

ABOV SEMICONDUCTOR
8-BIT SINGLE-CHIP MICROCONTROLLERS

MC80F0704/0708

MC80F0804/0808

User's Manual (Ver. 1.03)



Version 1.03

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REVISION HISTORY

VERSION 1.03 (October 31, 2011) This Book

Logo is changed.

The dimensions of 28 SOP package outline drawing is fixed.

VERSION 1.02 (August 18, 2009)

Device order is rearranged and fixed some errata.

The figures of flash writer were updated in "1. OVERVIEW" on page 1.

Config Read Voltage(V_{CONFIG}), maximum VDD Start Voltage(V_{START}) and Figure 7-1 were added in "7.4 DC Electrical Characteristics" on page 17.

The recommended loadcapacitor values for main-oscillator circuit were added to 10pF~30pF in "10. CLOCK GENERATOR" on page 43.

In case AVREF voltage was less than VDD voltage for ADC, the table-note and note were added in "7.3 A/D Converter Characteristics" on page 16 and "14. ANALOG TO DIGITAL CONVERTER" on page 70.

VERSION 1.01 (JUN 3, 2008)

Internal OSC specification was changed.

VERSION 1.0 (FEB 27, 2008)

Added AVREF parameter minimum voltage in "7.3 A/D Converter Characteristics" on page 16.

Added characteristics graphs in "7.6 Typical Characteristics" on page 20.

VERSION 0.5 (SEP 28, 2007)

Fixed error in description and diagram of 8bit event counter.

VERSION 0.4 (MAY 5, 2007)

Added 2.2V ~ 5.5V @ 1 ~ 4MHz in "7.2 Recommended Operating Conditions" on page 16.

Fixed error in Figure 9-2 on page 38 : changed R04, R07 and EC0,EC1 of PSR1 to R05, R06 and T00, T20

VERSION 0.3 (MAY 2, 2007)

Added 28 QFNP package in "3. PIN ASSIGNMENT" on page 5.

VERSION 0.21 (MAR. 2007)

Changed 28 SOP package drawing in "4. PACKAGE DRAWING" on page 6.

VERSION 0.2 (MAR. 2007)

Added T_{VDD} parameter specification.

Note for configuration option was added and fix some errata.

VERSION 0.1 (AUG. 2006)

First Edition (Preliminary)

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MC80F0704/0708 MC80F0804/0808

CMOS SINGLE-CHIP 8-BIT MICROCONTROLLER WITH 10-BIT A/D CONVERTER

1. OVERVIEW

1.1 Description

The MC80F0704/0708/0804/0808 is advanced CMOS 8-bit microcontroller with 4K/8K bytes of FLASH(MTP). This is a powerful microcontroller which provides a highly flexible and cost effective solution to many embedded control applications. This provides the following features : 8K bytes of FLASH, 256 bytes of RAM, 8/16-bit timer/counter, watchdog timer, 10-bit A/D converter, 8-bit Serial Input/Output, buzzer driving port, 10-bit PWM output and on-chip oscillator and clock circuitry. It also has ONP, noise filter, PFD for improving noise immunity. In addition, the MC80F0704/0708/0804/0808 supports power saving modes to reduce power consumption.

This document **explains the base MC80F0808**, the other's eliminated functions are same as below table.

| Device Name | FLASH Size | RAM | ADC | I/O PORT | Package |
|------------------|------------|------|------------|----------|----------|
| MC80F0704G/0708G | 4K/8K | 256B | 16 channel | 26 port | 28 SKDIP |
| MC80F0704D/0708D | | | | | 28 SOP |
| MC80F0704U/0708U | | | | | 28 QFN |
| MC80F0804K/0808K | | | | 30 port | 32 SDIP |
| MC80F0804D/0808D | | | | | 32 SOP |

1.2 Features

- **8K/4K Bytes On-chip Code FLASH (MTP)**
- **FLASH Memory**
 - Endurance : 100 cycles
 - Data retention time : 10 years
- **256 Bytes On-chip Data RAM (Included stack memory)**
- **Minimum Instruction Execution Time:**
 - 333ns at 12MHz (NOP instruction)
- **Programmable I/O pins (LED direct driving can be a source and sink)**
 - MC80F0804/0808 : 29/30
 - MC80F0704/0708 : 25/26
- **One 8-bit Basic Interval Timer**
- **Four 8-bit Timer/counters (or two 16-bit Timer/counter)**
- **One Watchdog timer**
- **One 8-bit Serial Communication Interface:**
 - One Serial Input/Output (SIO)
- **Two 10-bit High Speed PWM Outputs**
- **10-bit A/D converter : 16 channels**
- **One Buzzer Driving port**
 - 488Hz ~ 250kHz@4MHz
- **Four External Interrupt input ports**
- **On-chip POR (Power on Reset)**
- **Twelve Interrupt sources**
 - External input : 4
 - Timer : 6
 - A/D Conversion : 1
 - SIO : 1
- **Built in Noise Immunity Circuit**
 - Noise filter
 - PFD (Power fail detector)
 - ONP (Oscillation Noise Protector)
- **Power Down Mode**
 - Stop mode
 - Sleep mode
 - Internal RC-Oscillated watchdog timer mode
- **Operating Voltage & Frequency**
 - 2.2V ~ 5.5V (at 1 ~ 4MHz)
 - 2.7V ~ 5.5V (at 1 ~ 6MHz)
 - 3.0V ~ 5.5V (at 1 ~ 8MHz)
 - 4.5V ~ 5.5V (at 1 ~ 12MHz)

- **Operating Temperature** : -40°C ~ 85°C
- **Oscillator Type**
 - Crystal
 - Ceramic resonator
 - External RC Oscillator (C can be omitted)

- Internal Oscillator (4MHz/2MHz)
- **Package**
 - 28SKDIP, 28SOP, 28QFN, 32SKDIP, 32SDIP
 - Available Pb free package

1.3 Development Tools

The MC80F0704/0708/0804/0808 is supported by a full-featured macro assembler, HMS800 C compiler, an in-circuit emulator CHOICE-Dr.TM and OTP/FLASH programmers. There are two different type of programmers such as single type and gang type. Macro assembler operates under the MS-Windows 95 and upversioned Windows OS.

Please contact sales part of ABOV semiconductor.

| | |
|---------------------|---|
| Software | - MS-Windows based assembler - MS-Windows based Debugger - HMS800 C compiler |
| Hardware (Emulator) | - CHOICE-Dr. - CHOICE-Dr. EVA80C0x B/D |
| FLASH Writer | - PGM Plus USB (Single writer) - Stand Alone GANG4 USB (Gang writer) - CHOICE - SIGMA II(Single writer) |



Figure 1-2 Choice-Dr. (Emulator, USB Interface)



Figure 1-1 PGM plus USB (Single Writer)



Figure 1-3 Stand Alone Gang4 USB (Gang Writer)

1.4 Ordering Information

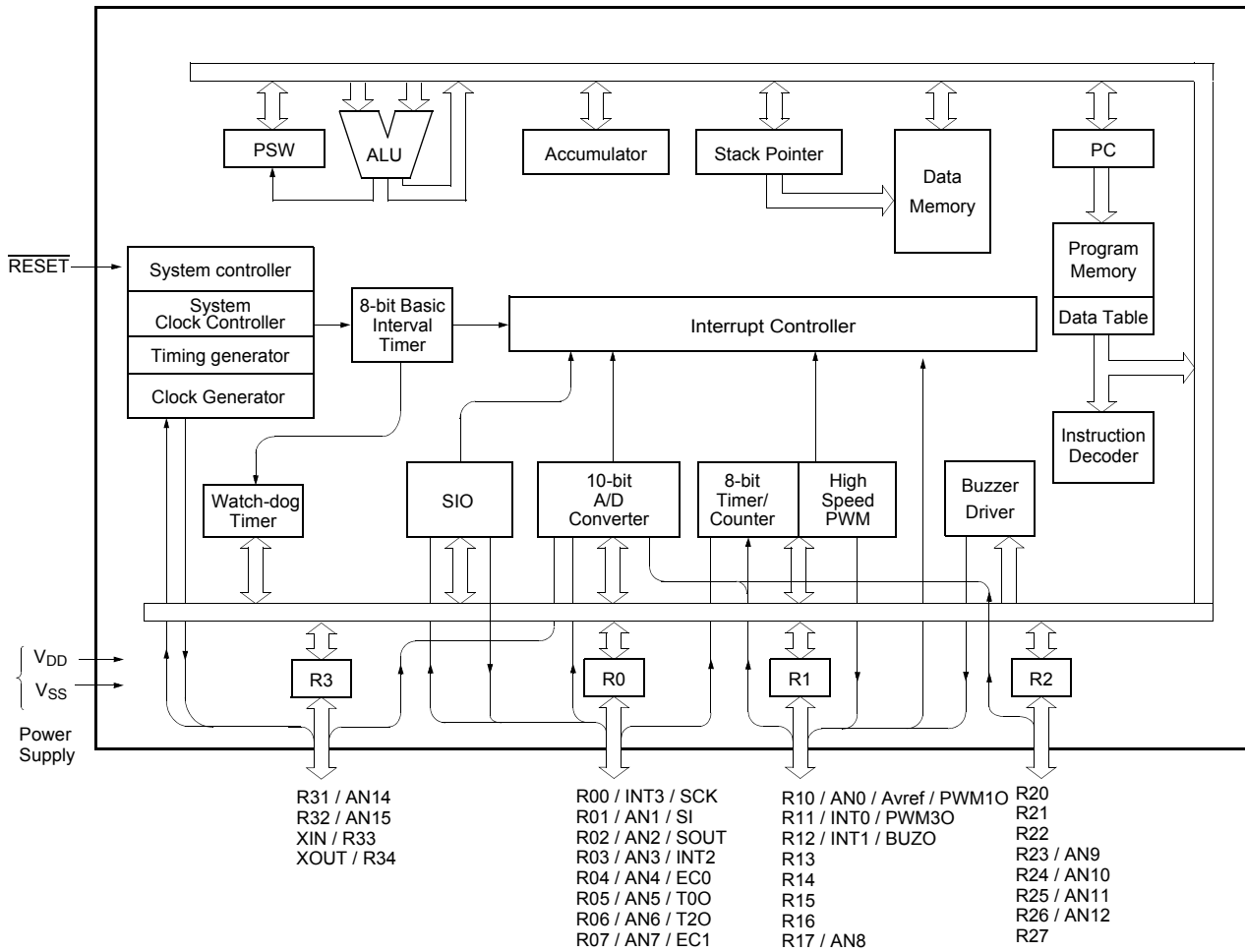
| Device name | FLASH ROM | RAM | Package |
|--|-----------|-----------|--|
| MC80F0704G MC80F0704D MC80F0704U MC80F0804K MC80F0804D | 4K bytes | 256 bytes | 28SKDIP 28SOP 28QFN 32SDIP 32SOP |
| MC80F0708G MC80F0708D MC80F0708U MC80F0808K MC80F0808D | 8K bytes | 256 bytes | 28SKDIP 28SOP 28QFN 32SDIP 32SOP |

Pb free package:

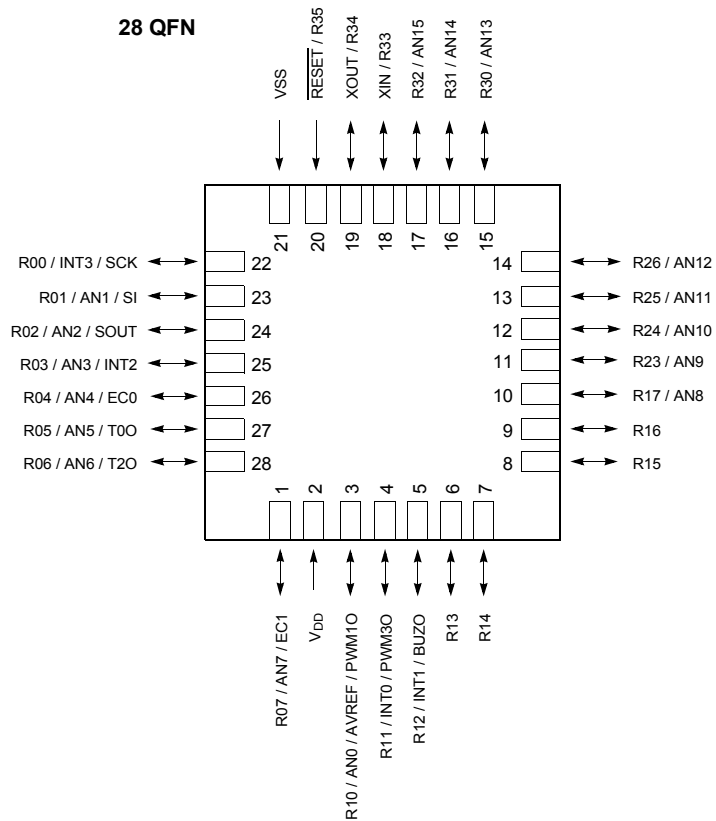
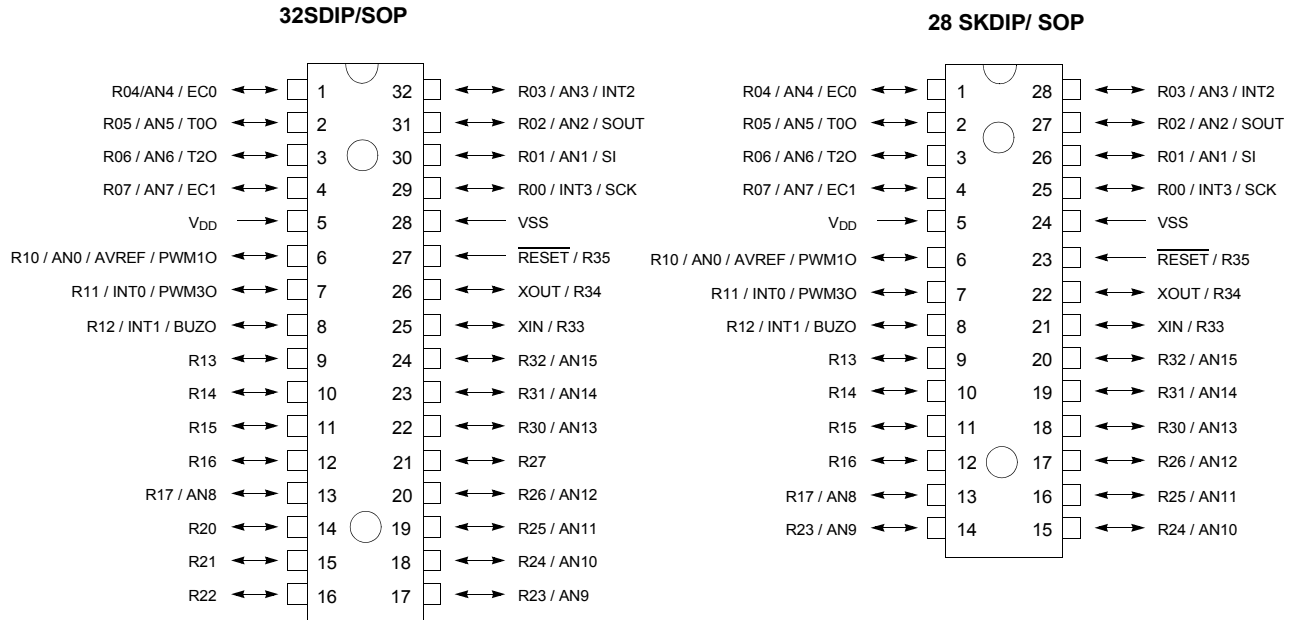
The “P” Suffix will be added at the original part number.

For example; MC80F0708G(Normal package), MC80F0708G P
(Pb free package)

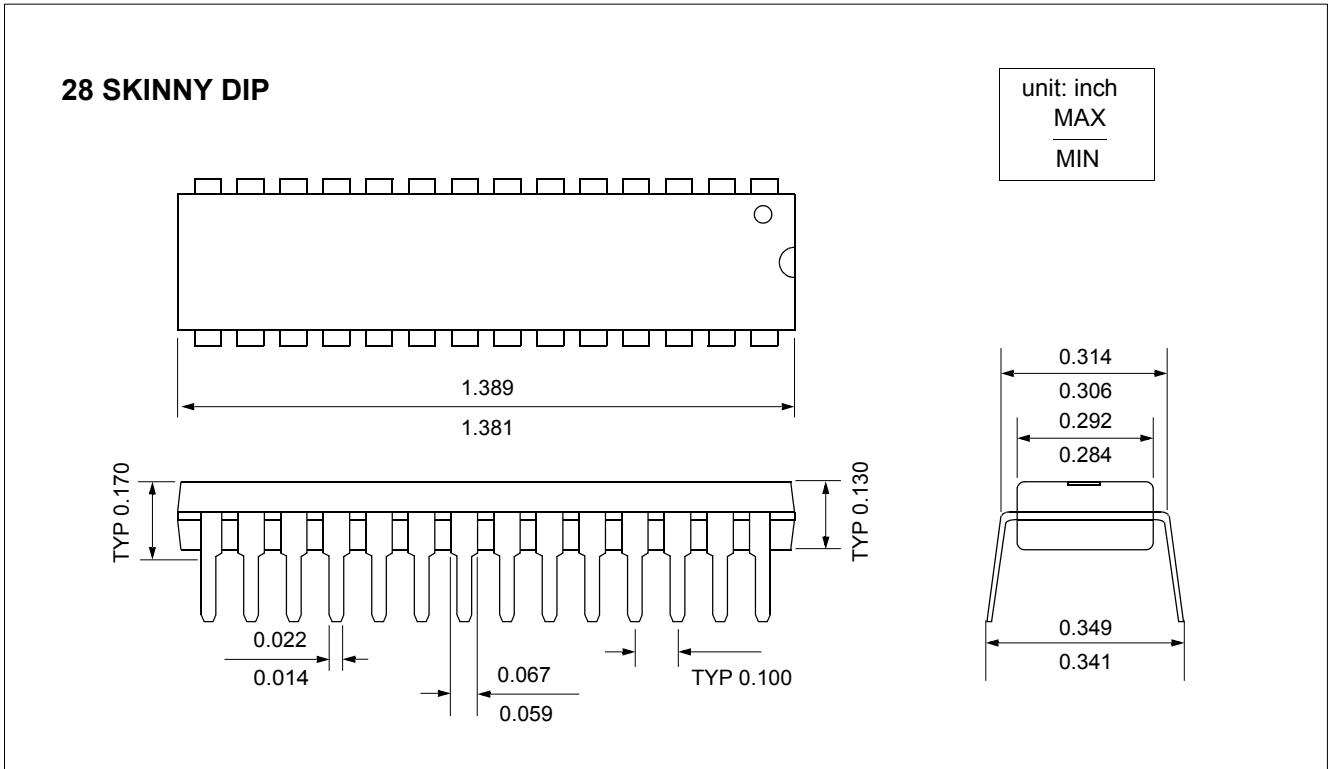
2. BLOCK DIAGRAM



3. PIN ASSIGNMENT

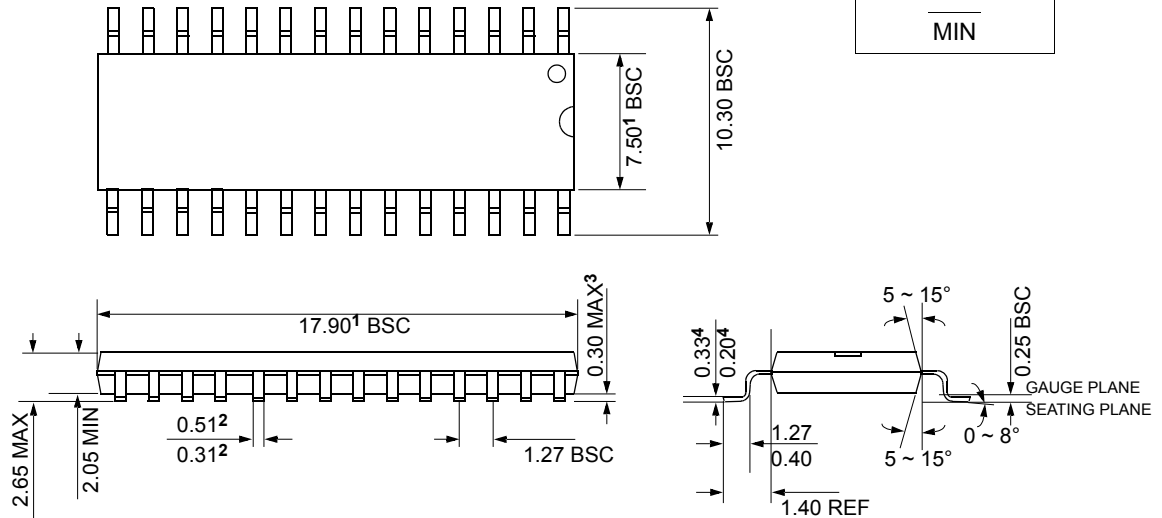


4. PACKAGE DRAWING



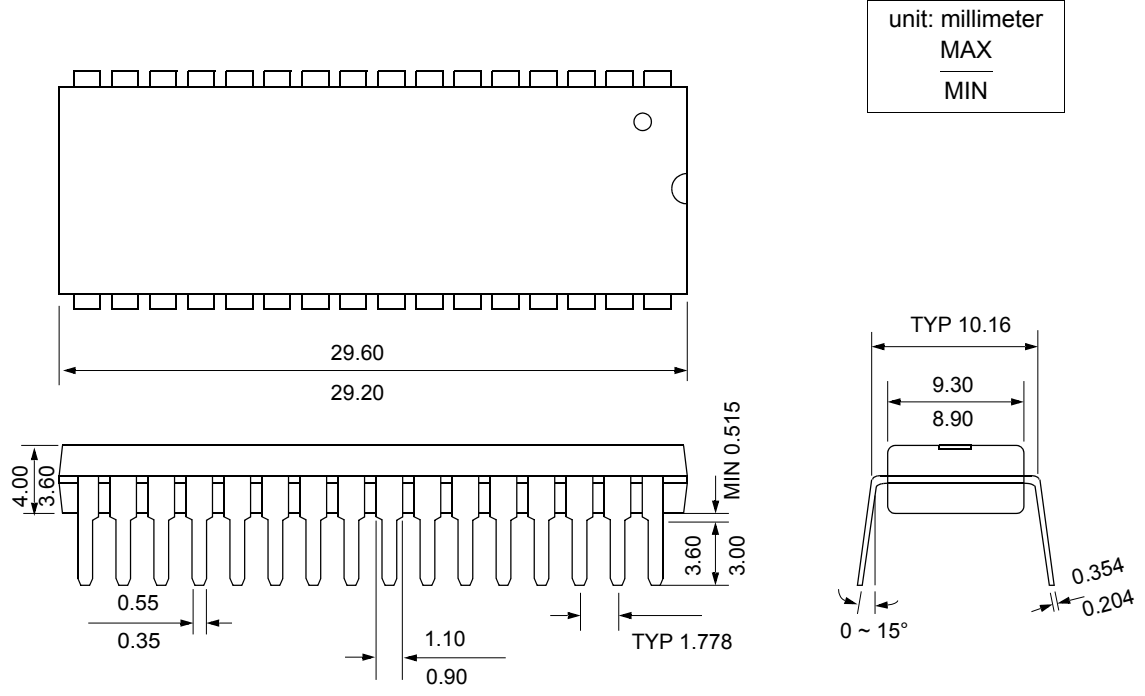
28 SOP

| |
|-------------------|
| unit: millimetres |
| MAX |
| MIN |

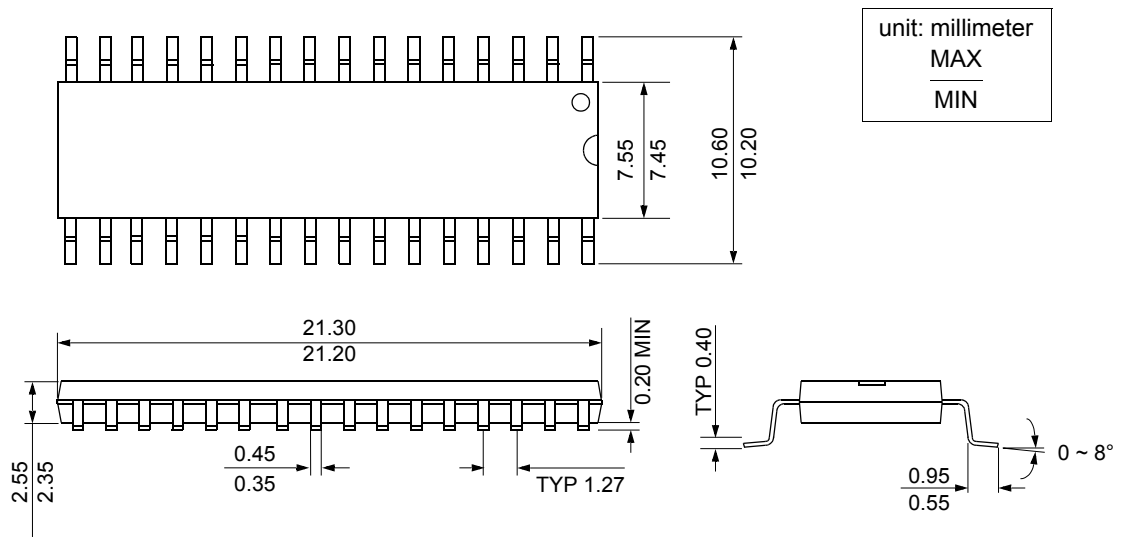


1. 17.90 dimension does not include mold FLASH, protrusions or gate burrs. Mold FLASH, protrusions or gate burrs shall not exceed 0.15mm per end. 7.50 dimension does not include interlead FLASH or protrusion. Interlead FLASH or protrusion shall not exceed 0.25mm per side. The package top may be smaller than the package bottom. 17.90 and 7.50 dimensions are determined at the outermost extremes of the plastic body exclusive of mold FLASH. Tie bar burrs, gate burrs and interlead FLASH, but including any mismatch between the top and bottom of the plastic body.
2. This dimensions apply to the flat section of the lead between 0.10 to 0.25 mm from the lead tip. Dimension does not include dambar protrusion. Allowable dambar protrusion shall be 0.10 mm total in excess of the dimension maximum material condition. The dambar may not be located on the lower radius of the foot.
3. This is defined as the vertical distance from the seating plane to the lowers point on the package body excluding the thermal enhancemet on cavity down package configurations.
4. This dimensions apply to the flat section of the lead between 0.10 to 0.25 mm from the lead tip.

32 SDIP



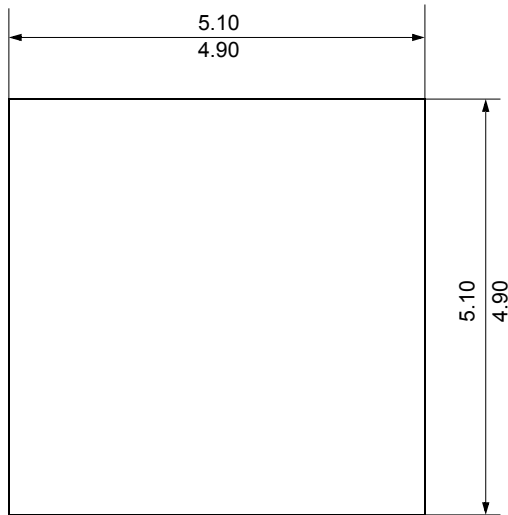
32 SOP



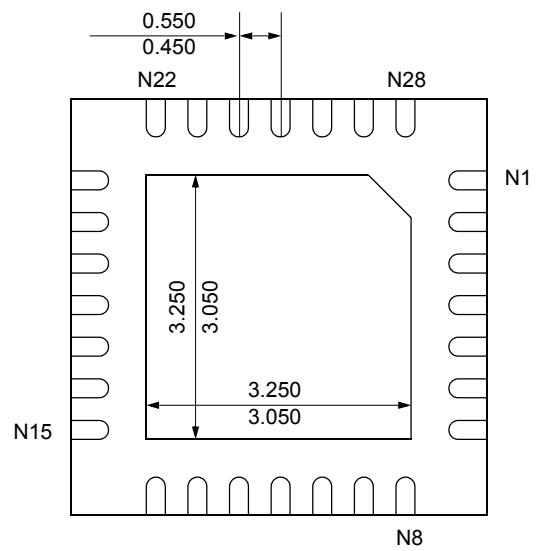
28 QFN

unit: millimetres
MAX
MIN

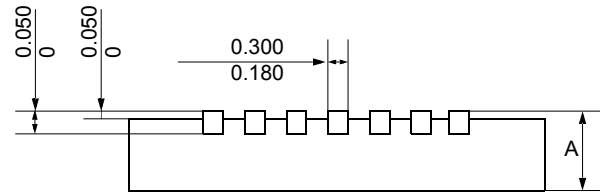
Top View



Bottom View



| | MIN. | NORM. | MAX. |
|---|-------|-------|-------|
| A | 0.700 | 0.750 | 0.800 |
| | 0.800 | 0.850 | 0.900 |



Side View

5. PIN FUNCTION

V_{DD}: Supply voltage.

V_{SS}: Circuit ground.

RESET: Reset the MCU.

X_{IN}: Input to the inverting oscillator amplifier and input to the internal main clock operating circuit.

X_{OUT}: Output from the inverting oscillator amplifier.

R00~R07: R0 is an 8-bit, CMOS, bidirectional I/O port. R0 pins can be used as outputs or inputs according to “1” or “0” written the their Port Direction Register(R0IO).

| Port pin | Alternate function |
|----------|--|
| R00 | INT3 (External Interrupt Input Port3) SCK (SPI CLK) |
| R01 | AN1 (Analog Input Port 1) SI (SPI Serial Data Input) |
| R02 | AN2 (Analog Input Port 2) SOUT (SPI Serial Data Output) |
| R03 | AN3 (Analog Input Port 3) INT2 (External Interrupt Input Port2) |
| R04 | AN4 (Analog Input Port 4) EC0 (Event Counter Input Source 0) |
| R05 | AN5 (Analog Input Port 5) T00 (Timer0 Clock Output) |
| R06 | AN6 (Analog Input Port 6) T20 (Timer2 Clock Output) |
| R07 | AN7 (Analog Input Port 7) EC1 (Event Counter Input Source 1) |

Table 5-1 R0 Port

In addition, R0 serves the functions of the various special features in Table 5-1 .

R10~R17: R1 is an 8-bit, CMOS, bidirectional I/O port. R1 pins can be used as outputs or inputs according to “1” or “0” written the their Port Direction Register (R1IO).

R1 serves the functions of the various following special features

in Table 5-2

| Port pin | Alternate function |
|----------|---|
| R10 | AN0 (Analog Input Port 0) AVref (External Analog Reference Pin) PWM1O (PWM1 Output) |
| R11 | INT0 (External Interrupt Input Port 0) PWM3O (PWM3 Output) |
| R12 | INT1 (External Interrupt Input Port 1) BUZ (Buzzer Driving Output Port) |
| R13 | - |
| R14 | - |
| R15 | - |
| R16 | - |
| R17 | AN8 (Analog Input Port 8) |

Table 5-2 R1 Port

R20~R27 : R2 is an 8-bit, CMOS, bidirectional I/O port. R2 pins can be used as outputs or inputs according to “1” or “0” written the their Port Direction Register(R2IO)

In addition, R2 serves the functions of the various special features in Table 5-3 .

| Port pin | Alternate function |
|----------|-------------------------------|
| R20 | - |
| R21 | - |
| R22 | - |
| R23 | AN9 (Analog Input Port 9) |
| R24 | AN10 (Analog Input Port 10) |
| R25 | AN11 (Analog Input Port 11) |
| R26 | AN12 (Analog Input Port 12) |
| R27 | - |

Table 5-3 R2 Port

R31~R35: R3 is a 6-bit, CMOS, bidirectional I/O port. R3 pins can be used as outputs or inputs according to “1” or “0” written the their Port Direction Register (R3IO).

