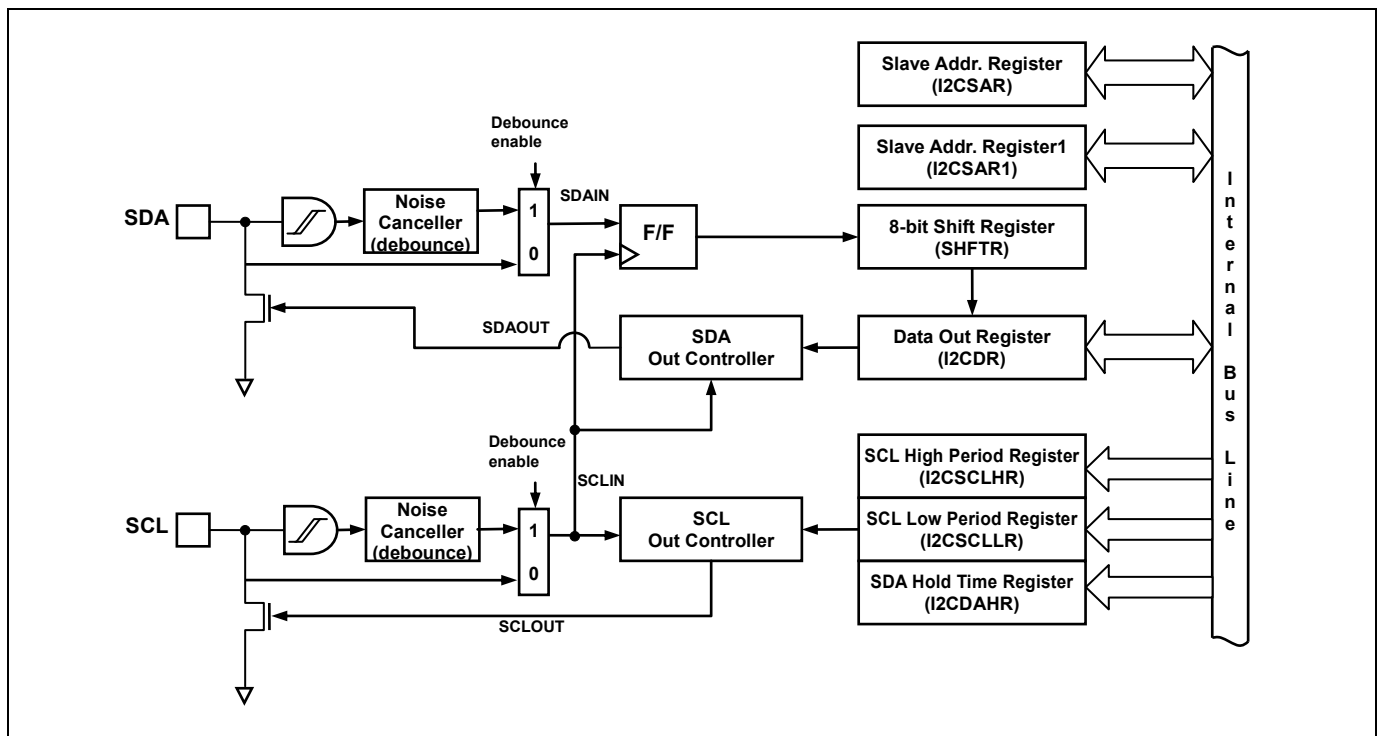


Figure 11.51 I2C Block Diagram

11.9.3 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.

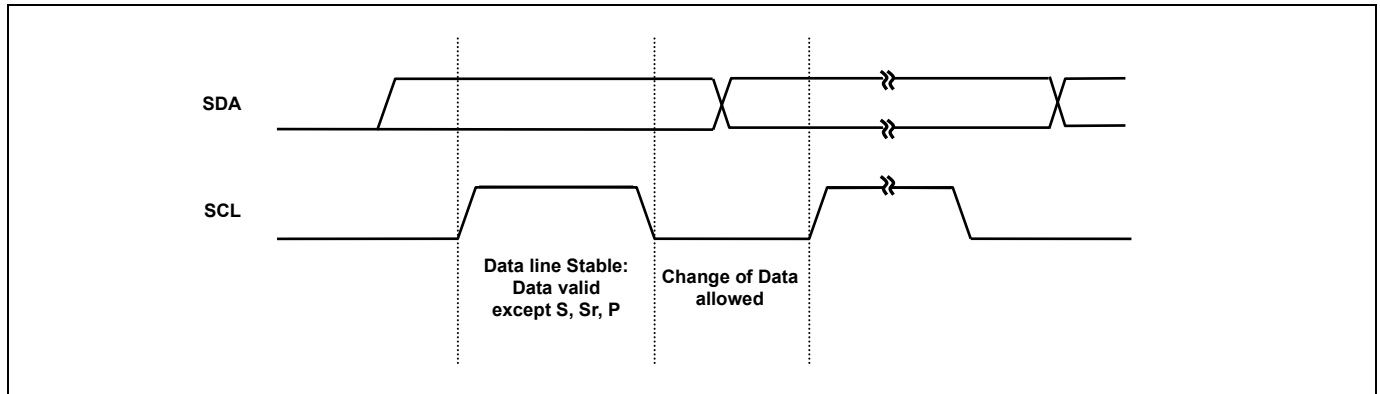


Figure 11.52 Bit Transfer on the I2C-Bus

11.9.4 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.

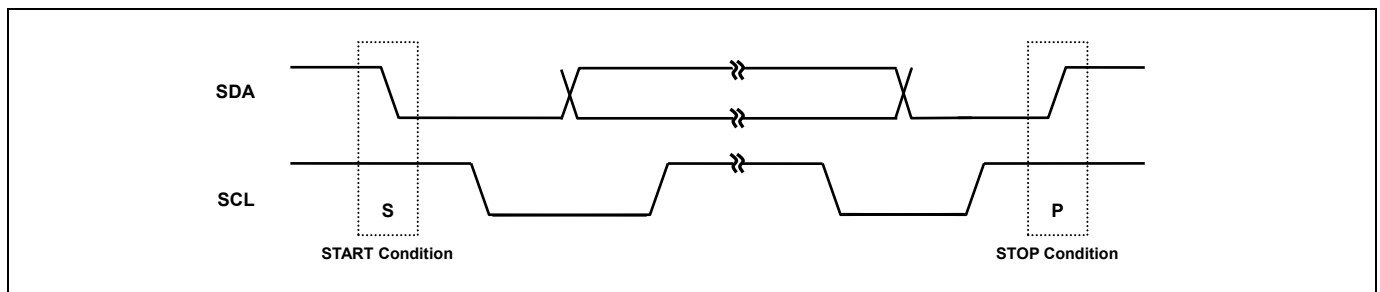


Figure 11.53 START and STOP Condition

11.9.5 Data Transfer

Every byte put on the SDA line must be 8-bit 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.

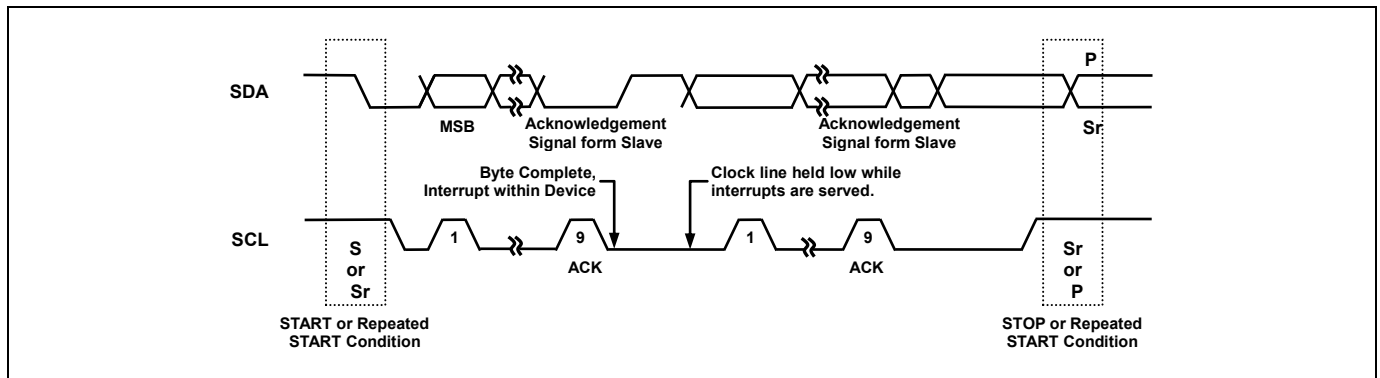


Figure 11.54 STOP or Repeated START Condition

11.9.6 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.

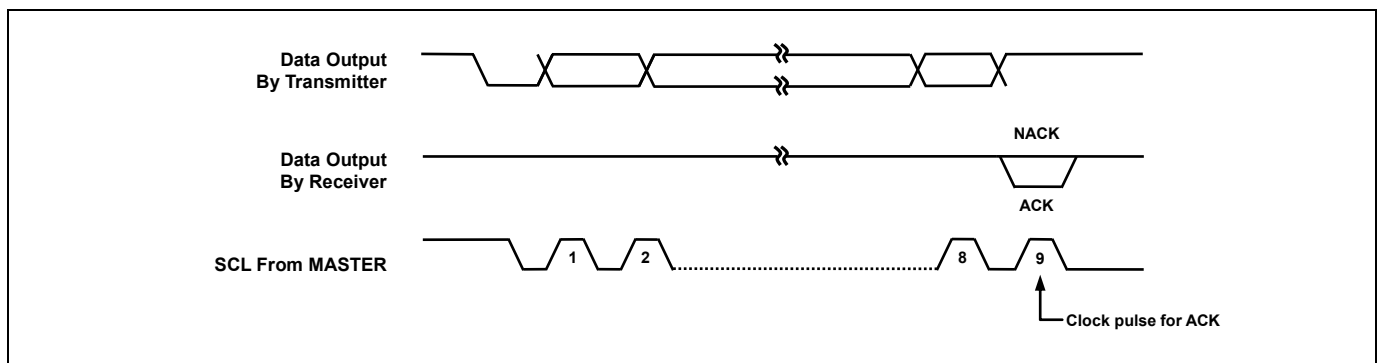


Figure 11.55 Acknowledge on the I2C-Bus

11.9.7 Synchronization / Arbitration

Clock synchronization is performed by 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.

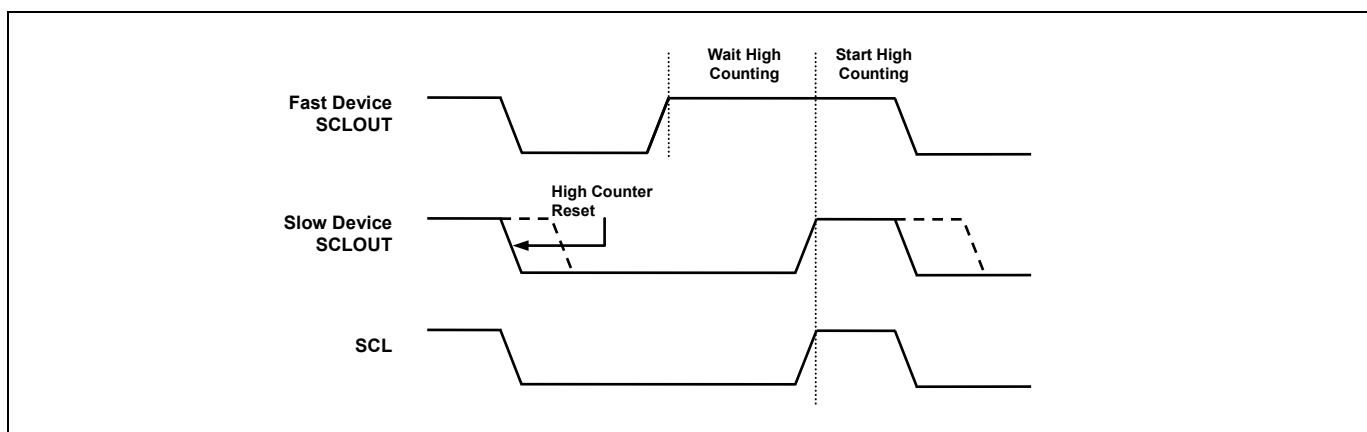


Figure 11.56 Clock Synchronization during Arbitration Procedure

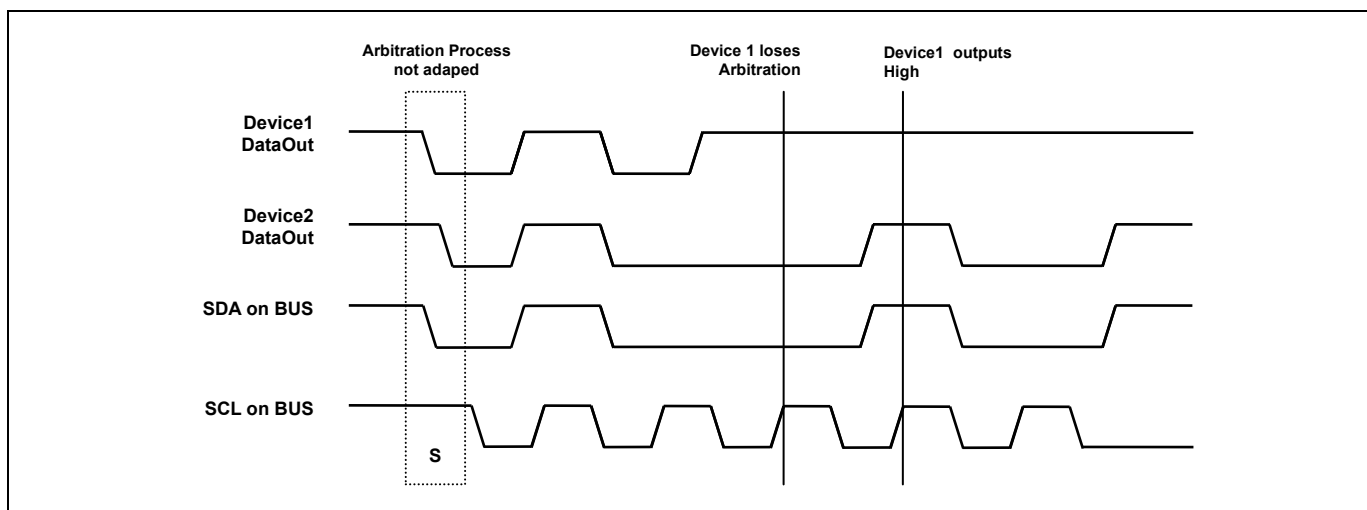


Figure 11.57 Arbitration Procedure of Two Masters

11.9.8 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 execute other operations during a I2C byte transfer.

Note that when a I2C interrupt is generated, IIF flag in I2CMR register is set, it is cleared by writing an arbitrary value to I2CSR. When I2C interrupt occurs, the SCL line is hold LOW until writing any value to I2CSR. When the IIF 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.

11.9.8.1 Master Transmitter

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

1. Enable I2C by setting IICEN bit in I2CMR. This provides main clock to the peripheral.
2. 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.
3. Configure baud rate by writing desired value to both I2CSCLLR and I2CSCLHR for the Low and High period of SCL line.
4. Configure the I2CSDAHR 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 I2CSCLLR to the I2CSDAHR.
5. Set the START bit in I2CMR. This transmits a START condition. And also configure how to handle interrupt and ACK signal. When the START 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 MLSOT bit in I2CSR is set, the ACKEN bit in I2CMR 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 STOP bit in I2CMR.
- 3) Master transmits repeated START condition with not checking ACK signal. In this case, load SLA+R/W into the I2CDR and set START bit in I2CMR.

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 '1' go to master receiver section.

7. 1-byte of data is being transmitted. During data transfer, bus arbitration continues.
8. This is ACK signal processing stage for data packet transmitted by master. I2C holds the SCL as 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 STOP bit in I2CMR.
- 3) Master transmits repeated START condition with not checking ACK signal. In this case, load SLA+R/W into the I2CDR and set the START bit in I2CMR.

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 '1' go to master receiver section.

9. 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 arbitrary value to I2CSR. After this, I2C enters idle state.

11.9.8.2 Master Receiver

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

1. Enable I2C by setting IICEN bit in I2CMR. 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 I2CSCLLR and I2CSCLHR for the Low and High period of SCL line.
4. Configure the I2CSDAHR 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 I2CSCLLR to the I2CSDAHR.
5. Set the START bit in I2CMR. This transmits a START condition. And also configure how to handle interrupt and ACK signal. When the START 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 MLSOT bit in I2CSR is set, the ACKEN bit in I2CMR 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 I2CMR 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 STOP bit in I2CMR.
- 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 START bit in I2CMR.

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.

I2C 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 I2CMR to ACKnowledge and 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 I2CMR.
- 3) Because no ACK signal is detected, master terminates data transfer. In this case, set the STOP bit in I2CMR.
- 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 START bit in I2CMR.

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 arbitrary value to I2CSR. After this, I2C enters idle state.

11.9.8.3 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 I2CSDAHR 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 $SDAH \times \text{period of SCLK}$ where SDAH is multiple of number of SCLK coming from I2CSDAHR. 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 IICEN bit and INTEN bit in I2CMR. 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 as 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 STOP bit indicates that data transfer between master and slave is over. To clear I2CSR, write arbitrary value to I2CSR. After this, I2C enters idle state.

11.9.8.4 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 I2CSDAHR 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 $SDAH \times \text{period of SCLK}$ where SDAH is multiple of number of SCLK coming from I2CSDAHR. 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 IICEN bit and INTEN bit in I2CMR. 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 STOP bit indicates that data transfer between master and slave is over. To clear I2CSR, write arbitrary value to I2CSR. After this, I2C enters idle state.

11.9.9 Register Map

Name	Address	Dir	Default	Description
I2CMR	DAH	R/W	00H	I2C Mode Control Register
I2CSR	DBH	R	00H	I2C Status Register
I2CSCLLR	DCH	R/W	3FH	SCL Low Period Register
I2CSCLHR	DDH	R/W	3FH	SCL High Period Register
I2CSDAHR	DEH	R/W	01H	SDA Hold Time Register
I2CDR	DFH	R/W	FFH	I2C Data Register
I2CSAR	D7H	R/W	00H	I2C Slave Address Register
I2CSAR1	D6H	R/W	00H	I2C Slave Address Register 1

Table 11.20 Register Map

11.9.10 I2C Register Description

I2C Registers are composed of I2C Mode Control Register (I2CMR), I2C Status Register (I2CSR), SCL Low Period Register (I2CSCLLR), SCL High Period Register (I2CSCLHR), SDA Hold Time Register (I2CSDAHR), I2C Data Register (I2CDR), and I2C Slave Address Register (I2CSAR).

11.9.11 Register Description for I2C

I2CMR (I2C Mode Control Register) : DAH

7	6	5	4	3	2	1	0
IIF	IICEN	RESET	INTEN	ACKEN	MASTER	STOP	START
RW	RW	RW	RW	RW	R	RW	RW

Initial value : 00H

IIF	This is interrupt flag bit. 0 No interrupt is generated or interrupt is cleared 1 An interrupt is generated
IICEN	Enable I2C Function Block (by providing clock) 0 I2C is inactive 1 I2C is active
RESET	Initialize internal registers of I2C. 0 No operation 1 Initialize I2C, auto cleared
INTEN	Enable interrupt generation of I2C. 0 Disable interrupt, operates in polling mode 1 Enable interrupt
ACKEN	Controls ACK signal generation at ninth SCL period. Note) ACK signal is output (SDA=0) for the following 3 cases. When received address packet equals to SLA bits in I2CSAR When received address packet equals to value 0x00 with GCALL enabled When I2C operates as a receiver (master or slave) 0 No ACK signal is generated (SDA=1) 1 ACK signal is generated (SDA=0)
MASTER	Represent operating mode of I2C 0 I2C is in slave mode 1 I2C is in master mode
STOP	When I2C is master, generates STOP condition. 0 No operation 1 STOP condition is to be generated
START	When I2C is master, generates START condition. 0 No operation 1 START or repeated START condition is to be generated

I2CSR (I2C Status Register) : DBH

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

Initial value : 00H

GCALL	This bit has different meaning depending on whether I2C is master or slave. NOTE) When I2C is a master, this bit represents whether it received AACK (Address ACK) from slave. When I2C is a slave, this bit is used to indicate general call. 0 No AACK is received (Master mode) 1 AACK is received (Master mode) 0 Received address is not general call address (Slave mode) 1 General call address is detected (Slave mode)
TEND	This bit is set when 1-byte of data is transferred completely. NOTE) 0 1-byte of data is not completely transferred 1 1-byte of data is completely transferred
STOP	This bit is set when STOP condition is detected. NOTE) 0 No STOP condition is detected 1 STOP condition is detected
SSEL	This bit is set when I2C is addressed by other master. NOTE) 0 I2C is not selected as slave 1 I2C is addressed by other master and acts as a slave
MLOST	This bit represents the result of bus arbitration in master mode. NOTE) 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 any 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 generated at ninth SCL period

NOTE)

- These bits can be source of interrupt.