R3 serves the functions of the serial interface following special features in Table 5-4 .

| Port pin | Alternate function |
|----------|---|
| R30 | AN13 (Analog Input Port 13) |
| R31 | AN14 (Analog Input Port 14) |
| R32 | AN15 (Analog Input Port 15) |
| R33 | X _{IN} (Oscillation Input) |
| R34 | X _{OUT} (Oscillation Output) |
| R35 | RESETB (Reset input port) |

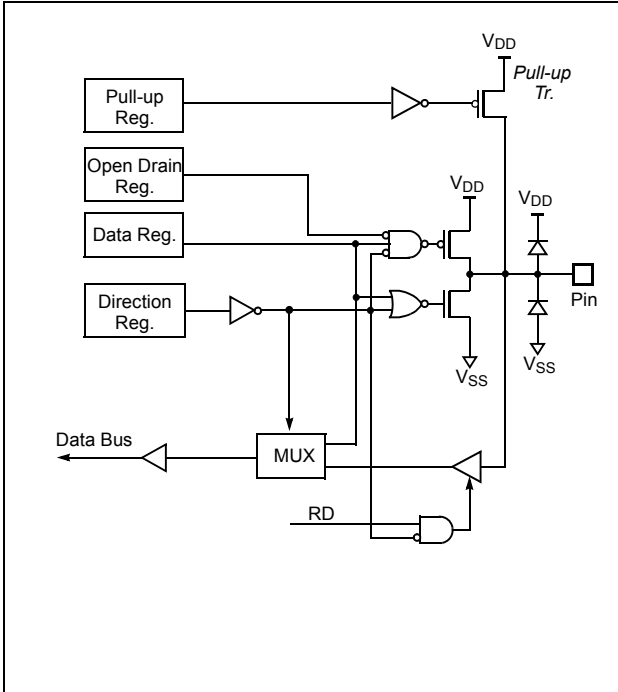
Table 5-4 R3 Port

| PIN NAME | Pin No. | | | In/Out | Function | | | |
|---------------------------|---------|----|--------|--------|----------------------|----------------------|--------------------------|--------------|
| | 32 | 28 | 28 QFN | | First | Second | Third | Forth |
| V _{DD} | 5 | 5 | 2 | - | Supply voltage | | | |
| V _{SS} | 28 | 24 | 21 | - | Circuit ground | | | |
| RESET (R35) | 27 | 23 | 20 | I | Reset signal input | Input only port | - | - |
| X _{IN} (R33) | 25 | 21 | 18 | I | Oscillation Input | Normal I/O Port | - | - |
| X _{OUT} (R34) | 26 | 22 | 19 | O | Oscillation Output | Normal I/O Port | - | - |
| R00 (INT3/SCK) | 29 | 25 | 22 | I/O | Normal I/O Ports | External Interrupt 3 | SPI clock Input | - |
| R01 (AN1/SI) | 30 | 26 | 23 | I/O | | Analog Input Port 1 | SPI Data Input | - |
| R02 (AN2/SOUT) | 31 | 27 | 24 | I/O | | Analog Input Port 2 | SPI Data Output | - |
| R03 (AN3/INT2) | 32 | 28 | 25 | I/O | | Analog Input Port 3 | External Interrupt2 | - |
| R04 (AN4/EC0) | 1 | 1 | 26 | I/O | | Analog Input Port 4 | Event Counter | - |
| R05 (AN5/T0O) | 2 | 2 | 27 | I/O | | Analog Input Port 5 | Timer0 Output | - |
| R06 (AN6/T2O) | 3 | 3 | 28 | I/O | | Analog Input Port 6 | Timer2 Output | - |
| R07 (AN7/EC1) | 4 | 4 | 1 | I/O | | Analog Input Port 7 | Event Counter | - |
| R10 (AN0/AVref/ PWM1O) | 6 | 6 | 3 | I/O | | Analog Input Port 0 | Analog Reference | PWM 1 output |
| R11 (INT0/PWM3O) | 7 | 7 | 4 | I/O | | External Interrupt 0 | PWM 3 output | - |
| R12 (INT1/BUZO) | 8 | 8 | 5 | I/O | | External Interrupt 1 | Buzzer Driving Output | - |
| R13 | 9 | 9 | 6 | I/O | | - | - | - |
| R14 | 10 | 10 | 7 | I/O | | - | - | - |
| R15 | 11 | 11 | 8 | I/O | | - | - | - |
| R16 | 12 | 12 | 9 | I/O | | - | - | - |
| R17 | 13 | 13 | 10 | I/O | | Analog Input Port 8 | - | - |
| R20 | 14 | - | - | I/O | | - | - | - |
| R21 | 15 | - | - | I/O | | - | - | - |
| R22 | 16 | - | - | I/O | | - | - | - |
| R23 | 17 | 14 | 11 | I/O | | Analog Input Port 9 | - | - |
| R24 | 18 | 15 | 12 | I/O | Analog Input Port 10 | - | - | |
| R25 | 19 | 16 | 13 | I/O | Analog Input Port 11 | - | - | |
| R26 | 20 | 17 | 14 | I/O | Analog Input Port 12 | - | - | |
| R27 | 21 | - | - | I/O | - | - | - | |
| R30(AN13) | 22 | 18 | 15 | I/O | Analog Input Port 13 | - | - | |
| R31 (AN14) | 23 | 19 | 16 | I/O | Analog Input Port 14 | - | - | |
| R32 (AN15) | 24 | 20 | 17 | I/O | Analog Input Port 15 | - | - | |

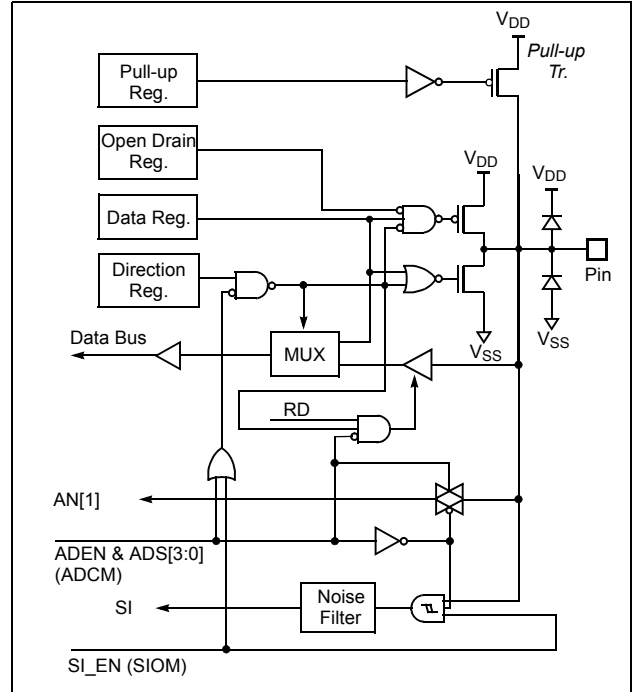
Table 5-5 Pin Description

6. PORT STRUCTURES

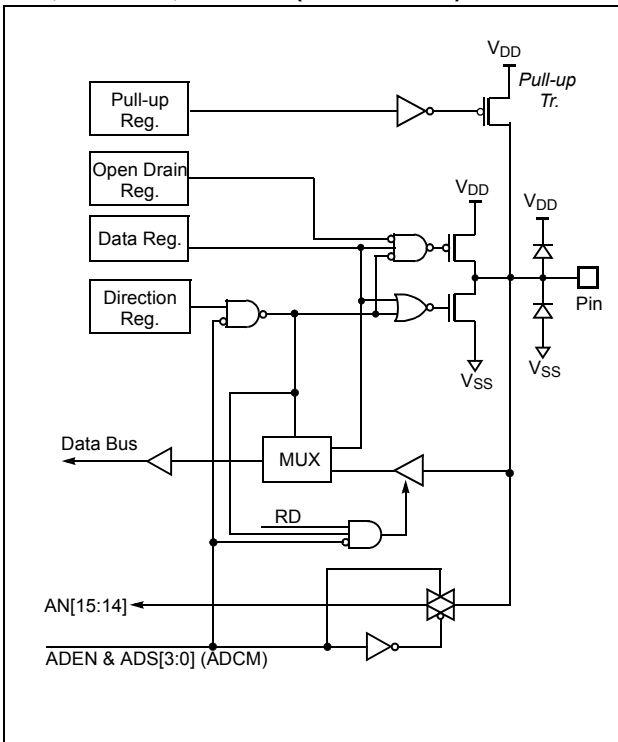
R13~R16,R20~R22,R27



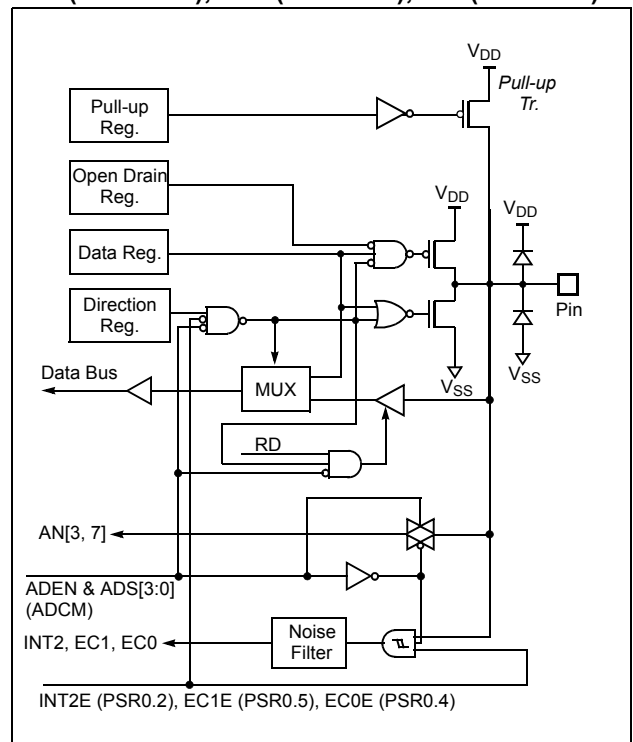
R01 (AN1 / SI)



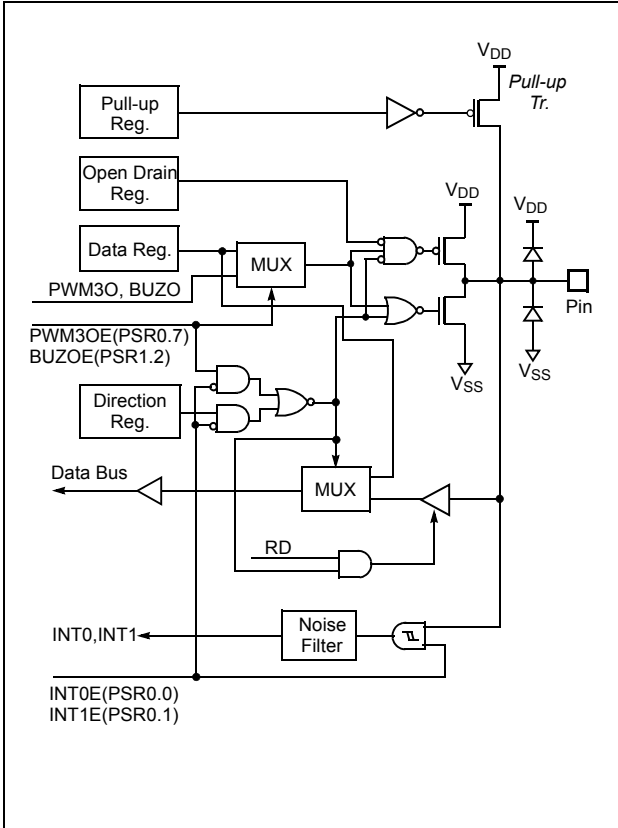
R17,R30~R32,R23~R26(AN8 ~ AN15)



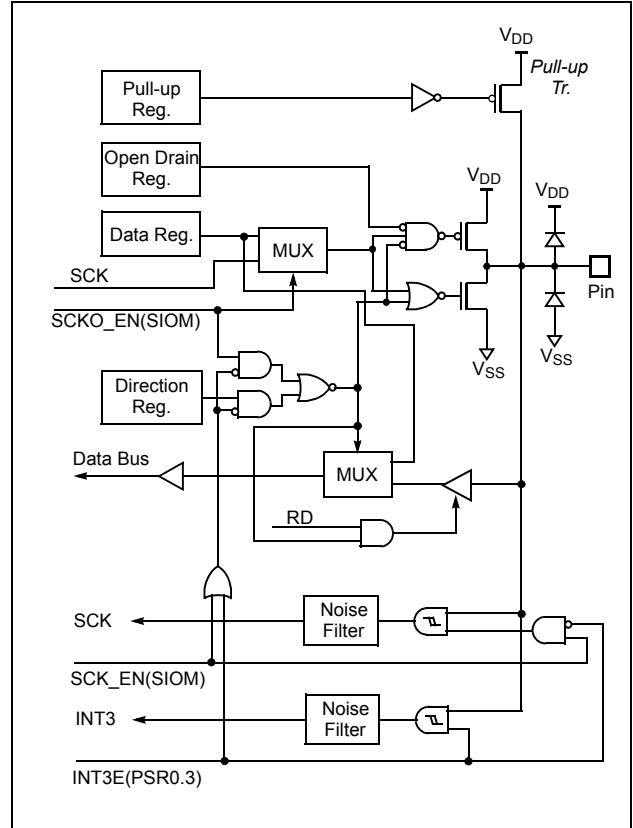
R03 (AN3/INT2), R04 (AN4/EC0),R07 (AN7/EC1)



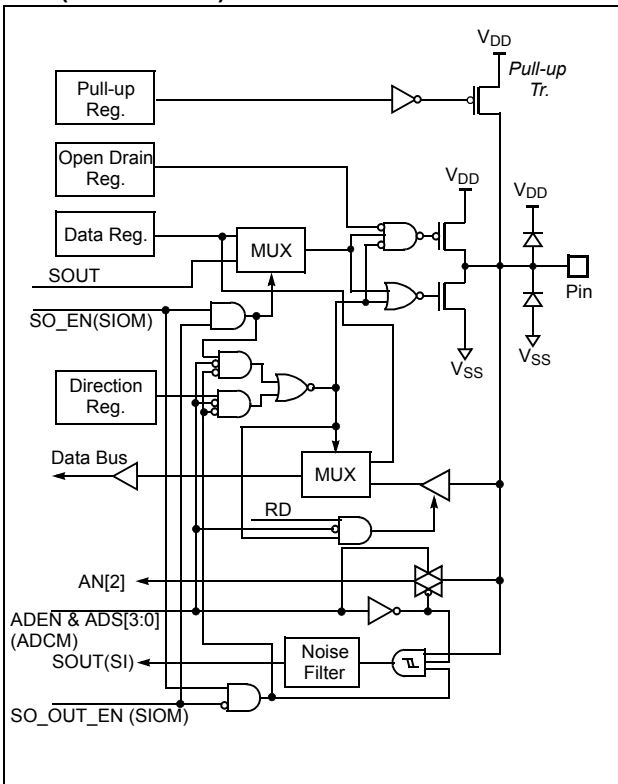
R11 (INT0 / PWM3O), R12 (INT1 / BUZO)



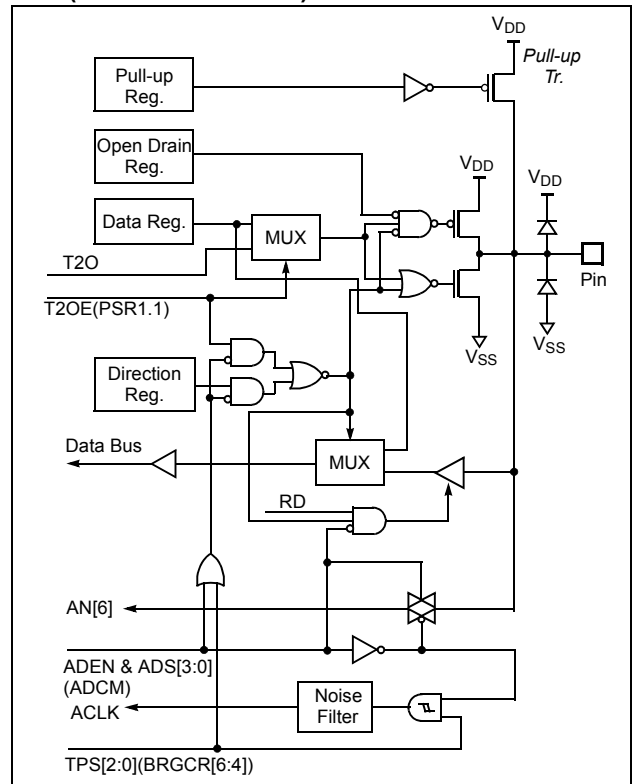
R00 (INT3 / SCK)



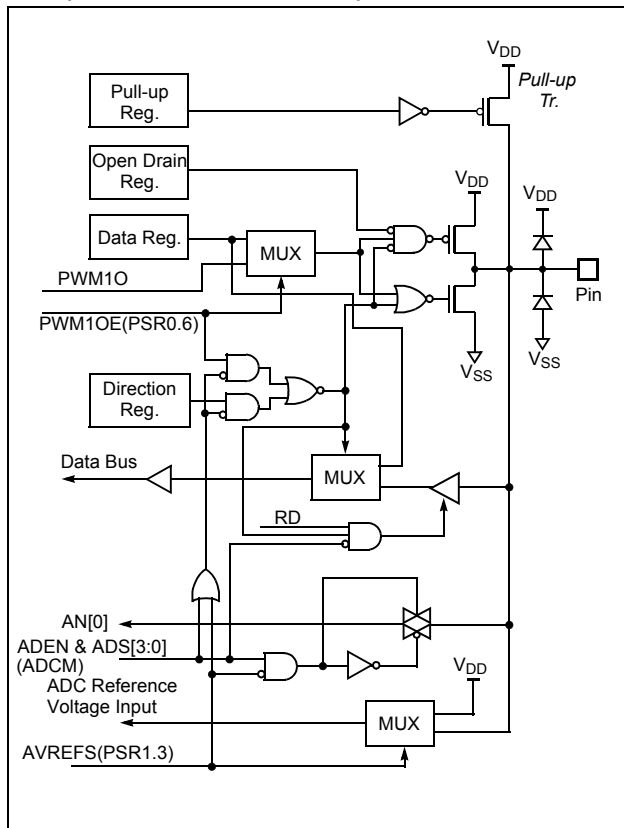
R02 (AN2 / SOUT)



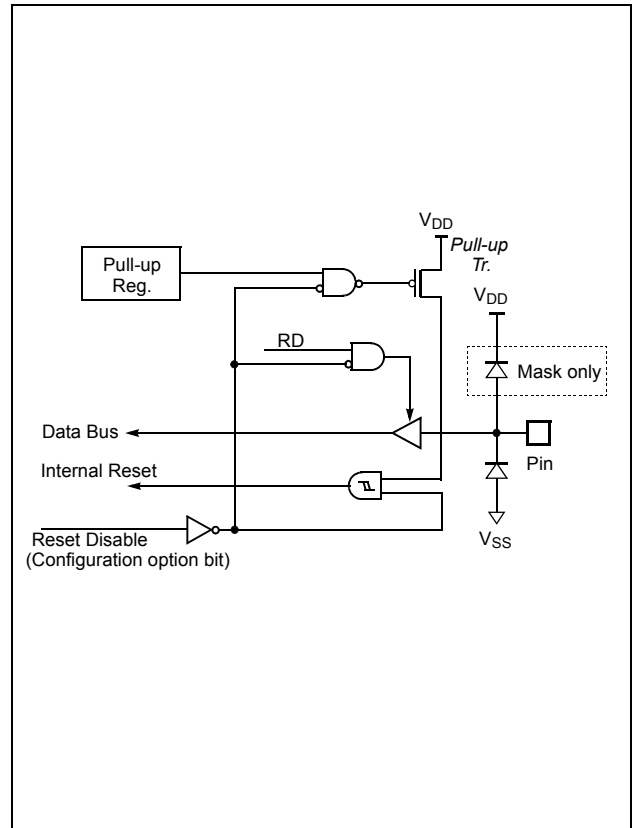
R06 (AN6 / T20 / ACLK)



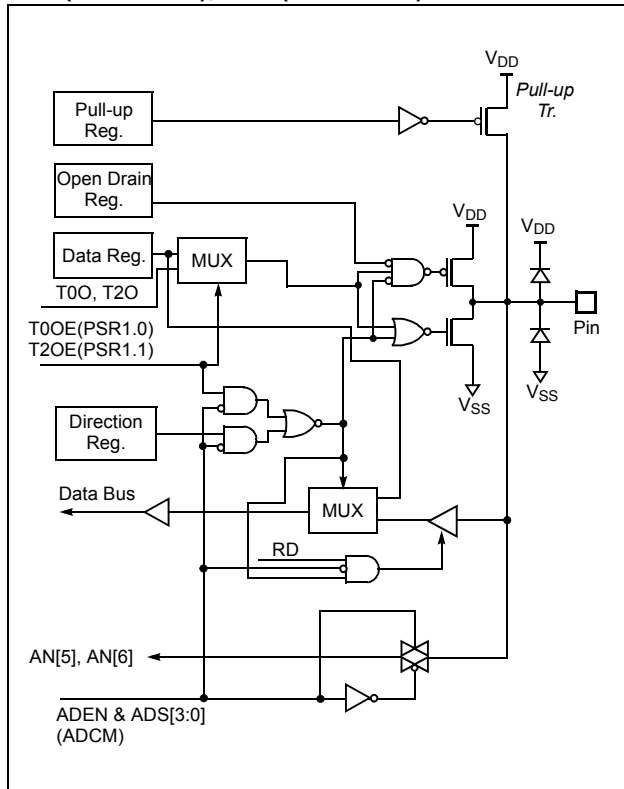
R10 (AN0 / AVREF / PWM10)



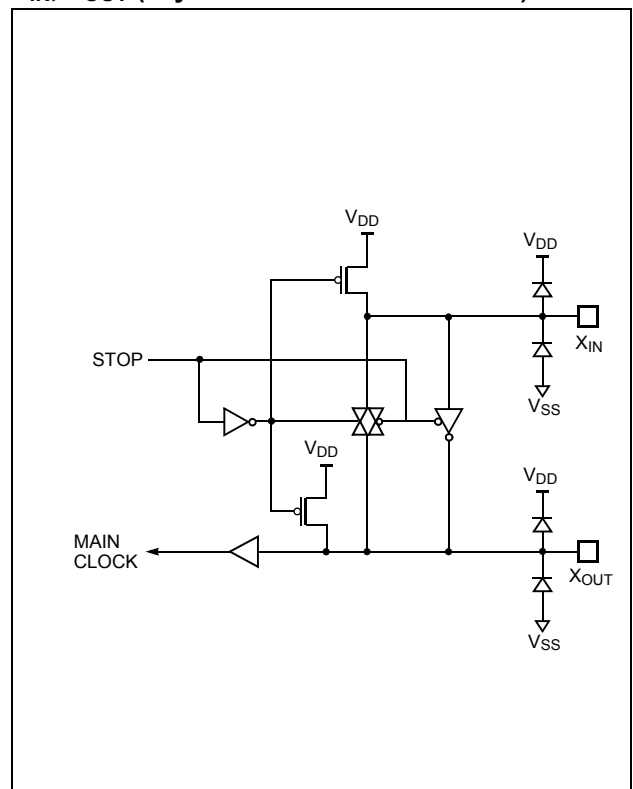
RESET



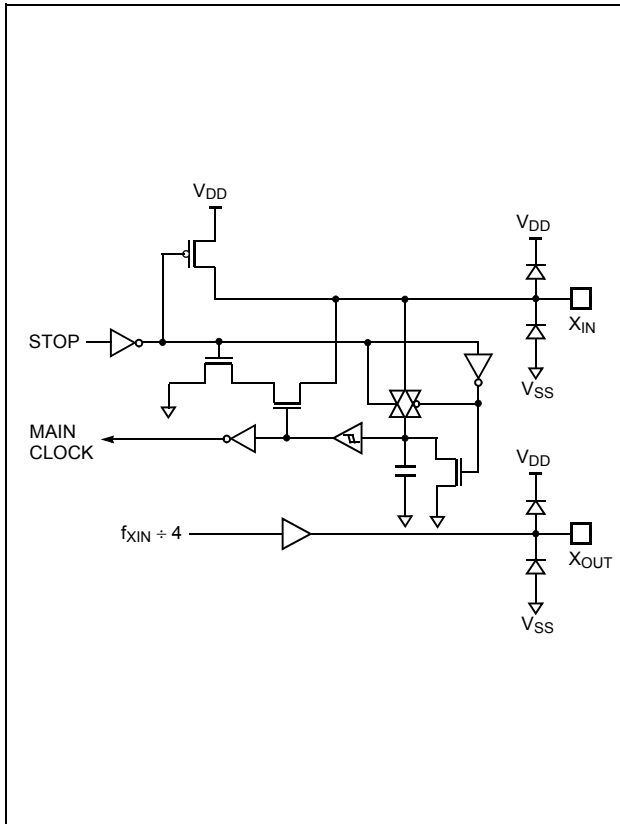
R05 (AN5 / T00), R06 (AN6 / T20)



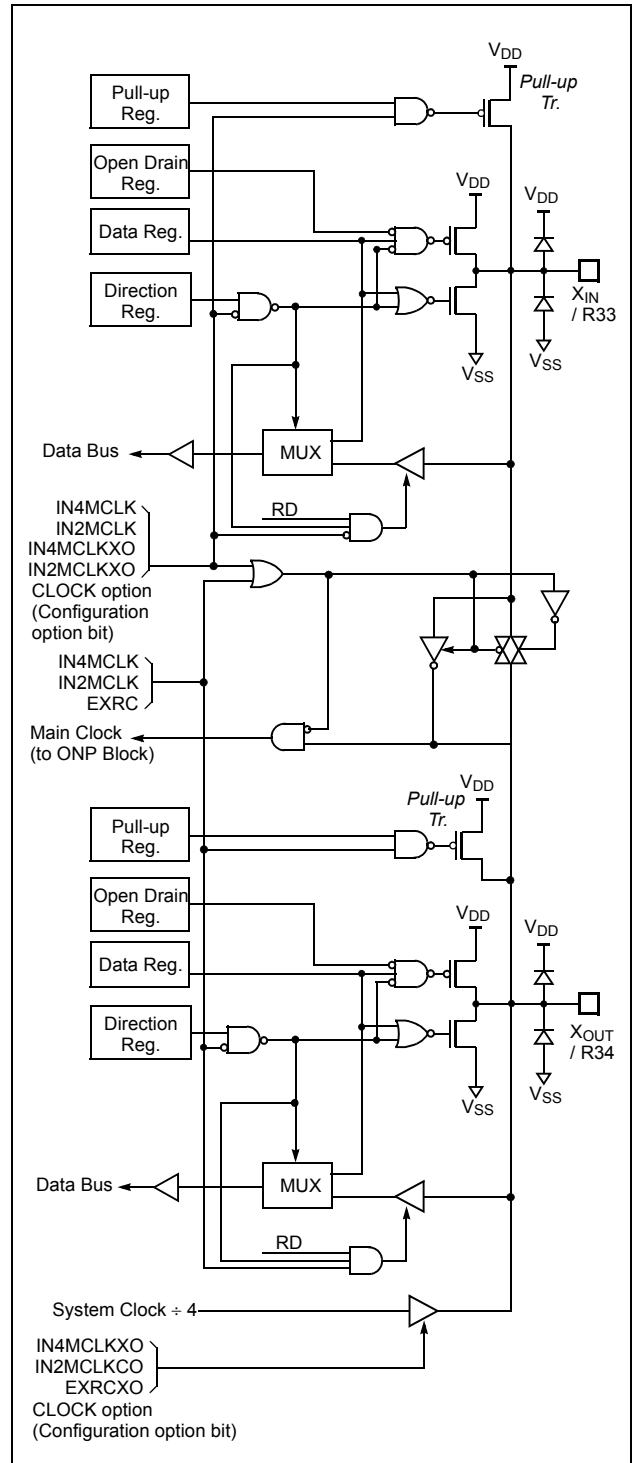
XIN, XOUT (Crystal or Ceramic Resonator)



X_{IN}, X_{OUT} (External RC or R oscillation)



R33 (X_{IN}), R34 (X_{OUT})



7. ELECTRICAL CHARACTERISTICS

7.1 Absolute Maximum Ratings

| | | | |
|---|-----------------------|--|--------|
| Supply voltage..... | -0.3 to +6.0 V | | 10 mA |
| Storage Temperature | -65 to +125 °C | Maximum current (ΣI_{OL})..... | 160 mA |
| Voltage on any pin with respect to Ground (V_{SS}) | -0.3 to $V_{DD}+0.3V$ | Maximum current (ΣI_{OH})..... | 80 mA |
| Maximum current out of V_{SS} pin..... | 180 mA | | |
| Maximum current into V_{DD} pin..... | 80 mA | | |
| Maximum current sunk by (I_{OL} per I/O Pin) | 20 mA | | |
| Maximum output current sourced by (I_{OH} per I/O Pin) | | | |

Note: Stresses above 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 above 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

| Parameter | Symbol | Condition | Specifications | | Unit |
|-----------------------|-----------|--|--------------------------|--------------------------|------|
| | | | Min. | Max. | |
| Supply Voltage | V_{DD} | $f_{XIN}=1\sim 12MHz$ $f_{XIN}=1\sim 8MHz$ $f_{XIN}=1\sim 6MHz$ $f_{XIN}=1\sim 4MHz$ | 4.5 3.0 2.7 2.2 | 5.5 5.5 5.5 5.5 | V |
| Operating Frequency | f_{XIN} | $V_{DD}=4.5\sim 5.5V$ $V_{DD}=3.0\sim 5.5V$ $V_{DD}=2.7\sim 5.5V$ $V_{DD}=2.2\sim 5.5V$ | 1 1 1 1 | 12 8 6 4 | MHz |
| Operating Temperature | T_{OPR} | $V_{DD}=2.7\sim 5.5V$ | -40 | 85 | °C |

7.3 A/D Converter Characteristics

($T_a = -40\sim 85^\circ C$, $V_{SS} = 0V$, $V_{DD} = AV_{REF} = 5.12V, 3.072V$)

| Parameter | Symbol | Conditions | Min. | Typ. | Max. | Unit |
|----------------------------------|--------------|------------------------------|----------|------|----------------------------|---------|
| Resolution | | - | - | 10 | - | BIT |
| Overall Accuracy | - | - | - | - | ± 3 | LSB |
| Non Linearity Error | NNLE | $f_{XIN}=4MHz$ | - | - | ± 3 | LSB |
| Differential NON Linearity Error | NDNLE | | - | - | ± 3 | LSB |
| Zero Offset Error | NZOE | | - | - | ± 3 | LSB |
| Full Scale Error | NFSE | | - | - | ± 3 | LSB |
| Gain Error | NGE | | - | - | ± 3 | LSB |
| Conversion Time | T_{CONV} | - | 13 | - | - | μS |
| Analog Input Voltage | V_{AIN} | - | V_{SS} | - | V_{DD} (AV_{REF}) | V |
| Analog Voltage Reference | AV_{REF}^1 | - | 2.7V | - | V_{DD} | V |
| Conversion Current | I_{CON} | $V_{DD}=5.12V, f_{XIN}=8MHz$ | - | 80 | 200 | μA |

1. If the AVREF voltage is less than VDD voltage and analog input pins (ANX), shared with various alternate function, are used bidirectional I/O port, the leakage current may flow VDD pin to AVREF pin in output high mode or analog input pins (ANX) to AVREF pin in input high mode.

7.4 DC Electrical Characteristics

(TA=-40~85°C, VDD=5.0V, VSS=0V),

| Parameter | Symbol | Pin | Condition | Specifications | | | Unit |
|-------------------------------------|----------------------------------|---|--|---------------------|------|---------------------|------|
| | | | | Min. | Typ. | Max. | |
| Input High Voltage | V _{IH1} | X _{IN} , $\overline{\text{RESET}}$ | | 0.8 V _{DD} | - | V _{DD} | V |
| | V _{IH2} | Hysteresis Input ¹ | | 0.8 V _{DD} | - | V _{DD} | |
| | V _{IH3} | Normal Input | | 0.7 V _{DD} | - | V _{DD} | |
| Input Low Voltage | V _{IL1} | X _{IN} , $\overline{\text{RESET}}$ | | 0 | - | 0.2 V _{DD} | V |
| | V _{IL2} | Hysteresis Input ¹ | | 0 | - | 0.2 V _{DD} | |
| | V _{IL3} | Normal Input | | 0 | - | 0.3 V _{DD} | |
| Output High Voltage | V _{OH} | All Output Port | V _{DD} =5V, I _{OH} =-5mA | V _{DD} - 1 | - | - | V |
| Output Low Voltage | V _{OL} | All Output Port | V _{DD} =5V, I _{OL} =10mA | - | - | 1 | V |
| Input Pull-up Current | I _P | Normal Input | V _{DD} =5V | -60 | - | -150 | μA |
| Input High Leakage Current | I _{IH1} | All Pins (except X _{IN}) | V _{DD} =5V | - | - | 5 | μA |
| | I _{IH2} | X _{IN} | V _{DD} =5V | - | - | 13 | μA |
| Input Low Leakage Current | I _{IL1} | All Pins (except X _{IN}) | V _{DD} =5V | -5 | - | - | μA |
| | I _{IL2} | X _{IN} | V _{DD} =5V | -13 | - | - | μA |
| Hysteresis | V _T | Hysteresis Input ¹ | V _{DD} =5V | 0.5 | - | - | V |
| PFD Voltage | V _{PFD} | V _{DD} | | 2.0 | 2.8 | 3.2 | V |
| Internal RC WDT Period | T _{RCWDT} | X _{OUT} | V _{DD} =5.0V | 25 | 65 | 95 | μS |
| Operating Current ² | I _{DD} | V _{DD} | V _{DD} =5.5V, f _{XIN} =12MHz | - | 8.8 | 15 | mA |
| Sleep Mode Current | I _{SLEEP} | V _{DD} | V _{DD} =5.5V, f _{XIN} =12MHz | - | 1 | 2 | mA |
| RCWDT Mode Current at STOP Mode | I _{RCWDT} | V _{DD} | V _{DD} =5.5V, f _{XIN} =12MHz | - | 20 | 50 | μA |
| Stop Mode Current | I _{STOP} | V _{DD} | V _{DD} =5.5V, f _{XIN} =12MHz | - | 4 | 10 | μA |
| Internal 4MHz Oscillation Frequency | T _{IN4MCLK} | X _{OUT} | V _{DD} =5V, 25°C | 3.5 | 4 | 4.5 | MHz |
| Internal 2MHz Oscillation Frequency | T _{IN2MCLK} | X _{OUT} | V _{DD} =5V, 25°C | 1.75 | 2 | 2.25 | MHz |
| V _{DD} Rising Time | T _{VDD} ³ | V _{DD} | | - | - | 40 | ms/V |
| V _{DD} Start Voltage | V _{START} ³ | V _{DD} | | V _{SS} | - | 0.7 | V |
| Config Read Voltage | V _{CONFIG} ³ | V _{DD} | T _{VDD} =40ms/V, V _{START} =V _{SS} | 1.8 | - | - | V |
| Power On Reset | V _{POR} | V _{DD} | | 2.4 | 2.9 | 3.4 | V |

| Parameter | Symbol | Pin | Condition | Specifications | | | Unit |
|----------------------------------|--------------|--------------------------------|--|----------------|------|------|------|
| | | | | Min. | Typ. | Max. | |
| External RC Oscillator Frequency | f_{RC-OSC} | $f_{XOUT} = f_{RC-OSC} \div 4$ | $V_{DD}=5.5V$ $R=30k\Omega, C=10pF$ | 0.5 | 1.5 | 2.5 | MHz |
| | f_{R-OSC} | $f_{XOUT} = f_{R-OSC} \div 4$ | $V_{DD}=5.5V, R=30k\Omega$ | 1 | 2 | 3 | MHz |

1. Hysteresis Input: INT0 ~INT3(R11,R12,R03,R00),SIO(R00,R01,R02), EC0,EC1(R04,R07)
2. This parameter is measured in internal PROM operation at the all I/O port defined input mode.
3. These parameters are presented for design guidance only and not tested or guaranteed.

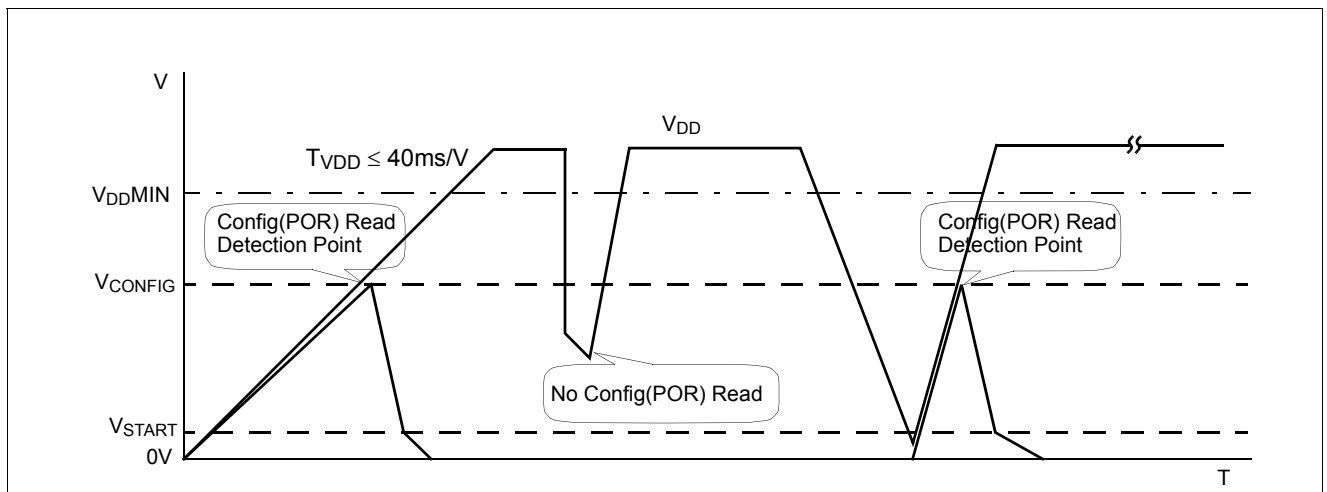


Figure 7-1 Config Read Voltage including POR vs Supply Voltage

7.5 AC Characteristics

($T_A=-40\sim+85^\circ C, V_{DD}=5V\pm 10\%, V_{SS}=0V$)

| Parameter | Symbol | Pins | Specifications | | | Unit |
|------------------------------------|--------------------|------------------------------------|----------------|------|------|-----------|
| | | | Min. | Typ. | Max. | |
| Operating Frequency | f_{CP} | X_{IN} | 1 | - | 12 | MHz |
| External Clock Pulse Width | t_{CPW} | X_{IN} | 35 | - | - | nS |
| External Clock Transition Time | t_{RCP}, t_{FCP} | X_{IN} | - | - | 20 | nS |
| Oscillation Stabilizing Time(4MHz) | t_{ST} | X_{IN}, X_{OUT} | - | - | 20 | mS |
| External Input Pulse Width | t_{EPW} | INT0, INT1, INT2, INT3 EC0, EC1 | 2 | - | - | t_{SYS} |
| \overline{RESET} Input Width | t_{RST} | \overline{RESET} | 8 | - | - | t_{SYS} |

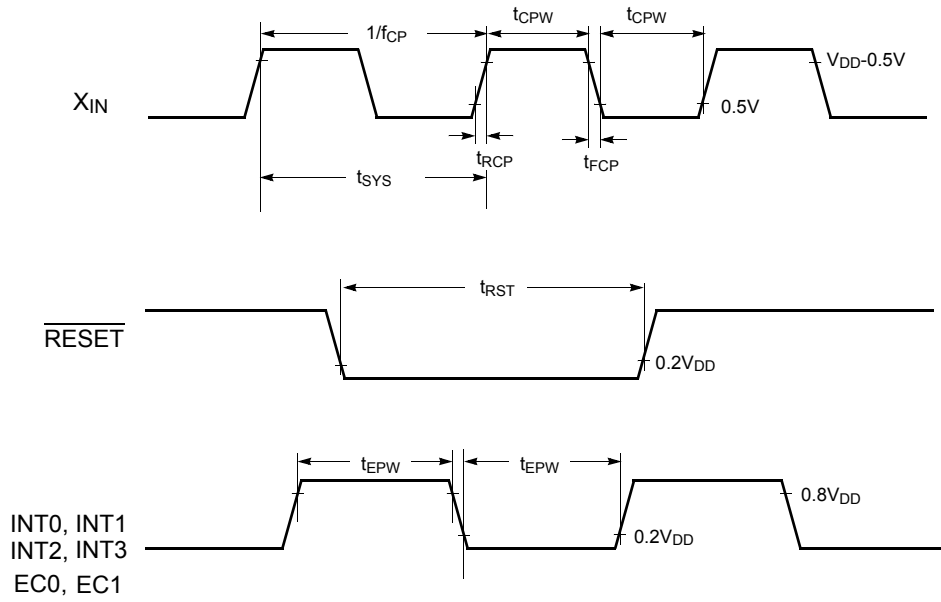


Figure 7-2 Timing Chart

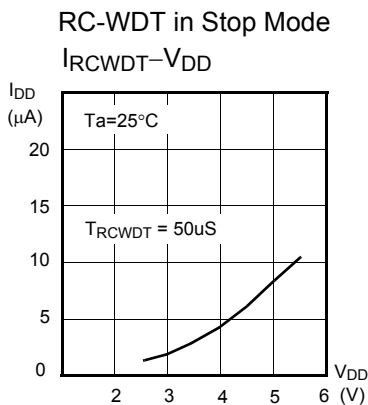
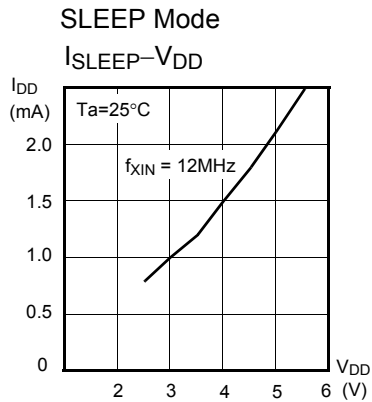
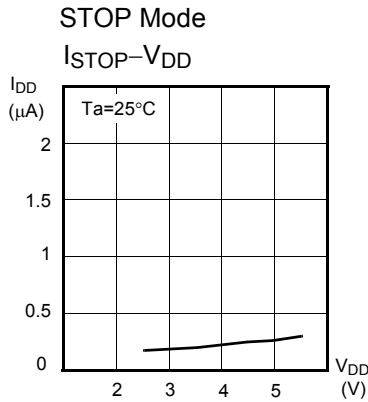
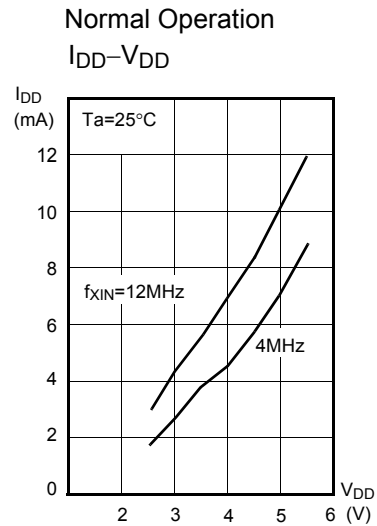
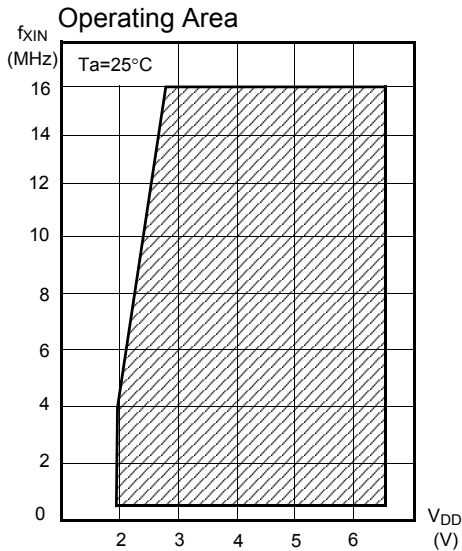
7.6 Typical Characteristics

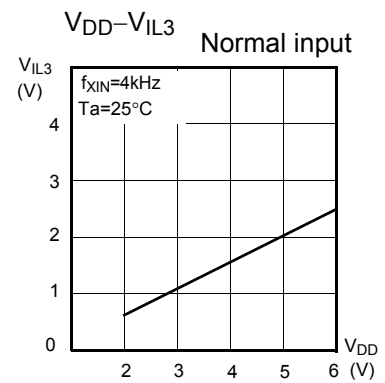
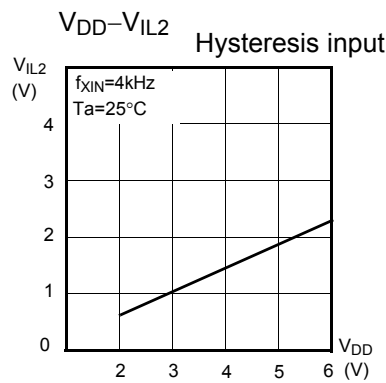
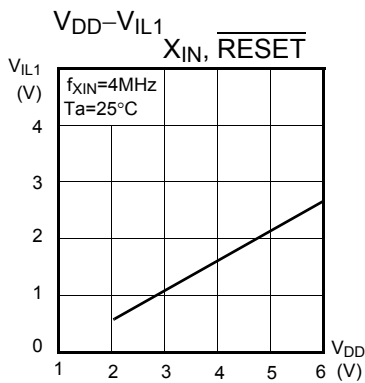
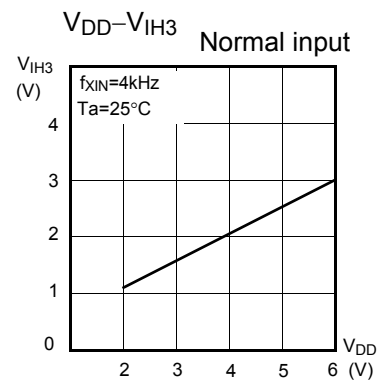
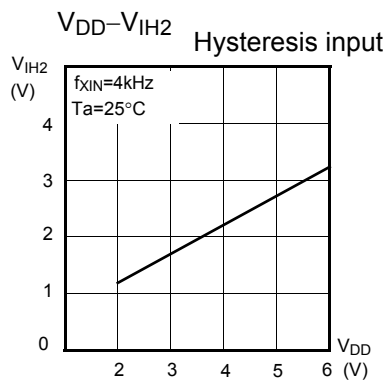
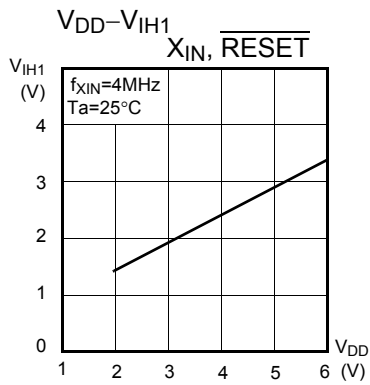
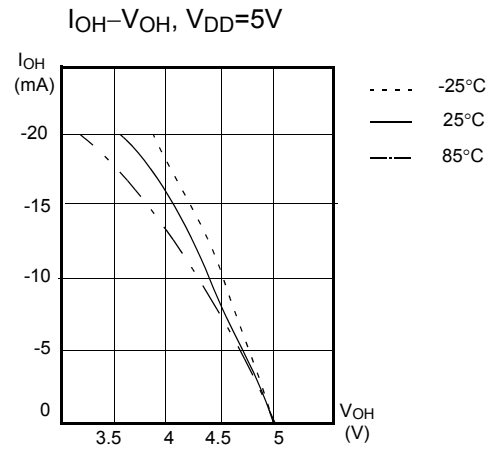
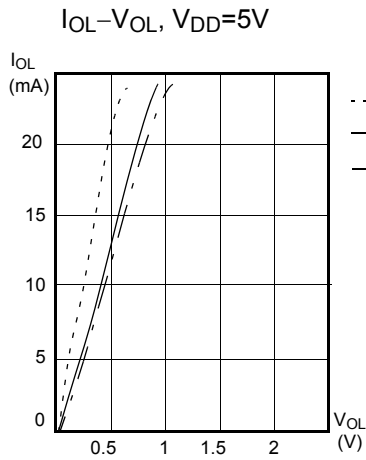
These graphs and tables provided in this section are for design guidance only and are not tested or guaranteed.

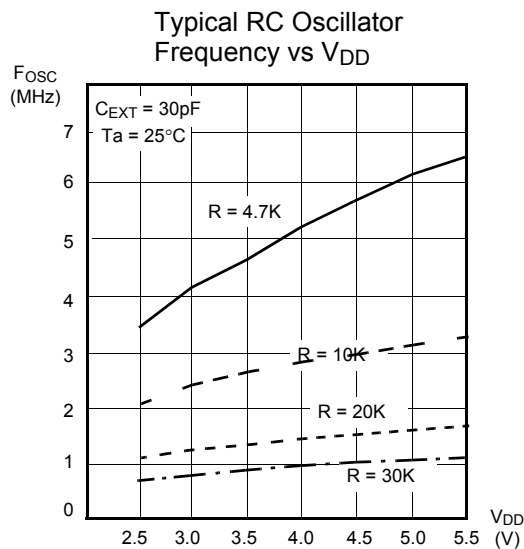
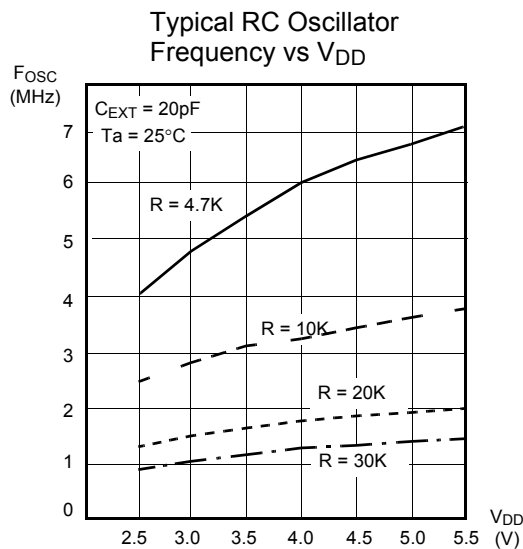
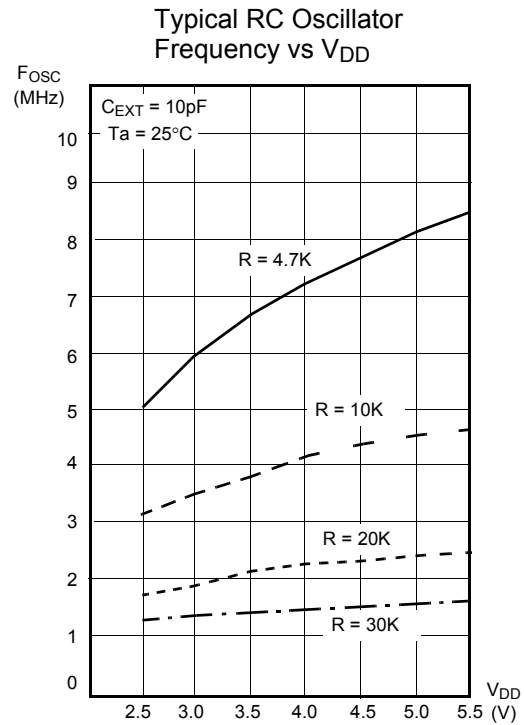
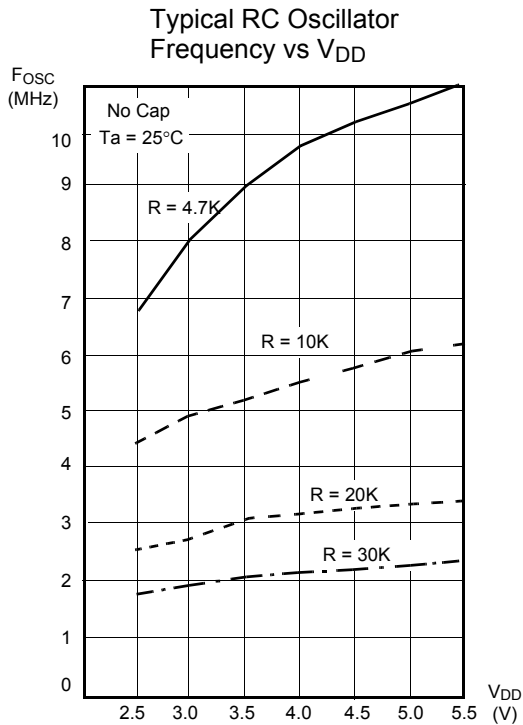
In some graphs or tables the data presented are outside specified operating range (e.g. outside specified V_{DD} range). This is for information only and devices are guaranteed to operate properly only within the

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.



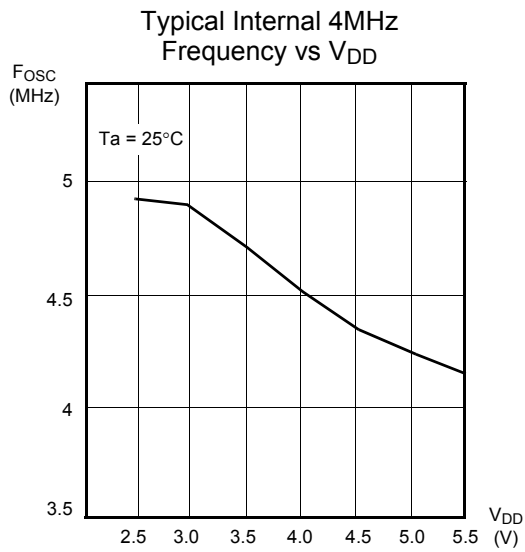




Note: The external RC oscillation frequencies shown in above are provided for design guidance only and not tested or guaranteed. The user needs to take into account that the external RC oscillation frequencies generated by the same circuit design may be not the same. Because there are variations in the resistance and capacitance due to the tolerance of external R and C components. The parasitic capacitance difference due to the different wiring length and layout may change the external RC oscillation frequencies.

Note: There may be the difference between package types(PDIP, SOP, TSSOP). The user should modify the value of R and C components to get the proper frequency in MC80F0704/0708/0804/0808 or one package type to another package type.

by sample, voltage and temperature. The internal oscillation can be used only in timing insensitive application.



Note: The internal 4MHz oscillation frequencies shown in above are provided for design guidance only and not tested or guaranteed. The user needs to take into account that the internal oscillation of the MC80F0704/0708/0804/0808 or MC80F0808(4) may show different frequency with sample

8. MEMORY ORGANIZATION

The MC80F0704/0708/0804/0808 has separate address spaces for Program memory and Data Memory. 4K bytes program memory can only be read, not written to.

8.1 Registers

This device has six registers that are the Program Counter (PC), a Accumulator (A), two index registers (X, Y), the Stack Pointer (SP), and the Program Status Word (PSW). The Program Counter consists of 16-bit register.

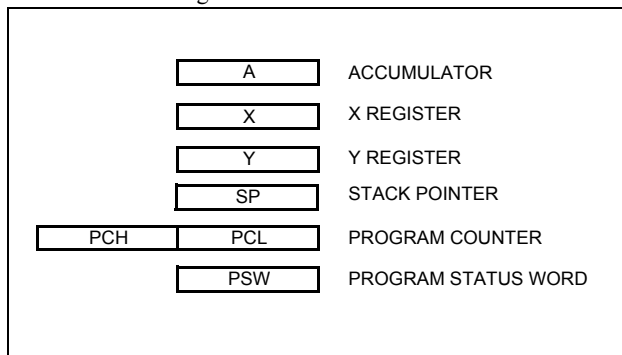


Figure 8-1 Configuration of Registers

Accumulator: The Accumulator is the 8-bit general purpose register, used for data operation such as transfer, temporary saving, and conditional judgement, etc.

The Accumulator can be used as a 16-bit register with Y Register as shown below.

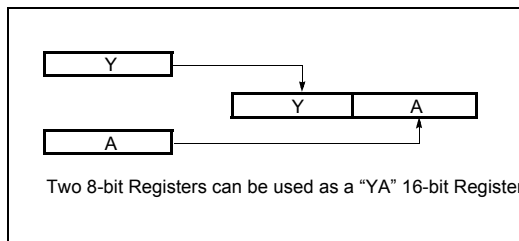


Figure 8-2 Configuration of YA 16-bit Register

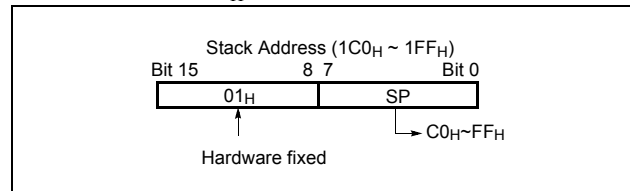
X, Y Registers: In the addressing mode which uses these index registers, the register contents are added to the specified address, which becomes the actual address. These modes are extremely effective for referencing subroutine tables and memory tables. The index registers also have increment, decrement, comparison and data transfer functions, and they can be used as simple accumulators.

Stack Pointer: The Stack Pointer is an 8-bit register used for occurrence interrupts and calling out subroutines. Stack Pointer identifies the location in the stack to be accessed (save or restore).

Data memory can be read and written to up to 256 bytes including the stack area.

Generally, SP is automatically updated when a subroutine call is executed or an interrupt is accepted. However, if it is used in excess of the stack area permitted by the data memory allocating configuration, the user-processed data may be lost.

The stack can be located at any position within 1C0H to 1FFH of the internal data memory. The SP is not initialized by hardware, requiring to write the initial value (the location with which the use of the stack starts) by using the initialization routine. Normally, the initial value of "FFH" is used.



Note: The Stack Pointer must be initialized by software because its value is undefined after Reset.

Example: To initialize the SP

```
LDX    #0FFH
TXSP                      ; SP ← FFH
```

Program Counter: The Program Counter is a 16-bit wide which consists of two 8-bit registers, PCH and PCL. This counter indicates the address of the next instruction to be executed. In reset state, the program counter has reset routine address (PCH:0FFH, PCL:0FEH).

Program Status Word: The Program Status Word (PSW) contains several bits that reflect the current state of the CPU. The PSW is described in Figure 8-3. It contains the Negative flag, the Overflow flag, the Break flag the Half Carry (for BCD operation), the Interrupt enable flag, the Zero flag, and the Carry flag.

[Carry flag C]

This flag stores any carry or borrow from the ALU of CPU after an arithmetic operation and is also changed by the Shift Instruction or Rotate Instruction.

[Zero flag Z]

This flag is set when the result of an arithmetic operation or data transfer is "0" and is cleared by any other result.

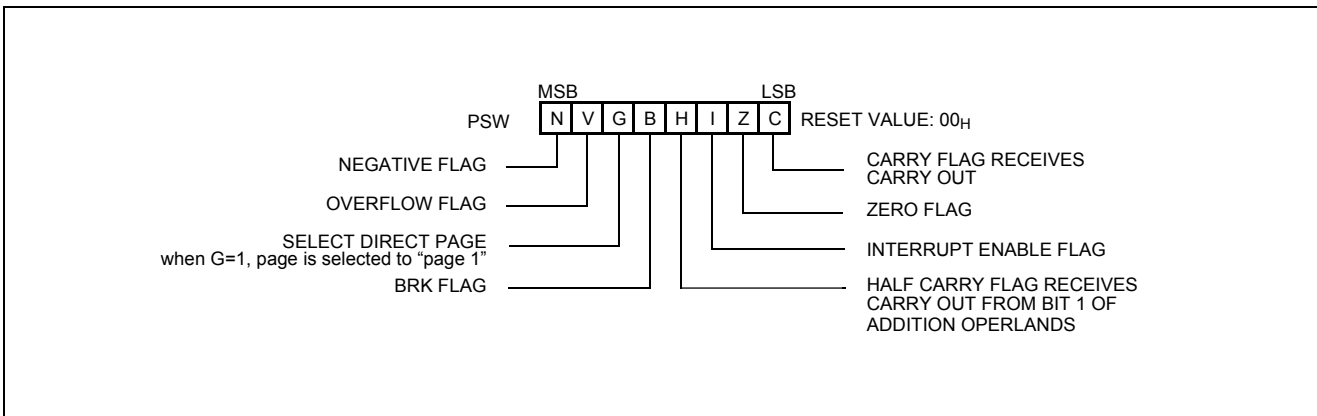


Figure 8-3 PSW (Program Status Word) Register

[Interrupt disable flag I]

This flag enables/disables all interrupts except interrupt caused by Reset or software BRK instruction. All interrupts are disabled when cleared to "0". This flag immediately becomes "0" when an interrupt is served. It is set by the EI instruction and cleared by the DI instruction.

[Half carry flag H]

After operation, this is set when there is a carry from bit 3 of ALU or there is no borrow from bit 4 of ALU. This bit can not be set or cleared except CLRV instruction with Overflow flag (V).

[Break flag B]

This flag is set by software BRK instruction to distinguish BRK from TCALL instruction with the same vector address.

[Direct page flag G]

This flag assigns RAM page for direct addressing mode. In the direct addressing mode, addressing area is from zero page 00_H to 0F_H when this flag is "0". If it is set to "1", addressing area is assigned 100_H to 1F_H. It is set by SETG instruction and cleared by CLRG.

[Overflow flag V]

This flag is set to "1" when an overflow occurs as the result of an arithmetic operation involving signs. An overflow occurs when the result of an addition or subtraction exceeds +127(7F_H) or -128(80_H). The CLRV instruction clears the overflow flag. There is no set instruction. When the BIT instruction is executed, bit 6 of memory is copied to this flag.

[Negative flag N]

This flag is set to match the sign bit (bit 7) status of the result of a data or arithmetic operation. When the BIT instruction is executed, bit 7 of memory is copied to this flag.