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

I2CSCLLR (SCL Low Period Register) : DCH

7	6	5	4	3	2	1	0
SCLL7	SCLL6	SCLL5	SCLL4	SCLL3	SCLL2	SCLL1	SCLL0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 3FH

SCLL[7:0] This register defines the LOW period of SCL when I2C operates in master mode. The base clock is SCLK, the system clock, and the period is calculated by the formula : $t_{SCLK} \times (4 \times SCLL + 1)$ where t_{SCLK} is the period of SCLK.

I2CSCLHR (SCL High Period Register) : DDH

7	6	5	4	3	2	1	0
SCLH7	SCLH6	SCLH5	SCLH4	SCLH3	SCLH2	SCLH1	SCLH0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 3FH

SCLH[7:0] This register defines the HIGH period of SCL when I2C operates in master mode. The base clock is SCLK, the system clock, and the period is calculated by the formula : $t_{SCLK} \times (4 \times SCLH + 3)$ where t_{SCLK} is the period of SCLK.

So, the operating frequency of I2C in master mode (fI2C) is calculated by the following equation.

$$fI2C = \frac{1}{t_{SCLK} \times (4 (SCLL + SCLH) + 4)}$$

I2CSDAHR (SDA Hold Time Register) : DEH

7	6	5	4	3	2	1	0
SDAH7	SDAH6	SDAH5	SDAH4	SDAH3	SDAH2	SDAH1	SDAH0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 01H

SDAH[7:0] This register is used to control SDA output timing from the falling edge of SCL. Note that SDA is changed after $t_{SCLK} \times SDAH$. In master mode, load half the value of SCLL 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 $t_{SCLK} \times (SDAH + 1)$. So, to insure normal operation in slave mode, the value $t_{SCLK} \times (SDAH + 1)$ must be smaller than the period of SCL.

I2CDR (I2C Data Register) : DFH

7	6	5	4	3	2	1	0
ICD7	ICD6	ICD5	ICD4	ICD3	ICD2	ICD1	ICD0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : FFH

ICD[7:0] When I2C is configured as a transmitter, load this register with data to be transmitted. When I2C is a receiver, the received data is stored into this register.

I2CSAR (I2C Slave Address Register) : D7H

7	6	5	4	3	2	1	0
SLA7	SLA6	SLA5	SLA4	SLA3	SLA2	SLA1	GCALLEN
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

SLA[7:1] These bits configure the slave address of this I2C module when I2C operates in slave mode.

GCALLEN This bit decides whether I2C allows general call address or not when I2C operates in slave mode.

0 Ignore general call address

1 Allow general call address

I2CSAR1 (I2C Slave Address Register 1) : D6H

7	6	5	4	3	2	1	0
SLA7	SLA6	SLA5	SLA4	SLA3	SLA2	SLA1	GCALLEN
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

SLA[7:1] These bits configure the slave address of this I2C module when I2C operates in slave mode.

GCALLEN This bit decides whether I2C allows general call address or not when I2C operates in slave mode.

0 Ignore general call address

1 Allow general call address

11.10 12-bit A/D Converter

11.10.1 Overview

The analog-to-digital converter (A/D) allows conversion of an analog input signal to a corresponding 12-bit digital value. The A/D module has tenth analog inputs. The output of the multiplex is the input into the converter, which generates the result via successive approximation. The A/D module has four registers which are the control register ADCM (A/D Converter Mode Register), ADCM2 (A/D Converter Mode Register 2) and A/D result register ADCRH (A/D Converter Result High Register) and ADCRL (A/D Converter Result Low Register). It is selected for the corresponding channel to be converted by setting ADSEL[3:0]. To executing A/D conversion, ADST bit sets to '1'. The register ADCRH and ADCRL contains the results of the A/D conversion. When the conversion is completed, the result is loaded into the ADCRH and ADCRL, the A/D conversion status bit AFLAG is set to '1', and the A/D interrupt is set. For processing A/D conversion, AFLAG bit is read as '0'. If using STBY (power down) bit, the ADC is disabled. Also internal timer, external generating event, comparator, the trigger of timer1pwm and etc. can start ADC regardless of interrupt occurrence.

$$\text{ADC Conversion Time} = \text{ADCLK} * 60 \text{ cycles}$$

After STBY bit is reset (ADC power enable) and it is restarted, during some cycle, ADC conversion value may have an inaccurate value.

11.10.2 Block Diagram

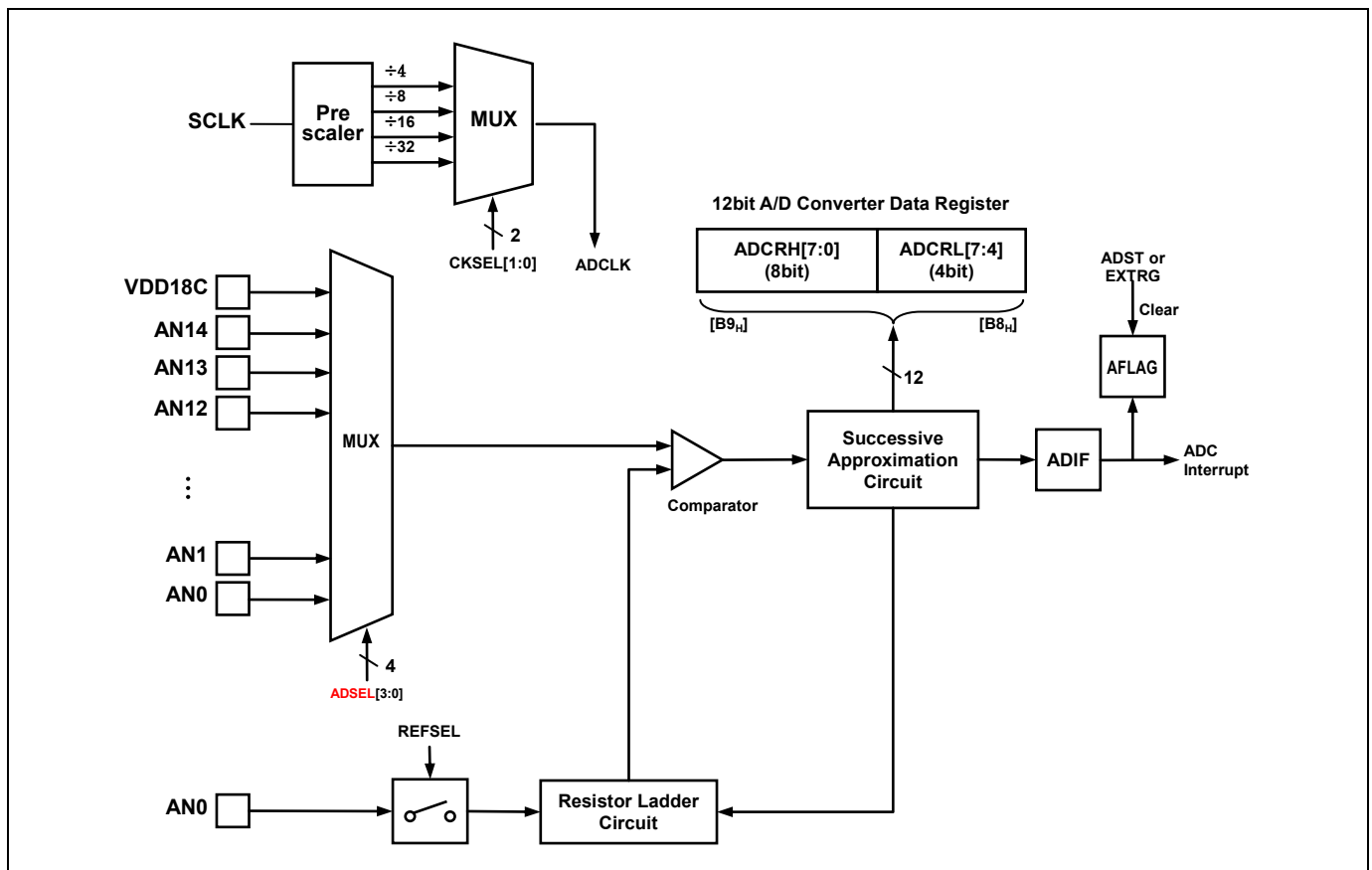


Figure 11.58 ADC Block Diagram

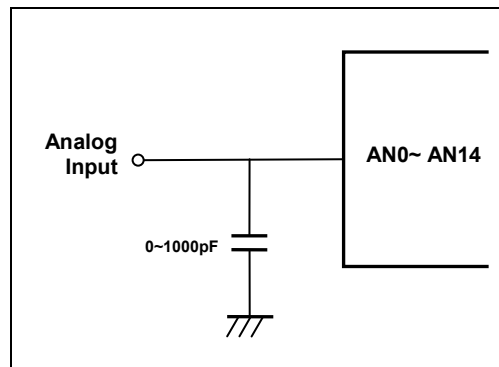


Figure 11.59 A/D Analog Input Pin Connecting Capacitor

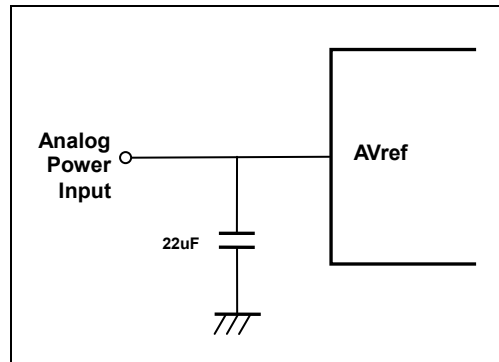


Figure 11.60 AVref Pin Connecting Capacitor

11.10.3 ADC Operation

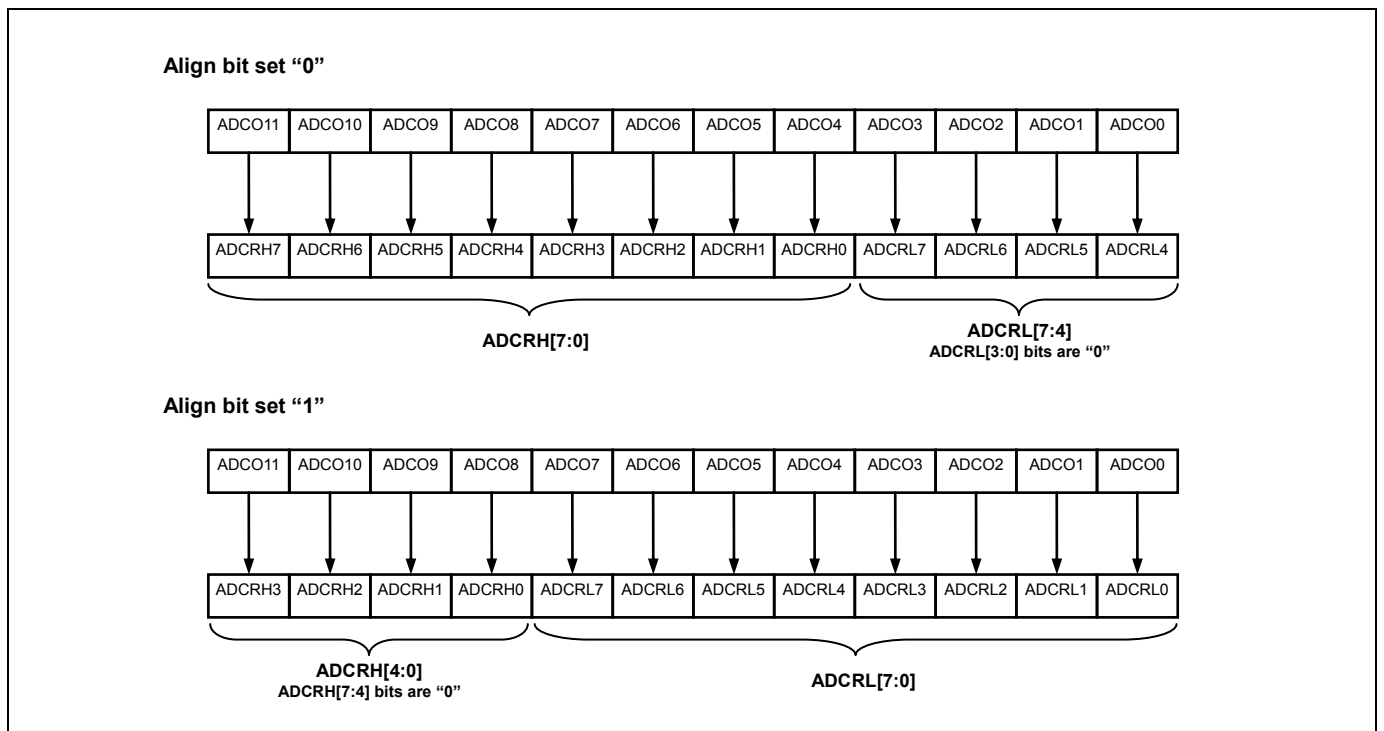


Figure 11.61 ADC Operation for Align bit

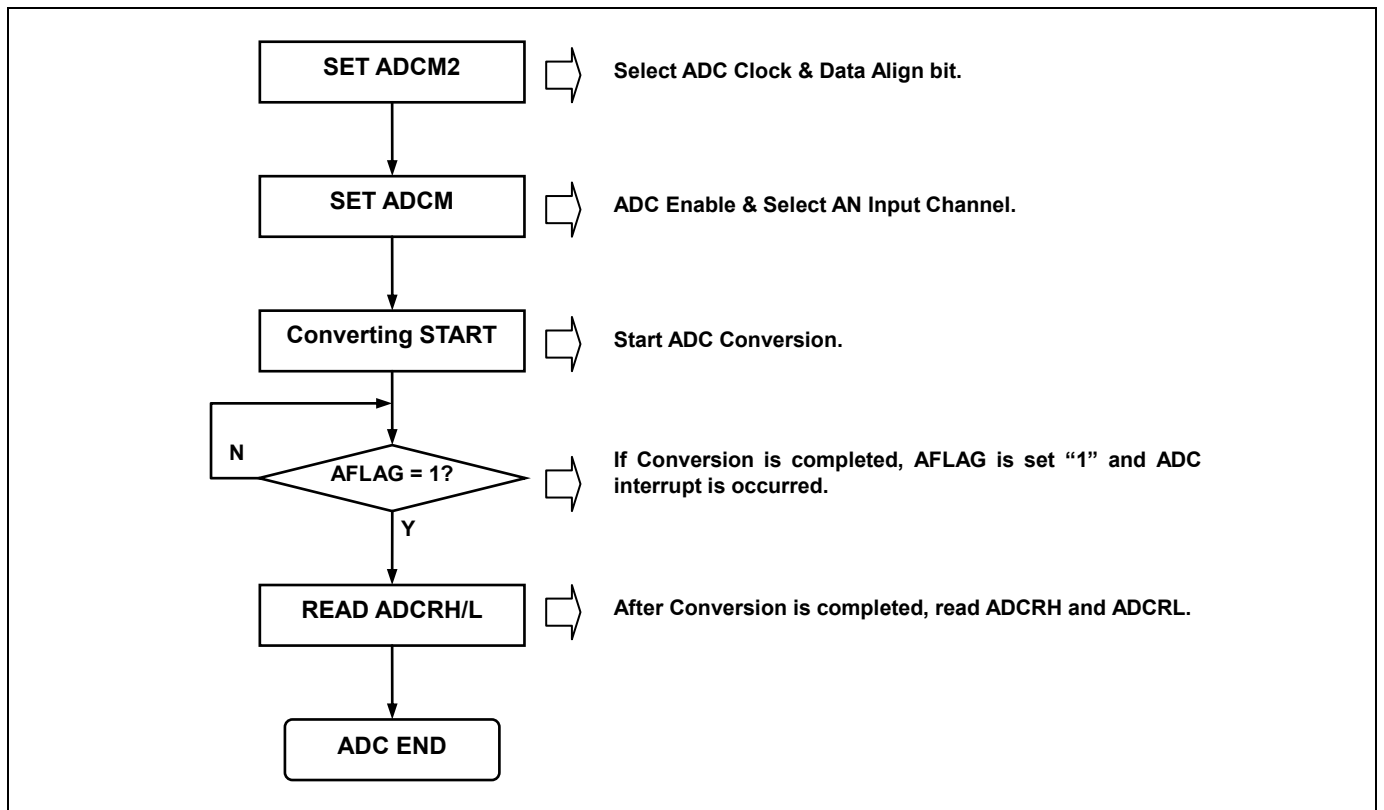


Figure 11.62 Converter Operation Flow

11.10.4 Register Map

Name	Address	Dir	Default	Description
ADCM	C0H	R/W	8FH	A/D Converter Mode Register
ADCRL	C8H	R	-	A/D Converter Result High Register
ADCRH	C9H	R	-	A/D Converter Result Low Register
ADCM2	C1H	R/W	8FH	A/D Converter Mode 2 Register

Table 11.21 Register Map

11.10.5 ADC Register Description

The ADC Register consists of A/D Converter Mode Register (ADCM), A/D Converter Result High Register (ADCRH), A/D Converter Result Low Register (ADCRL), A/D Converter Mode 2 Register (ADCM2).

11.10.6 Register Description for ADC

ADCM (A/D Converter Mode Register) : C0H

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

Initial value : 8FH

STBY Control operation of A/D standby (power down)

0 ADC module enable

1 ADC module disable (power down)

ADST Control A/D Conversion stop/start.

0 ADC Conversion Stop

1 ADC Conversion Start

REFSEL A/D Converter reference selection

0 Internal Reference (VDD)

1 External Reference(AVREF, AN0 disable)

AFLAG A/D Converter operation state

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	Channel0(AN0)
0	0	0	1	Channel1(AN1)
0	0	1	0	Channel2(AN2)
0	0	1	1	Channel3(AN3)
0	1	0	0	Channel4(AN4)
0	1	0	1	Channel5(AN5)
0	1	1	0	Channel6(AN6)
0	1	1	1	Channel7(AN7)
1	0	0	0	Channel8(AN8)
1	0	0	1	Channel9(AN9)
1	0	1	0	Channel10(AN10)
1	0	1	1	Channel11(AN11)
1	1	0	0	Channel12(AN12)
1	1	0	1	Channel13(AN13)
1	1	1	0	Channel14(AN14)
1	1	1	1	Channel15(VDD18)

ADCRH (A/D Converter Result High Register) : C9H

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 result (8-bit)

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

ADCRL (A/D Converter Result Low Register) : C8H

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 result (4-bit)

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

ADCM2 (A/D Converter Mode Register) : C1H

7	6	5	4	3	2	1	0
EXTRG	TSEL2	TSEL1	TSEL0	AMUXEN	ALIGN	CKSEL1	CKSEL0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 01H

EXTRG A/D external Trigger

0 External Trigger disable

1 External Trigger enable

TSEL[2:0] A/D Trigger Source selection

TSEL2 TSEL1 TSEL0 Description

0 0 0 Ext. Interrupt 0

0 0 1 Analog Comparator Low to High Transition

0 1 0 Analog Comparator High to Low Transition

0 1 1 Timer1PWM overflow event

1 0 0 Timer1PWM A-ch event compare match

1 0 1 Timer1PWM B-ch event compare match

1 1 0 Timer1PWM C-ch event compare match

1 1 1 Timer3(PWM) interrupt

AMUXEN Control A/D Converter MUX output for Comparator AC+ Signaling

0 A/D Converter MUX output disable

1 When STBY=1, A/D Converter MUX output enable

ALIGN A/D Converter data align selection.