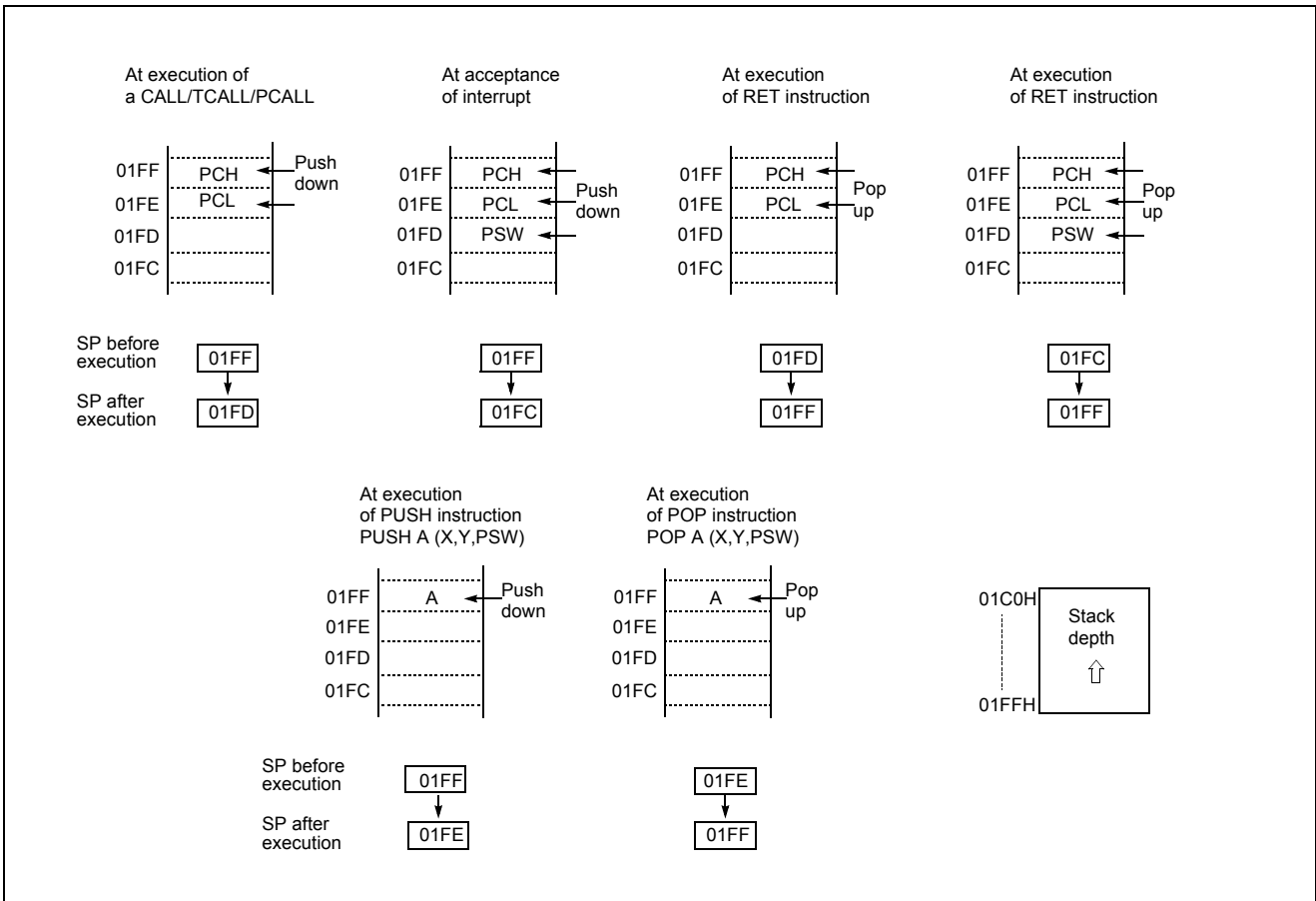


Figure 8-4 Stack Operation

8.2 Program Memory

A 16-bit program counter is capable of addressing up to 64K bytes, but this device has 4K/8K/16K bytes program memory space only physically implemented. Accessing a location above FFFF_H will cause a wrap-around to 0000_H.

Figure 8-5, shows a map of Program Memory. After reset, the CPU begins execution from reset vector which is stored in address FFFE_H and FFFF_H as shown in Figure 8-6.

As shown in Figure 8-5, each area is assigned a fixed location in Program Memory. Program Memory area contains the user program

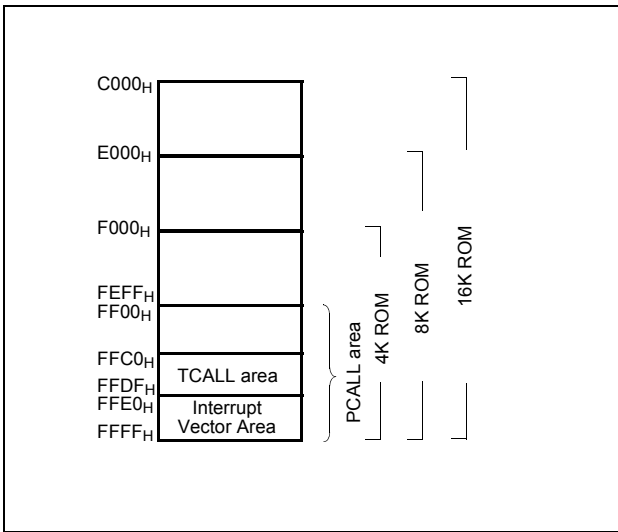


Figure 8-5 Program Memory Map

Page Call (PCALL) area contains subroutine program to reduce program byte length by using 2 bytes PCALL instead of 3 bytes CALL instruction. If it is frequently called, it is more useful to save program byte length.

Table Call (TCALL) causes the CPU to jump to each TCALL address, where it commences the execution of the service routine. The Table Call service area spaces 2-byte for every TCALL: 0FFC0_H for TCALL15, 0FFC2_H for TCALL14, etc., as shown in Figure 8-7.

Example: Usage of TCALL

```

LDA    #5
TCALL  0FH
:
:
; ;1BYTE INSTRUCTION
; ;INSTEAD OF 3 BYTES
; ;NORMAL CALL

; ;TABLE CALL ROUTINE
;
FUNC_A: LDA    LRG0
        RET
;
FUNC_B: LDA    LRG1
        RET
;
; ;TABLE CALL ADD. AREA
;
        ORG    0FFC0H
        DW    FUNC_A
        DW    FUNC_B
    
```

The interrupt causes the CPU to jump to specific location, where it commences the execution of the service routine. The External interrupt 0, for example, is assigned to location 0FFFC_H. The interrupt service locations spaces 2-byte interval: 0FFFA_H and 0FFFB_H for External Interrupt 1, 0FFFC_H and 0FFFD_H for External Interrupt 0, etc.

Any area from 0FF00_H to 0FFFF_H, if it is not going to be used, its service location is available as general purpose Program Memory.

| Address | Vector Area Memory |
|--------------------|---------------------------|
| 0FFE0 _H | Basic Interval Timer |
| E2 | Watchdog Timer Interrupt |
| E4 | A/D Converter |
| E6 | - |
| E8 | Timer/Counter 3 Interrupt |
| EA | Timer/Counter 2 Interrupt |
| EC | Timer/Counter 1 Interrupt |
| EE | Timer/Counter 0 Interrupt |
| F0 | Serial Input/Output (SIO) |
| F2 | - |
| F4 | - |
| F6 | External Interrupt 3 |
| F8 | External Interrupt 2 |
| FA | External Interrupt 1 |
| FC | External Interrupt 0 |
| FE | RESET |

Figure 8-6 Interrupt Vector Area

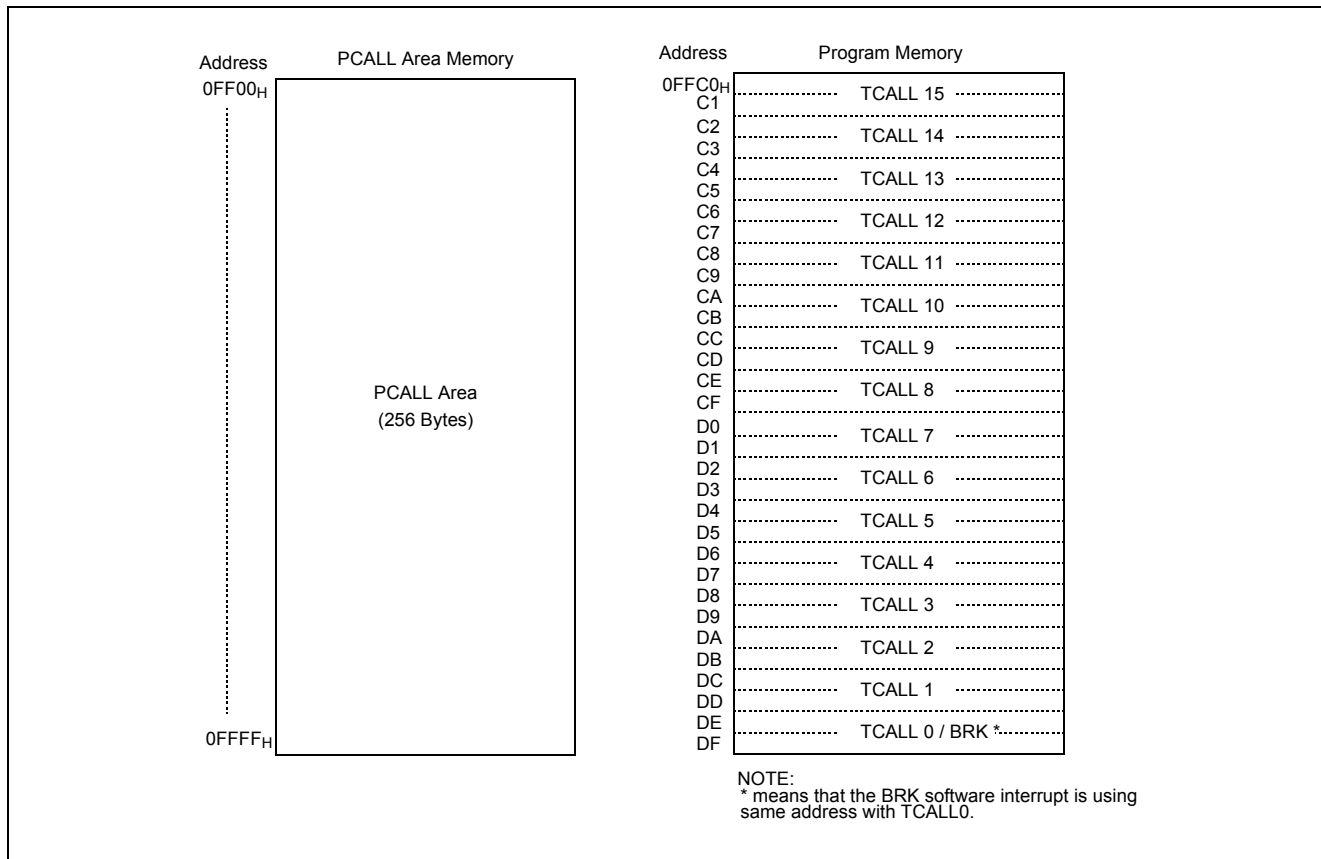
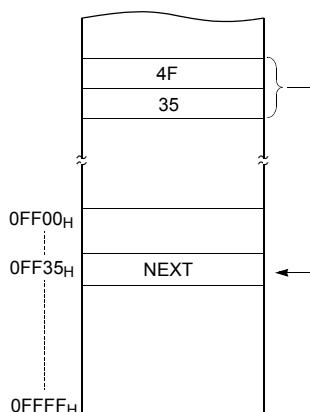


Figure 8-7 PCALL and TCALL Memory Area

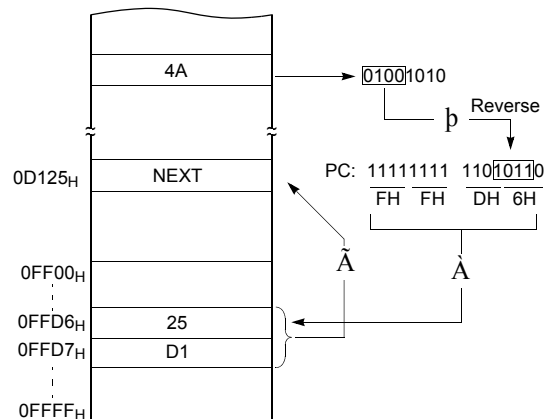
PCALL → rel

4F35 PCALL 35H



TCALL → n

4A TCALL 4



Example: The usage software example of Vector address

8.3 Data Memory

Figure 8-8 shows the internal Data Memory space available. Data Memory is divided into three groups, a user RAM, control registers, and Stack memory.

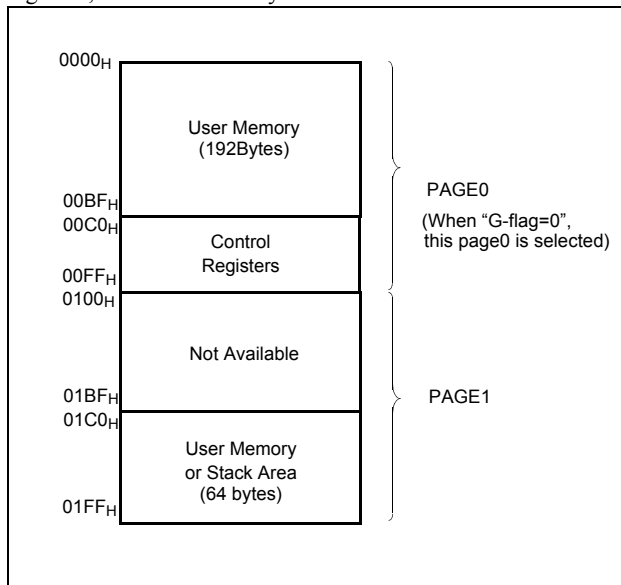


Figure 8-8 Data Memory Map

User Memory

The MC80F0704/0708/0804/0808 has 256×8 bits for the user memory (RAM). RAM pages are selected by RPR (See Figure 8-9).

Note: After setting RPR(RAM Page Select Register), be sure to execute SETG instruction. When executing CLRG instruction, be selected PAGE0 regardless of RPR.

Control Registers

The control registers are used by the CPU and Peripheral function

blocks for controlling the desired operation of the device. Therefore these registers contain control and status bits for the interrupt system, the timer/ counters, analog to digital converters and I/O ports. The control registers are in address range of 0C0H to 0FFH.

Note that unoccupied addresses may not be implemented on the chip. Read accesses to these addresses will in general return random data, and write accesses will have an indeterminate effect.

More detailed informations of each register are explained in each peripheral section.

Note: Write only registers can not be accessed by bit manipulation instruction. Do not use read-modify-write instruction. Use byte manipulation instruction, for example "LDM".

Example: To write at CKCTLR

```
LDM CKCTLR, #0AH ;Divide ratio(÷32)
```

Stack Area

The stack provides the area where the return address is saved before a jump is performed during the processing routine at the execution of a subroutine call instruction or the acceptance of an interrupt.

When returning from the processing routine, executing the subroutine return instruction [RET] restores the contents of the program counter from the stack; executing the interrupt return instruction [RETI] restores the contents of the program counter and flags.

The save/restore locations in the stack are determined by the stack pointed (SP). The SP is automatically decreased after the saving, and increased before the restoring. This means the value of the SP indicates the stack location number for the next save. Refer to Figure 8-4 on page 26.

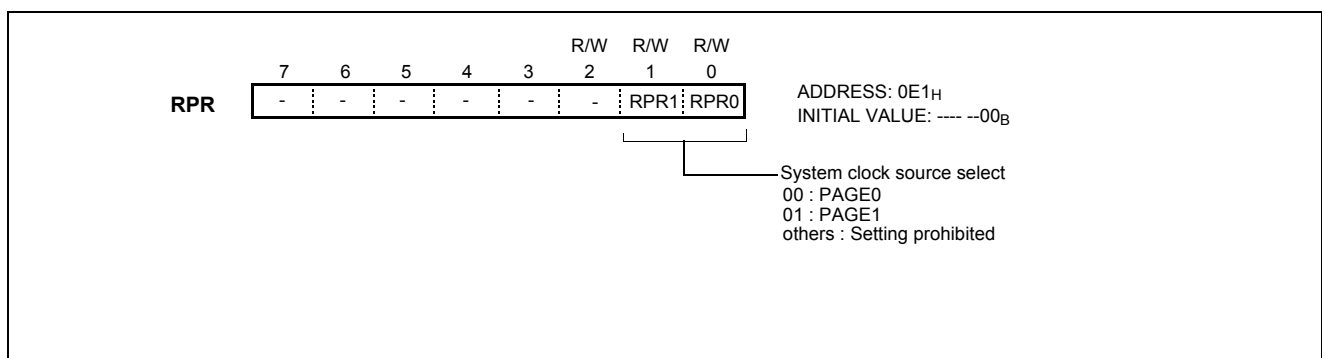


Figure 8-9 RPR(RAM Page Select Register)

| Address | Register Name | Symbol | R/W | Initial Value | | | | | | | | Addressing Mode | |
|---------|--------------------------------------|--------|-----|---------------|---|---|---|---|---|---|---|-----------------|------------------------|
| | | | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | | |
| 00C0 | R0 port data register | R0 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit ¹ |
| 00C1 | R0 port I/O direction register | R0IO | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte ² |
| 00C2 | R1 port data register | R1 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00C3 | R1 port I/O direction register | R1IO | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00C4 | R2 port data register | R2 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00C5 | R2 port I/O direction register | R2IO | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00C6 | R3 port data register | R3 | R/W | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00C7 | R3 port I/O direction register | R3IO | W | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00C8 | Port 0 Open Drain Selection Register | R0OD | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00C9 | Port 1 Open Drain Selection Register | R1OD | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00CA | Port 2 Open Drain Selection Register | R2OD | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00CB | Port 3 Open Drain Selection Register | R3OD | W | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00D0 | Timer 0 mode control register | TM0 | R/W | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00D1 | Timer 0 register | T0 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| | Timer 0 data register | TDR0 | W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | Timer 0 capture data register | CDR0 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 00D2 | Timer 1 mode control register | TM1 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00D3 | Timer 1 data register | TDR1 | W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | byte |
| | Timer 1 PWM period register | T1PPR | W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | byte |
| 00D4 | Timer 1 register | T1 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| | Timer 1 capture data register | CDR1 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Timer 1 PWM duty register | T1PDR | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 00D5 | Timer 1 PWM high register | T1PWHR | W | - | - | - | - | 0 | 0 | 0 | 0 | 0 | bit |
| 00D6 | Timer 2 mode control register | TM2 | R/W | - | - | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00D7 | Timer 2 register | T2 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| | Timer 2 data register | TDR2 | W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| | Timer 2 capture data register | CDR2 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| 00D8 | Timer 3 mode control register | TM3 | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00D9 | Timer 3 data register | TDR3 | W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | byte |
| | Timer 3 PWM period register | T3PPR | W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | |
| 00DA | Timer 3 register | T3 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| | Timer 3 PWM duty register | T3PDR | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |
| | Timer 3 capture data register | CDR3 | R | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | |

Table 8-1 Control Registers

| Address | Register Name | Symbol | R/W | Initial Value | | | | | | | | Addressing Mode |
|---------|-------------------------------------|--------|------|---------------|---|---|-----------|---|---|---|---|-----------------|
| | | | | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| 00DB | Timer 3 PWM high register | T3PWHR | W | - | - | - | - | 0 | 0 | 0 | 0 | byte |
| 00E0 | Buzzer driver register | BUZR | W | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | byte |
| 00E1 | RAM page selection register | RPR | R/W | - | - | - | - | - | 0 | 0 | 0 | byte, bit |
| 00E2 | SIO mode control register | SIOM | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | byte, bit |
| 00E3 | SIO data shift register | SIOR | R/W | Undefined | | | | | | | | byte, bit |
| 00EA | Interrupt enable register high | IENH | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00EB | Interrupt enable register low | IENL | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00EC | Interrupt request register high | IRQH | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00ED | Interrupt request register low | IRQL | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00EE | Interrupt edge selection register | IEDS | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte, bit |
| 00EF | A/D converter mode control register | ADCM | R/W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | byte, bit |
| 00F0 | A/D converter result high register | ADCRH | R(W) | 0 | 1 | 0 | Undefined | | | | | byte |
| 00F1 | A/D converter result low register | ADCRL | R | Undefined | | | | | | | | byte |
| 00F2 | Basic interval timer register | BITR | R | Undefined | | | | | | | | byte |
| | Clock control register | CKCTLR | W | 0 | - | 0 | 1 | 0 | 1 | 1 | 1 | |
| 00F4 | Watch dog timer register | WDTR | W | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | byte |
| | Watch dog timer data register | WDTDR | R | Undefined | | | | | | | | |
| 00F5 | Stop & sleep mode control register | SSCR | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00F7 | PFD control register | PFDR | R/W | - | - | - | - | - | 0 | 0 | 0 | byte, bit |
| 00F8 | Port selection register 0 | PSR0 | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00F9 | Port selection register 1 | PSR1 | W | - | - | - | - | 0 | 0 | 0 | 0 | byte |
| 00FC | Pull-up selection register 0 | PU0 | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00FD | Pull-up selection register 1 | PU1 | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00FD | pull-up selection register 2 | PU2 | W | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | byte |
| 00FF | Pull-up selection register 3 | PU3 | W | - | - | 0 | 0 | 0 | 0 | 0 | 0 | byte |

Table 8-1 Control Registers

1. The 'byte, bit' means registers are controlled by both bit and byte manipulation instruction.
Caution) The R/W register except T1PDR and T3PDR are both can be byte and bit manipulated.
2. The 'byte' means registers are controlled by only byte manipulation instruction. Do not use bit manipulation instruction such as SET1, CLR1 etc. If bit manipulation instruction is used on these registers, content of other seven bits are may varied to unwanted value.

*The mark of '-' means this bit location is reserved.

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---------|-------------------|---|----------|--------|--------|--------------------------|-------|-------|-------|
| 0C0H | R0 | R0 Port Data Register | | | | | | | |
| 0C1H | R0IO | R0 Port Direction Register | | | | | | | |
| 0C2H | R1 | R1 Port Data Register | | | | | | | |
| 0C3H | R1IO | R1 Port Direction Register | | | | | | | |
| 0C4H | R2 | R2 Port Data Register | | | | | | | |
| 0C5H | R2IO | R2Port Data Register | | | | | | | |
| 0C6H | R3 | R3 Port Data Register | | | | | | | |
| 0C7H | R3IO | R3 Port Direction Register | | | | | | | |
| 0C8H | R0OD | R0 Open Drain Selection Register | | | | | | | |
| 0C9H | R1OD | R1 Open Drain Selection Register | | | | | | | |
| 0CAH | R2OD | R2 Open Drain Selection Register | | | | | | | |
| 0CBH | R3OD | R3 Open Drain Selection Register | | | | | | | |
| 0D0H | TM0 | - | - | CAP0 | T0CK2 | T0CK1 | T0CK0 | T0CN | T0ST |
| 0D1H | T0/TDR0/ CDR0 | Timer0 Register / Timer0 Data Register / Timer0 Capture Data Register | | | | | | | |
| 0D2H | TM1 | T1_POL | T1_16BIT | PWM1E | CAP1 | T1CK1 | T1CK0 | T1CN | T1ST |
| 0D3H | TDR1/ T1PPR | Timer1 Data Register / Timer1 PWM Period Register | | | | | | | |
| 0D4H | T1/CDR1 | Timer1 Register / Timer1 Capture Data Register | | | | | | | |
| 0D5H | PWM1HR | - | - | - | - | Timer1 PWM High Register | | | |
| 0D6H | TM2 | - | - | CAP2 | T2CK2 | T2CK1 | T2CK0 | T2CN | T2ST |
| 0D7H | T2/TDR2/ CDR2 | Timer2 Register / Timer2 Data Register / Timer2 Capture Data Register | | | | | | | |
| 0D8H | TM3 | T3_POL | T3_16BIT | PWM3E | CAP3 | T3CK1 | T3CK0 | T3CN | T3ST |
| 0D9H | TDR3/ T3PPR | Timer3 Data Register / Timer3 PWM Period Register | | | | | | | |
| 0DAH | T3/CDR3/ T3PDR | Timer3 Register / Timer3 Capture Data Register / Timer3 PWM Duty Register | | | | | | | |
| 0DBH | PWM3HR | - | - | - | - | Timer3 PWM High Register | | | |
| 0E0H | BUZR | BUCK1 | BUCK0 | BUR5 | BUR4 | BUR3 | BUR2 | BUR1 | BUR0 |
| 0E1H | RPR | - | - | - | - | - | RPR2 | RPR1 | RPR0 |
| 0E2H | SIOM | POL | IOSW | SM1 | SM0 | SCK1 | SCK0 | SIOST | SIOSF |
| 0E3H | SIOR | SIO Data Shift Register | | | | | | | |
| 0EAH | IENH | INT0E | INT1E | INT2E | INT3E | - | - | SIOE | T0E |
| 0EBH | IENL | T1E | T2E | T3E | - | ADCE | WDTE | WTE | BITE |
| 0ECH | IRQH | INT0IF | INT1IF | INT2IF | INT3IF | - | - | SIOIF | T0IF |
| 0EDH | IRQL | T1IF | T2IF | T3IF | T4IF | ADCIF | WDTIF | WTIF | BITIF |

Table 8-2 Control Register Function Description

| Address | Name | Bit 7 | Bit 6 | Bit 5 | Bit 4 | Bit 3 | Bit 2 | Bit 1 | Bit 0 |
|---------|---------------------|---|-------------------------------|-------|-------|-------|-------|----------------------|-------|
| 0EEH | IEDS | IED3H | IED3L | IED2H | IED2L | IED1H | IED1L | IED0H | IED0L |
| 0EFH | ADCM | ADEN | ADCK | ADS3 | ADS2 | ADS1 | ADS0 | ADST | ADSF |
| 0F0H | ADCRH | PSSEL1 | PSSEL0 | ADC8 | - | - | - | ADC Result Reg. High | |
| 0F1H | ADCRL | ADC Result Register Low | | | | | | | |
| 0F2H | BITR ¹ | Basic Interval Timer Data Register | | | | | | | |
| | CKCTLR ¹ | ADRST | - | RCWDT | WDTON | BTCL | BTS2 | BTS1 | BTS0 |
| 0F4H | WDTR | WDTCL | 7-bit Watchdog Timer Register | | | | | | |
| | WDTDR | Watchdog Timer Data Register (Counter Register) | | | | | | | |
| 0F5H | SSCR | Stop & Sleep Mode Control Register | | | | | | | |
| 0F7H | PFDR | - | - | - | - | - | PFDEN | PFDM | PFDS |
| 0F8H | PSR0 | PWM3O | PWM1O | EC1E | EC0E | INT3E | INT2E | INT1E | INT0E |
| 0F9H | PSR1 | - | - | - | - | XTEN | BUZO | T2O | T0O |
| 0FCH | PU0 | R0 Pull-up Selection Register | | | | | | | |
| 0FDH | PU1 | R1 Pull-up Selection Register | | | | | | | |
| 0FEH | PU2 | R2 Pull-up Selection Register | | | | | | | |
| 0FFH | PU3 | R3 Pull-up Selection Register | | | | | | | |

Table 8-2 Control Register Function Description

1. The register BITR and CKCTLR are located at same address. Address ECH is read as BITR, written to CKCTLR.

Caution) The registers of dark-shaded area can not be accessed by bit manipulation instruction such as "SET1, CLR1", but should be accessed by register operation instruction such as "LDM dp,#imm".

8.4 Addressing Mode

The MC8 series MCU uses six addressing modes;

- Register addressing
- Immediate addressing
- Direct page addressing
- Absolute addressing
- Indexed addressing
- Register-indirect addressing

Register Addressing

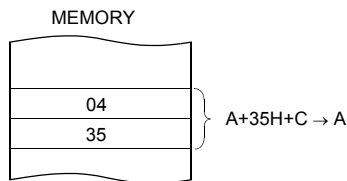
Register addressing accesses the A, X, Y, C and PSW.

Immediate Addressing → #imm

In this mode, second byte (operand) is accessed as a data immediately.

Example:

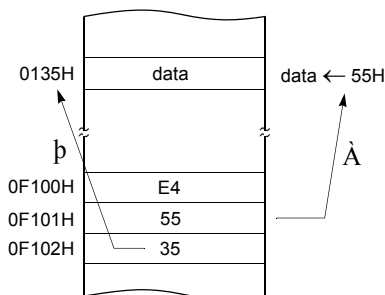
```
0435   ADC   #35H
```



When G-flag is 1, then RAM address is defined by 16-bit address which is composed of 8-bit RAM paging register (RPR) and 8-bit immediate data.

Example: G=1

```
E45535  LDM  35H, #55H
```

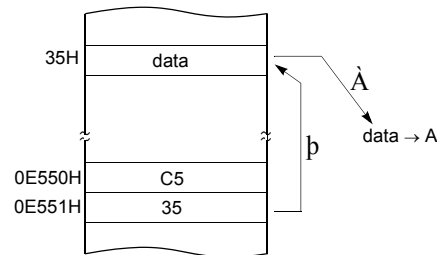


Direct Page Addressing → dp

In this mode, a address is specified within direct page.

Example; G=0

```
C535   LDA   35H           ; A ← RAM[35H]
```



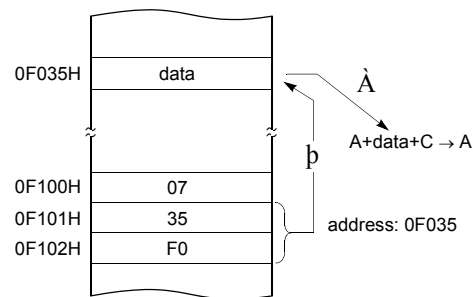
Absolute Addressing → !abs

Absolute addressing sets corresponding memory data to Data, i.e. second byte (Operand I) of command becomes lower level address and third byte (Operand II) becomes upper level address. With 3 bytes command, it is possible to access to whole memory area.

ADC, AND, CMP, CMPX, CMPY, EOR, LDA, LDX, LDY, OR, SBC, STA, STX, STY

Example;

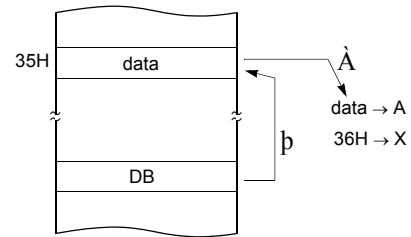
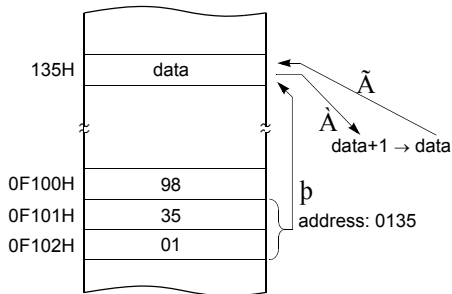
```
0735F0  ADC   !0F035H     ; A ← ROM[0F035H]
```



The operation within data memory (RAM)
ASL, BIT, DEC, INC, LSR, ROL, ROR

Example; Addressing accesses the address 0135H regardless of G-flag.


```
983501 INC !0135H ;A ←ROM[135H]
```



Indexed Addressing

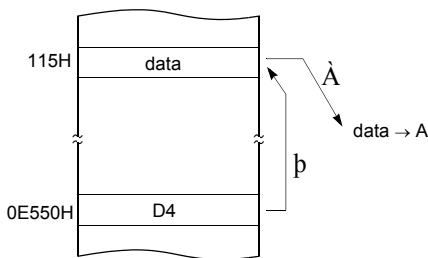
X indexed direct page (no offset) → {X}

In this mode, a address is specified by the X register.

ADC, AND, CMP, EOR, LDA, OR, SBC, STA, XMA

Example; X=15H, G=1

```
D4 LDA {X} ;ACC←RAM[X].
```



X indexed direct page, auto increment → {X}+

In this mode, a address is specified within direct page by the X register and the content of X is increased by 1.

LDA, STA

Example; G=0, X=35H

```
DB LDA {X}+
```

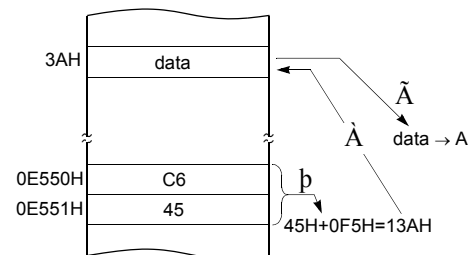
X indexed direct page (8 bit offset) → dp+X

This address value is the second byte (Operand) of command plus the data of X-register. And it assigns the memory in Direct page.

ADC, AND, CMP, EOR, LDA, LDY, OR, SBC, STA, STY, XMA, ASL, DEC, INC, LSR, ROL, ROR

Example; G=0, X=0F5H

```
C645 LDA 45H+X
```



Y indexed direct page (8 bit offset) → dp+Y

This address value is the second byte (Operand) of command plus the data of Y-register, which assigns Memory in Direct page.

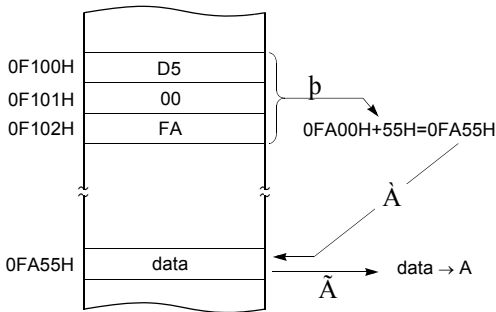
This is same with above (2). Use Y register instead of X.

Y indexed absolute → !abs+Y

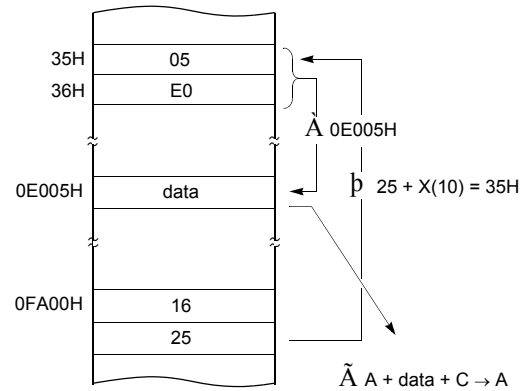
Sets the value of 16-bit absolute address plus Y-register data as Memory. This addressing mode can specify memory in whole area.

Example; Y=55H

D500FA LDA !0FA00H+Y



1625 ADC [25H+X]



Indirect Addressing

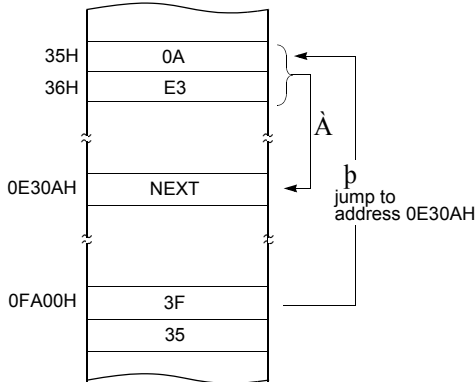
Direct page indirect → [dp]

Assigns data address to use for accomplishing command which sets memory data (or pair memory) by Operand. Also index can be used with Index register X,Y.

JMP, CALL

Example; G=0

3F35 JMP [35H]



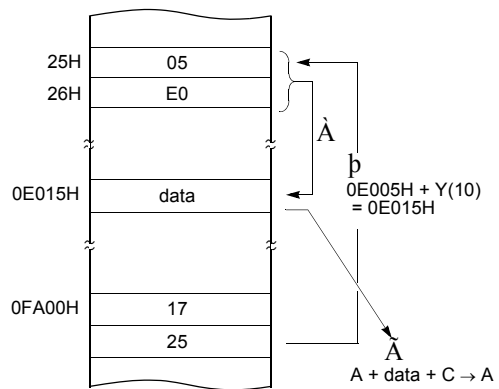
Y indexed indirect → [dp]+Y

Processes memory data as Data, assigned by the data [dp+1][dp] of 16-bit pair memory paired by Operand in Direct page plus Y-register data.

ADC, AND, CMP, EOR, LDA, OR, SBC, STA

Example; G=0, Y=10H

1725 ADC [25H]+Y



X indexed indirect → [dp+X]

Processes memory data as Data, assigned by 16-bit pair memory which is determined by pair data [dp+X+1][dp+X] Operand plus X-register data in Direct page.

ADC, AND, CMP, EOR, LDA, OR, SBC, STA

Example; G=0, X=10H

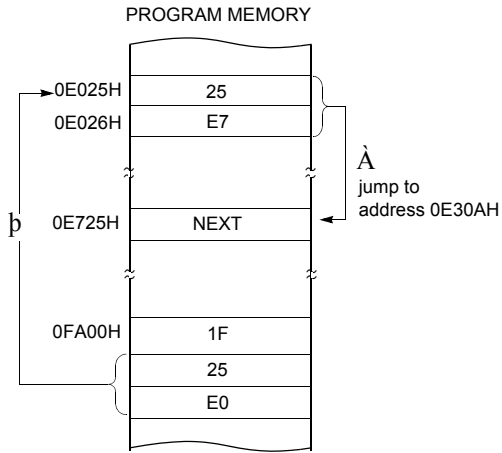
Absolute indirect → [!abs]

The program jumps to address specified by 16-bit absolute address.

JMP

Example; G=0

1F25E0 JMP [!0C025H]



9. I/O PORTS

The MC80F0704/0708/0804/0808 has three ports (R0, R1 and R3). These ports pins may be multiplexed with an alternate function for the peripheral features on the device. All port can drive maximum 20mA of high current in output low state, so it can directly drive LED device.

All pins have data direction registers which can define these ports as output or input. A “1” in the port direction register configure the corresponding port pin as output. Conversely, write “0” to the corresponding bit to specify it as input pin. For example, to use the even numbered bit of R0 as output ports and the odd numbered bits as input ports, write “55H” to address 0C1H (R0 port direction register) during initial setting as shown in Figure 9-1 .

All the port direction registers in the MC80F0704/0708/0804/0808 have 0 written to them by reset function. On the other hand, its initial status is input.

9.1 R0 and R0IO register

R0 is an 8-bit CMOS bidirectional I/O port (address 0C0H). Each I/O pin can independently used as an input or an output through the R0IO register (address 0C1H). When R00 through R07 pins are used as input ports, an on-chip pull-up resistor can be connect-

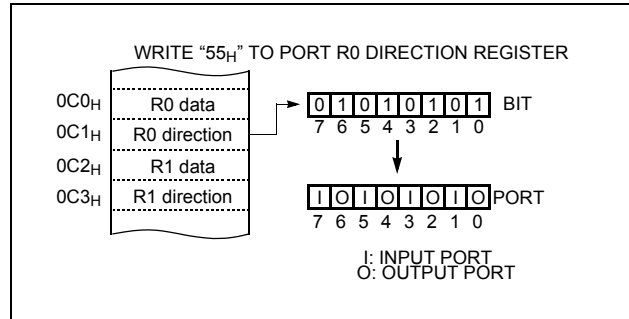


Figure 9-1 Example of port I/O assignment

ed to them in 1-bit units with a pull-up selection register 0 (PU0). Each I/O pin of R0 port can be used to open drain output port by setting the corresponding bit of the open drain selection register 0 (ROOD).

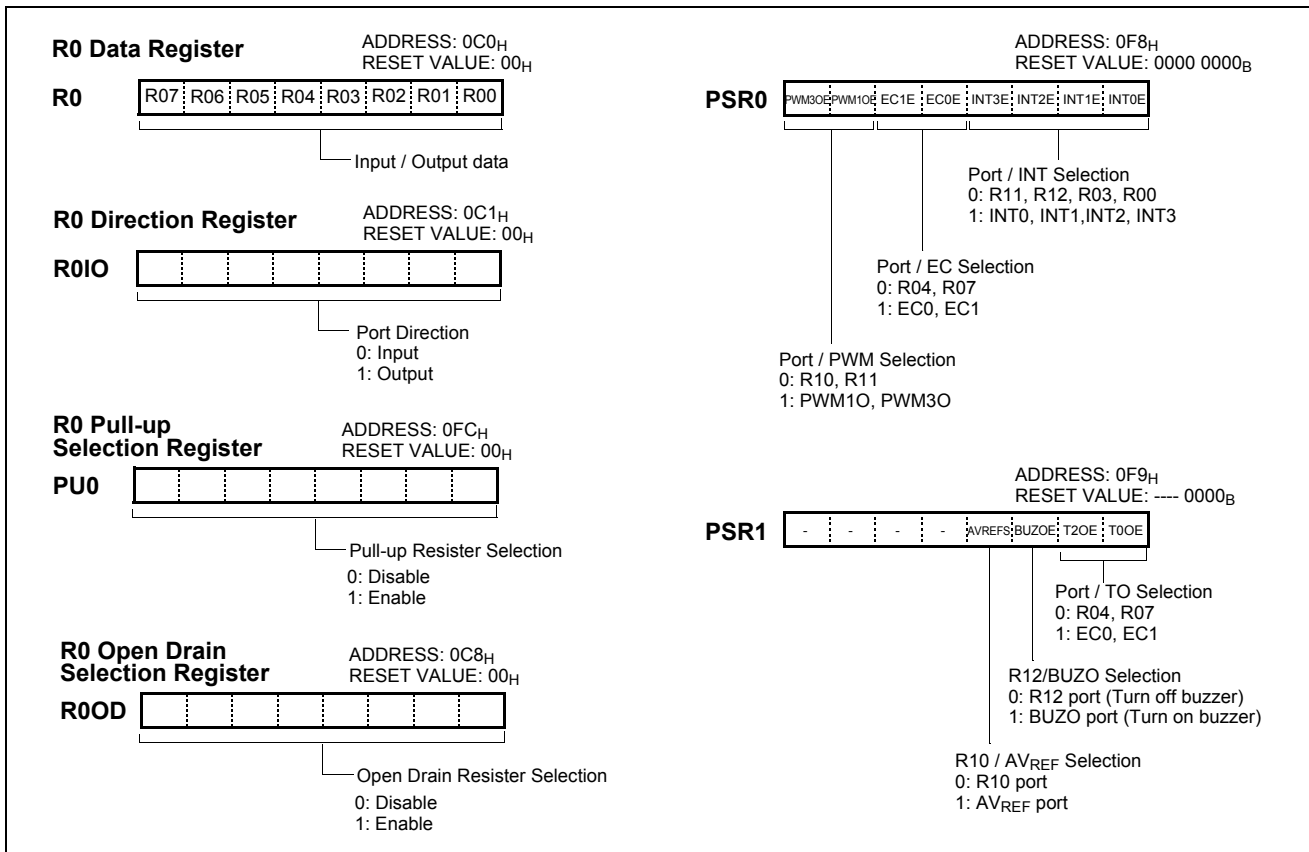


Figure 9-2 R0 Port Register

In addition, Port R0 is multiplexed with various alternate functions. The port selection register PSR0 (address 0F8H) and PSR1 (address 0F9H) control the selection of alternate functions such as

external interrupt 3 (INT3), external interrupt 2 (INT2), event counter input 0 (EC0), timer 0 output (T00), timer 2 output (T20) and event counter input 1 (EC1). When the alternate func-

tion is selected by writing “1” in the corresponding bit of PSR0 or PSR1, port pin can be used as a corresponding alternate features regardless of the direction register R0IO.

The ADC input channel 1~7 (AN1~AN7) and SIO data input (SI), SIO data output (SOUT), SIO clock input/output (SCK) can be selected by setting ADCM(00EF_H) and SIOM(00E2_H) register to enable the corresponding peripheral operation and select operation mode.

| Port Pin | Alternate Function |
|----------|---|
| R00- | INT3 (External interrupt 3) SCK (SIO clock input/output) |
| R01 | AN1(ADC Input channel 1) SI (SIO data input) |
| R02 | AN2 (ADC Input channel 2) SOUT (SIO data output) |
| R03 | AN3 (ADC Input channel 3) INT2 (External interrupt 2) |
| R04 | AN4 (ADC Input channel 4) EC0 (Event counter input 0) |
| R05 | AN5 (ADC Input channel 5) T00 (Timer output 0) |
| R06 | AN6 (ADC Input channel 6) T20 (Timer output 2) |
| R07 | AN7 (ADC Input channel 7) EC1 (Event counter input 1) |

9.2 R1 and R1IO register

R1 is a 5-bit CMOS bidirectional I/O port (address 0C2_H). Each I/O pin can independently used as an input or an output through the R1IO register (address 0C3_H). When R10 through R17 pins are used as input ports, an on-chip pull-up resistor can be connected to them in 1-bit units with a pull-up selection register 1 (PU1). Each I/O pin of R1 port can be used to open drain output port by setting the corresponding bit of the open drain selection register 1 (R1OD).

In addition, Port R1 is multiplexed with various alternate functions. The port selection register PSR0 (address 0F8_H) and PSR1 (address 0F9_H) control the selection of alternate functions such as Analog reference voltage input (AVREF), external interrupt 0 (INT0), external interrupt 1 (INT1), PWM 1 output (PWM1O), PWM 3 output (PWM3O) and buzzer output (BUZO). When the alternate function is selected by writing “1” in the corresponding bit of PSR0 or PSR1, port pin can be used as a corresponding alternate features regardless of the direction register R1IO.

The ADC input channel 0 (AN0) and channel 8(AN8) can be selected by setting ADCM(00EF_H) register to enable ADC and se-

lect channel 0 and channel 8 .

| Port Pin | Alternate Function |
|----------|---|
| R10 | AN0 (ADC input channel 0) AVREF (Analog reference voltage) |
| R11 | PWM1O (PWM 1 output) INT0 (External Interrupt 0) |
| R12 | PWM3O (PWM 3 output) INT1 (External Interrupt 1) BUZO (Buzzer output) |
| R13 | - |
| R14 | - |
| R15 | - |
| R16 | - |
| R17 | AN8 |

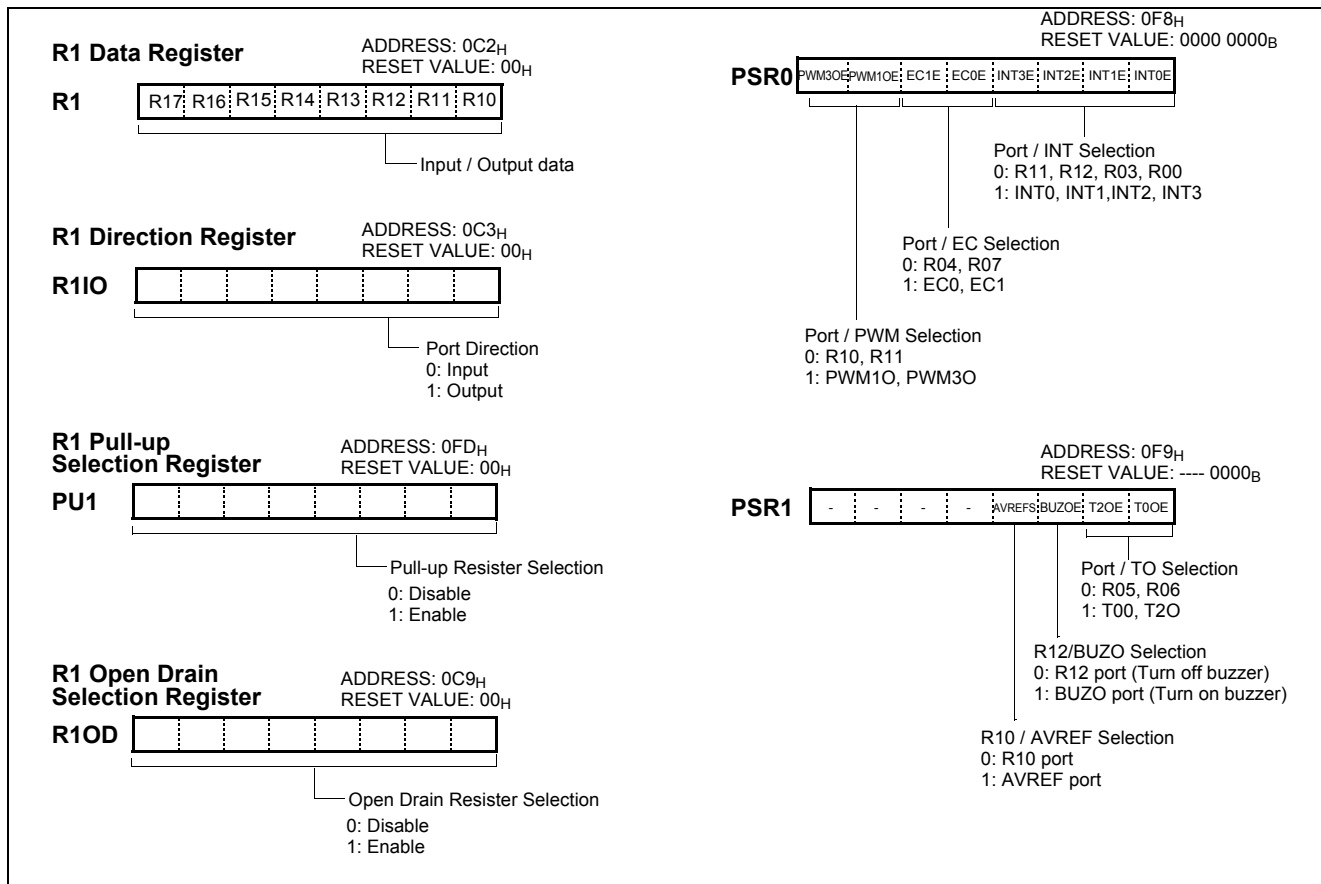


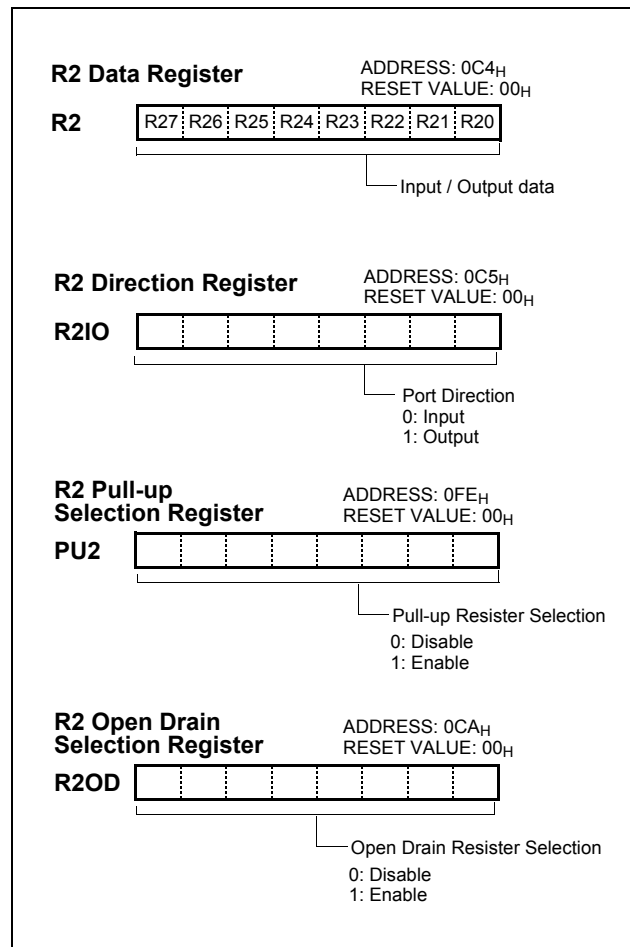
Figure 9-3 R1 Port Register

9.3 R2 and R2IO register

R2 is an 8-bit CMOS bidirectional I/O port (address 0C4H). Each I/O pin can independently used as an input or an output through the R3IO register (address 0C5H). When R20 through R27 pins are used as input ports, an on-chip pull-up resistor can be connected to them in 1-bit units with a pull-up selection register 2 (PU2). R20 through R27 pins can be used to open drain output port by setting the corresponding bit of the open drain selection register 2 (R2OD).

In addition, Port R2 is multiplexed with alternate functions. R23 R24,R25,and R26 can be used as ADC input channel 9 to 12 by setting ADCM to enable ADC and select channel 9 to 12.

| Port Pin | Alternate Function |
|----------|-----------------------------|
| R20 | - |
| R21 | - |
| R22 | - |
| R23 | AN9 (ADC input channel 9) |
| R24 | AN10 (ADC input channel 10) |
| R25 | AN11 (ADC input channel 11) |
| R26 | AN12 (ADC input channel 12) |
| R27 | - |



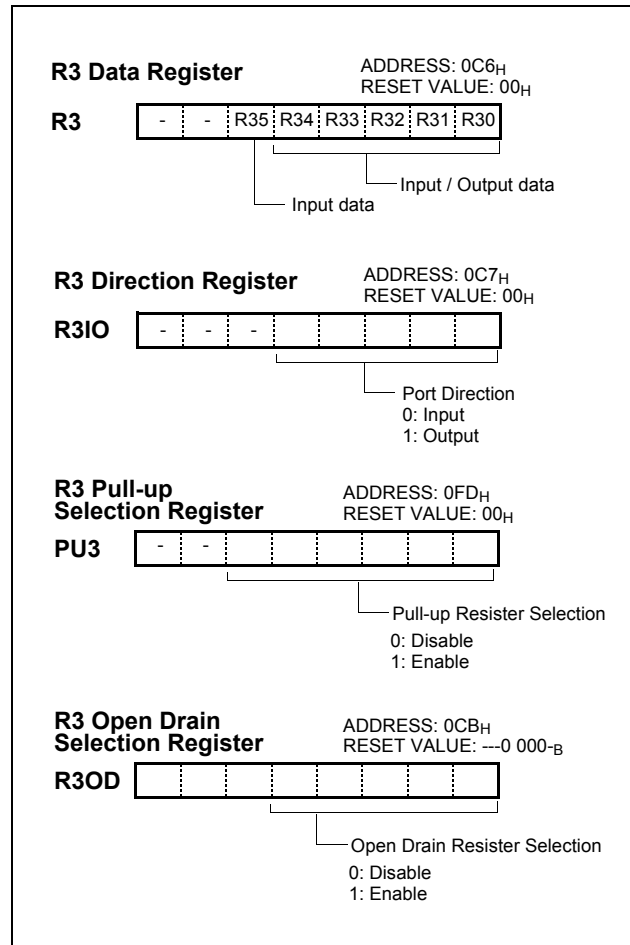
9.4 R3 and R3IO register

R3 is a 6-bit CMOS bidirectional I/O port (address 0C6H). Each I/O pin (except R35) can independently used as an input or an output through the R3IO register (address 0C7H). R35 is an input only port. When R30 through R35 pins are used as input ports, an on-chip pull-up resistor can be connected to them in 1-bit units with a pull-up selection register 3 (PU3). R30 through R34 pins can be used to open drain output port by setting the corresponding bit of the open drain selection register 1 (R3OD).

In addition, Port R3 is multiplexed with alternate functions. R30, R31, and R32 can be used as ADC input channel 13, 14 and 15 by setting ADCM to enable ADC and select channel 13, 14 and 15.

| Port Pin | Alternate Function |
|----------|-----------------------------|
| R30 | AN13 (ADC input channel 13) |
| R31 | AN14 (ADC input channel 14) |
| R32 | AN15 (ADC input channel 15) |

R33, R34 and R35 is multiplexed with X_{IN} , X_{OUT} , and \overline{RESET} pin.



10. CLOCK GENERATOR

As shown in Figure 10-1, 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 or a ceramic resonator between the X_{IN} and X_{OUT} pin, respectively. The system clock can also be obtained from the external oscillator. In this case, it is necessary to input a external clock signal to the X_{IN} pin and open the X_{OUT} pin. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is

through a divide-by-two flip-flop, but minimum and maximum high and low times specified on the data sheet must be observed.

To the peripheral block, the clock among the not-divided original clock, clocks divided by 1, 2, 4, ..., up to 4096 can be provided. Peripheral clock is enabled or disabled by STOP instruction. The peripheral clock is controlled by clock control register (CKCTRL). See "11. BASIC INTERVAL TIMER" on page 45 for details.

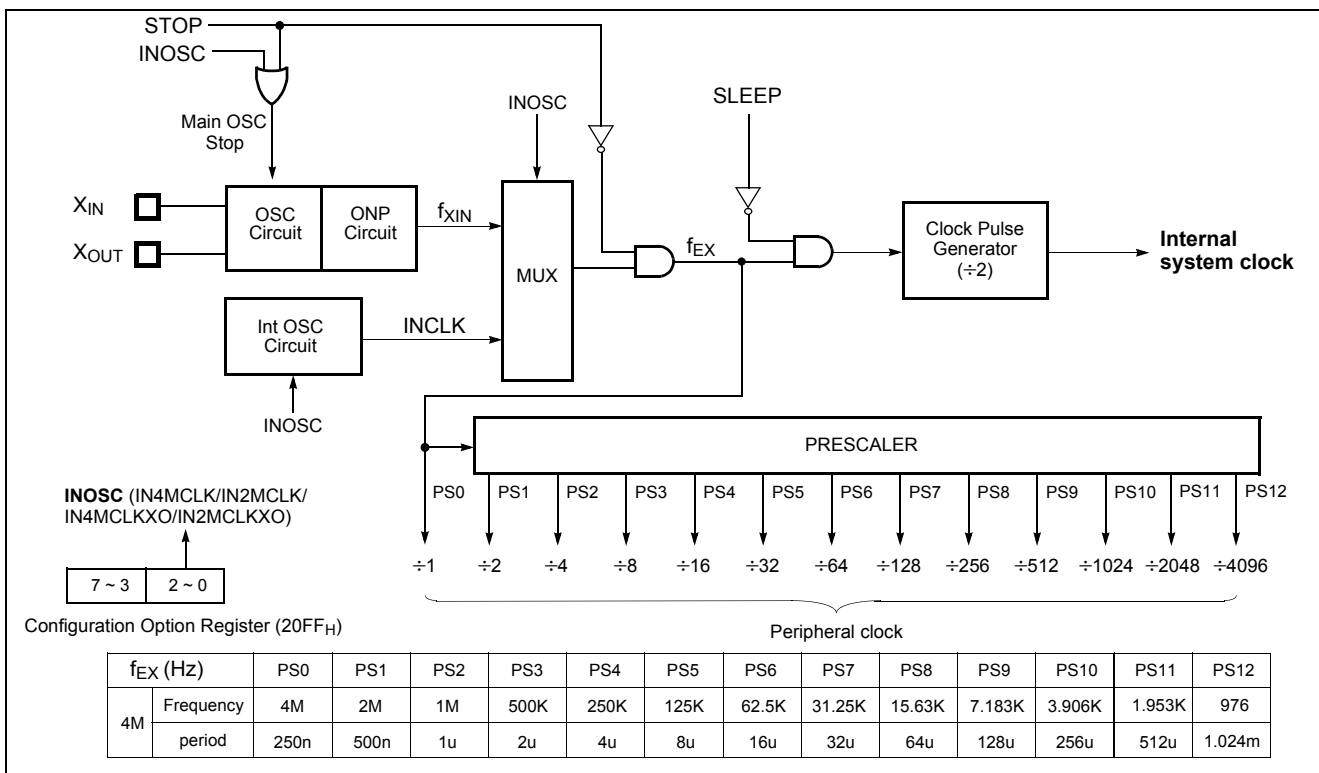


Figure 10-1 Block Diagram of Clock Generator

10.1 Oscillation Circuit

X_{IN} and X_{OUT} are the input and output, respectively, a inverting amplifier which can be set for use as an on-chip oscillator, as

shown in Figure 10-2.

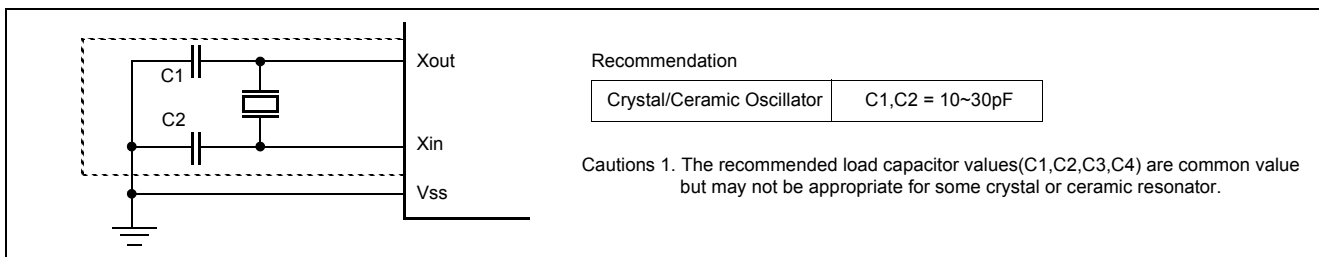


Figure 10-2 Oscillator Connections

Note: When using a system clock oscillator, carry out wiring in the broken line area in Figure 10-2 to prevent any effects from wir-

ing capacities.

- Minimize the wiring length.
- Do not allow wiring to intersect with other signal conductors.
- Do not allow wiring to come near changing high current.
- Set the potential of the grounding position of the oscillator capacitor to that of Vss. Do not ground to any ground pattern where high current is present.
- Do not fetch signals from the oscillator.

In addition, see Figure 10-3 for the layout of the crystal.

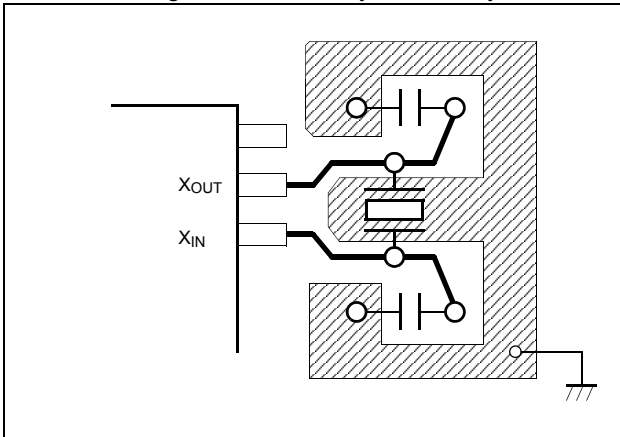


Figure 10-3 Layout of Oscillator PCB circuit

To drive the device from an external clock source, Xout should be left unconnected while Xin is driven as shown in Figure 10-4. There are no requirements on the duty cycle of the external clock signal, since the input to the internal clocking circuitry is through a divide-by-two flip-flop, but minimum and maximum high and low times specified on the data sheet must be observed.

Oscillation circuit is designed to be used either with a ceramic resonator or crystal oscillator. Since each crystal and ceramic resonator have their own characteristics, the user should consult the crystal manufacturer for appropriate values of external components.

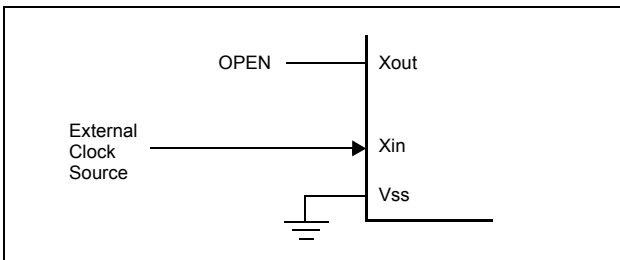


Figure 10-4 External Clock Connections

In addition, the MC80F0704/0708/0804/0808 has an ability for the external RC oscillated operation. It offers additional cost savings for **timing insensitive applications**. The RC oscillator frequency is a function of the supply voltage, the external resistor (R_{EXT}) and capacitor (C_{EXT}) values, and the operating temperature.

The user needs to take into account variation due to tolerance of external R and C components used.

Figure 10-1 shows how the RC combination is connected to the MC80F0704/0708/0804/0808. External capacitor (C_{EXT}) can be omitted for more cost saving. However, the characteristics of external R only oscillation are more variable than external RC oscillation.