0 MSB align (ADCRH[7:0], ADCRL[7:4])

1 LSB align (ADCRH[3:0], ADCRL[7:0])

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

CKSEL1 CKSEL0 ADC Clock ADC VDD

0 0 fx/4 Test Only

0 1 fx/8 3V~5V

1 0 fx/16 2.7V~3V

1 1 fx/32 2.4V~2.7V

NOTE)

1. fx : system clock
2. ADC clock have to be used 3MHz under

11.11 Analog Comparator

11.11.1 Overview

The Analog Comparator compares the input values on the positive pin AC+ and the negative pin AC-. When the voltage on the positive pin AC+ is higher than the voltage on the negative pin AC-, the Analog Comparator output, ACOUT, is set.

11.11.2 Block Diagram

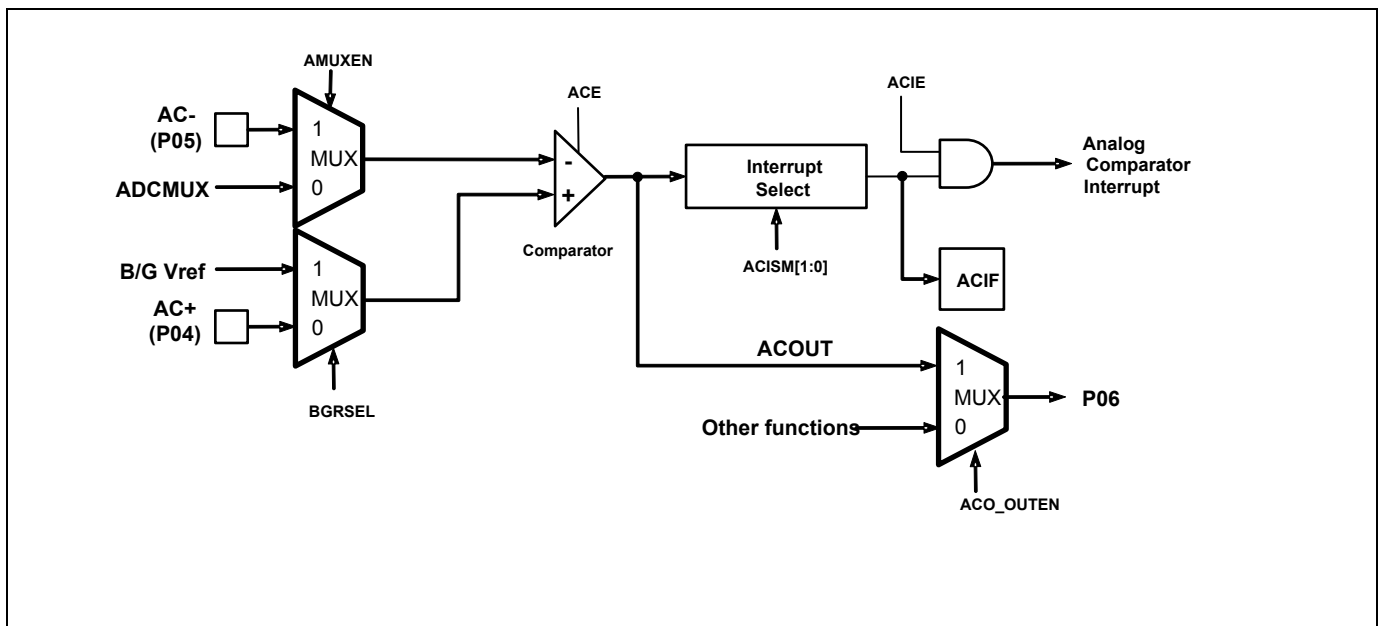


Figure 11.63 Analog Comparator Block Diagram

11.11.3 IN/OUT signal description

ACE : This enables Analog Comparator. When ACE is '0', the output of Comparator goes LOW.

B/G Vref(BGR) : Band Gap Reference Voltage

ACBG : This selects (+) input source between BGR and AC+. When ACBG is '1', the (+) input to AC is BGR.

AC- : This can be (-) input to the AC, and comes directly from external analog pad.

AC+ : This can be (+) input to the AC, and comes directly from external analog pad.

ACOUT : This is the output of Comparator.

ACO_OUTEN : Analog Comparator output port Enable.

11.11.4 Register Map

Name	Address	Dir	Default	Description
ACCSR	F9H	R/W	00H	Analog Comparator Control & Status Register

Table 11.22 Register Map

11.11.5 Analog Comparator Register Description

Analog Comparator Register has one control register, Analog Comparator Control & Status Register (ACCSR). Note that AMUXENB is the inverted signal of AMUXEN bit which comes from ADC's ADCM2 register.

11.11.6 Register Description for USI0

ACCSR (Analog Comparator Control & Status Register) : F9H

7	6	5	4	3	2	1	0
ACE	BGRSEL	ACO	ACIF	ACIE	ACO_OUTEN	ACISM1	ACISM0
RW	RW	R	R	RW	RW	RW	RW

Initial value : 00H

ACE	Enable Analog Comparator (AC).		
	0	Disable AC (power down)	
	1	Enable AC	
BGRSEL	Select (+) input source of AC, Band Gap Reference Voltage or AN4.		
	0	(+) input is from AN4	
	1	(+) input is from Band Gap Reference Voltage	
ACO	This bit represents the value of ACOOUT (Output of Analog Comparator). When ACE is '0', this bit is also cleared.		
	0	Comparator output is LOW	
	1	Comparator output is HIGH	
ACIF	This bit is set when an Analog Comparator Interrupt is generated according to the ACISM[1:0] bits. This bit is cleared when Analog Comparator Interrupt is executed or '0' is written to this bit field.		
	0	No interrupt generated or cleared	
	1	Interrupt generated	
ACIE	Enable Analog Comparator Interrupt.		
	0	Disable Interrupt, Polling mode operation	
	1	Enable Interrupt	
ACO_OUTEN	Analog Comparator output port Enable		
	0	Disable	
	1	Enable	
ACISM[1:0]	Select Interrupt Mode of Analog Comparator.		
	ACISM1	ACISM0	Description
	0	0	Interrupt on rising edge of ACOOUT
	0	1	Interrupt on falling edge of ACOOUT
	1	0	Interrupt on both edge of ACOOUT
	1	1	Interrupt on both edge of ACOOUT

12 Power Down Operation

12.1 Overview

The MC97FG316 has three 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, IDLE, STOP1 and STOP2 mode. In three modes, program is stopped.

12.2 Peripheral Operation in IDLE/STOP Mode

Peripheral	IDLE Mode	STOP1 Mode	STOP2 Mode
CPU	ALL CPU Operation are Disable	ALL CPU Operation are Disable	ALL CPU Operation are Disable
RAM	Retain	Retain	Retain
Basic Interval Timer	Operates Continuously	Operates Continuously	Stop
Watch Dog Timer	Operates Continuously	Operates Continuously	Stop
Watch Timer	Operates Continuously	Stop (Only operate in sub clock mode)	Stop (Only operate in sub clock mode)
TimerP0~4	Operates Continuously	Halted (Only when the Event Counter Mode is Enable, Timer operates Normally)	Halted (Only when the Event Counter Mode is Enable, Timer operates Normally)
ADC	Operates Continuously	Stop	Stop
BUZ	Operates Continuously	Stop	Stop
SPI/SCI	Operates Continuously	Only operate with external clock	Only operate with external clock
I2C	Operates Continuously	Stop	Stop
Internal OSC (8MHz)	Oscillation	Stop	Stop
Main OSC (1~12MHz)	Oscillation	Stop	Stop
Sub OSC (32.768kHz)	Oscillation	Oscillation	Oscillation
Internal RCOSC (125kHz)	Oscillation	Oscillation	Stop
I/O Port	Retain	Retain	Retain
Control Register	Retain	Retain	Retain
Address Data Bus	Retain	Retain	Retain
Release Method	By RESET, all Interrupts	By RESET, Timer Interrupt (EC0, EC2), SIO (External clock), External Interrupt, UART by ACK PCI, I2C (slave mode), WT (sub clock), AC, WDT, BIT	By RESET, Timer Interrupt (EC0, EC2), SIO (External clock), External Interrupt, UART by ACK PCI, I2C (slave mode), WT (sub clock), AC

Table 12.1 Peripheral Operation during Power Down Mode

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.

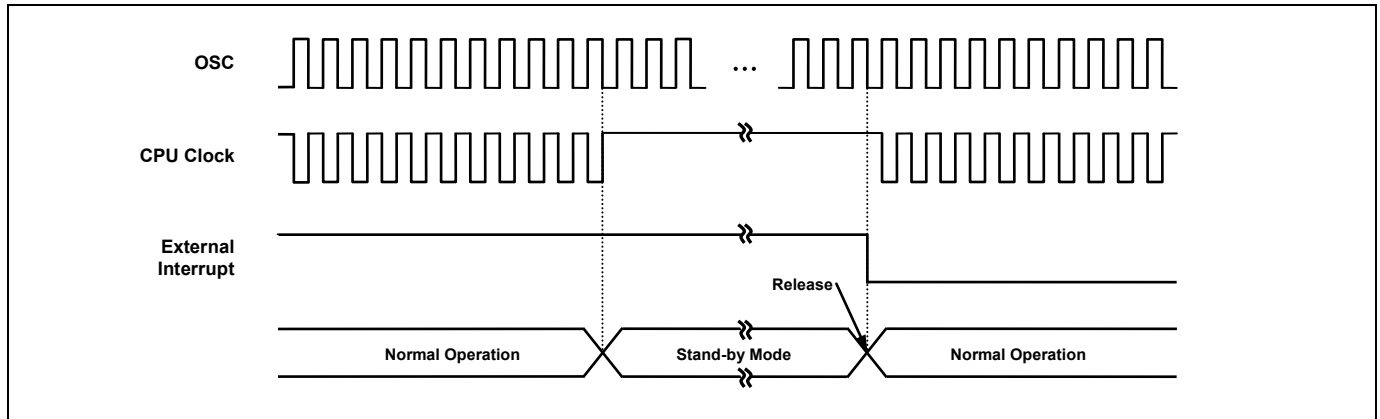


Figure 12.1 IDLE Mode Release Timing by External Interrupt

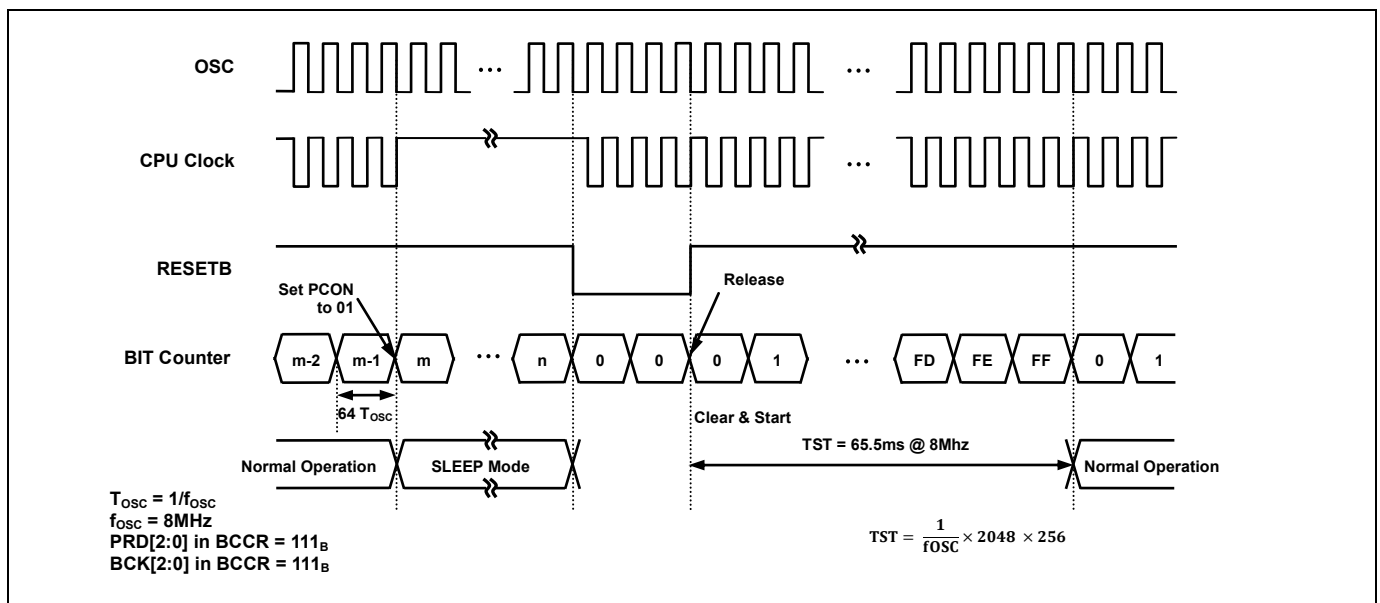


Figure 12.2 IDLE Mode Release Timing by /RESET

(Ex) MOV PCON, #0000_0001b ; setting of IDLE mode : set the bit of STOP and IDLE Control register (PCON)

12.4 STOP Mode

The power control register is set to '03h' to enter the STOP Mode. In the stop mode, the main oscillator, system clock and peripheral clock is stopped, but watch timer continue to operate. With the clock frozen, all functions are stopped, but the on-chip RAM and control registers are held.

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 12.3 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 prescaler divide ratio to have long enough time (more than 20msec). this guarantees that oscillator has started and stabilized.

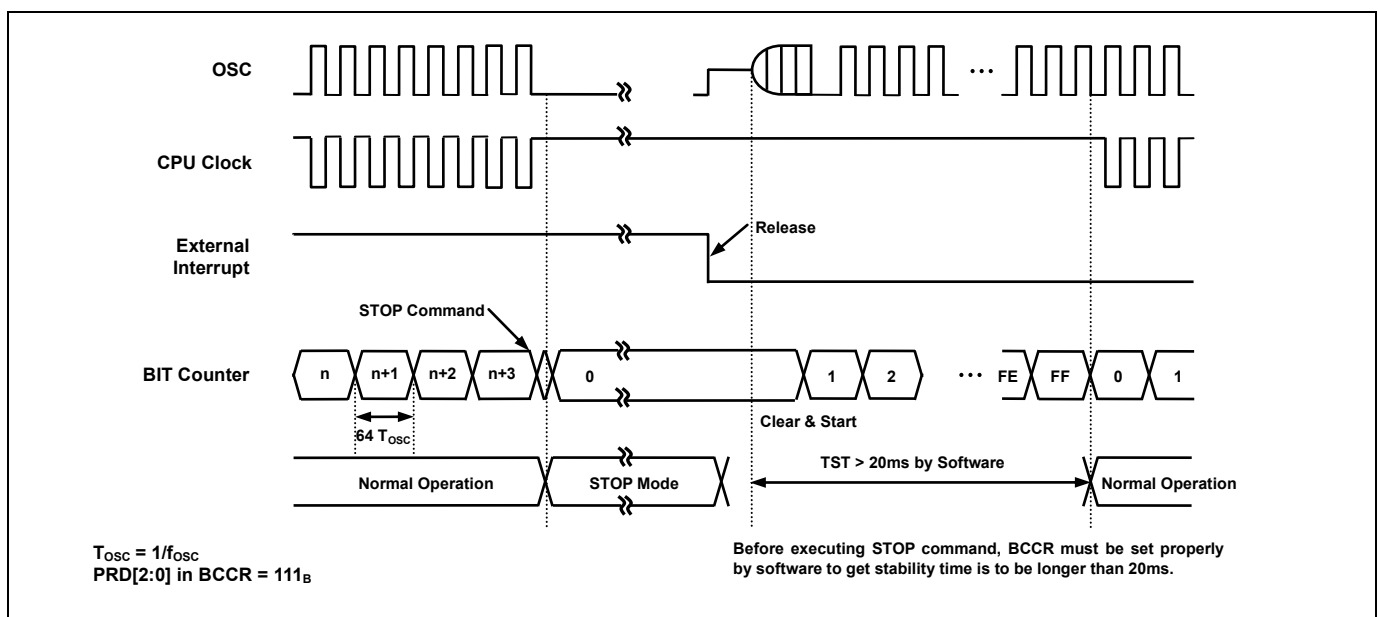


Figure 12.3 STOP Mode Release Timing by External Interrupt

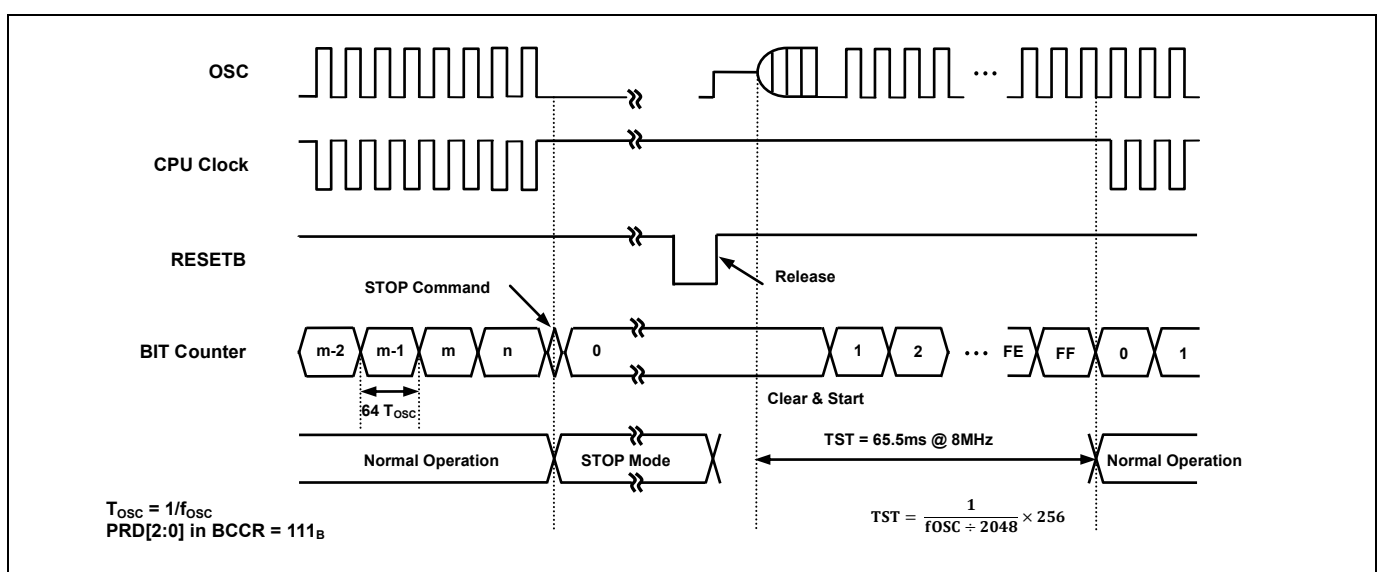


Figure 12.4 STOP Mode Release Timing by /RESET

12.5 Release Operation of STOP1, 2 Mode

After STOP1, 2 mode is released, the operation begins according to content of related interrupt register just before STOP1, 2 mode start (Figure 12.5). Interrupt Enable Flag of All (EA) of IE should be set to `1`. Released by only interrupt which each interrupt enable flag = `1`, and jump to the relevant interrupt service routine.