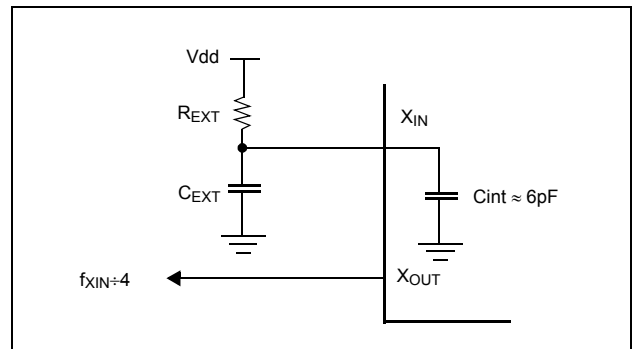


Figure 10-1 RC Oscillator Connections

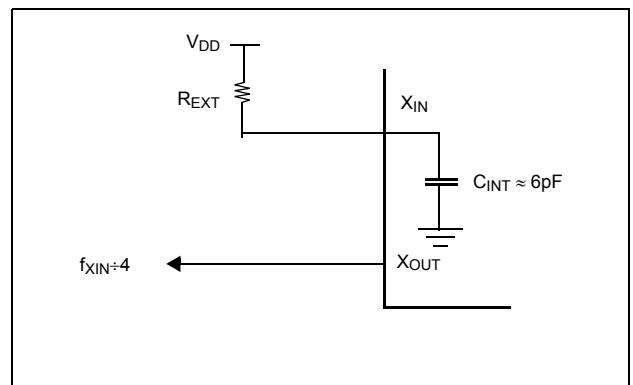


Figure 10-2 R Oscillator Connections

To use the RC oscillation, the CLK option of the configuration bits (20FF_H) should be set to “EXRC or EXRCXO”.

The oscillator frequency, divided by 4, is output from the Xout pin, and can be used for test purpose or to synchronize other logic.

In addition to external crystal/resonator and external RC/R oscillation, the MC80F0704/0708/0804/0808 provides the internal 4MHz or 2MHz oscillation. The internal 4MHz/2MHz oscillation needs no external parts.

To use the internal 4MHz/2MHz oscillation, the CLK option of the configuration bits should be set to “IN4MCLK”, “IN2MCLK”, “IN4MCLKXO” or “IN2MCLKXO”. For detail description on the configuration bits, refer to “22.. Device Configuration Area” on page 101

11. BASIC INTERVAL TIMER

The MC80F0704/0708/0804/0808 has one 8-bit Basic Interval Timer that is free-run and can not stop. Block diagram is shown in Figure 11-1 . In addition, the Basic Interval Timer generates the time base for watchdog timer counting. It also provides a Basic interval timer interrupt (BITIF).

The 8-bit Basic interval timer register (BITR) is increased every internal count pulse which is divided by prescaler. Since prescaler has divided ratio by 8 to 1024, the count rate is 1/8 to 1/1024 of the oscillator frequency. As the count overflow from FFH to 00H, this overflow causes the interrupt to be generated.

The Basic Interval Timer is controlled by the clock control register (CKCTRL) shown in Figure 11-2. If the RCWDT bit is set to "1", the clock source of the BITR is changed to the internal RC oscillation.

When write "1" to bit BTCL of CKCTRL, BITR register is cleared to "0" and restart to count-up. The bit BTCL becomes "0" after one machine cycle by hardware.

If the STOP instruction executed after writing "1" to bit RCWDT of CKCTRL, it goes into the internal RC oscillated watchdog timer mode. In this mode, all of the block is halted except the internal RC oscillator, Basic Interval Timer and Watchdog Timer. More detail informations are explained in Power Saving Function. The bit WDTON decides Watchdog Timer or the normal 7-bit timer. Source clock can be selected by lower 3 bits of CKCTRL.

BITR and CKCTRL are located at same address, and address 0F2H is read as a BITR, and written to CKCTRL.

Note: All control bits of Basic interval timer are in CKCTRL register which is located at same address of BITR (address EC_H). Address EC_H is read as BITR, written to CKCTRL. Therefore, the CKCTRL can not be accessed by bit manipulation instruction.

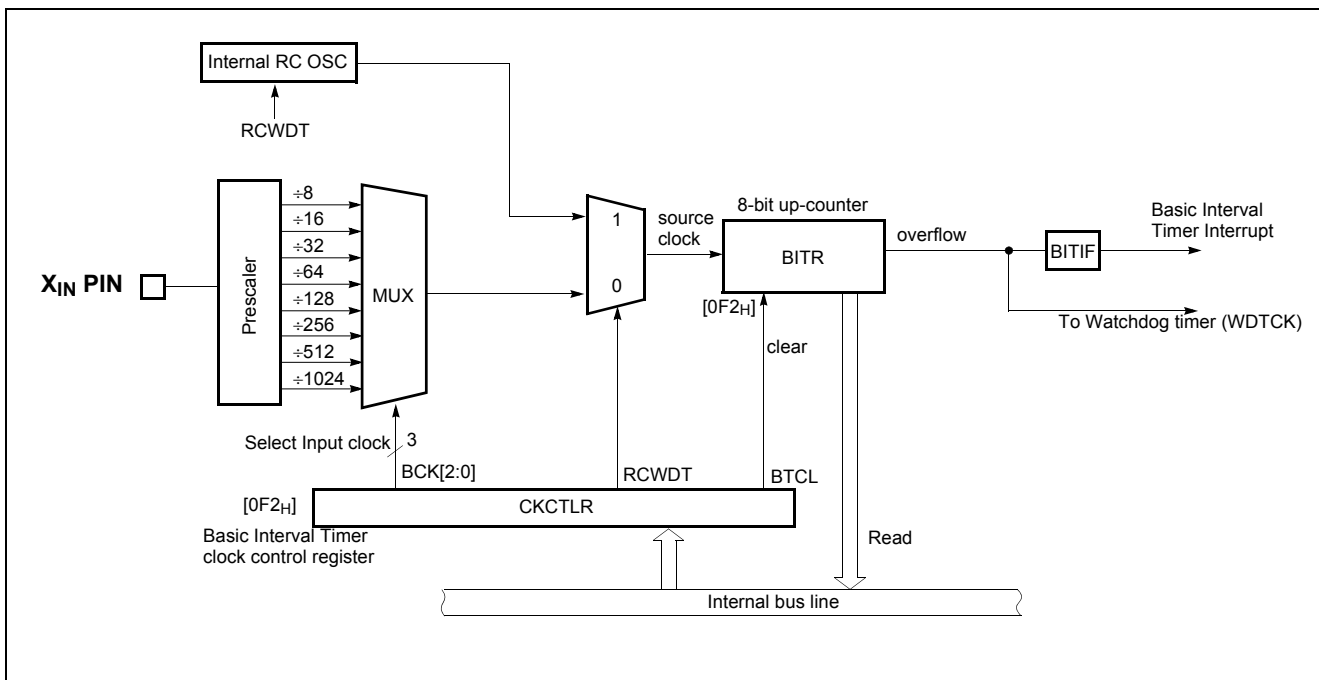


Figure 11-1 Block Diagram of Basic Interval Timer

| CKCTLR [2:0] | Source clock | Interrupt (overflow) Period (ms) @ $f_{XIN} = 8\text{MHz}$ |
|--------------|---------------------|---|
| 000 | $f_{XIN} \div 8$ | 0.256 |
| 001 | $f_{XIN} \div 16$ | 0.512 |
| 010 | $f_{XIN} \div 32$ | 1.024 |
| 011 | $f_{XIN} \div 64$ | 2.048 |
| 100 | $f_{XIN} \div 128$ | 4.096 |
| 101 | $f_{XIN} \div 256$ | 8.192 |
| 110 | $f_{XIN} \div 512$ | 16.384 |
| 111 | $f_{XIN} \div 1024$ | 32.768 |

Table 11-1 Basic Interval Timer Interrupt Period

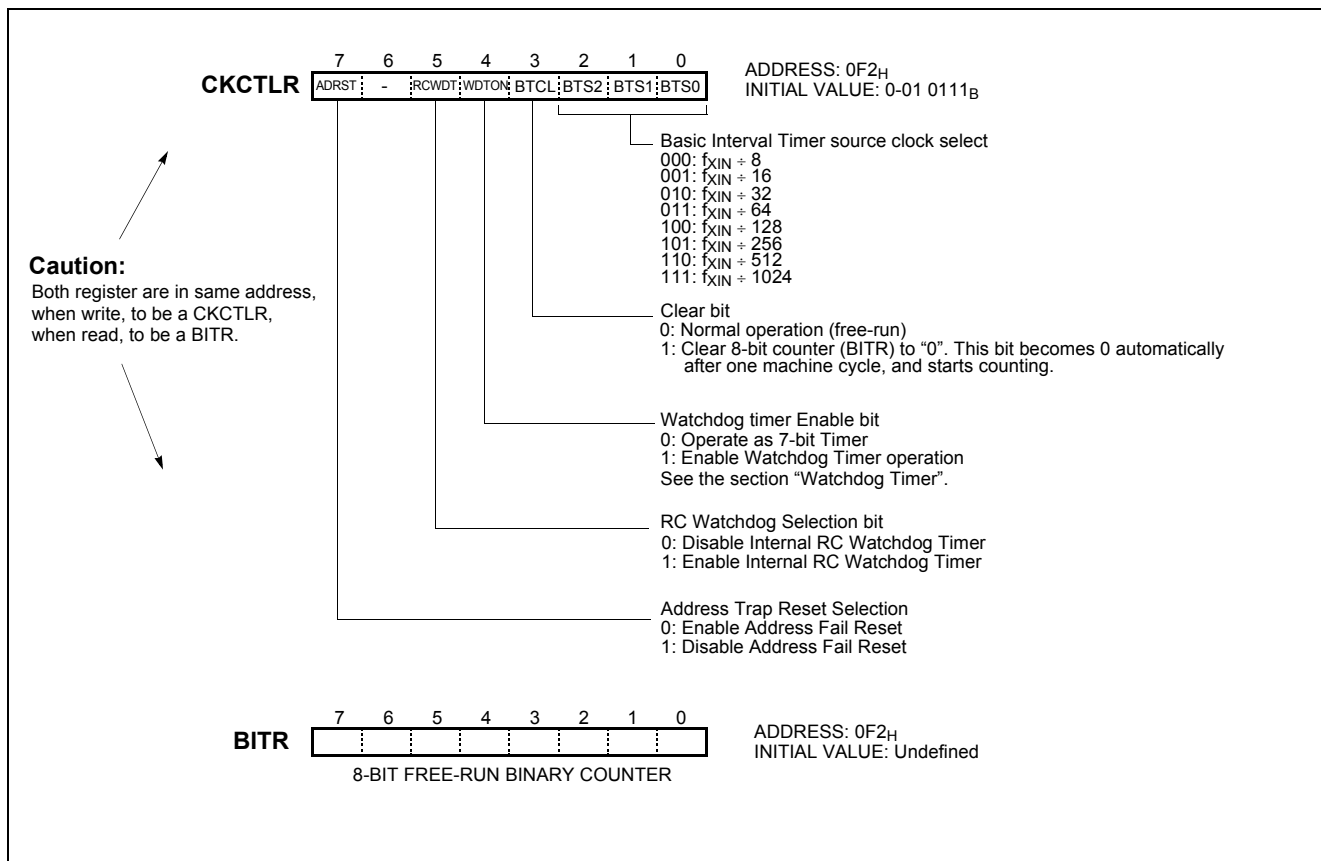


Figure 11-2 BITR: Basic Interval Timer Mode Register

Example 1:

Interrupt request flag is generated every 8.192ms at 4MHz.

```

:
LDM  CKCTLR, #1BH
SET1  BITE
EI
:
    
```

Example 2:

Interrupt request flag is generated every 8.192ms at 8MHz.

```

:
LDM  CKCTLR, #1CH
SET1  BITE
EI
:
    
```

12. WATCHDOG TIMER

The watchdog timer rapidly detects the CPU malfunction such as endless looping caused by noise or the like, and resumes the CPU to the normal state. The watchdog timer signal for detecting malfunction can be selected either a reset CPU or a 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.

The watchdog timer has two types of clock source. The first type is an on-chip RC oscillator which does not require any external components. This RC oscillator is separate from the external oscillator of the X_{IN} pin. It means that the watchdog timer will run, even if the clock on the X_{IN} pin of the device has been stopped, for example, by entering the STOP mode. The other type is a prescaled system clock.

The watchdog timer consists of 7-bit binary counter and the watchdog timer data register. When the value of 7-bit binary counter is equal to the lower 7 bits of WDTR, the interrupt request flag is generated. This can be used as Watchdog timer interrupt or reset the CPU in accordance with the bit WDTON.

Note: Because the watchdog timer counter is enabled after clearing Basic Interval Timer, after the bit WDTON set to "1", maximum error of timer is depend on prescaler ratio of Basic Interval Timer. The 7-bit binary counter is cleared by setting WDTCL(bit7 of WDTR) and the WDTCL is cleared automatically after 1 machine cycle.

The RC oscillated watchdog timer is activated by setting the bit

RCWDT as shown below.

```
LDM    CKCTLR, #3FH; enable the RC-OSC WDT
LDM    WDTR, #0FFH ; set the WDT period
LDM    SSCR, #5AH ; ready for STOP mode
STOP   ; enter the STOP mode
NOP
NOP    ; RC-OSC WDT running
:
```

The RC-WDT oscillation period is vary with temperature, V_{DD} and process variations from part to part (approximately, 33~100uS). The following equation shows the RCWDT oscillated watchdog timer time-out.

$$T_{RCWDT} = CLK_{RCWDT} \times 2^8 \times WDTR + (CLK_{RCWDT} \times 2^8) / 2$$

where, $CLK_{RCWDT} = 33 \sim 100 \mu S$

In addition, this watchdog timer can be used as a simple 7-bit timer by interrupt WDTIF. The interval of watchdog timer interrupt is decided by Basic Interval Timer. Interval equation is as below.

$$T_{WDT} = (WDTR + 1) \times \text{Interval of BIT}$$

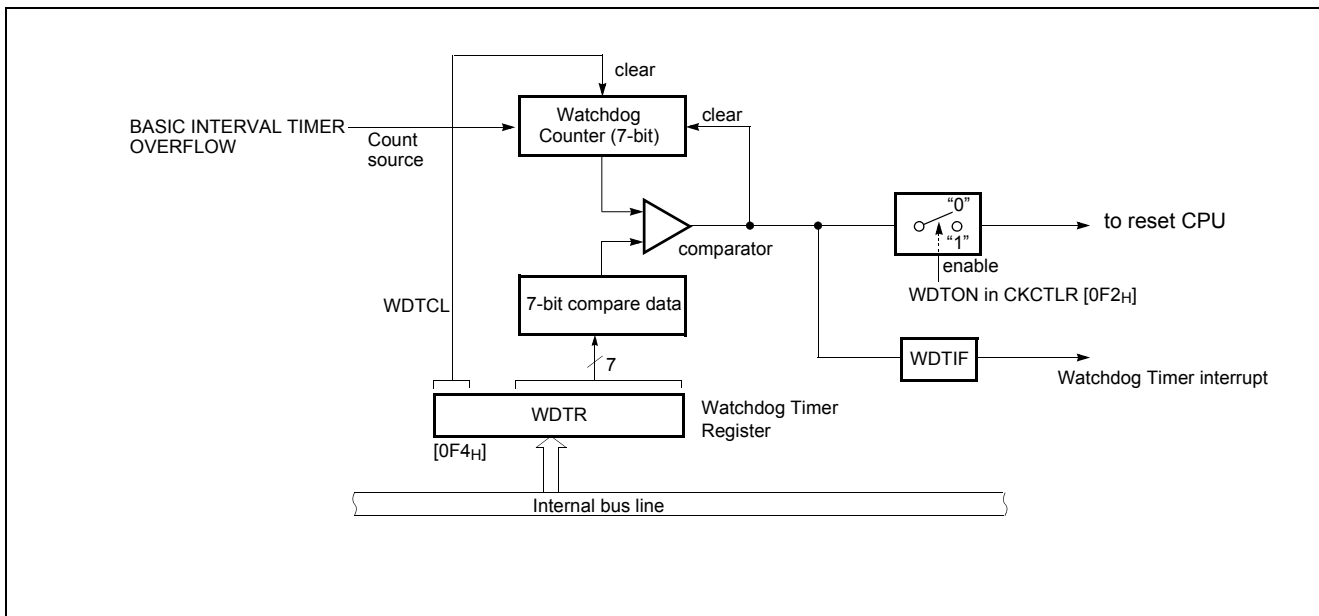


Figure 12-1 Block Diagram of Watchdog Timer

Watchdog Timer Control

Figure 12-2 shows the watchdog timer control register. The

watchdog timer is automatically disabled after reset.

The CPU malfunction is detected during setting of the detection

time, selecting of output, and clearing of the binary counter. Clearing the binary counter is repeated within the detection time.

If the malfunction occurs for any cause, the watchdog timer output will become active at the rising overflow from the binary counters unless the binary counter is cleared. At this time, when WDTON=1, a reset is generated, which drives the RESET pin to

low to reset the internal hardware. When WDTON=0, a watchdog timer interrupt (WDTIF) is generated. The WDTON bit is in register CLKCTLR.

The watchdog timer temporarily stops counting in the STOP mode, and when the STOP mode is released, it automatically restarts (continues counting).

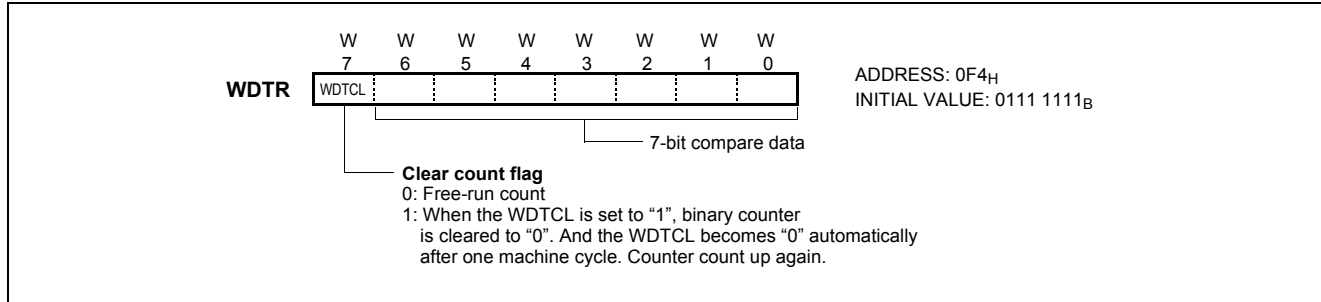


Figure 12-2 WDTR: Watchdog Timer Control Register

Example: Sets the watchdog timer detection time to 1 sec. at 4.194304MHz

```

LDM    CKCTLR, #3FH ; Select 1/1024 clock source, WDTON ← 1, Clear Counter
LDM    WDTR, #08FH

Within WDT detection time
:
:
LDM    WDTR, #08FH ; Clear counter
:
:
Within WDT detection time
:
:
LDM    WDTR, #08FH ; Clear counter
    
```

Enable and Disable Watchdog

Watchdog timer is enabled by setting WDTON (bit 4 in CKCTLR) to “1”. WDTON is initialized to “0” during reset and it should be set to “1” to operate after reset is released.

Example: Enables watchdog timer for Reset

```

:
LDM    CKCTLR, #xxx1_ xxxxB; WDTON ← 1
:
:
    
```

The watchdog timer is disabled by clearing bit 4 (WDTON) of CKCTLR. The watchdog timer is halted in STOP mode and restarts automatically after STOP mode is released.

Watchdog Timer Interrupt

The watchdog timer can be also used as a simple 7-bit timer by clearing bit4 of CKCTLR to “0”. The interval of watchdog timer interrupt is decided by Basic Interval Timer. Interval equation is shown as below.

$$T_{WDT} = (WDTR+1) \times Interval\ of\ BIT$$

The stack pointer (SP) should be initialized before using the watchdog timer output as an interrupt source.

Example: 7-bit timer interrupt set up.

```

LDM    CKCTLR, #xxx0_ xxxxB; WDTON ← 0
LDM    WDTR, #8FH ; WDTCL ← 1

:
    
```

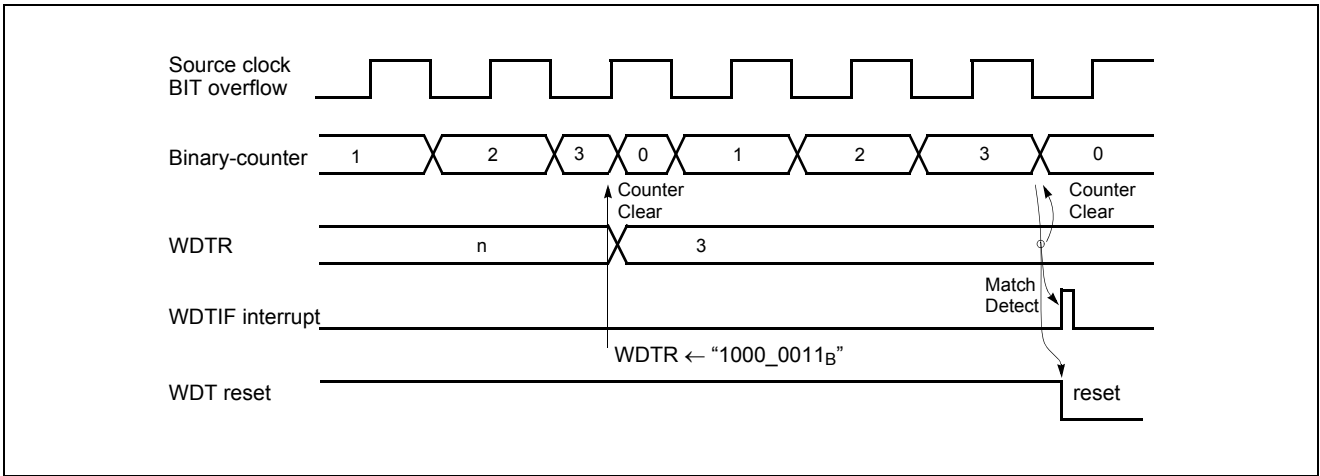


Figure 12-3 Watchdog timer Timing

If the watchdog timer output becomes active, a reset is generated, which drives the $\overline{\text{RESET}}$ pin low to reset the internal hardware.

set is generated in sub clock mode.

The main clock oscillator also turns on when a watchdog timer re-

13. TIMER/EVENT COUNTER

The MC80F0704/0708/0804/0808 has Four Timer/Counter registers. Each module can generate an interrupt to indicate that an event has occurred (i.e. timer match).

Timer 0 and Timer 1 are can be used either two 8-bit Timer/Counter or one 16-bit Timer/Counter with combine them. Also Timer 2 and Timer 3 are same. Timer 4 is 16-bit Timer/Counter.

In the “timer” function, the register is increased every internal clock input. Thus, one can think of it as counting internal clock input. Since a least clock consists of 2 and most clock consists of 2048 oscillator periods, the count rate is 1/2 to 1/2048 of the oscillator frequency.

In the “counter” function, the register is increased in response to a 0-to-1 (rising edge) transition at its corresponding external input pin, EC0 or EC1.

In addition the “capture” function, the register is increased in response external or internal clock sources same with timer or

counter function. When external clock edge input, the count register is captured into Timer data register correspondingly. When external clock edge input, the count register is captured into capture data register CDRx.

Timer 0 and Timer 1 is shared with "PWM" function and "Compare output" function. It has six operating modes: "8-bit timer/counter", "16-bit timer/counter", "8-bit capture", "16-bit capture", "8-bit compare output", and "10-bit PWM" which are selected by bit in Timer mode register TM0 and TM1 as shown in Table 13-1, Figure 13-1 .

Timer 2 and Timer 3 is shared with "PWM" function and "Compare output" function. It has six operating modes: "8-bit timer/counter", "16-bit timer/counter", "8-bit capture", "16-bit capture", "8-bit compare output", and "10-bit PWM" which are selected by bit in Timer mode register TM2 and TM3 as shown in Table 13-2, Figure 13-2 .

| 16BIT | CAP0 | CAP1 | PWM1E | T0CK [2:0] | T1CK [1:0] | PWM1O | TIMER 0 | TIMER 1 |
|-------|------|------|-------|------------|------------|-------|---------------------------------|----------------------|
| 0 | 0 | 0 | 0 | XXX | XX | 0 | 8-bit Timer | 8-bit Timer |
| 0 | 0 | 1 | 0 | 111 | XX | 0 | 8-bit Event counter | 8-bit Capture |
| 0 | 1 | 0 | 0 | XXX | XX | 1 | 8-bit Capture (internal clock) | 8-bit Compare Output |
| 0 | X | 0 | 1 | XXX | XX | 1 | 8-bit Timer/Counter | 10-bit PWM |
| 1 | 0 | 0 | 0 | XXX | 11 | 0 | 16-bit Timer | |
| 1 | 0 | 0 | 0 | 111 | 11 | 0 | 16-bit Event counter | |
| 1 | 1 | 1 | 0 | XXX | 11 | 0 | 16-bit Capture (internal clock) | |

Table 13-1 Operation Modes of Timer 0, 1

1. X means the value of “0” or “1” corresponds to user operation.

| 16BIT | CAP2 | CAP3 | PWM3E | T2CK [2:0] | T3CK [1:0] | PWM3O | TIMER 2 | TIMER 3 |
|-------|------|------|-------|------------|------------|-------|---------------------------------|----------------------|
| 0 | 0 | 0 | 0 | XXX | XX | 0 | 8-bit Timer | 8-bit Timer |
| 0 | 0 | 1 | 0 | 111 | XX | 0 | 8-bit Event counter | 8-bit Capture |
| 0 | 1 | 0 | 0 | XXX | XX | 1 | 8-bit Capture (internal clock) | 8-bit Compare Output |
| 0 | X | 0 | 1 | XXX | XX | 1 | 8-bit Timer/Counter | 10-bit PWM |
| 1 | 0 | 0 | 0 | XXX | 11 | 0 | 16-bit Timer | |
| 1 | 0 | 0 | 0 | 111 | 11 | 0 | 16-bit Event counter | |
| 1 | 1 | 1 | 0 | XXX | 11 | 0 | 16-bit Capture (internal clock) | |

Table 13-2 Operating Modes of Timer 2, 3

TM0

| | | | | | | | |
|-----|-----|------|-------|-------|-------|------|------|
| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
| 5 | 4 | 3 | 2 | 1 | 0 | | |
| - | - | CAP0 | T0CK2 | T0CK1 | T0CK0 | T0CN | T0ST |

ADDRESS: 0D0_H
INITIAL VALUE: --00 0000_B

| Bit Name | Bit Position | Description |
|----------|--------------|---|
| CAP0 | TM0.5 | 0: Timer/Counter mode 1: Capture mode selection flag |
| T0CK2 | TM0.4 | 000: 8-bit Timer, Clock source is $f_{XIN} \div 2$ |
| T0CK1 | TM0.3 | 001: 8-bit Timer, Clock source is $f_{XIN} \div 4$ |
| T0CK0 | TM0.2 | 010: 8-bit Timer, Clock source is $f_{XIN} \div 8$ 011: 8-bit Timer, Clock source is $f_{XIN} \div 32$ 100: 8-bit Timer, Clock source is $f_{XIN} \div 128$ 101: 8-bit Timer, Clock source is $f_{XIN} \div 512$ 110: 8-bit Timer, Clock source is $f_{XIN} \div 2048$ 111: EC0 (External clock) |
| T0CN | TM0.1 | 0: Timer count pause 1: Timer count start |
| T0ST | TM0.0 | 0: When cleared, stop the counting. 1: When set, Timer 0 Count Register is cleared and start again. |

TM1

| | | | | | | | | |
|-----|-------|-------|------|-------|-------|------|------|-----|
| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| POL | 16BIT | PWM1E | CAP1 | T1CK1 | T1CK0 | T1CN | T1ST | |

ADDRESS: 0D2_H
INITIAL VALUE: 00_H

| Bit Name | Bit Position | Description |
|----------|--------------|--|
| POL | TM1.7 | 0: PWM Duty Active Low 1: PWM Duty Active High |
| 16BIT | TM1.6 | 0: 8-bit Mode 1: 16-bit Mode |
| PWM1E | TM1.5 | 0: Disable PWM 1: Enable PWM |
| CAP1 | TM1.4 | 0: Timer/Counter mode 1: Capture mode selection flag |
| T1CK1 | TM1.3 | 00: 8-bit Timer, Clock source is f_{XIN} |
| T1CK0 | TM1.2 | 01: 8-bit Timer, Clock source is $f_{XIN} \div 2$ 10: 8-bit Timer, Clock source is $f_{XIN} \div 8$ 11: 8-bit Timer, Clock source is Using the Timer 0 Clock |
| T1CN | TM1.1 | 0: Timer count pause 1: Timer count start |
| T1ST | TM1.0 | 0: When cleared, stop the counting. 1: When set, Timer 0 Count Register is cleared and start again. |

| | | | | | | | | |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|
| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| TDR0 | □ | □ | □ | □ | □ | □ | □ | □ |

ADDRESS: 0D1_H
INITIAL VALUE: 0FF_H

| | | | | | | | | |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|
| R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W |
| 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| TDR1 | □ | □ | □ | □ | □ | □ | □ | □ |

ADDRESS: 0D3_H
INITIAL VALUE: 0FF_H

Read: Count value read
Write: Compare data write

Figure 13-1 TM0, TM1 Registers

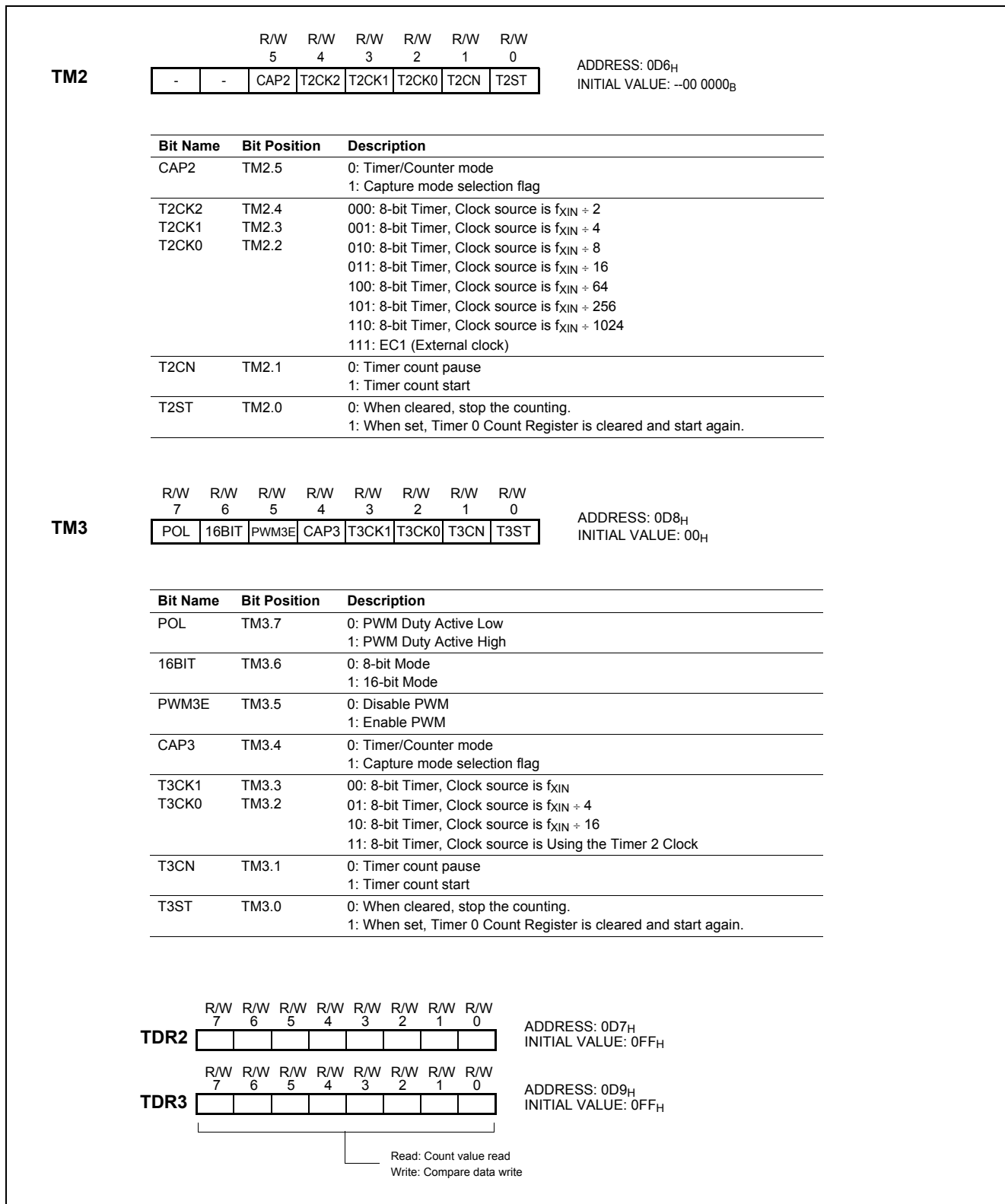


Figure 13-2 TM2, TM3 Registers

13.1 8-bit Timer / Counter Mode

The MC80F0704/0708/0804/0808 has four 8-bit Timer/Counters, Timer 0, Timer 1, Timer 2, Timer 3. The Timer 0, Timer 1 are shown in Figure 13-3 and Timer 2, Timer 3 are shown in Figure 13-4.

The “timer” or “counter” function is selected by control registers TM0, TM1, TM2, TM3 as shown in Figure 13-1. To use as an 8-bit timer/counter mode, bit CAP0, CAP1, CAP2, or CAP3 of TMx should be cleared to “0” and 16BIT and PWM1E or

PWM3E of TM1 or TM3 should be cleared to “0” (Figure 13-3). These timers have each 8-bit count register and data register. The count register is increased by every internal or external clock input. The internal clock has a prescaler divide ratio option of 1, 2, 4, 8, 16, 32, 64, 128, 256, 512, 1024, 2048 or external clock (selected by control bits TxCK0, TxCK1, TxCK2 of register TMx).

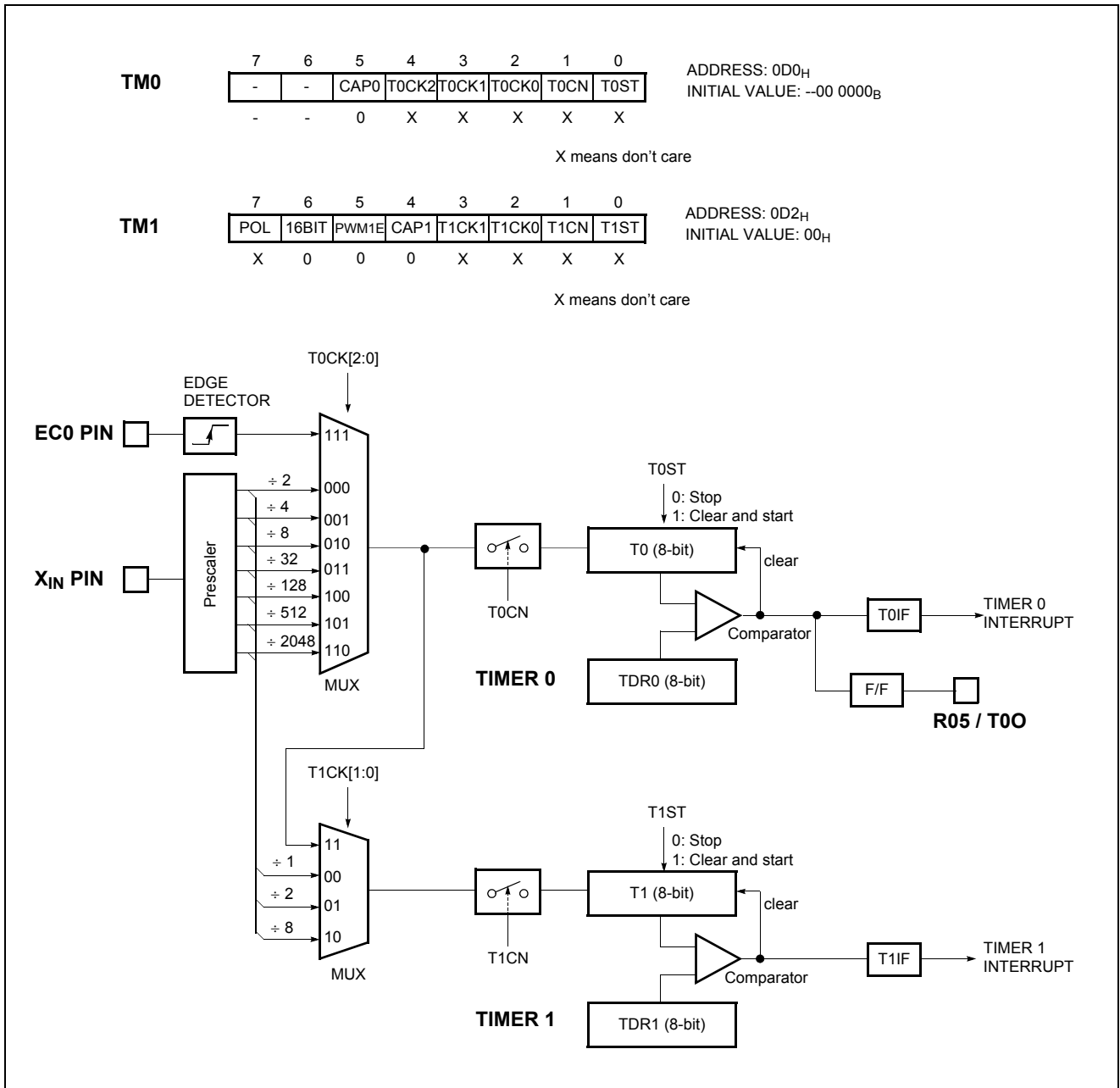


Figure 13-3 8-bit Timer/Counter 0, 1

| | | | | | | | | | |
|------------|---|---|------|-------|-------|-------|------|------|--|
| TM2 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | ADDRESS: 0D6H INITIAL VALUE: --00000B |
| | - | - | CAP2 | T2CK2 | T2CK1 | T2CK0 | T2CN | T2ST | |
| | - | - | 0 | X | X | X | X | X | X means don't care |

| | | | | | | | | | |
|------------|-----|-------|-------|------|-------|-------|------|------|-------------------------------------|
| TM3 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | ADDRESS: 0D8H INITIAL VALUE: 00H |
| | POL | 16BIT | PWM3E | CAP3 | T3CK1 | T3CK0 | T3CN | T3ST | |
| | X | 0 | 0 | 0 | X | X | X | X | X means don't care |

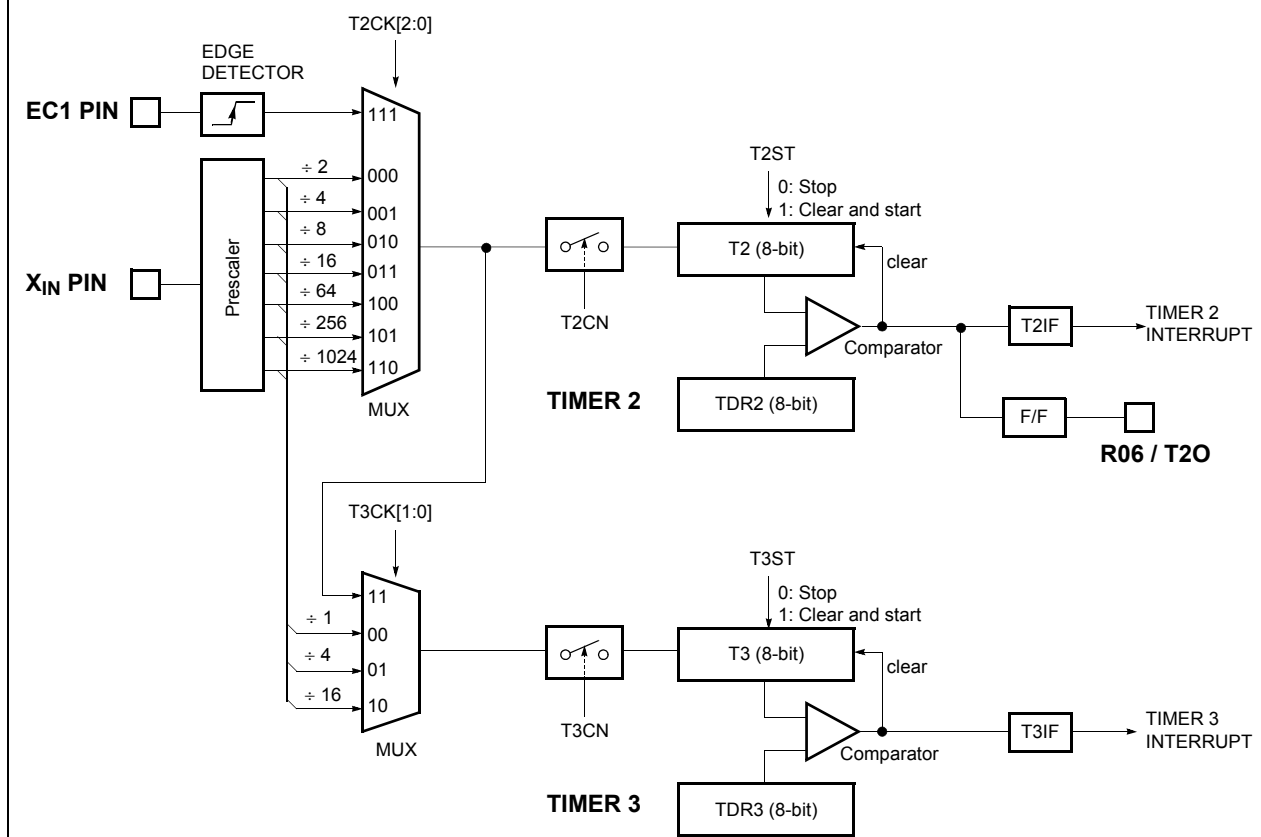


Figure 13-4 8-bit Timer/Counter 2, 3

Example 1:

Timer0 = 2ms 8-bit timer mode at 4MHz
 Timer1 = 0.5ms 8-bit timer mode at 4MHz
 Timer2 = 1ms 8-bit timer mode at 4MHz
 Timer3 = 1ms 8-bit timer mode at 4MHz

```
LDM TDR0, #249
LDM TDR1, #249
LDM TDR2, #249
LDM TDR3, #249
LDM TM0, #0000_1111B
LDM TM1, #0000_1011B
LDM TM2, #0000_1111B
LDM TM3, #0000_1011B
SET1 T0E
SET1 T1E
SET1 T2E
SET1 T3E
EI
```

Example 2:

Timer0 = 8-bit event counter mode
 Timer1 = 0.5ms 8-bit timer mode at 4MHz
 Timer2 = 8-bit event counter mode
 Timer3 = 1ms 8-bit timer mode at 4MHz

```
LDM TDR0, #249
LDM TDR1, #249
LDM TDR2, #249
LDM TDR3, #249
LDM TM0, #0001_1111B
LDM TM1, #0000_1011B
LDM TM2, #0001_1111B
LDM TM3, #0000_1011B
SET1 T0E
SET1 T1E
SET1 T2E
SET1 T3E
EI
```

These timers have each 8-bit count register and data register. The count register is increased by every internal or external clock input. The internal clock has a prescaler divide ratio option of 2, 4, 8, 32, 128, 512, 2048 selected by control bits T0CK[2:0] of register TM0 or 1, 2, 8 selected by control bits T1CK[1:0] of register TM1, or 2, 4, 8, 16, 64, 256, 1024 selected by control bits T2CK[2:0] of register TM2, or 1, 4, 16 selected by control bits T3CK[1:0] of register TM3. In the Timer 0, timer register T0 increases from 00_H until it matches TDR0 and then reset to 00_H. The match output of Timer 0 generates Timer 0 interrupt (latched in TOIF bit).

In counter function, the counter is increased every 0-to-1 (rising edge) transition of EC0 pin. In order to use counter function, the bit EC0 of the Port Selection Register (PSR0.4) is set to "1". The Timer 0 can be used as a counter by pin EC0 input, but Timer 1 can not. Likewise, In order to use Timer2 as counter function, the bit EC1 of the Port Selection Register (PSR0.5) is set to "1". The Timer 2 can be used as a counter by pin EC1 input, but Timer 3 can not.

8-bit Timer Mode

In the timer mode, the internal clock is used for counting up. Thus, you can think of it as counting internal clock input. The contents of TDR_n are compared with the contents of up-counter, T_n. If match is found, a timer *n* interrupt (T_nIF) is generated and the up-counter is cleared to 0. Counting up is resumed after the up-counter is cleared.

As the value of TDR_n is changeable by software, time interval is set as you want.

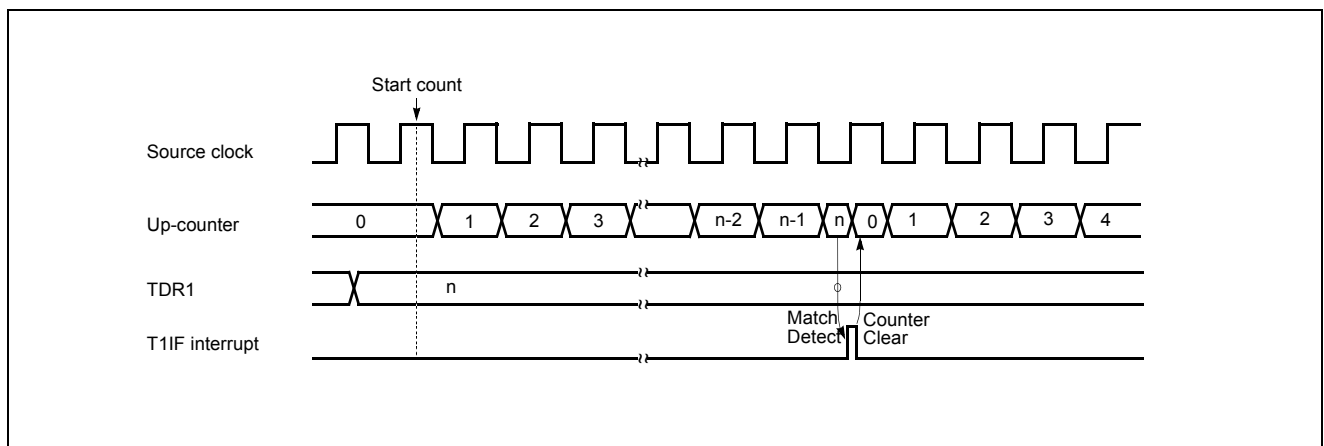


Figure 13-5 Timer Mode Timing Chart

Example: Make 1ms interrupt using by Timer0 at 4MHz

```

LDM    TM0, #0FH    ; divide by 32
LDM    TDR0, #124   ; 8us x (124+1) = 1ms
SET1   TOE         ; Enable Timer 0 Interrupt
EI     ; Enable Master Interrupt
    
```

When $\left\{ \begin{array}{l} TM0 = 0000\ 1111_B \text{ (8-bit Timer mode, Prescaler divide ratio} = 32) \\ TDR0 = 124_D = 7C_H \\ f_{XIN} = 4 \text{ MHz} \end{array} \right.$

$$\text{INTERRUPT PERIOD} = \frac{1}{4 \times 10^6 \text{ Hz}} \times 32 \times (124+1) = 1 \text{ ms}$$

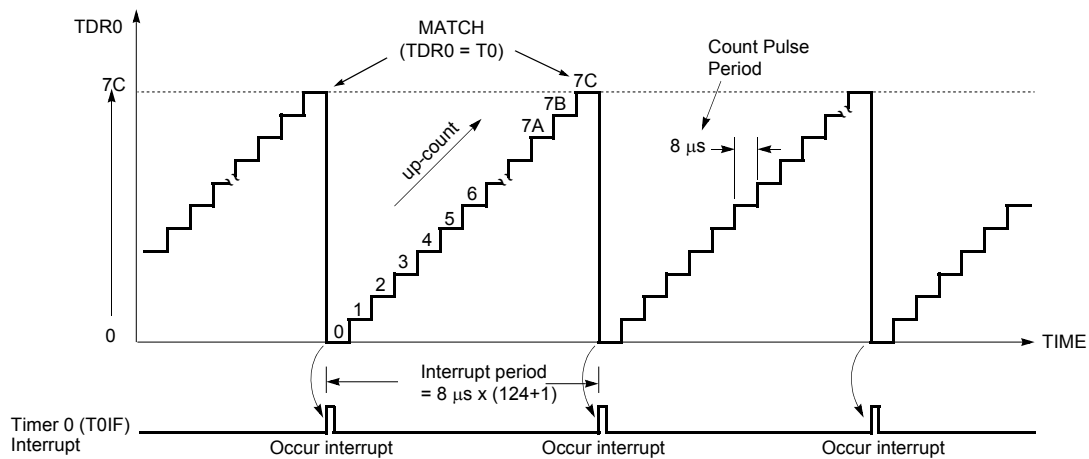


Figure 13-6 Timer Count Example

8-bit Event Counter Mode

In this mode, counting up is started by an external trigger. This trigger means rising edge of the EC0 or EC1 pin input. Source clock is used as an internal clock selected with timer mode register TM0 or TM2. The contents of timer data register TDRn (n = 0,1,2,3) are compared with the contents of the up-counter Tn. If a match is found, an timer interrupt request flag TnIF is generated, and the counter is cleared to “0”. The counter is restart and count up continuously by every rising edge of the EC0 or EC1 pin input. The maximum frequency applied to the EC0 or EC1 pin is $f_{XIN}/2$ [Hz].

In order to use event counter function, the bit 4, 5 of the Port Selection Register PSR0(address 0F8H) is required to be set to “1”.

After reset, the value of timer data register TDRn is initialized to "0", The interval period of Timer is calculated as below equation.

$$\text{Period (sec)} = \frac{1}{f_{XIN}} \times 2 \times \text{Divide Ratio} \times (TDRn + 1)$$

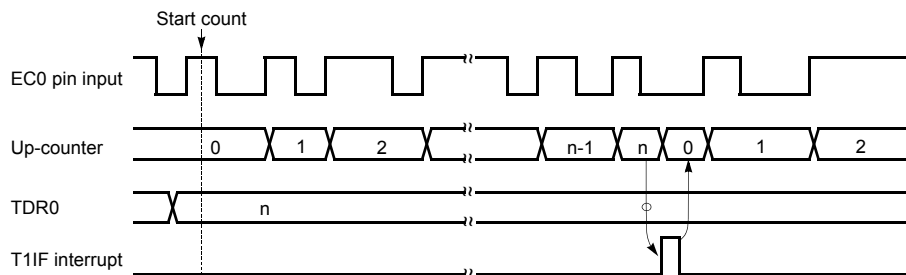


Figure 13-7 Event Counter Mode Timing Chart

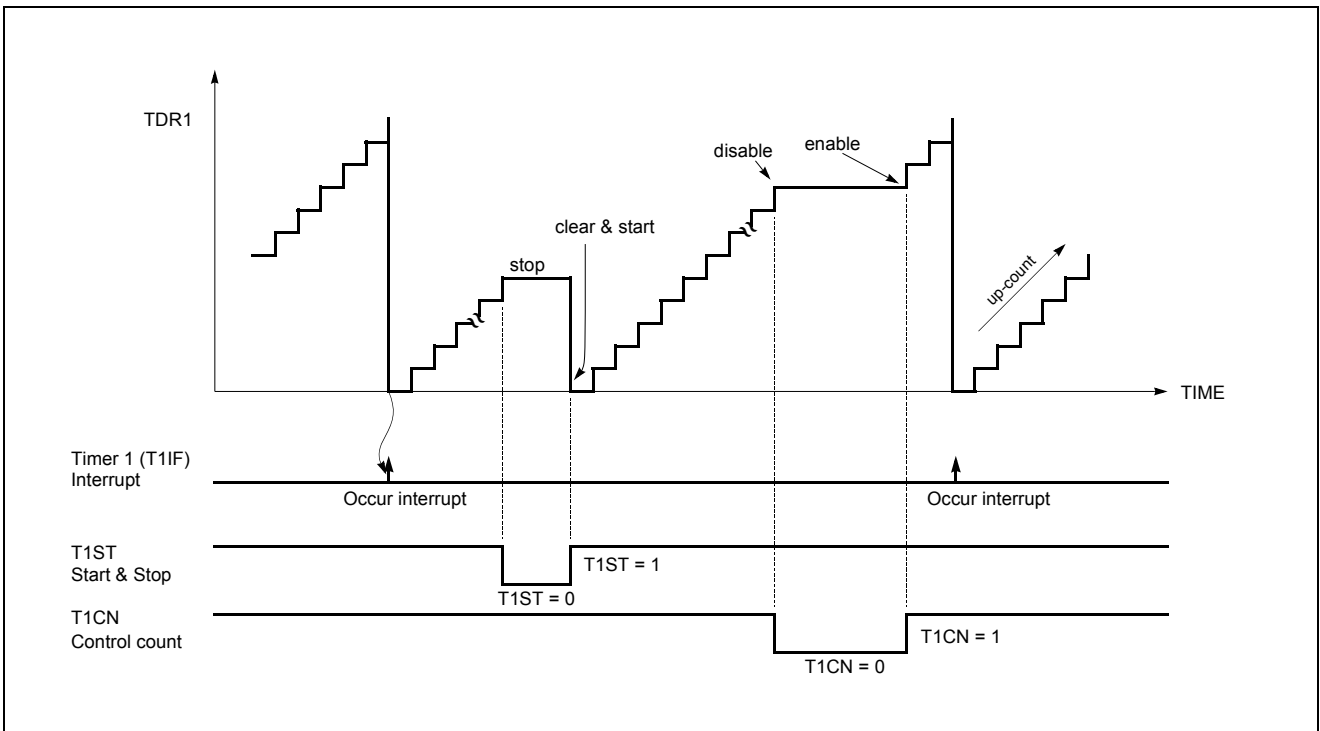


Figure 13-8 Count Operation of Timer / Event counter

13.2 16-bit Timer / Counter Mode

The Timer register is being run with all 16 bits. A 16-bit timer/counter register T0, T1 are incremented from 0000_H until it matches TDR0, TDR1 and then resets to 0000_H. The match output generates Timer 0 interrupt.

The clock source of the Timer 0 is selected either internal or external clock by bit T0CK[2:0]. In 16-bit mode, the bits T1CK[1:0] and 16BIT of TM3 should be set to "1" respectively as shown in Figure 13-9 .

Likewise, A 16-bit timer/counter register T2, T3 are incremented from 0000_H until it matches TDR2, TDR3 and then resets to 0000_H. The match output generates Timer 2 interrupt.

The clock source of the Timer 2 is selected either internal or external clock by bit T2CK[2:0]. In 16-bit mode, the bits T3CK[1:0] and 16BIT of TM3 should be set to "1" respectively as shown in Figure 13-10 .

Even if the Timer 0 (including Timer 1) is used as a 16-bit timer, the Timer 2 and Timer 3 can still be used as either two 8-bit timer or one 16-bit timer by setting the TM3. Reversely, even if the Timer 2 (including Timer 3) is used as a 16-bit timer, the Timer 0 and Timer 1 can still be used as 8-bit timer independently.

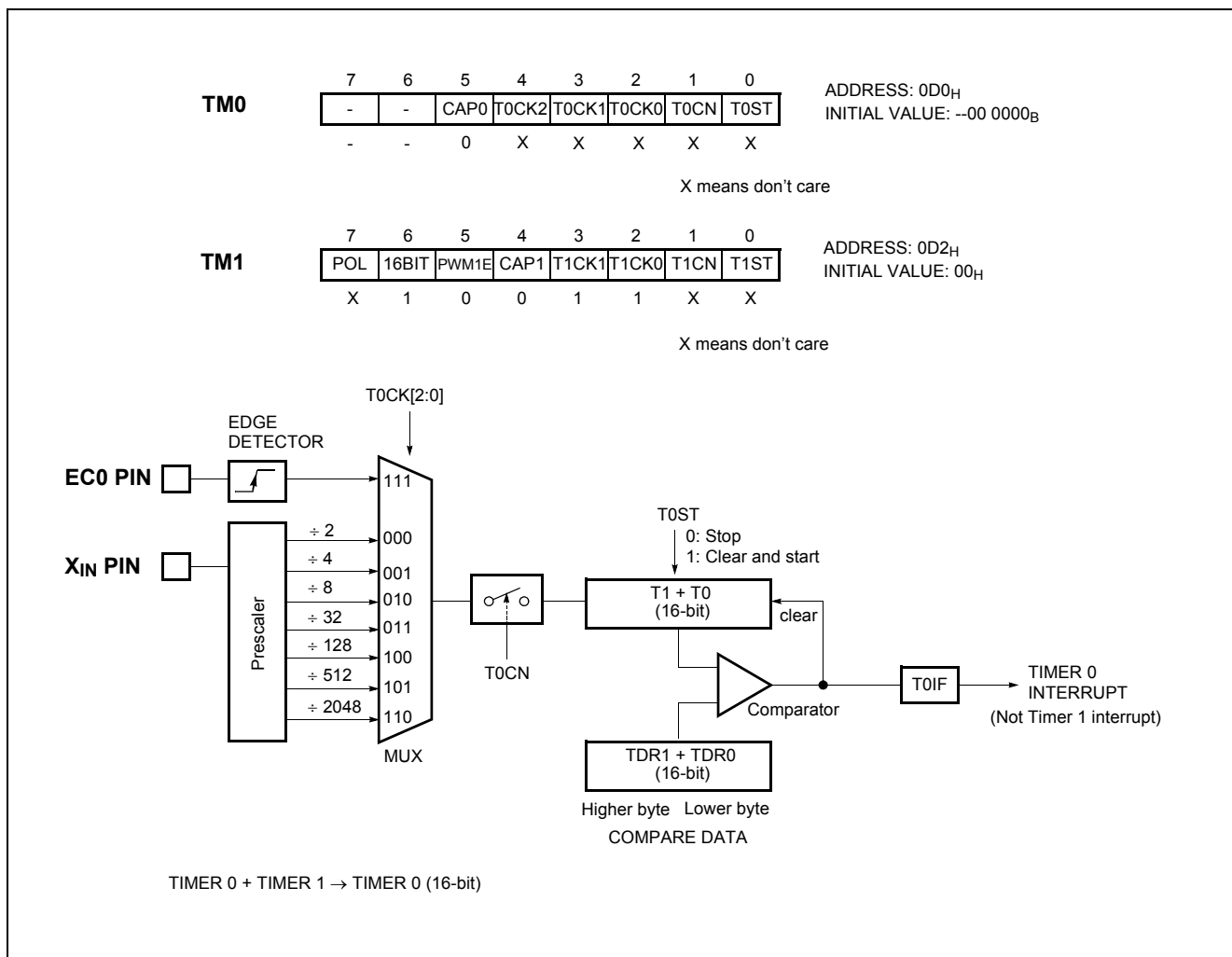


Figure 13-9 16-bit Timer/Counter for Timer 0, 1

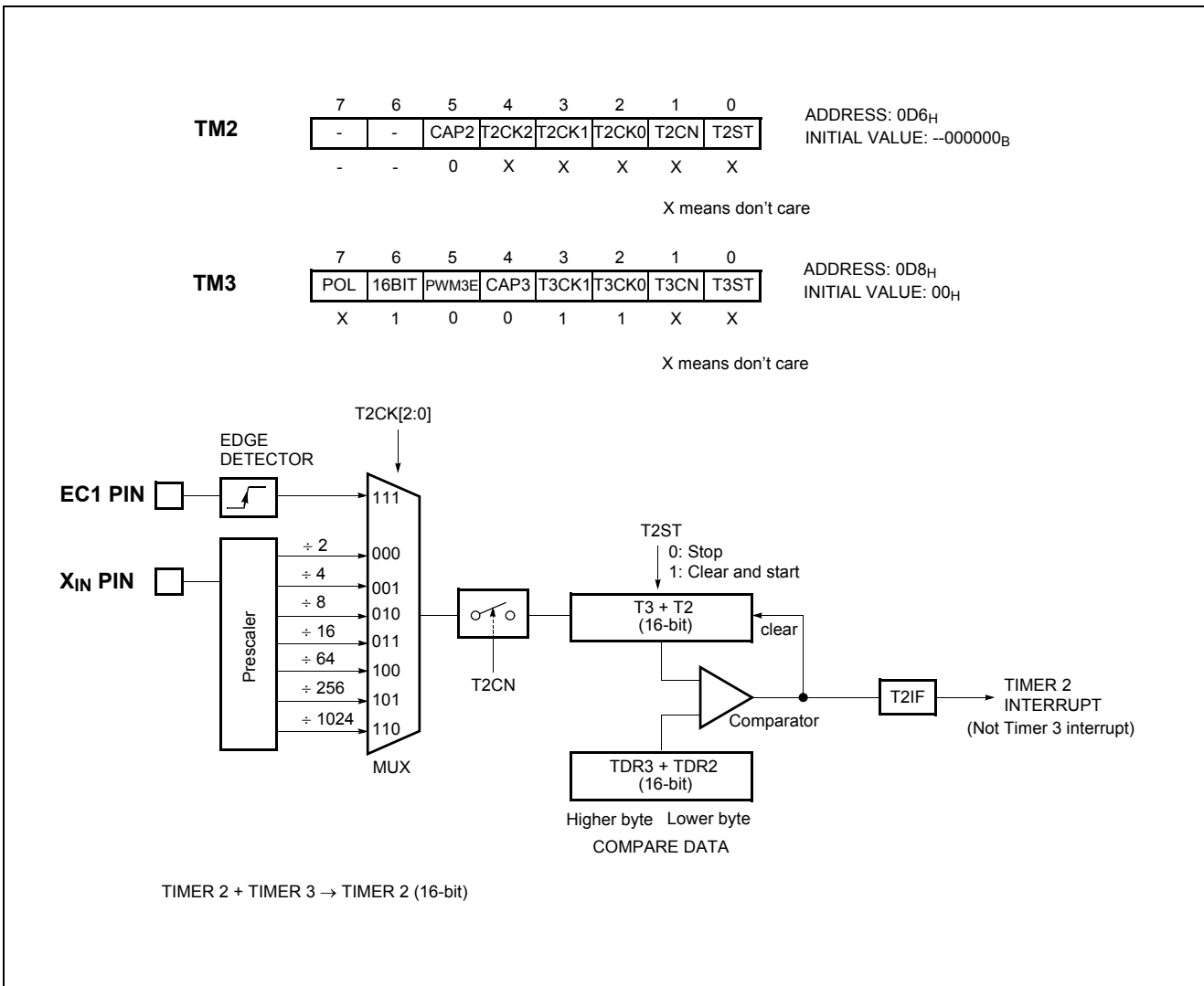


Figure 13-10 16-bit Timer/Counter for Timer 2, 3

13.3 8-bit Compare Output (16-bit)

The MC80F0704/0708/0804/0808 has Timer Compare Output function. To pulse out, the timer match can go to port pin (T0O or T2O) as shown in Figure 13-3 or Figure 13-4. Thus, pulse out is generated by the timer match. These operation is implemented to pin, R05/AN5//T0O or R06/AN6//T2O.

In this mode, the bit T0OE or T2OE bit of Port Selection register1 (PSR1.0 or PSR1.1) should be set to "1". This pin output the sig-

nal having a 50 : 50 duty square wave, and output frequency is same as below equation.

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

13.4 8-bit Capture Mode

The Timer 0 capture mode is set by bit CAP0 of timer mode register TM0 (bit CAP1 of timer mode register TM1 for Timer 1) as shown in Figure 13-11. Likewise, the Timer 2 capture mode is set by bit CAP2 of timer mode register TM2 (bit CAP3 of timer mode register TM3 for Timer 3) as shown in Figure 13-12.