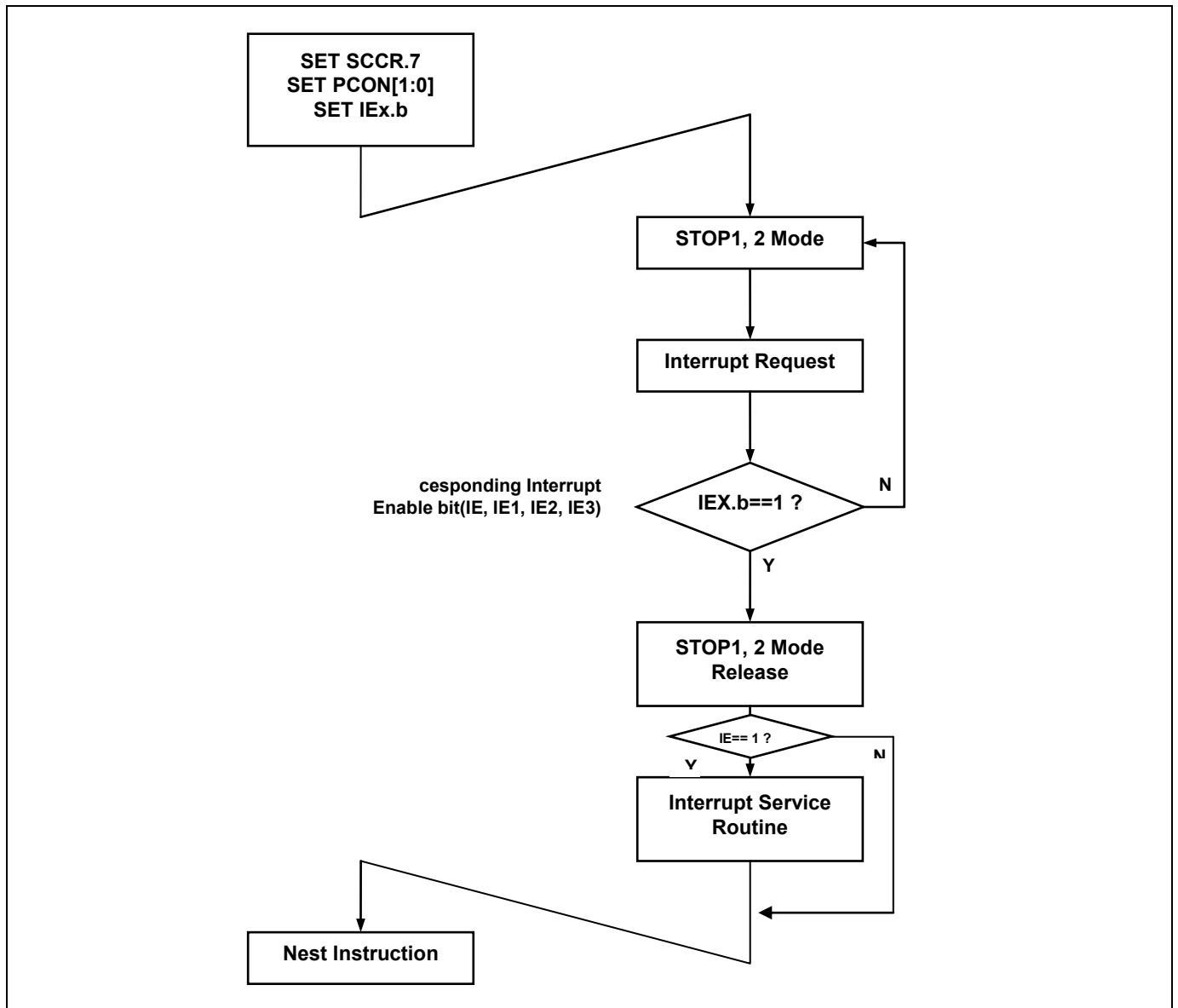


Figure 12.5 STOP1, 2 Mode Release Flow

12.5.1 Register Map

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

Table 12.2 Register Map

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
bit7	bit6	bit5	bit4	bit3	bit2	bit1	bit0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

IDLE Mode

01H IDLE mode enable

STOP1, 2 Mode

03H STOP1, 2 mode enable

NOTE)

1. To enter IDLE mode, PCON must be set to '01H'.
2. To STOP1,2 mode, PCON must be set to '03H'.
3. (In STOP1,2 mode, PCON register is cleared automatically by interrupt or reset)
4. When PCON is set to '03H', if SCCR[7] is set to '1', it enters the STOP1 mode. if SCCR[7] is cleared to '0', it enters the STOP2 mode
5. The different thing in STOP 1,2 is only clock operation of internal 125kHz-OSC during STOP mode operating.

13 RESET

13.1 Overview

The MC97FG316 has reset by external RESETB pin. The following is the hardware setting value.

On Chip Hardware	Initial Value
Program Counter (PC)	0000h
Accumulator	00h
Stack Pointer (SP)	07h
Peripheral Clock	On
Control Register	Peripheral Registers refer
Brown-Out Detector	Enable

Table 13.1 Reset state

13.2 Reset Source

The MC97FG316 has five types of reset generation procedures. The following is the reset sources.

- External RESETB
- Power ON RESET (POR)
- WDT Overflow Reset (In the case of WDTEN = '1')
- LVR Reset (In the case of LVREN = '1')
- OCD Reset

13.3 RESET Block Diagram

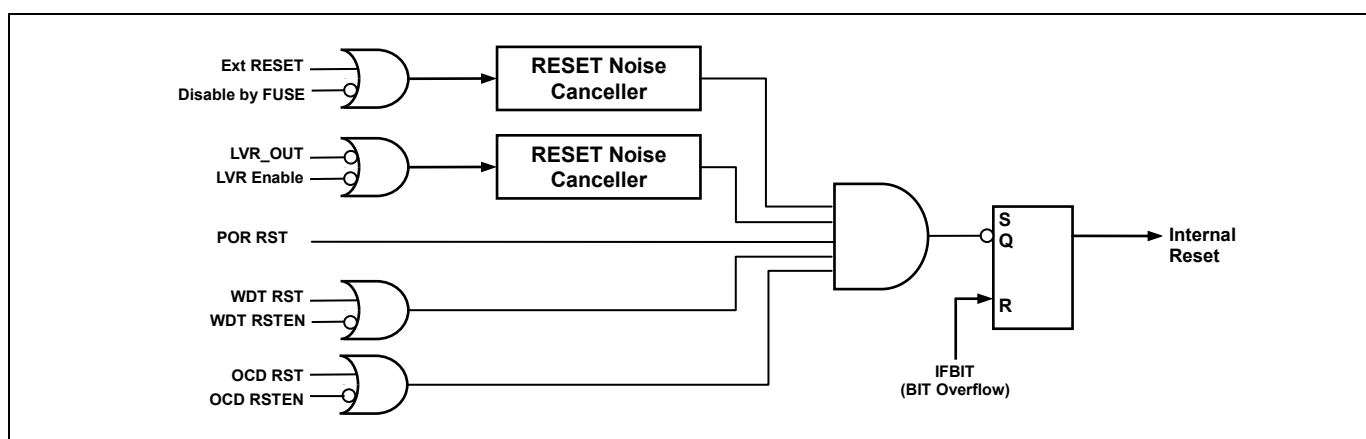


Figure 13.1 RESET Block Diagram

13.4 RESET Noise Canceller

The Figure 13.2 is the Noise canceller diagram for Noise cancel of RESET. It has the Noise cancel value of about 7us (@VDD=5V) to the low input of System Reset.

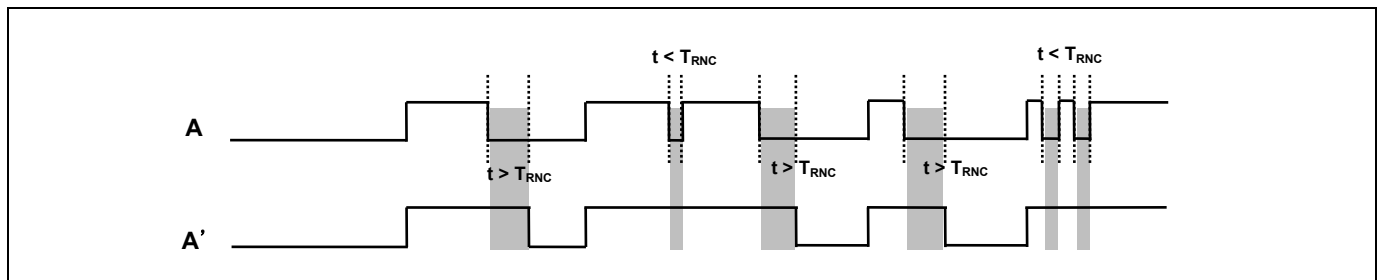


Figure 13.2 Reset noise canceller time diagram

13.5 Power on RESET

When rising device power, the POR (Power ON Reset) have a function to reset the device. If using POR, it executes the device RESET function instead of the RESET IC or the RESET circuits. And External RESET PIN is able to use as Normal I/O pin.

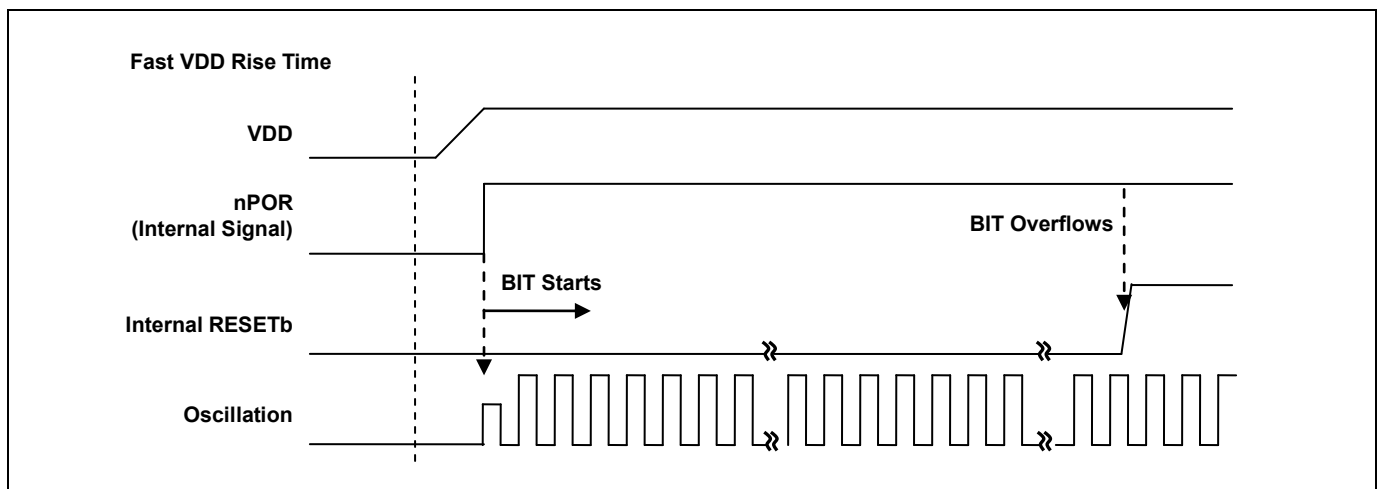


Figure 13.3 Fast VDD rising time

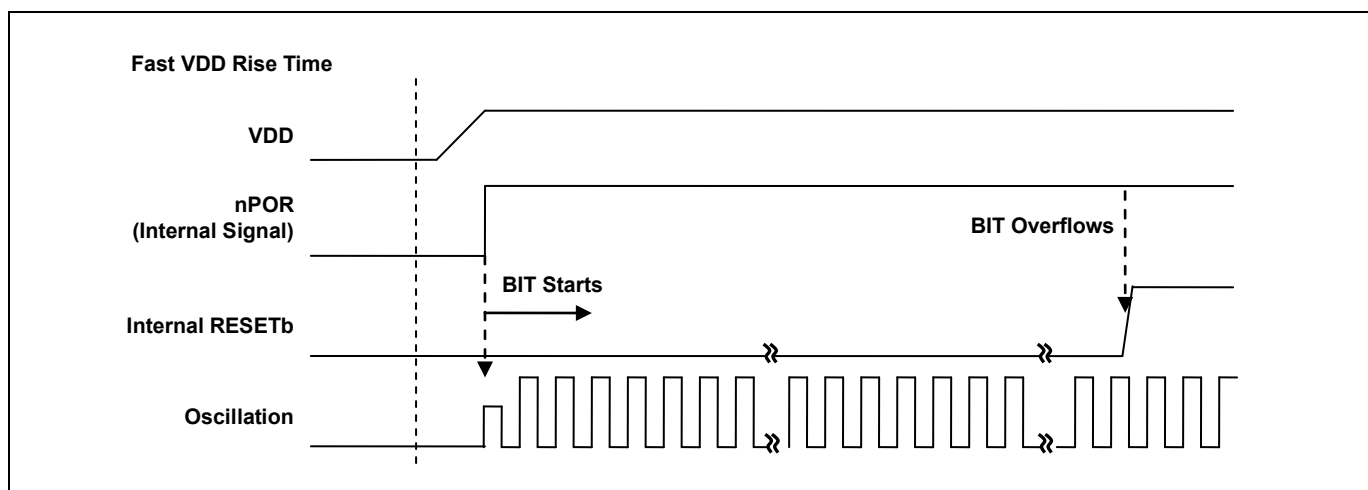


Figure 13.4 Internal RESET Release Timing On Power-Up

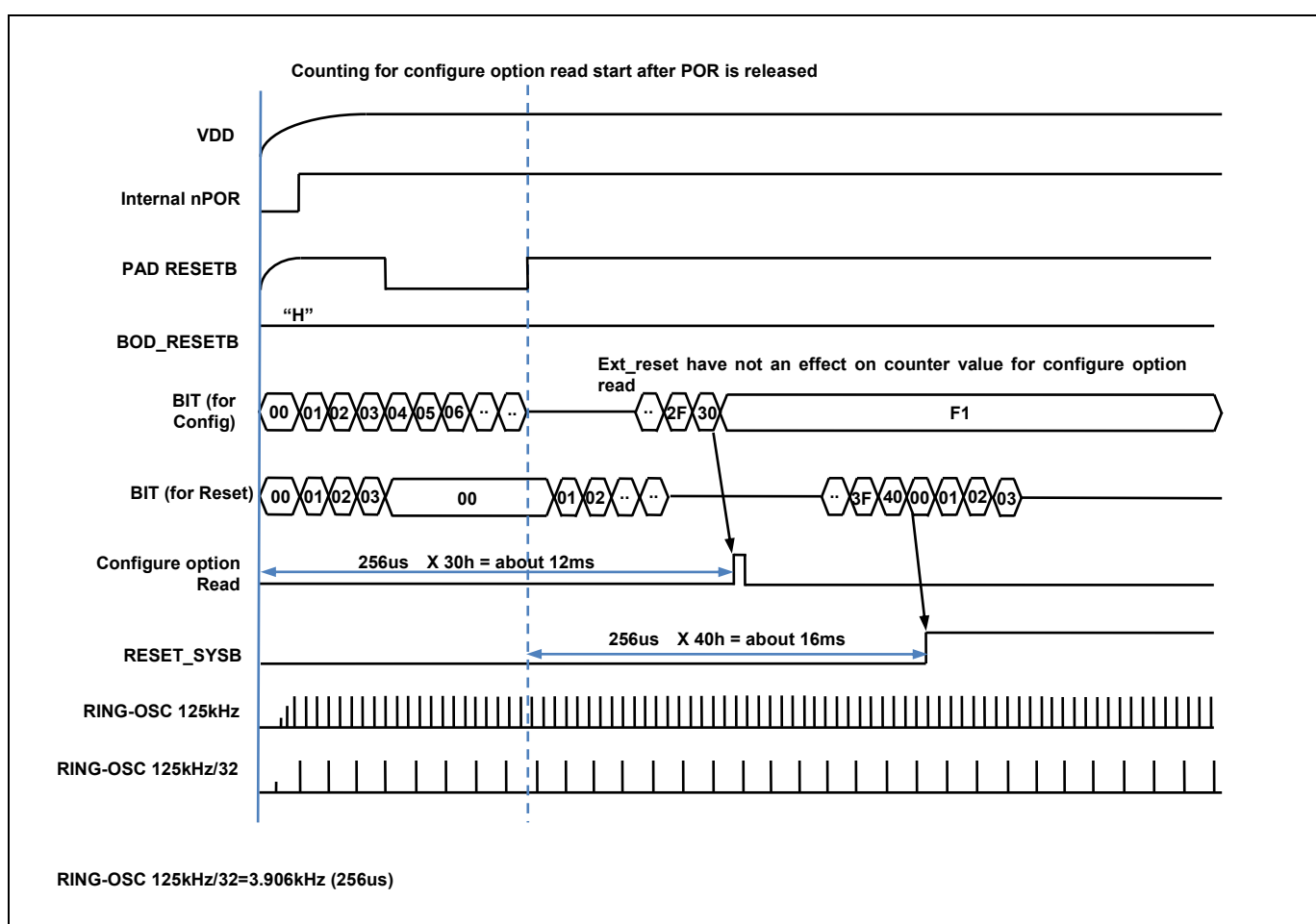


Figure 13.5 Configuration timing when Power-on

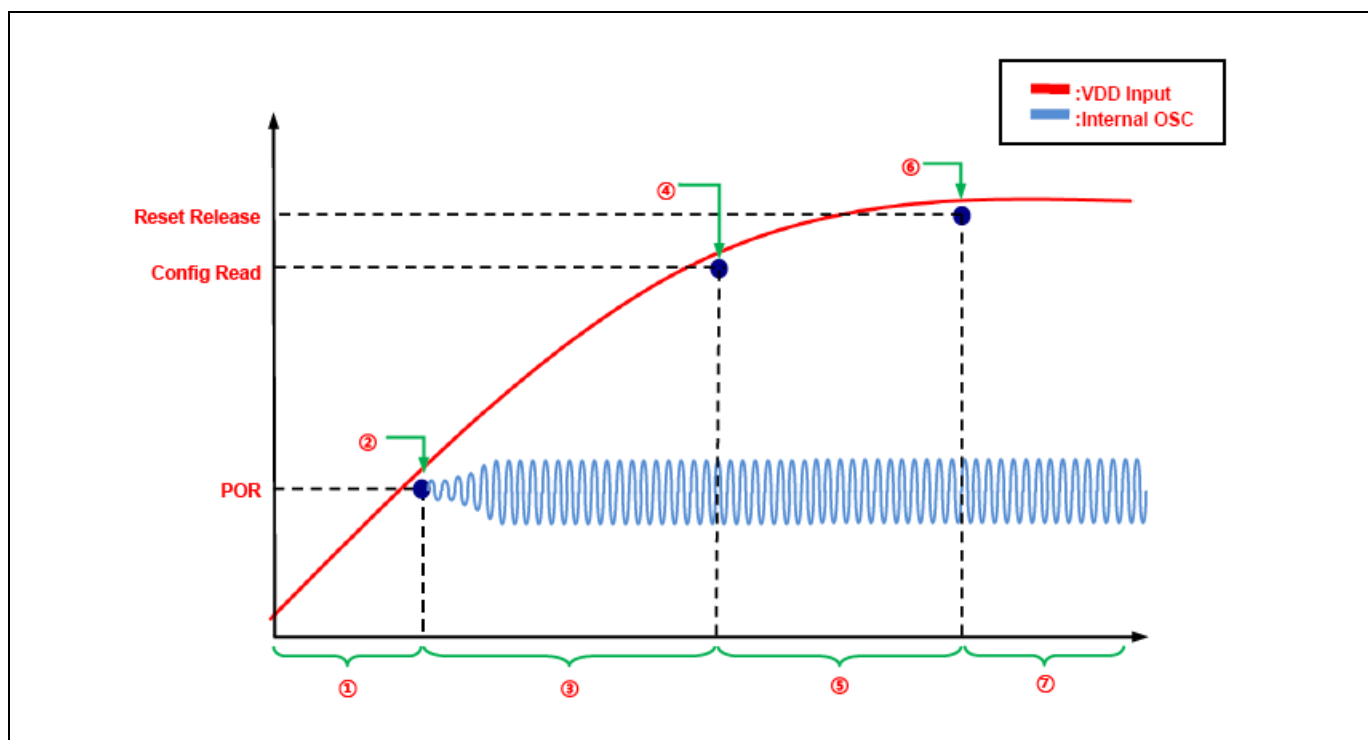


Figure 13.6 Boot Process Waveform

Process	Description	Remarks
①	-No Operation	
②	-1st POR level Detection -RING OSC (12kHz) ON	-about 1.4V ~ 1.5V
③	- (RING-OSC12kHz/32)×30h Delay section (=128ms) -VDD input voltage must rise over than flash operating voltage for Configure option read	-Slew Rate $\geq 0.025\text{V/ms}$
④	- Configure option read point	-about 1.5V ~ 1.6V -Configure option 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) after 16ms, after External Reset Release (External reset) ii) 16ms point after POR (POR only)	- BIT is used for Peripheral stability
⑦	-Normal operation	

Table 13.2 Boot Process Description

13.6 External RESETB Input

The External RESETB is the input to a Schmitt trigger. A reset is accomplished by holding the reset pin low for at least 7 μ s over, within the operating voltage range and oscillation stable status, 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.

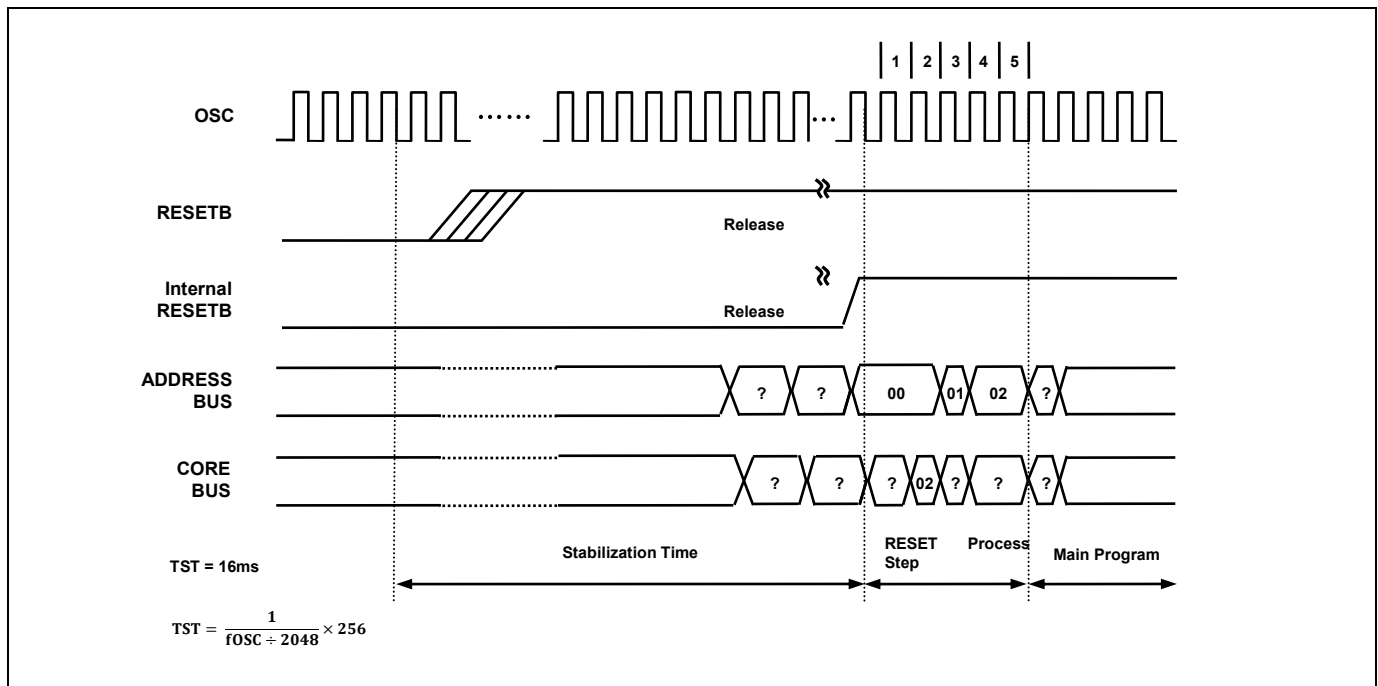


Figure 13.7 Timing Diagram after RESET

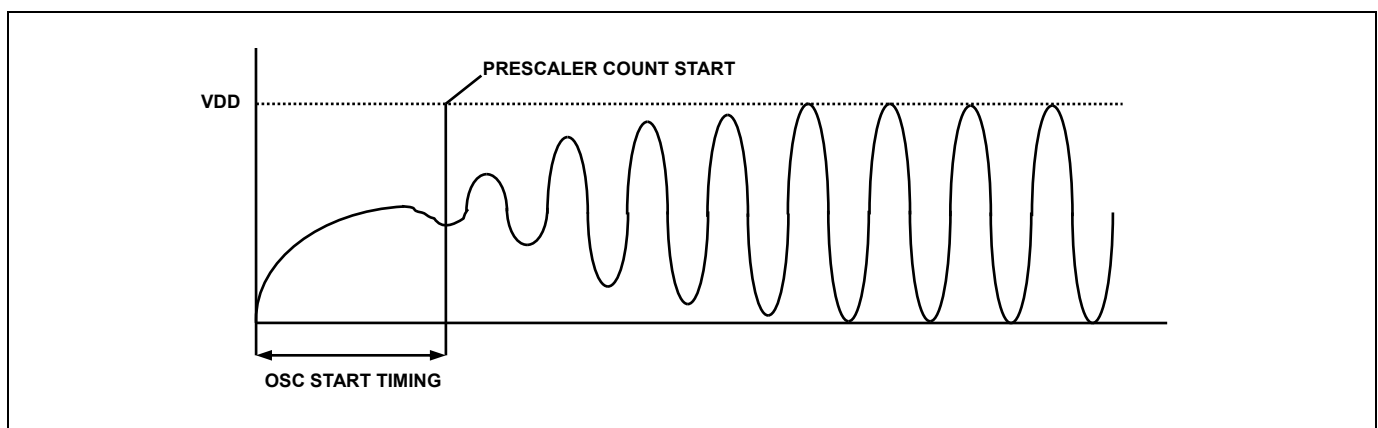


Figure 13.8 Oscillator generating waveform example

Note)

1. As shown Figure 13.8, the stable generating time is not included in the start-up time.

13.7 Low Voltage Reset Processor

The MC97FG316 has an On-chip Brown-out detection circuit for monitoring the VDD level by comparing it to a fixed trigger level. The trigger level for the LVR can be selected by LVRLS[1:0] bit to be 1.6V, 2.5V, 3.6V or 4.2V. 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.

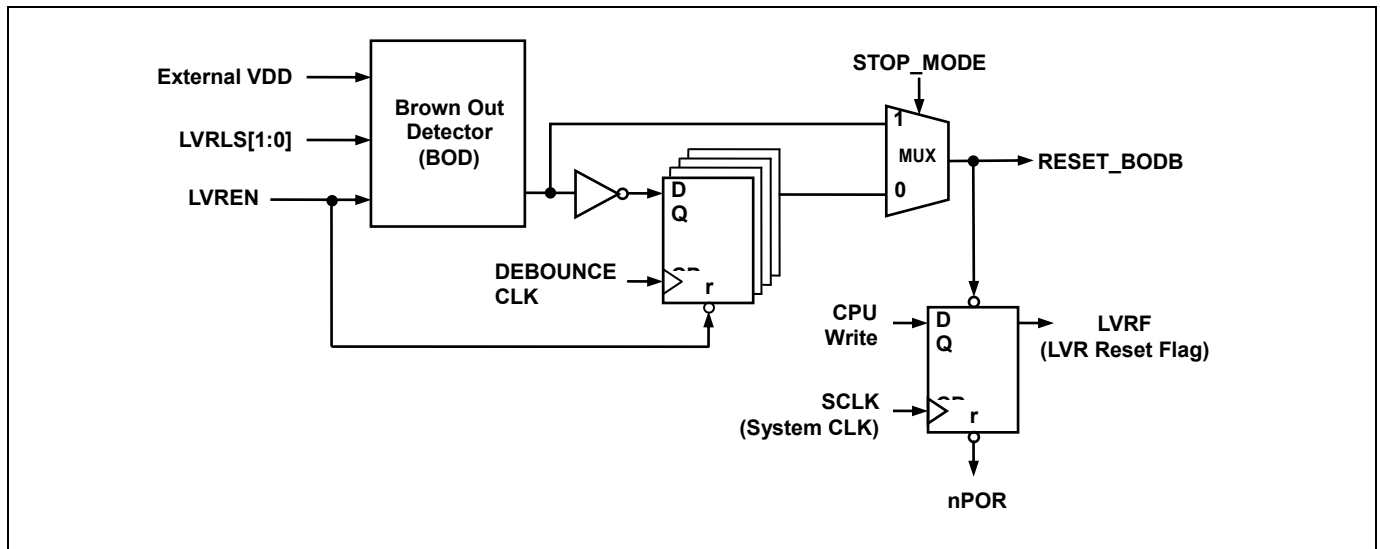


Figure 13.9 Block Diagram of LVR

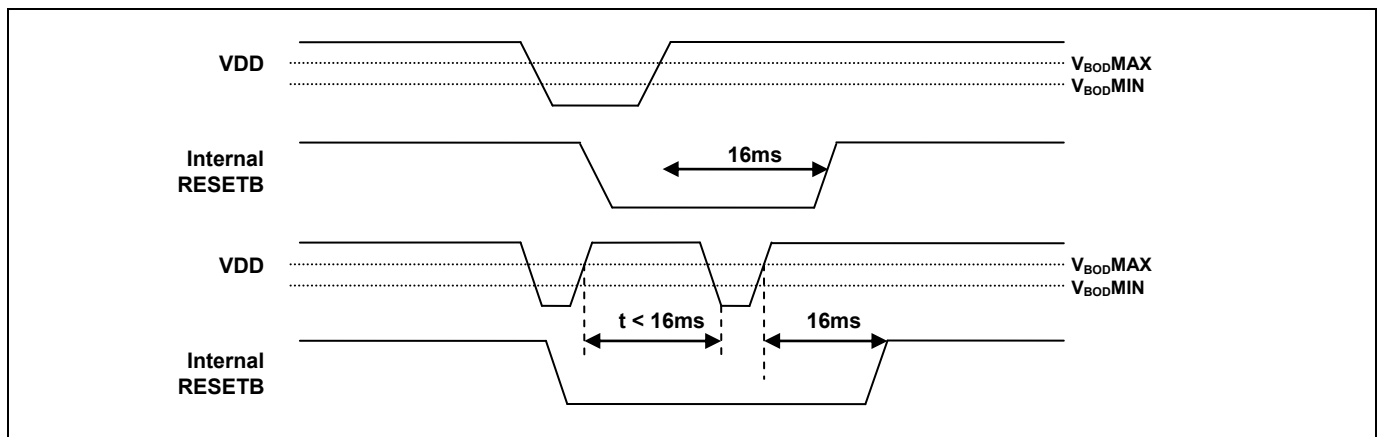


Figure 13.10 Internal Reset at the power fail situation

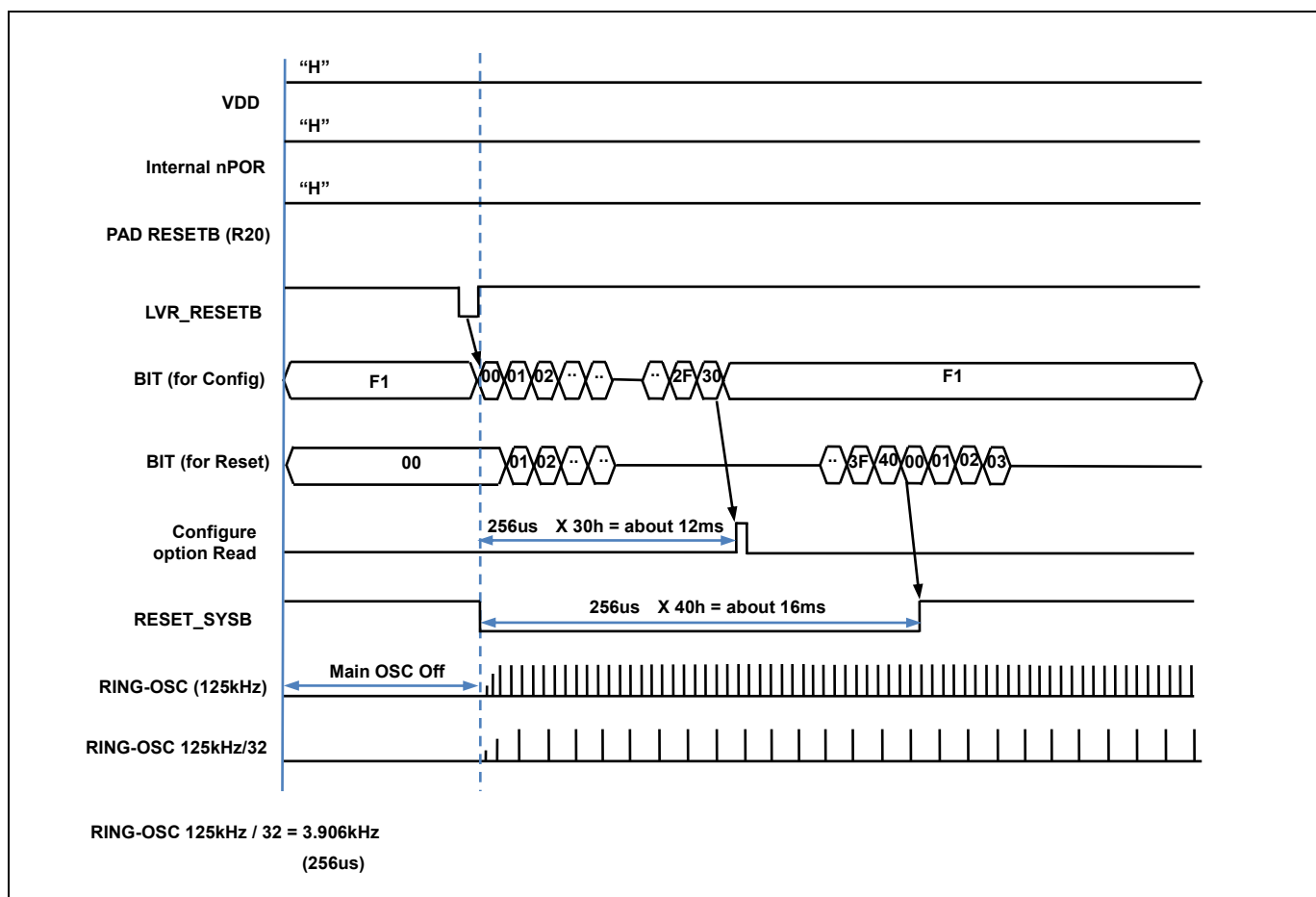


Figure 13.11 Configuration timing when LVR RESET

13.7.1 Register Map

Name	Address	Dir	Default	Description
LVRCCR	86H	R/W	81H	LVR Control Register

Table 13.3 Register Map

13.7.2 Reset Operation Register Description

Reset control Register consists of the LVR Control Register (LVRCCR).

13.7.3 Register Description for Reset Operation

LVRCCR (LVR Control Register) : 86H

7	6	5	4	3	2	1	0
PORF	EXTRF	WDTRF	OCDRF	LVRRF	LVRLS[1]	LVRLS[0]	LVREN
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 81H

PORF	Power-On Reset flag bit. The bit is reset by writing '0' to this bit.		
	0	No detection	
	1	Detection	
EXTRF	External Reset 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	
LVRLS[1:0]	LVR level Voltage		
	LVRLS1	LVRLS0	Description
	0	0	1.6V
	0	1	2.5V
	1	0	3.6V
	1	1	4.2V
LVREN	LVR operation		
	0	LVR disable	
	1	LVR enable	

14 On-chip Debug System

14.1 Overview

14.1.1 Description

On-chip debug System (OCD2) of MC97FG316 can be used for programming the non-volatile memories and on-chip debugging. Detailed descriptions for programming via the OCD2 interface can be found in the following chapter.

Figure 14.1 shows a block diagram of the OCD2 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

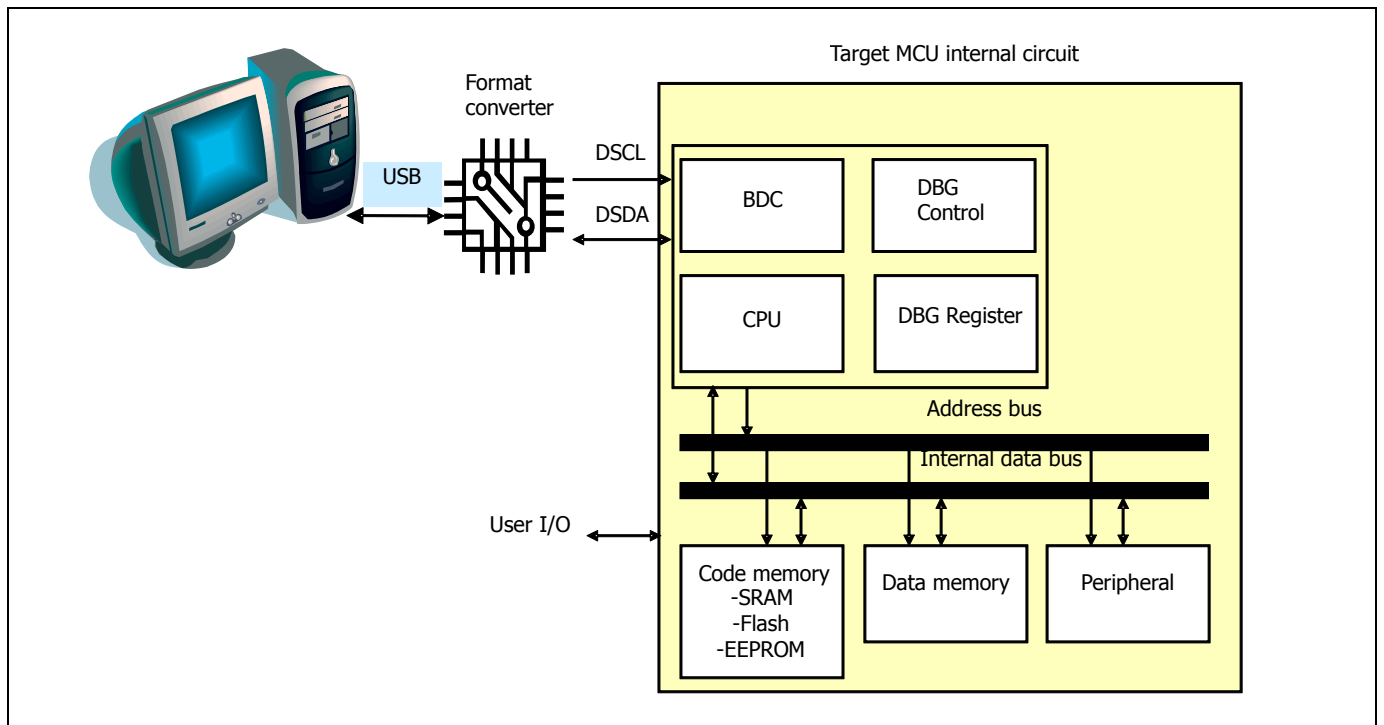


Figure 14.1 Block Diagram of On-chip Debug System

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.
- Star condition and stop condition notify the start and the stop of background debugger command respectively.

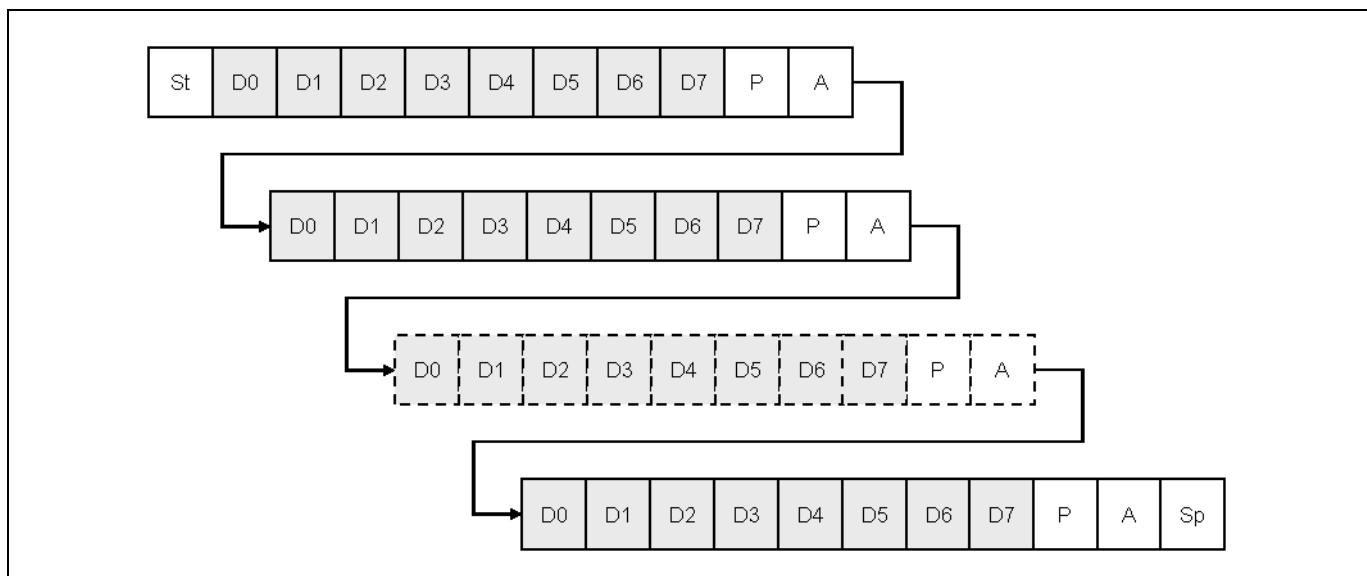


Figure 14.2 10-bit transmission packet

14.2.2 Packet Transmission Timing

14.2.2.1 Data Transfer

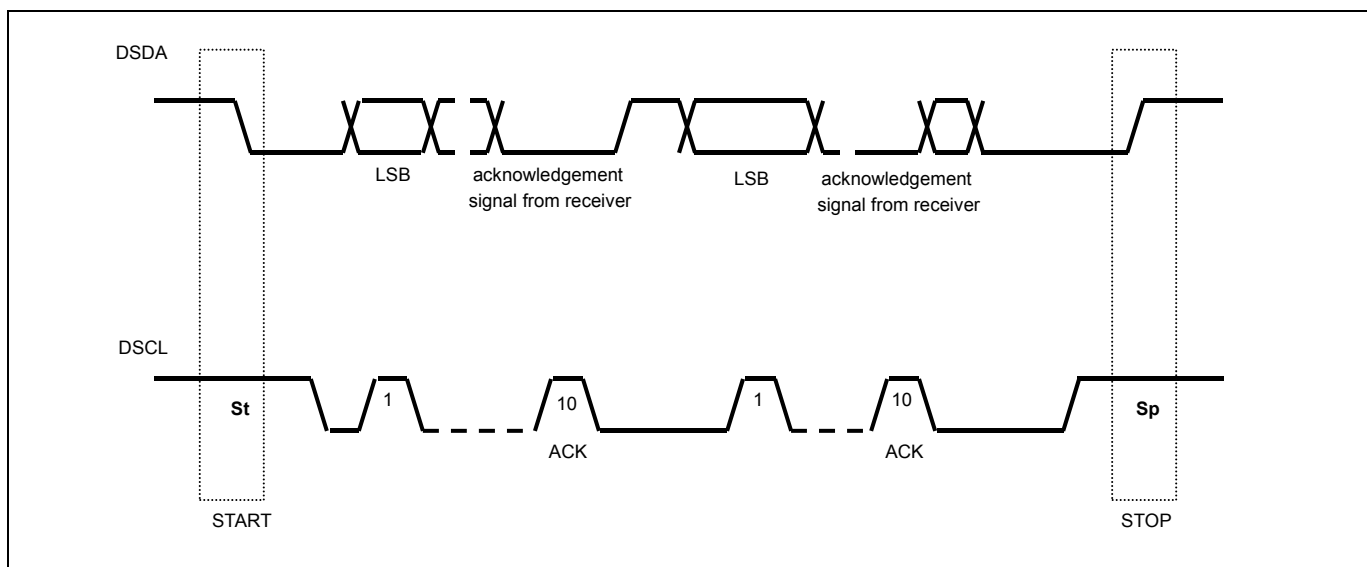


Figure 14.3 Data transfer on the twin bus

14.2.2.2 Bit Transfer

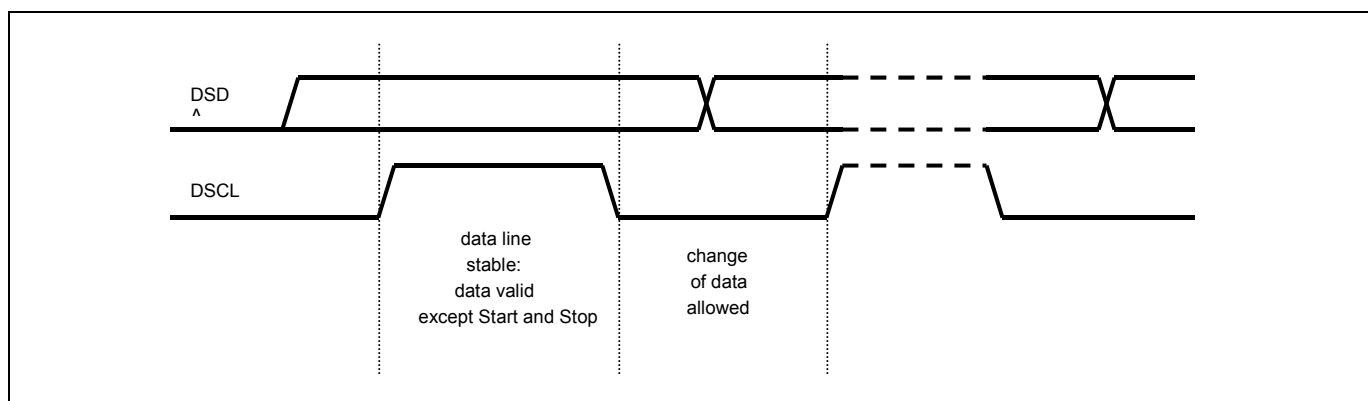


Figure 14.4 Bit transfer on the serial bus

14.2.2.3 Start and Stop Condition

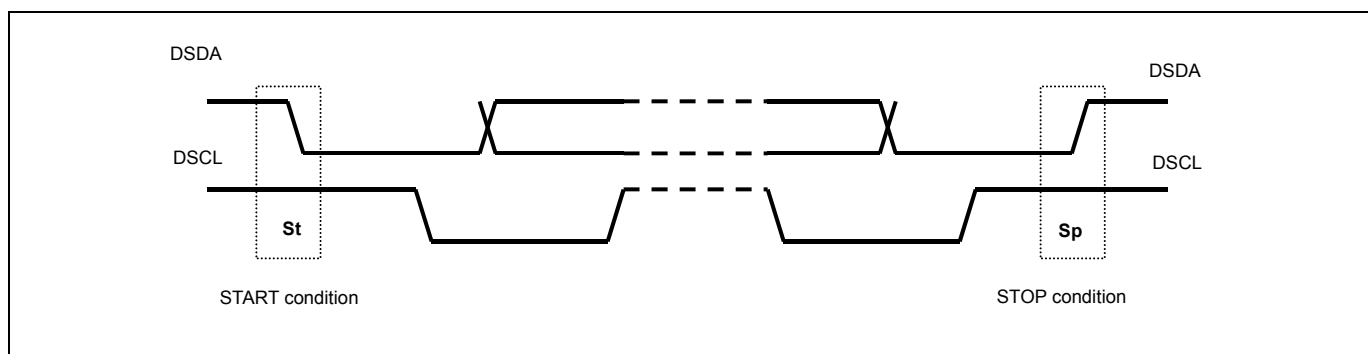


Figure 14.5 Start and stop condition

14.2.2.4 Acknowledge bit

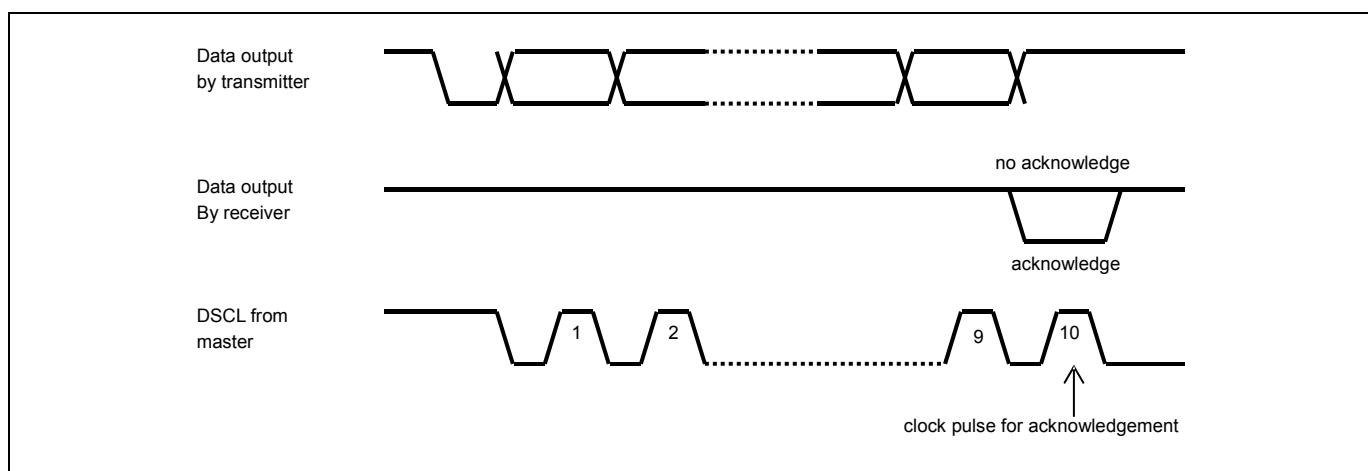


Figure 14.6 Acknowledge on the serial bus

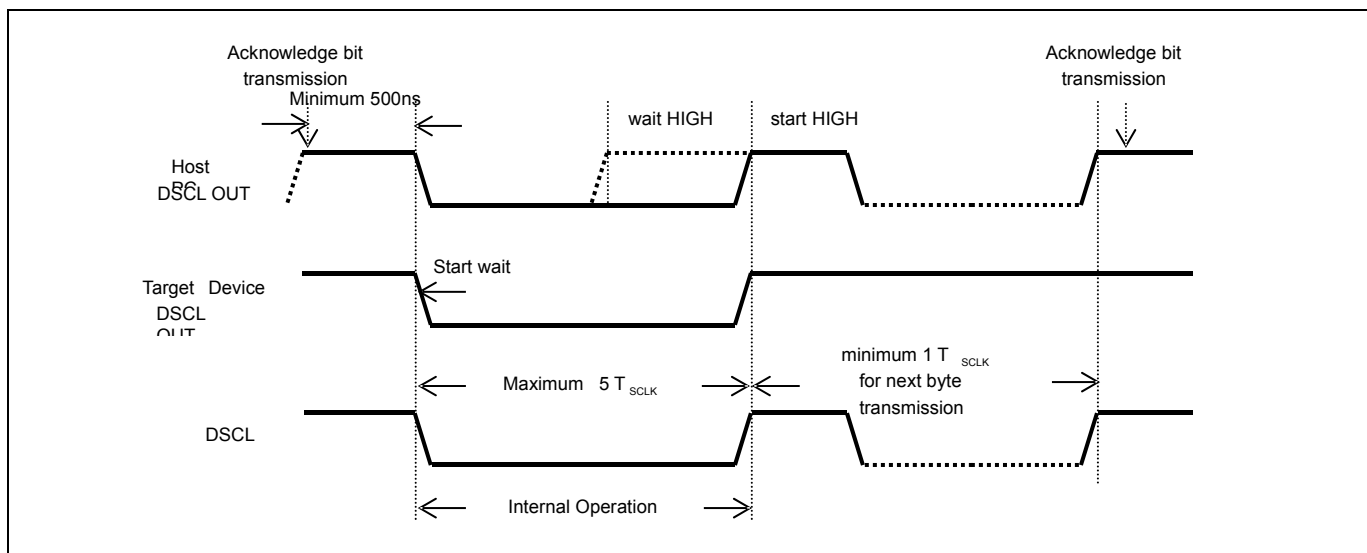


Figure 14.7 Clock synchronization during wait procedure

14.2.3 Connection of Transmission

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

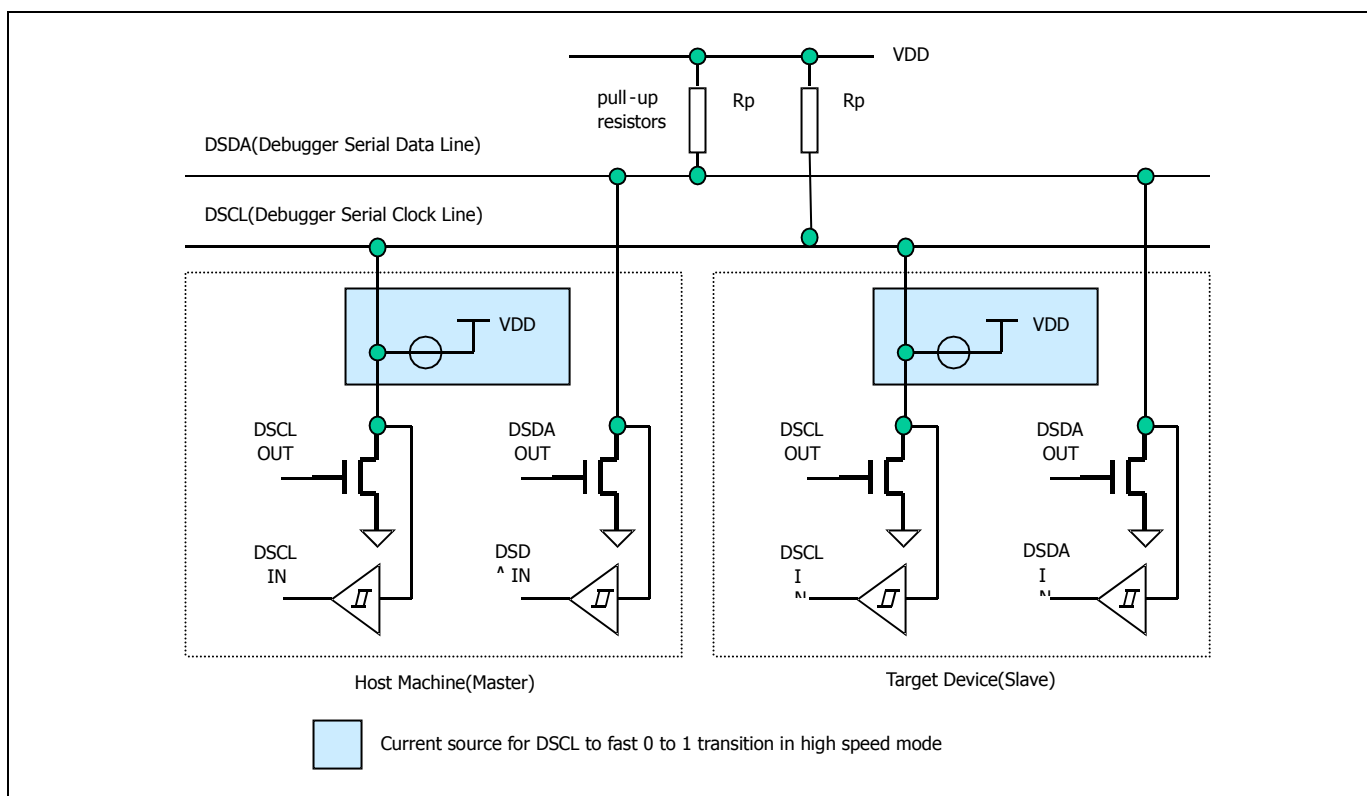


Figure 14.8 Connection of transmission

15 Memory Programming

15.1 Overview

15.1.1 Description

MC97FG316 incorporates flash and data EEPROM memory to which a program can be written, erased, and overwritten while mounted on the board. Also, data EEPROM can be programmed or erased in user program. Flash area can be programmed in only OCD2 or parallel ROM mode.

Serial ISP modes and byte-parallel ROM writer mode are supported.

15.1.2 Features

- Flash Size : 16Kbytes
- Single power supply program and erase
- Command interface for fast program and erase operation
- Up to 10,000 program/erase cycles at typical voltage and temperature for flash memory
- Up to 300,000 program/erase cycles at typical voltage and temperature for data EEPROM memory
- Security feature

15.2 Flash and EEPROM Control and status register

Registers to control Flash and Data EEPROM are Mode Register (FEMR), Control Register (FECR), Status Register (FESR), Time Control Register (FETCR), Address Low Register (FEARL), Address Middle Register (FEARM), address High Register (FEARH) and Data Register (FEDR). They are mapped to SFR area and can be accessed only in programming mode.

15.2.1 Register Map

Name	Address	Dir	Default	Description
FEMR	EAH	R/W	00H	Flash and EEPROM Mode Register
FECR	EBH	R/W	03H	Flash and EEPROM Control Register
FESR	ECH	R/W	80H	Flash and EEPROM Status Register
FETCR	EDH	R/W	00H	Flash and EEPROM Time Control Register
FEARL	F2H	R/W	00H	Flash and EEPROM Address Low Register
FEARM	F3H	R/W	00H	Flash and EEPROM Address Middle Register
FEARH	F4H	R/W	00H	Flash and EEPROM Address High Register
FEDR	F5H	R/W	00H	Flash and EEPROM Data Register

Table 15.1 Register Map

15.2.2 Register Description for Flash and EEPROM

FEMR (Flash and EEPROM Mode Register) : EAH

7	6	5	4	3	2	1	0
FSEL	ESEL	PGM	ERASE	PBUFF	OTPE	VFY	FEEN
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

FSEL	Select flash memory.
0	Deselect flash memory
1	Select flash memory
ESEL	Select data EEPROM
0	Deselect data EEPROM
1	Select data EEPROM
PGM	Enable program or program verify mode with VFY
0	Disable program or program verify mode
1	Enable program or program verify mode
ERASE	Enable erase or erase verify mode with VFY
0	Disable erase or erase verify mode
1	Enable erase or erase verify mode
PBUFF	Select page buffer
0	Deselect page buffer
1	Select page buffer
OTPE	Select OTP area instead of program memory
0	Deselect OTP area
1	Select OTP area
VFY	Set program or erase verify mode with PGM or ERASE
	Program Verify: PGM=1, VFY=1
	Erase Verify: ERASE=1, VFY=1
FEEN	Enable program and erase of Flash and data EEPROM. When inactive, it is possible to read as normal mode
0	Disable program and erase
1	Enable program and erase

FECR (Flash and EEPROM Control Register) : EBH

7	6	5	4	3	2	1	0
AEF	AEE	EXIT1	EXIT0	WRITE	READ	nFERST	nPBRST
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 03H

AEF	Enable flash bulk erase mode		
0	Disable bulk erase mode of Flash memory		
1	Enable bulk erase mode of Flash memory		
AEE	Enable data EEPROM bulk erase mode		
0	Disable bulk erase mode of data EEPROM		
1	Enable bulk erase mode of data EEPROM		
EXIT[1:0]	Exit from program mode. It is cleared automatically after 1 clock		
EXIT1	EXIT0	Description	
0	0	Don't exit from program mode	
0	1	Don't exit from program mode	
1	0	Don't exit from program mode	
1	1	Exit from program mode	
WRITE	Start to program or erase of Flash and data EEPROM. It is cleared automatically after 1 clock		
0	No operation		
1	Start to program or erase of Flash and data EEPROM		
READ	Start auto-verify of Flash or data EEPROM. It is cleared automatically after 1 clock		
0	No operation		
1	Start auto-verify of Flash or data EEPROM		
nFERST	Reset Flash or data EEPROM control logic. It is cleared automatically after 1 clock		
0	No operation		
1	Reset Flash or data EEPROM control logic.		
nPBRST	Reset page buffer with PBUFF. It is cleared automatically after 1 clock		
PBUFF	nPBRST	Description	
0	0	Page buffer reset	
1	0	Write checksum reset	

WRITE and READ bits can be used in program, erase and verify mode with FEAR registers. Read or writes for memory cell or page buffer uses read and write enable signals from memory controller. Indirect address mode with FEAR is only allowed to program, erase and verify

FESR (Flash and EEPROM Status Register) : ECH

7	6	5	4	3	2	1	0
PEVBSY	VFYGOOD	PCRCRD	-	ROMINT	WMODE	EMODE	VMODE
R	RW	R	R	RW	R	R	R

Initial value : 80H

PEVBSY	Operation status flag. It is cleared automatically when operation starts. Operations are program, erase or verification 0 Busy (Operation processing) 1 Complete Operation
VFYGOOD	Auto-verification result flag. 0 Auto-verification fails 1 Auto-verification successes
PCRCRD	Select read mode. 0 24-bit Check-Sum read mode (default) 1 16-bit Cyclic CRC result read mode
ROMINT	Flash and Data EEPROM interrupt request flag. Auto-cleared when program/erase/verify starts. Active in program/erase/verify completion 0 No interrupt request. 1 Interrupt request.
WMODE	Write mode flag
EMODE	Erase mode flag
VMODE	Verify mode flag

FEARL (Flash and EEPROM address low Register) : F2H

7	6	5	4	3	2	1	0
ARL7	ARL6	ARL5	ARL4	ARL3	ARL2	ARL1	ARL0
W	W	W	W	W	W	W	W

Initial value : 00H

ARL[7:0] Flash and EEPROM address low

FEARM (Flash and EEPROM address middle Register) : F3H

7	6	5	4	3	2	1	0
ARM7	ARM6	ARM5	ARM4	ARM3	ARM2	ARM1	ARM0
W	W	W	W	W	W	W	W

Initial value : 00H

ARM[7:0] Flash and EEPROM address middle

FEARH (Flash and EEPROM address high Register) : F4H

7	6	5	4	3	2	1	0
ARH7	ARH6	ARH5	ARH4	ARH3	ARH2	ARH1	ARH0
W	W	W	W	W	W	W	W

Initial value : 00H

ARH[7:0] Flash and EEPROM address high

FEAR registers are used for program, erase and auto-verify. In program and erase mode, it is page address and ignored the same least significant bits as the number of bits of page address. In auto-verify mode, address increases automatically by one.

FEARs are write-only register. Reading these registers returns 24-bit checksum or 16-bit CRC result by PCRCRD bit at FESR.

FEDR (Flash and EEPROM data control Register) : F5H

7	6	5	4	3	2	1	0
FEDR7	FEDR6	FEDR5	FEDR4	FEDR3	FEDR2	FEDR1	FEDR0
W	W	W	W	W	W	W	W

Initial value : 00H

FEDR[7:0] Flash and EEPROM data

Data register. In no program/erase/verify mode, READ/WRITE of FECD read or write data from EEPROM or FLASH to this register or from this register to Flash or EEPROM.

The sequence of writing data to this register is used for EEPROM program entry. The mode entrance sequence is to write 0xA5 and 0x5A to it in order.

FETCR (Flash and EEPROM Time control Register) : EDH

7	6	5	4	3	2	1	0
TCR7	TCR6	TCR5	TCR4	TCR3	TCR2	TCR1	TCR0
RW	RW	RW	RW	RW	RW	RW	RW

Initial value : 00H

TCR[7:0] Flash and EEPROM Time control

. Program and erase time is controlled by setting FETCR register. Program and erase timer uses 10-bit counter. It increases by one at each divided system clock frequency(=SCLK/128). It is cleared when program or erase starts. Timer stops when 10-bit counter is same to FETCR. PEVBSY is cleared when program, erase or verify starts and set when program, erase or verify stops.

Max program/erase time at 16MHz system clock : $(255+1) * 2 * (0.0625\mu s * 128) = 4.096\text{ms}$

In the case of 10% of error rate of counter source clock, program or erase time is 3.6~4.5ms

* Program/erase time calculation

for page write or erase, $T_{pe} = (TCON+1) * 2 * (SCLK * 128)$

for bulk erase, $T_{be} = (TCON+1) * 4 * (SCLK * 128)$

	Min	Typ	Max	Unit
program/erase Time	2.4	2.5	2.6	ms

Table 15.2 Program/erase Time

※ Recommended program/erase time at 16MHz (FETCR = 9Ch)

15.3 Memory map

15.3.1 Flash Memory Map

Program memory uses 16-Kbyte of Flash memory. It is read by byte and written by byte or page. One page is 32-byte

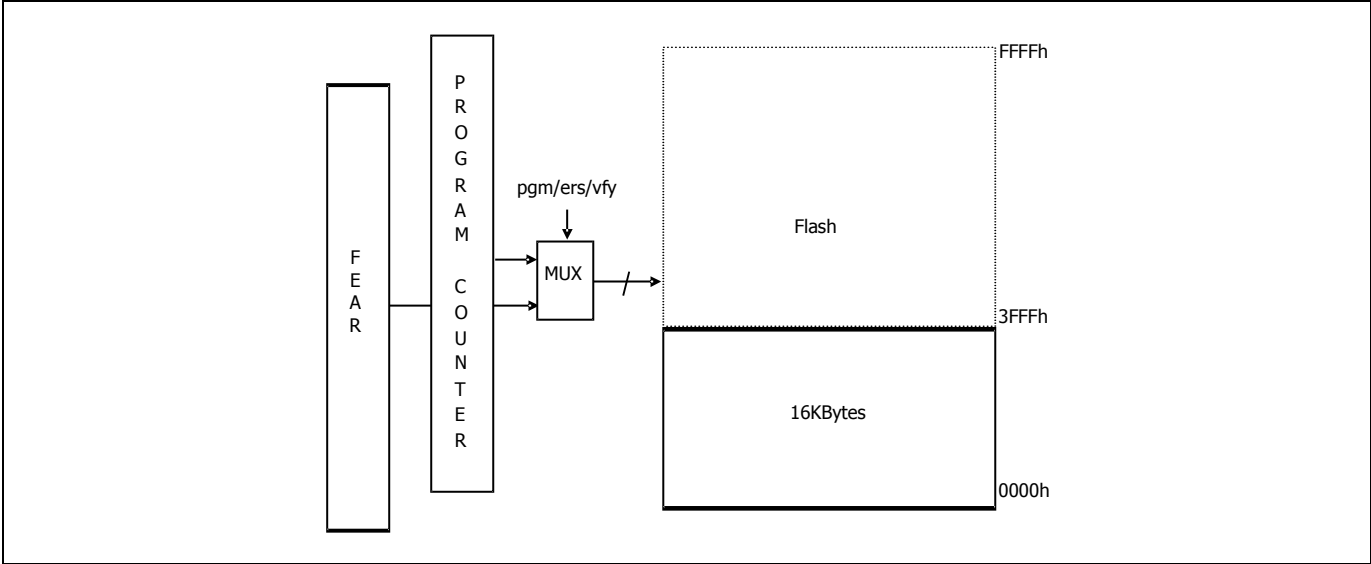


Figure 15.1 Flash Memory Map

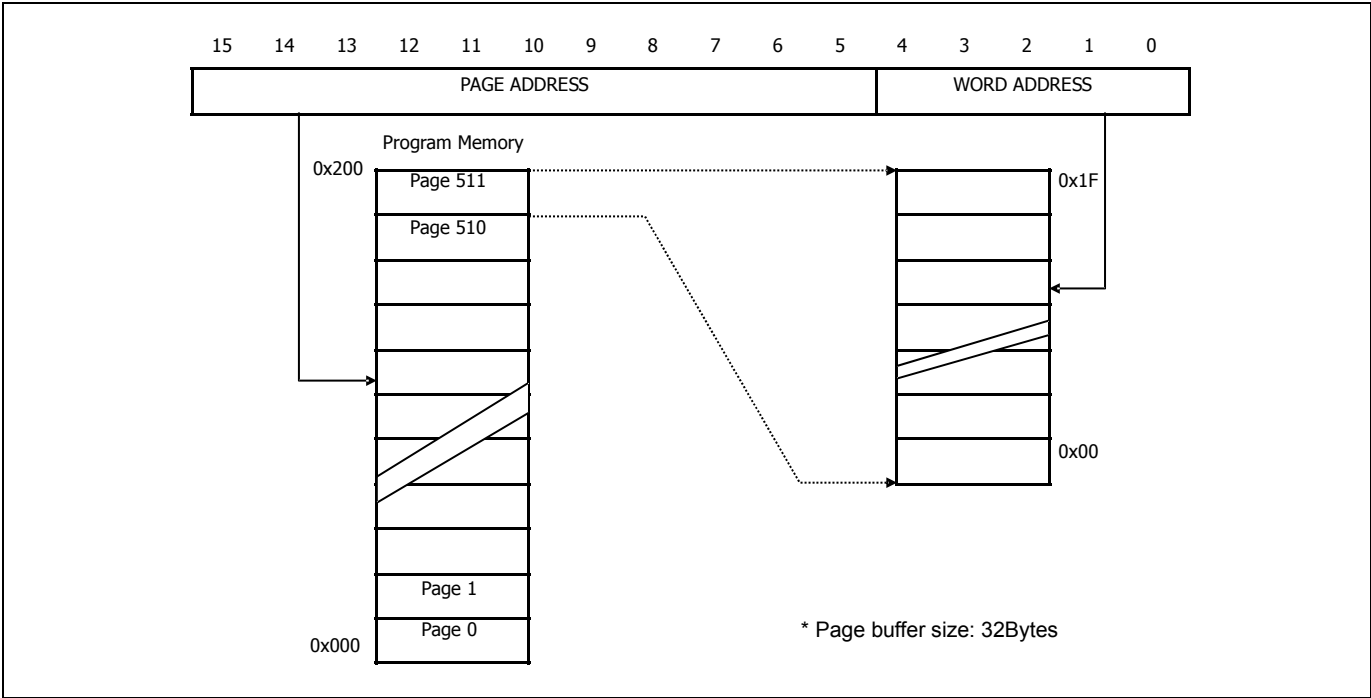


Figure 15.2 Address configuration of Flash memory

15.3.2 Data EEPROM Memory Map

Data EEPROM memory uses 512-byte of EEPROM. It is read by byte and written by byte or page. One page is 16-byte. It is mapped to external data memory of 8051

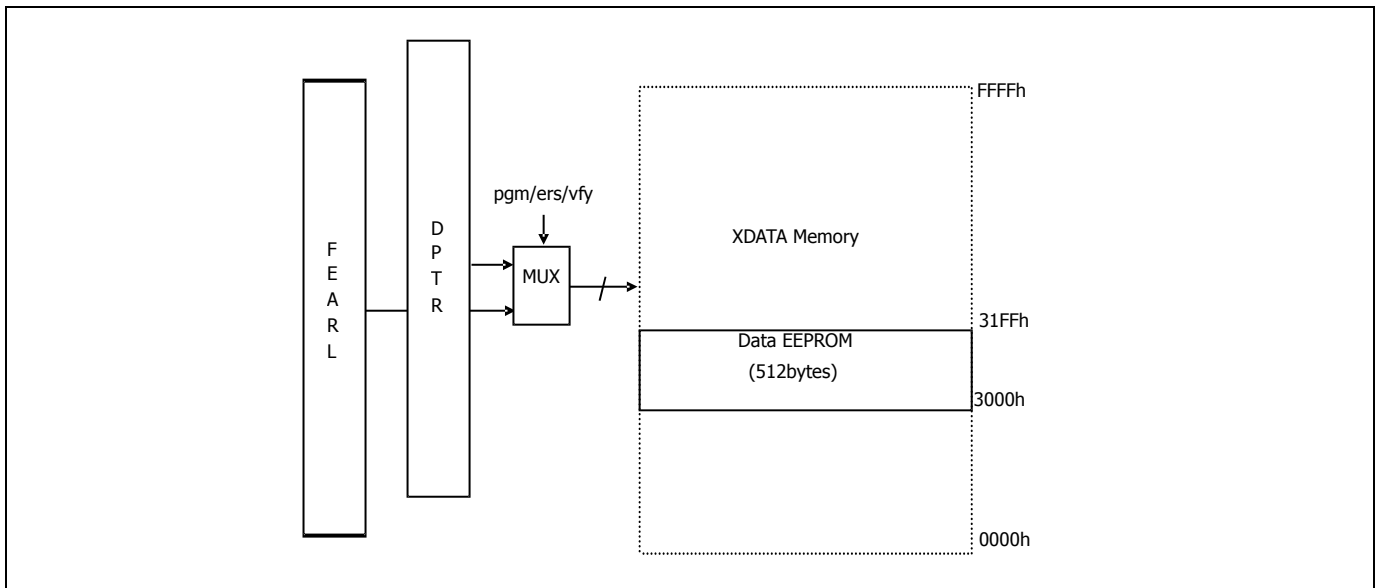


Figure 15.3 Data EEPROM memory map

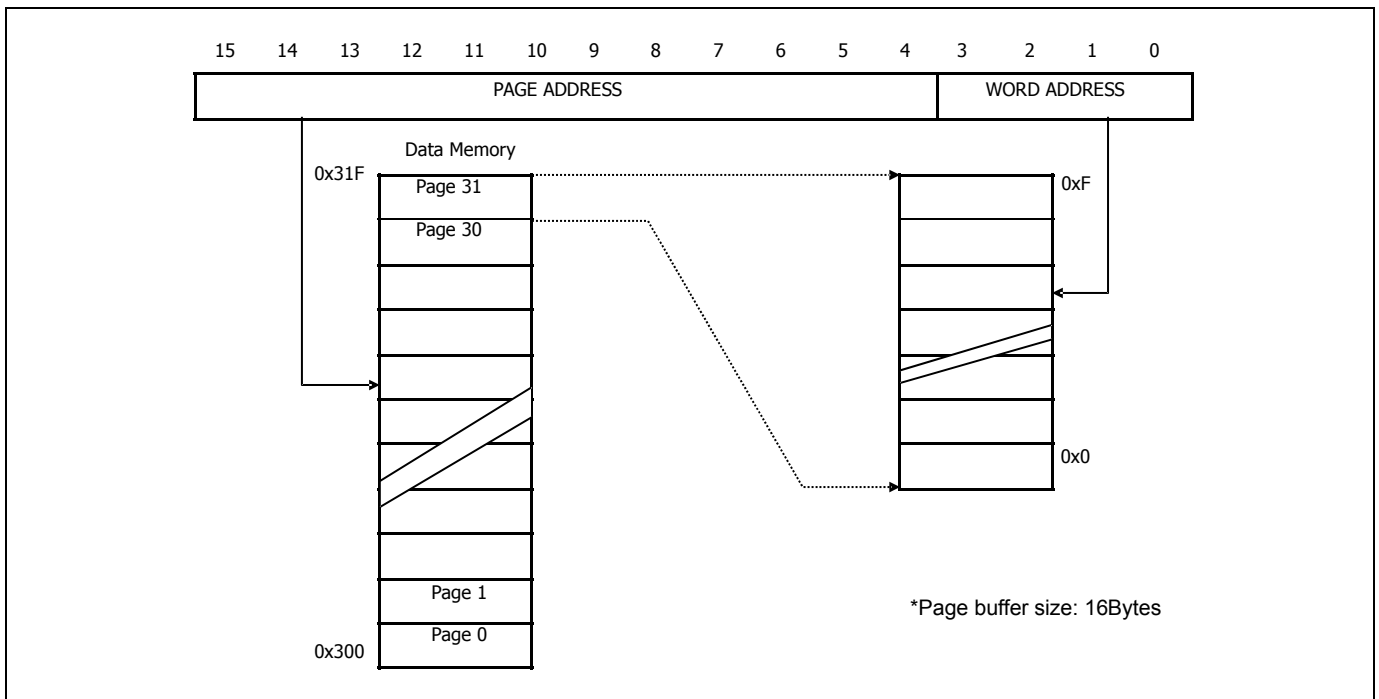


Figure 15.4 Address configuration of data EEPROM

15.4 Serial In-System Program Mode

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

15.4.1 Flash operation

Configuration (This Configuration is just used for follow description)

7	6	5	4	3	2	1	0
-	FEMR[4] & [1]	FEMR[5] & [1]	-	-	FEMR[2]	FEER[6]	FEER[7]
-	ERASE&VFY	PGM&VFY	-	-	OTPE	AEE	AEF

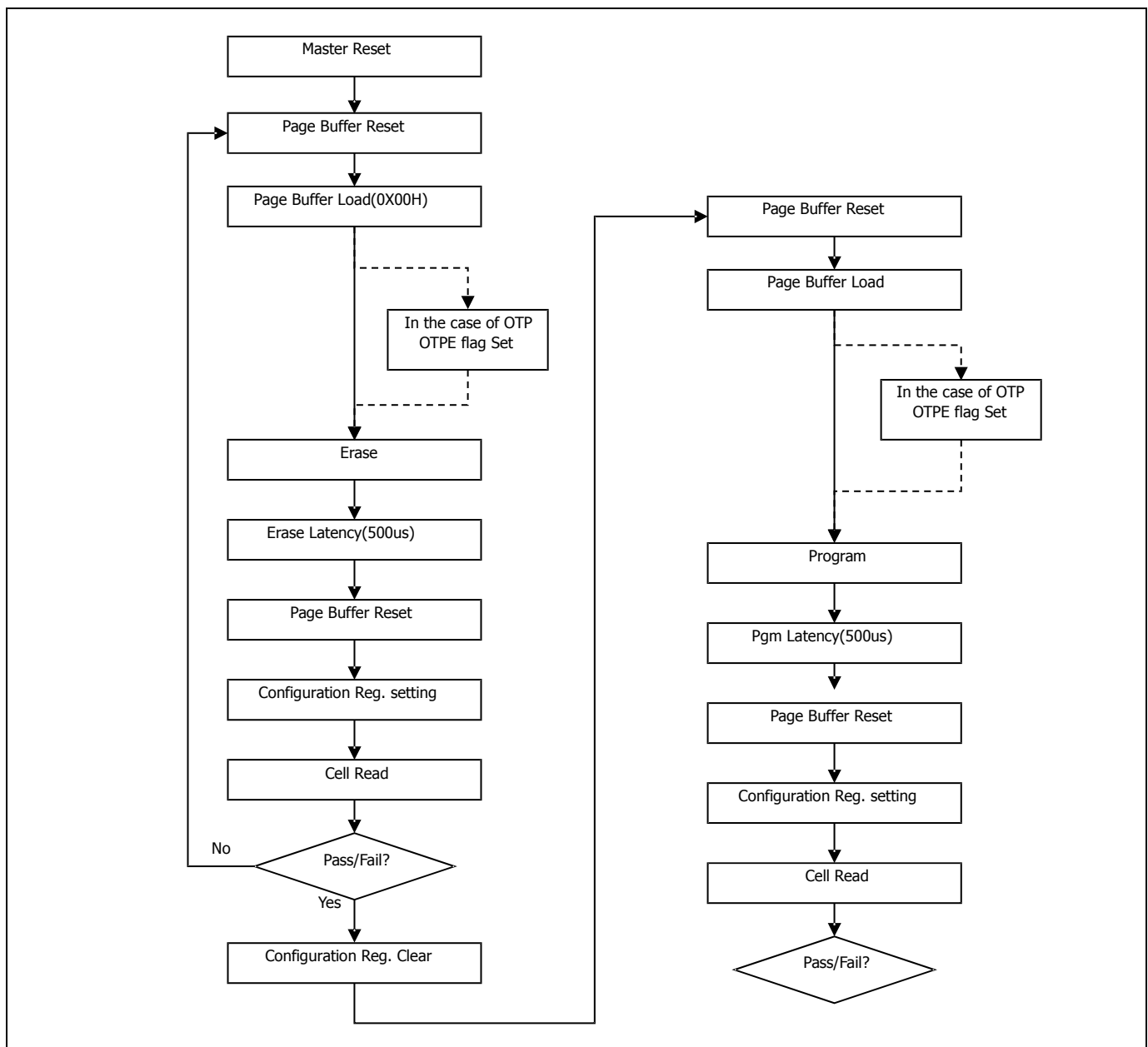


Figure 15.5 The sequence of page program and erase of Flash memory

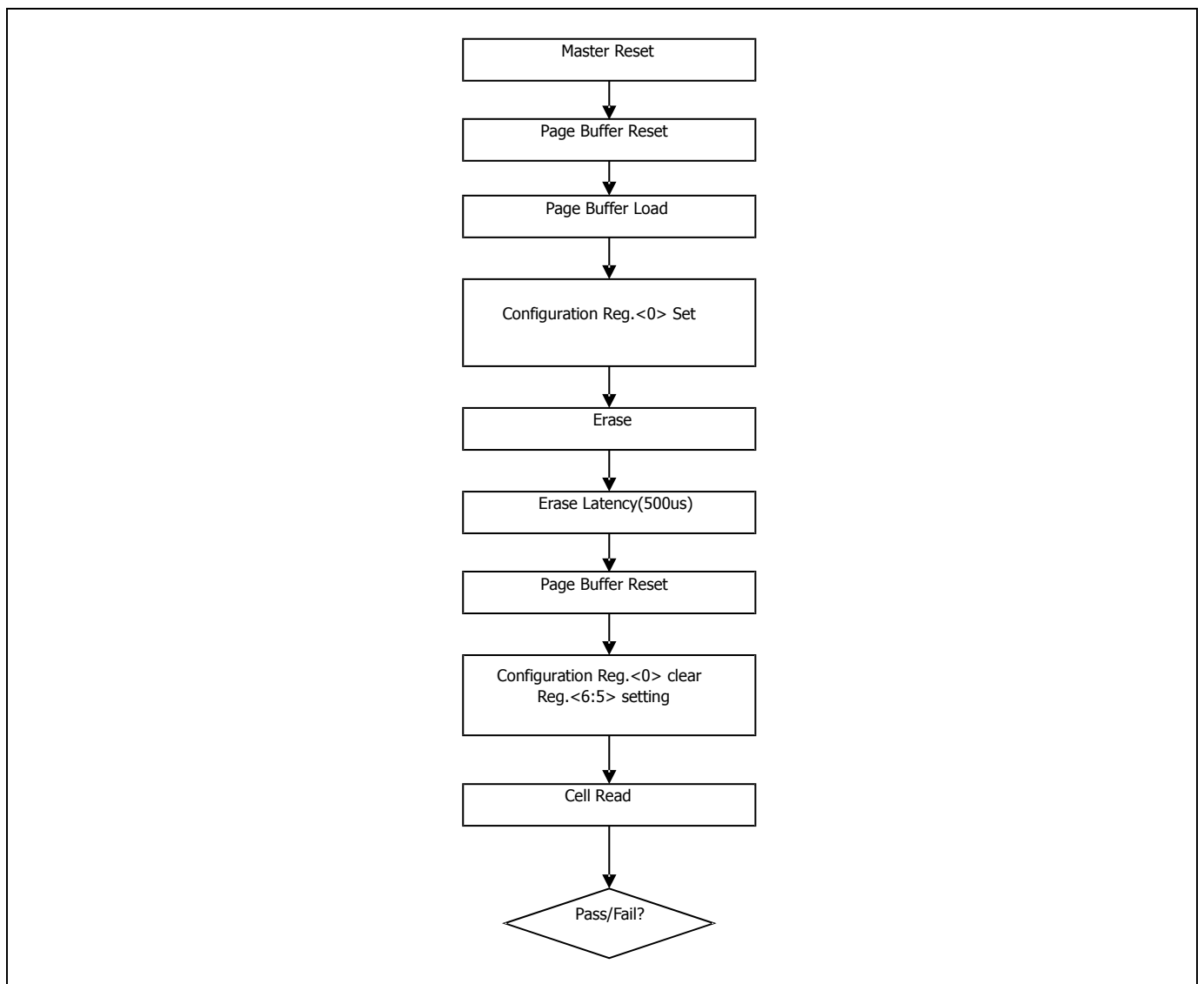


Figure 15.6 The sequence of bulk erase of Flash memory

15.4.1.1 Flash Read

- Step 1. Enter OCD(=ISP) mode.
- Step 2. Set ENBDM bit of BCR.
- Step 3. Enable debug and Request debug mode.
- Step 4. Read data from Flash.

15.4.1.2 Enable program mode

- Step 1. Enter OCD(=ISP) mode.¹
- Step 2. Set ENBDM bit of BCR.
- Step 3. Enable debug and Request debug mode.
- Step 4. Enter program/erase mode sequence.²
 - (1) Write 0xAA to 0xF555.
 - (2) Write 0x55 to 0xFAAA.

(3) Write 0xA5 to 0xF555.

¹ Refer to how to enter ISP mode..

² Command sequence to activate Flash write/erase mode. It is composed of sequentially writing data of Flash memory.

15.4.1.3 Flash write mode

- Step 1. Enable program mode.
- Step 2. Reset page buffer. FEMR: 1000_0001 FECR:0000_0010
- Step 3. Select page buffer. FEMR:1000_1001
- Step 4. Write data to page buffer.(Address automatically increases by twin.)
- Step 5. Set write mode. FEMR:1010_0001
- Step 6. Set page address. FEARH:FEARM:FEARL=20'hx_xxxx
- Step 7. Set FETCR.
- Step 8. Start program. FECR:0000_1011
- Step 9. Insert one NOP operation
- Step 10. Read FESR until PEVBSY is 1.
- Step 11. Repeat step2 to step 8 until all pages are written.

15.4.1.4 Flash page erase mode

- Step 1. Enable program mode.
- Step 2. Reset page buffer. FEMR: 1000_0001 FECR:0000_0010
- Step 3. Select page buffer. FEMR:1000_1001
- Step 4. Write 'h00 to page buffer. (Data value is not important.)
- Step 5. Set erase mode. FEMR:1001_0001
- Step 6. Set page address. FEARH:FEARM:FEARL=20'hx_xxxx
- Step 7. Set FETCR.
- Step 8. Start erase. FECR:0000_1011
- Step 9. Insert one NOP operation
- Step 10. Read FESR until PEVBSY is 1.
- Step 11. Repeat step2 to step 8 until all pages are erased.

15.4.1.5 Flash bulk erase mode

- Step 1. Enable program mode.
- Step 2. Reset page buffer. FEMR: 1000_0001 FECR:0000_0010
- Step 3. Select page buffer. FEMR:1000_1001
- Step 4. Write 'h00 to page buffer. (Data value is not important.)
- Step 5. Set erase mode. FEMR:1001_0001.

(Only main cell area is erased. For bulk erase including OTP area, select OTP area.(set FEMR to 1000_1101.)

- Step 6. Set FETCR

- Step 7. Start bulk erase. FECR:1000_1011
- Step 8. Insert one NOP operation
- Step 9. Read FESR until PEVBSY is 1.

15.4.1.6 Flash OTP area read mode

- Step 1. Enter OCD(=ISP) mode.
- Step 2. Set ENBDM bit of BCR.
- Step 3. Enable debug and Request debug mode.
- Step 4. Select OTP area. FEMR:1000_0101
- Step 5. Read data from Flash.

15.4.1.7 Flash OTP area write mode

- Step 1. Enable program mode.
- Step 2. Reset page buffer. FEMR: 1000_0001 FECR:0000_0010
- Step 3. Select page buffer. FEMR:1000_1001
- Step 4. Write data to page buffer.(Address automatically increases by twin.)
- Step 5. Set write mode and select OTP area. FEMR:1010_0101
- Step 6. Set page address. FEARH:FEARM:FEARL=20'hx_xxxx
- Step 7. Set FETCR.
- Step 8. Start program. FECR:0000_1011
- Step 9. Insert one NOP operation
- Step 10. Read FESR until PEVBSY is 1.

15.4.1.8 Flash OTP area erase mode

- Step 1. Enable program mode.
- Step 2. Reset page buffer. FEMR: 1000_0001 FECR:0000_0010
- Step 3. Select page buffer. FEMR:1000_1001
- Step 4. Write 'h00 to page buffer. (Data value is not important.)
- Step 5. Set erase mode and select OTP area. FEMR:1001_0101
- Step 6. Set page address. FEARH:FEARM:FEARL=20'hx_xxxx
- Step 7. Set FETCR.
- Step 8. Start erase. FECR:0000_1011
- Step 9. Insert one NOP operation
- Step 10. Read FESR until PEVBSY is 1.

15.4.1.9 Flash program verify mode

- Step 1. Enable program mode.
- Step 2. Set program verify mode. FEMR:1010_0011
- Step 3. Read data from Flash.

15.4.1.10 OTP program verify mode

- Step 1. Enable program mode.
- Step 2. Set program verify mode. FEMR:1010_0111
- Step 3. Read data from Flash.

15.4.1.11 Flash erase verify mode

- Step 1. Enable program mode.
- Step 2. Set erase verify mode. FEMR:1001_0011
- Step 3. Read data from Flash.

15.4.1.12 Flash page buffer read

- Step 1. Enable program mode.
- Step 2. Select page buffer. FEMR:1000_1001
- Step 3. Read data from Flash.

15.4.2 Data EEPROM operation

Program and erase operation of Data EEPROM are executed by direct and indirect address mode.
Direct address mode uses external data area of 8051. Indirect address mode uses address register of SFR area..

15.4.2.1 Data EEPROM Read

- Step 1. Enter OCD(=ISP) mode.
- Step 2. Set ENBDM bit of BCR.
- Step 3. Enable debug and Request debug mode.
- Step 4. Read data from Data EEPROM.

15.4.2.2 Enable program mode

- Step 1. Enter OCD(=ISP) mode.¹
- Step 2. Set ENBDM bit of BCR.
- Step 3. Enable debug and Request debug mode.
- Step 4. Enter program/erase mode sequence.²
 - (1) Write 0xA5 to FEDR.
 - (2) Write 0x5A to FEDR.

1 Refer to how to enter ISP mode..

2 Command sequence to activate data EEPROM write/erase mode. It is composed of sequentially writing to data register(FEDR)

15.4.2.3 EEPROM write mode

- Step 1. Enable program mode.
- Step 2. Reset page buffer. FEMR: 0100_0001 FECR:0000_0010
- Step 3. Select page buffer. FEMR:0100_1001
- Step 4. Write data to page buffer.(Address automatically increases by twin.)
- Step 5. Set write mode. FEMR:0110_0001
- Step 6. Set page address. FEARH:FEARM:FEARL=20'hx_xxxx
- Step 7. Set FETCR.
- Step 8. Start program. FECR:0000_1011
- Step 9. Insert one NOP operation
- Step 10. Read FESR until PEVBSY is 1.
- Step 11. Repeat step2 to step 8 until all pages are written.

15.4.2.4 EEPROM page erase mode

- Step 1. Enable program mode.
- Step 2. Reset page buffer. FEMR: 0100_0001 FECR:0000_0010
- Step 3. Select page buffer. FEMR:0100_1001
- Step 4. Write 'h00 to page buffer. (Data value is not important.)
- Step 5. Set erase mode. FEMR:0101_0001
- Step 6. Set page address. FEARH:FEARM:FEARL=20'hx_xxxx
- Step 7. Set FETCR.
- Step 8. Start erase. FECR:0000_1011
- Step 9. Insert one NOP operation
- Step 10. Read FESR until PEVBSY is 1.
- Step 11. Repeat step2 to step 8 until all pages are erased.

15.4.2.5 EEPROM bulk erase mode

- Step 1. Enable program mode.
- Step 2. Reset page buffer. FEMR: 0100_0001 FECR:0000_0010
- Step 3. Select page buffer. FEMR:0100_1001
- Step 4. Write 'h00 to page buffer. (Data value is not important.)
- Step 5. Set erase mode. FEMR:0101_0001.
- Step 6. Set FETCR
- Step 7. Start bulk erase. FECR:0100_1011
- Step 8. Insert one NOP operation
- Step 9. Read FESR until PEVBSY is 1.

15.4.2.6 Data EEPROM program verify mode

- Step 1. Enable program mode.

Step 2. Set program verify mode. FEMR:0110_0011

Step 3. Read data from Flash.

15.4.2.7 Data EEPROM erase verify mode

Step 1. Enable program mode.

Step 2. Set erase verify mode. FEMR:0101_0011

Step 3. Read data from Flash.

15.4.2.8 Data EEPROM page buffer read

Step 1. Enable program mode.

Step 2. Select page buffer. FEMR:0100_1001

Step 3. Read data from Flash.

15.4.3 Summary of Flash and Data EEPROM Program/Erase Mode

Operation mode		Description
F L A S H	Flash read	Read cell by byte.
	Flash write	Write cell by bytes or page.
	Flash page erase	Erase cell by page.
	Flash bulk erase	Erase the whole cells.
	Flash program verify	Read cell in verify mode after programming.
	Flash erase verify	Read cell in verify mode after erase.
	Flash page buffer load	Load data to page buffer.
E E P R O M	Data EEPROM read	Read cell by byte.
	Data EEPROM write	Write cell by bytes or page.
	Data EEPROM page erase	Erase cell by page.
	Data EEPROM bulk erase	Erase the whole cells.
	Data EEPROM program verify	Read cell in verify mode after programming.
	Data EEPROM erase verify	Read cell in verify mode after erase.
	Data EEPROM page buffer load	Load data to page buffer.

Table 15.3 Operation Mode

15.5 Mode entrance method of ISP and byte-parallel mode

15.5.1 Mode entrance method for ISP

TARGET MODE	DSDA	DSCL	DSDA
OCD(ISP)	'hC	'hC	'hC

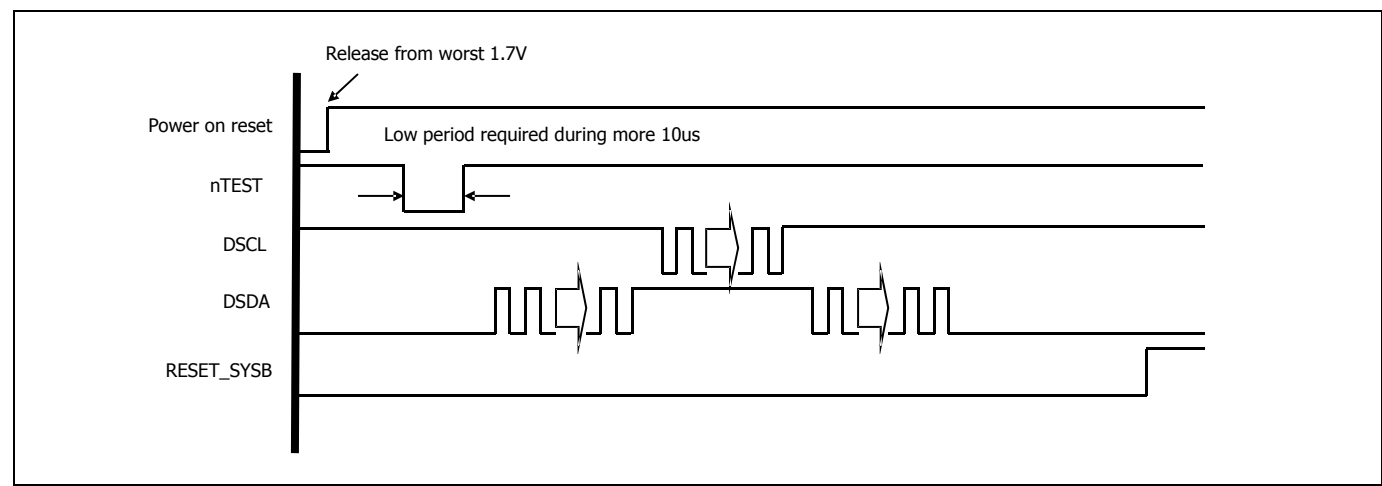


Figure 15.7 ISP mode

15.6 Security

MC97FG316 provides Lock bits which can be left unprogrammed ("0") or can be programmed ("1") to obtain the additional features listed in Table 15.6. The Lock bits can be erased to "0" with only the bulk erase command and a value of more than 0x80 at FETCR.

LOCK MODE		USER MODE												ISP/PMODE											
		FLASH				DATA EEPROM				OTP				FLASH				DATA EEPROM				OTP			
LOCK E	LOCK F	R	W	P E	B E	R	W	P E	B E	R	W	P E	B E	R	W	P E	B E	R	W	P E	B E	R	W	P E	B E
0	0	O	O	O	X	O	O	O	O	X	X	X	X	O	O	O	O	O	O	O	O	O	O	O	O
0	1	O	O	O	X	O	O	O	O	X	X	X	X	X	X	X	O	O	O	O	O	O	X	X	O
1	0	O	O	O	X	O	O	O	O	X	X	X	X	O	◇	◇	◇	X	X	X	O	O	◇	◇	◇
1	1	O	O	O	X	O	O	O	O	X	X	X	X	X	X	X	◇	X	X	X	O	O	X	X	◇

Table 15.4 Security policy using lock-bits

- LOCKF: Lock bit of Flash memory
- LOCKE: Lock bit of data EEPROM
- R: Read
- W: Write
- PE: Page erase
- BE: Bulk Erase
- O: Operation is possible.
- X: Operation is impossible.
- ◇: When LOCKE is programmed, each operation can be done after data EEPROM is erased with the bulk erase command.

16 Configure Option

16.1 Configure option Control Register

FUSE_CONF (Pseudo-Configure Data) : 2F50H

7	6	5	4	3	2	1	0
BSIZE1	BSIZE0	SXINEN	XINENA	RSTEN	LOCKB	LOCKE	LOCKF
RW	RW	RW	RW	RW	R	R	R

Initial value : 00H

BSIZE	Select Specific Area for Write Protection NOTE) when LOCKB='1', It is applied
00	0000H~07FFH (default)
01	0000H~09FFH
10	0000H~0BFFH
11	0000H~0DFFH
SXINEN	Enable External Sub Oscillator
0	External Sub OSC disable (default)
1	External Sub OSC Enable
XINENA	Enable External Main Oscillator
0	External Main OSC disable (default)
1	External Main OSC Enable
RSTEN	Enable RESETB pin
0	External RESETB disable
1	External RESETB enable
LOCKB	Enable Specific Area Write Protection
0	Boot LOCK Disable
1	Boot LOCK Enable
LOCKE	Data Read Protection
0	LOCK Disable
1	LOCK Enable
LOCKF	Code Read Protection
0	LOCK Disable
1	LOCK Enable

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
DAA	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	2	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. How to use external reset

Release reset before entering OCD mode by adjusting the external RC value of RESET pin.

When the external reset is used, the below RC value is recommended.(about 1ms).

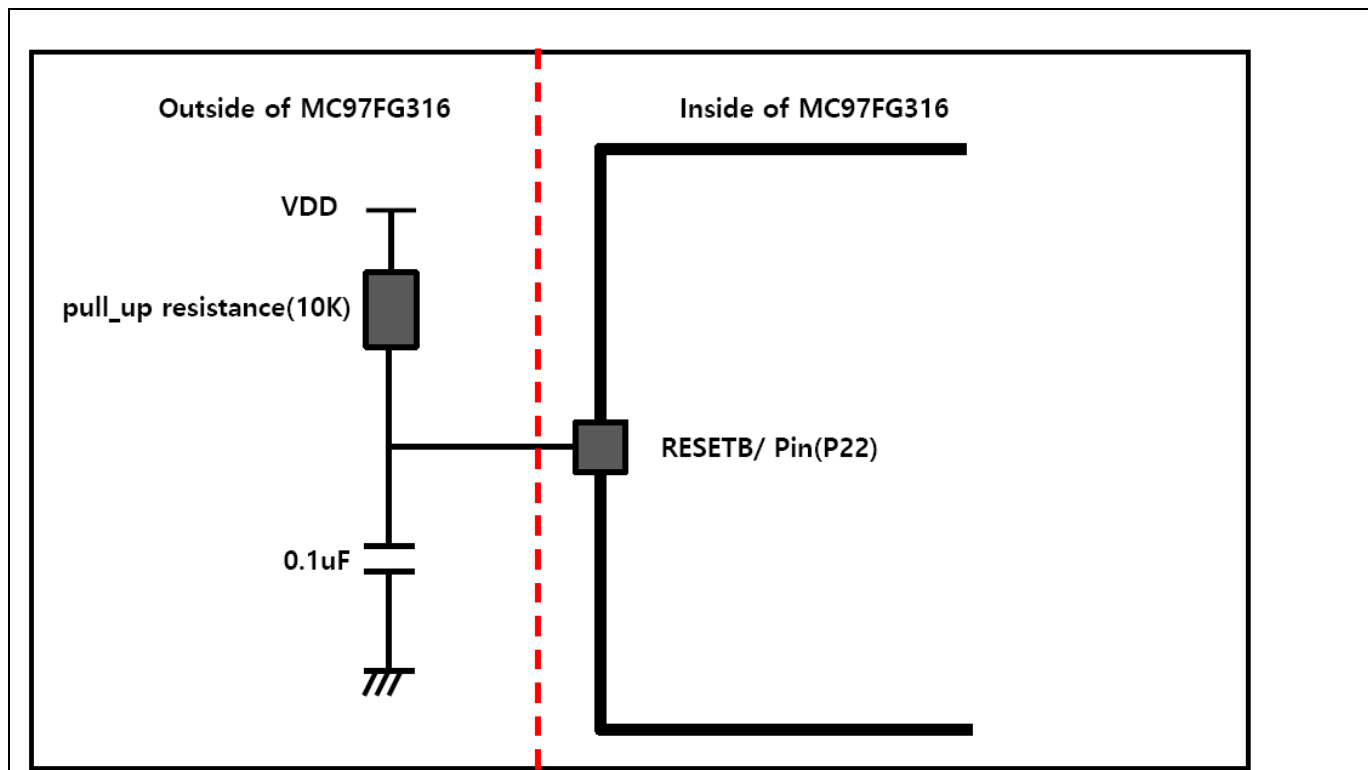


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