The Timer/Counter register is increased in response internal or

external input. This counting function is same with normal timer mode, and Timer interrupt is generated when timer register T0 (T1, T2, T3) increases and matches TDR0 (TDR1, TDR2, TDR3).

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

of Timer.

For example, in Figure 13-14, the pulse width of captured signal is wider than the timer data value (FF_H) over 2 times. When external interrupt is occurred, the captured value (13_H) is more little than wanted value. It can be obtained correct value by counting the number of timer overflow occurrence.

Timer/Counter still does the above, but with the added feature that a edge transition at external input $INTx$ pin causes the current value in the Timer x register ($T0, T1, T2, T3$), to be captured into registers $CDRx$ ($CDR0, CDR1, CDR2, CDR3$), respectively. Af-

ter captured, Timer x register is cleared and restarts by hardware. It has three transition modes: "falling edge", "rising edge", "both edge" which are selected by interrupt edge selection register $IEDS$. Refer to "17.4 External Interrupt" on page 85. In addition, the transition at $INTn$ pin generate an interrupt.

Note: The $CDRn$ and $TDRn$ are in same address. In the capture mode, reading operation is read the $CDRn$, not $TDRn$ because path is opened to the $CDRn$.

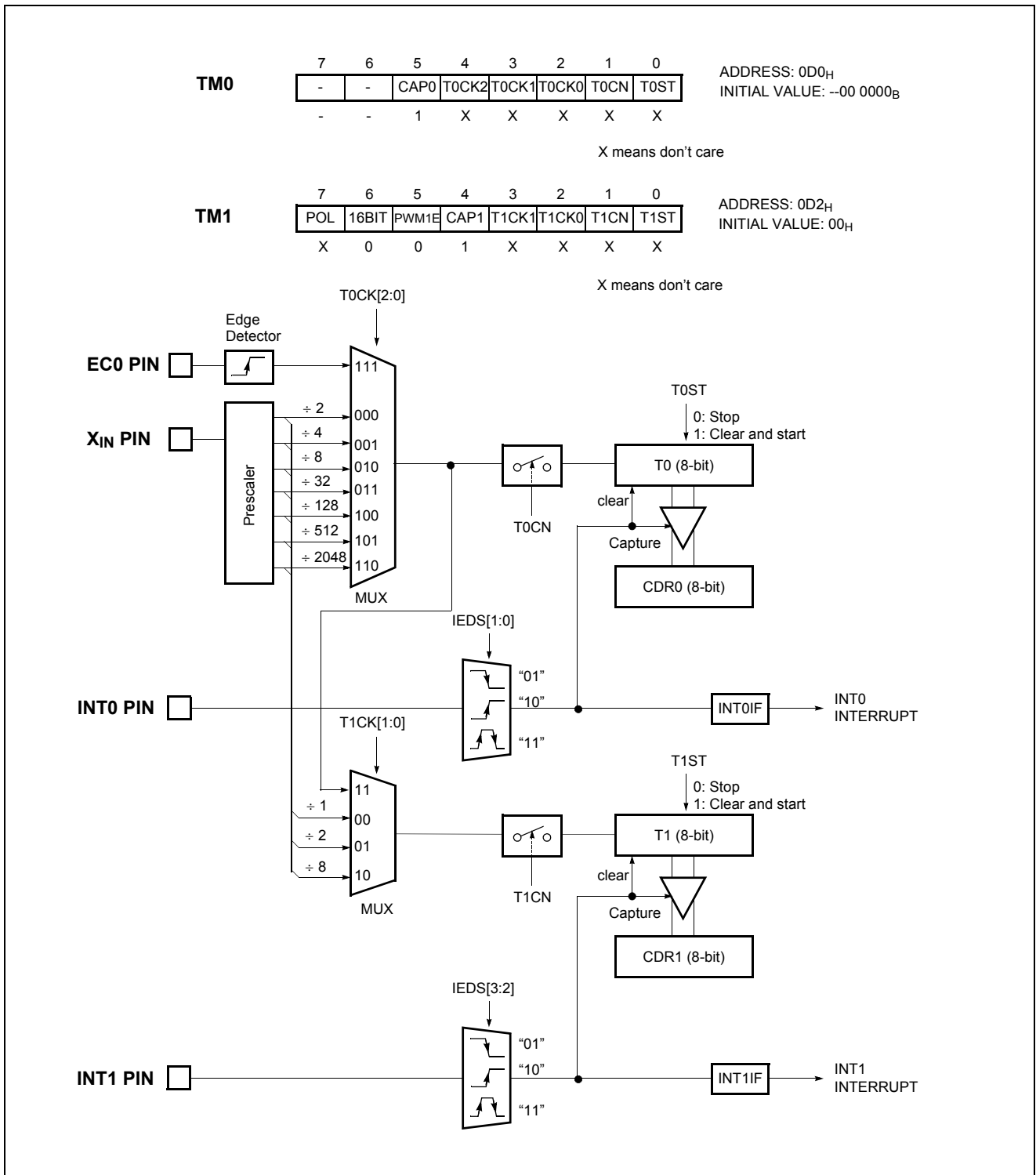


Figure 13-11 8-bit Capture Mode for Timer 0, 1

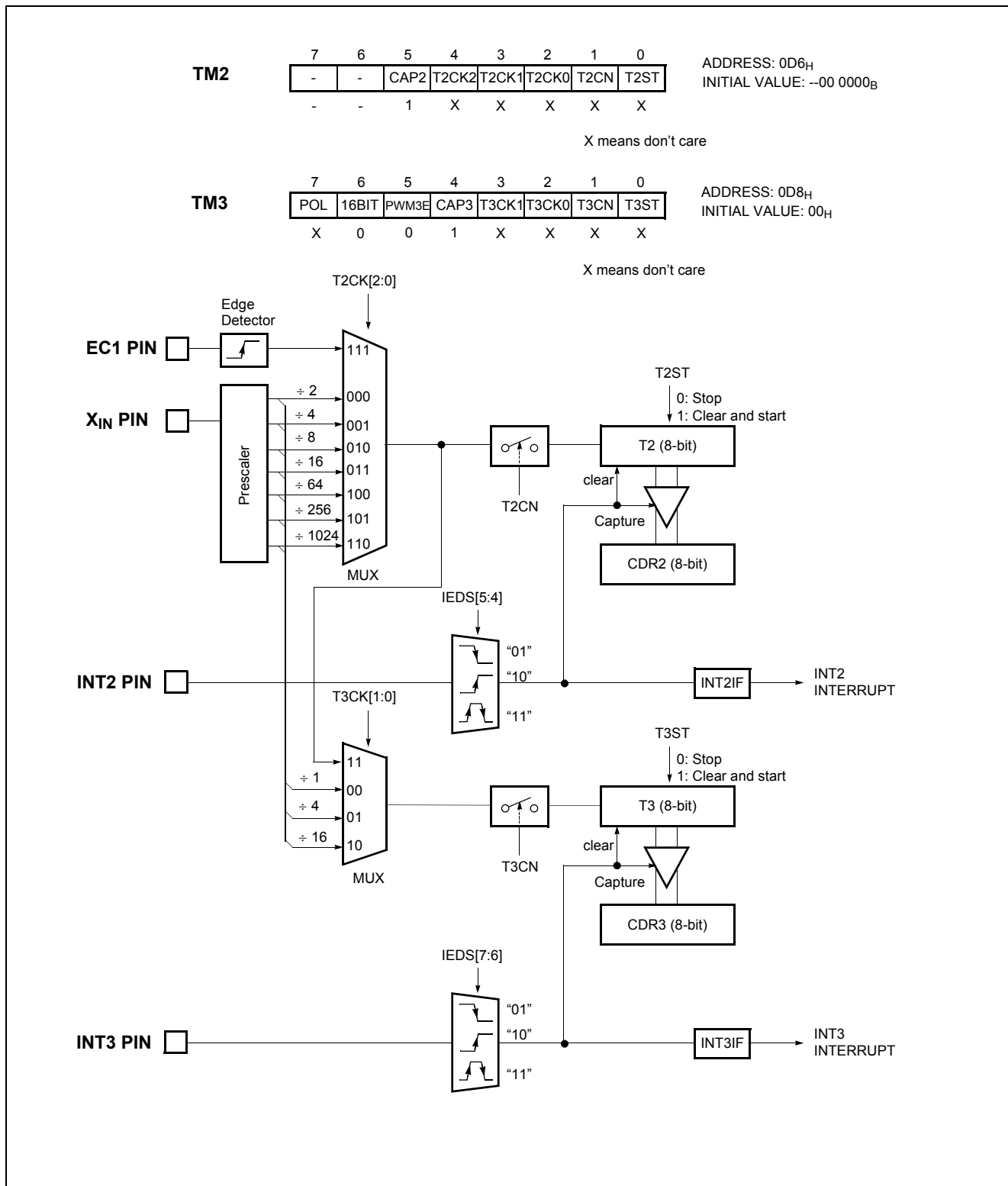


Figure 13-12 8-bit Capture Mode for Timer 2, 3

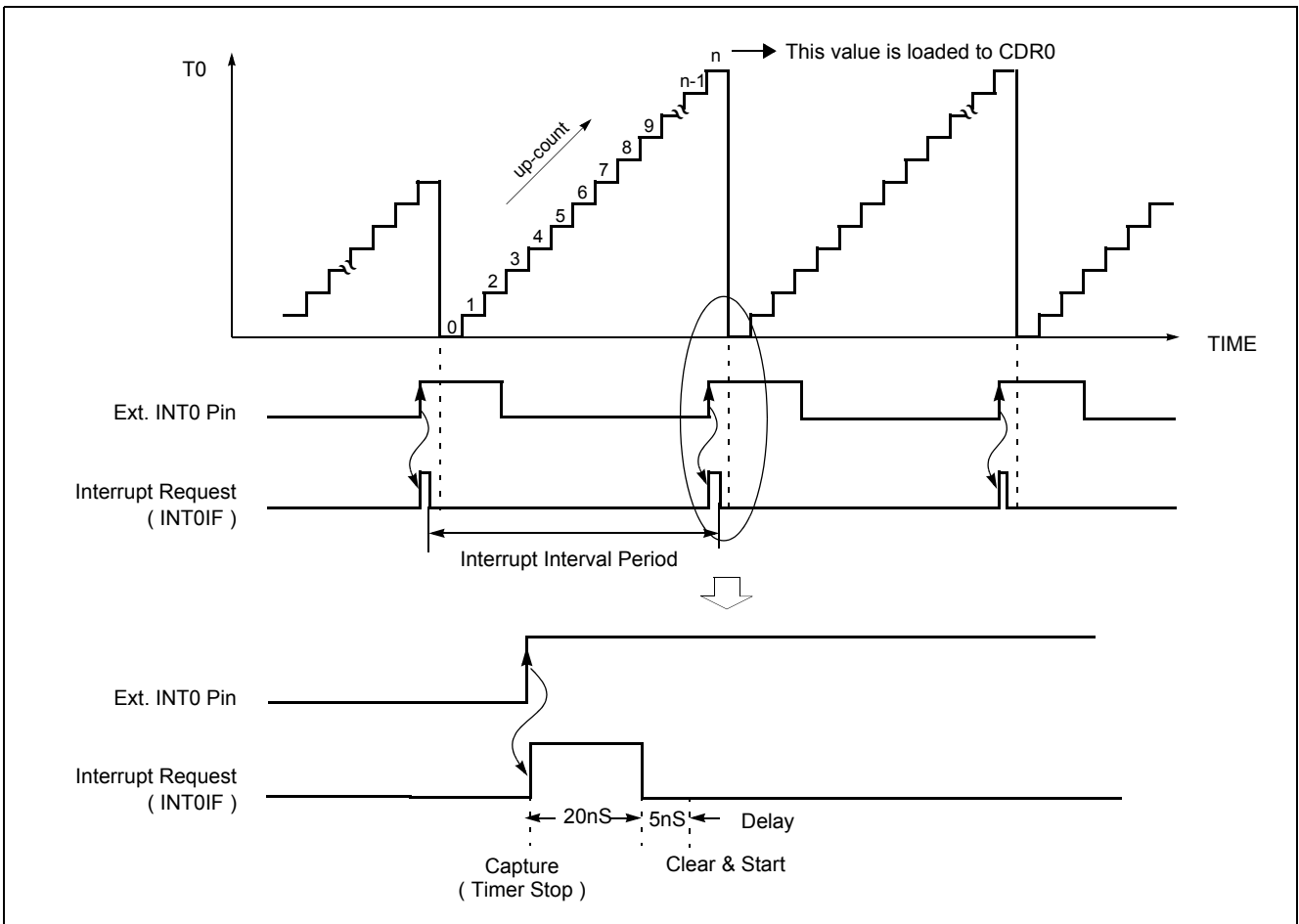


Figure 13-13 Input Capture Operation of Timer 0 Capture mode

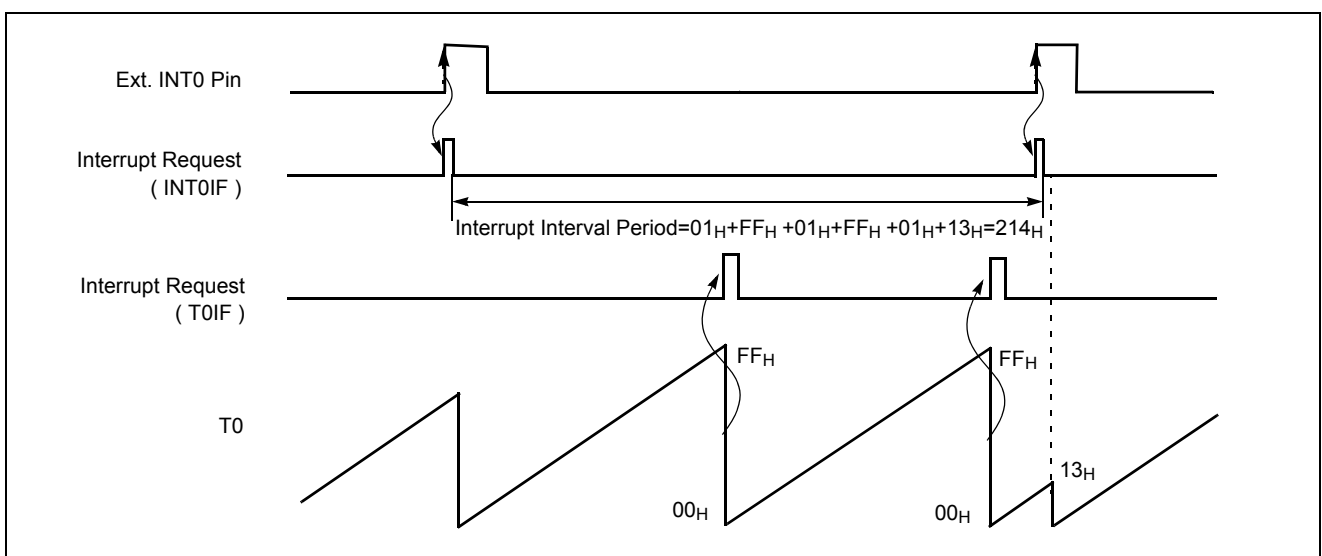


Figure 13-14 Excess Timer Overflow in Capture Mode

13.5 16-bit Capture Mode

16-bit capture mode is the same as 8-bit capture, except that the Timer register is being run will 16 bits. The clock source of the Timer 0 is selected either internal or external clock by bit T0CK[2:0]. In 16-bit mode, the bits T1CK1, T1CK0, CAP1 and 16BIT of TM1 should be set to "1" respectively as shown in Figure 13-15 .

The clock source of the Timer 2 is selected either internal or external clock by bit T2CK[2:0]. In 16-bit mode, the bits T3CK1, T3CK0, CAP3 and 16BIT of TM3 should be set to "1" respectively as shown in Figure 13-16 .

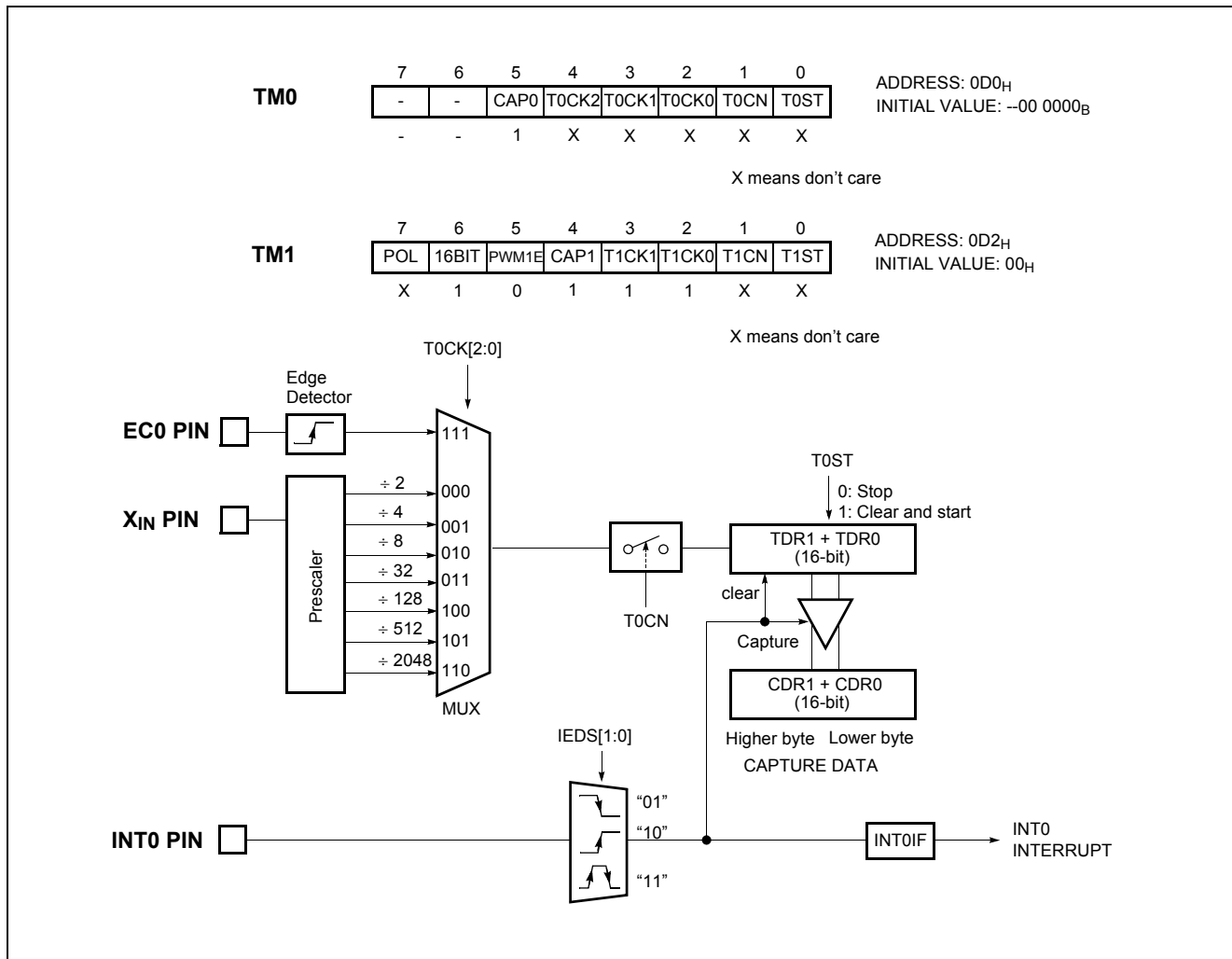


Figure 13-15 16-bit Capture Mode of Timer 0, 1

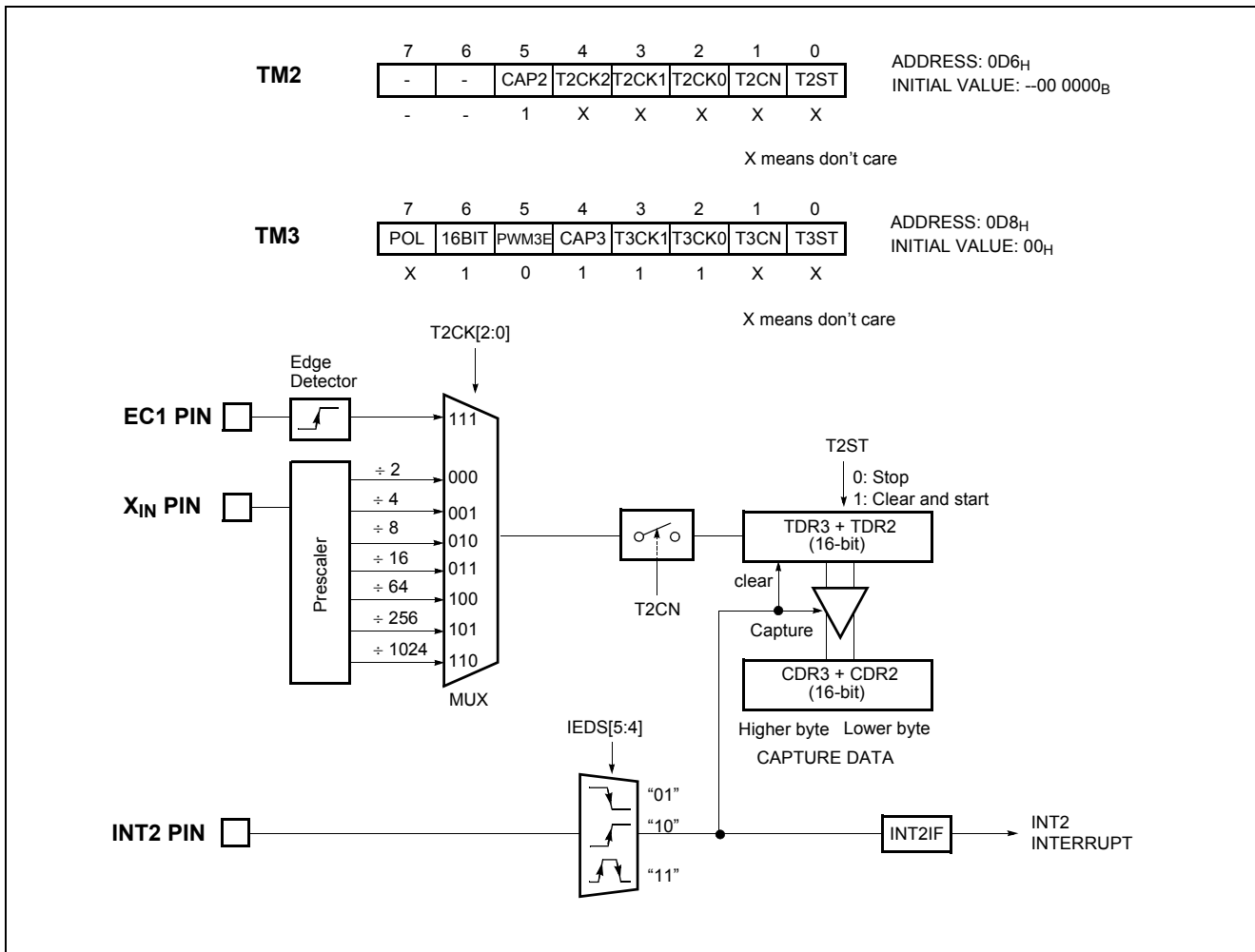


Figure 13-16 16-bit Capture Mode of Timer 2, 3

Example 1:

Timer0 = 16-bit timer mode, 0.5s at 4MHz

```

LDM  TM0,#0000_1111B;8uS
LDM  TM1,#0100_1100B;16bit Mode
LDM  TDR0,#<62499 ;8uS X 62500
LDM  TDR1,#>62499 ;=0.5s
SET1  T0E
EI
:
:

```

Example 2:

Timer0 = 16-bit event counter mode

```

LDM  PSR0,#0001_0000B;EC0 Set
LDM  TM0,#0001_1111B;Counter Mode
LDM  TM1,#0100_1100B;16bit Mode
LDM  TDR0,#<0FFH ;
LDM  TDR1,#>0FFH ;
SET1  T0E
EI
:
:

```

Example 3:

Timer0 = 16-bit capture mode

```

LDM  PSR0,#0000_0001B;INT0 set
LDM  TM0,#0010_1111B;Capture Mode
LDM  TM1,#0100_1100B;16bit Mode
LDM  TDR0,#<0FFH ;
LDM  TDR1,#>0FFH ;
LDM  IEDS,#01H;Falling Edge
SET1  T0E
EI
:
:

```

13.6 PWM Mode

The MC80F0704/0708/0804/0808 has high speed PWM (Pulse Width Modulation) functions which shared with Timer1 or Timer3.

In PWM mode, R10 / PWM1O or R11 / PWM3O pin output up to a 10-bit resolution PWM output. These pins should be configured as a PWM output by setting "1" bit PWM1OE and PWM3OE in PSR0 register.

The period of the PWM1 output is determined by the T1PPR (T1 PWM Period Register) and T1PWHR[3:2] (bit3,2 of T1 PWM High Register) and the duty of the PWM output is determined by the T1PDR (T1 PWM Duty Register) and T3PWHR[1:0] (bit1,0 of T1 PWM High Register).

The period of the PWM3 output is determined by the T3PPR (T3 PWM Period Register) and T3PWHR[3:2] (bit3,2 of T3 PWM High Register) and the duty of the PWM output is determined by the T3PDR (T3 PWM Duty Register) and T3PWHR[1:0] (bit1,0 of T3 PWM High Register).

The user writes the lower 8-bit period value to the T1(3)PPR and the higher 2-bit period value to the T1(3)PWHR[3:2]. And writes duty value to the T1(3)PDR and the T1(3)PWHR[1:0] same way.

The T1(3)PDR is configured as a double buffering for glitchless PWM output. In Figure 13-18, the duty data is transferred from the master to the slave when the period data matched to the counted value. (i.e. at the beginning of next duty cycle)

PWM1(3) Period = [PWM1(3)HR[3:2]T(2)3PPR] X Source Clock

PWM1(3) Duty = [PWM1(3)HR[1:0]T3PDR] X Source Clock

The relation of frequency and resolution is in inverse proportion. Table 13-3 shows the relation of PWM frequency vs. resolution.

If it needed more higher frequency of PWM, it should be reduced

resolution.

| Resolution | Frequency | | |
|------------|-----------------------|-----------------------|---------------------|
| | T1CK[1:0] = 00(250nS) | T1CK[1:0] = 01(500nS) | T1CK[1:0] = 10(2uS) |
| 10-bit | 3.9kHz | 0.98kHz | 0.49kHz |
| 9-bit | 7.8kHz | 1.95kHz | 0.97kHz |
| 8-bit | 15.6kHz | 3.90kHz | 1.95kHz |
| 7-bit | 31.2kHz | 7.81kHz | 3.90kHz |

Table 13-3 PWM Frequency vs. Resolution at 4MHz

The bit POL of TM1 or TM3 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).

It can be changed duty value when the PWM output. However the changed duty value is output after the current period is over. And it can be maintained the duty value at present output when changed only period value shown as Figure 13-20. As it were, the absolute duty time is not changed in varying frequency. But the changed period value must greater than the duty value.

Note: If changing the Timer1 to PWM function, it should be stop the timer clock firstly, and then set period and duty register value. If user writes register values while timer is in operation, these register could be set with certain values.

Ex) Sample Program @4MHz 2uS

```
LDM TM1,#1010_1000b ; Set Clock & PWM3E
LDM T1PPR,#199      ; Period :400uS=2uSX(199+1)
LDM T1PDR,#99       ; Duty:200uS=2uSX(99+1)
LDM PWM1HR,00H
LDM TM1,#1010_1011b ; Start timer1
```

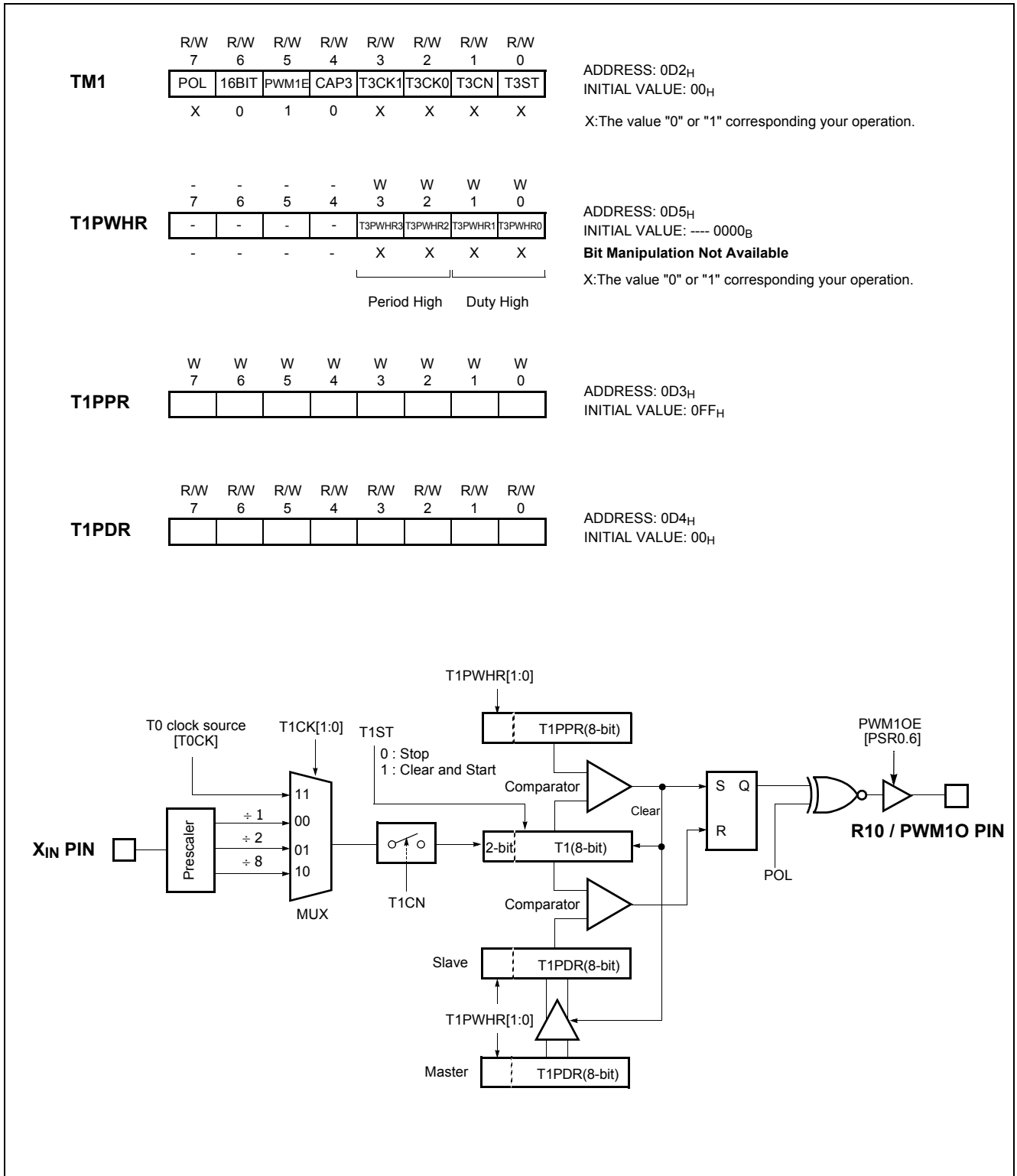



Figure 13-17 PWM1 Mode

| | | | | | | | | | |
|------------|-----|-------|-------|------|-------|-------|------|------|--|
| TM3 | R/W | R/W | R/W | R/W | R/W | R/W | R/W | R/W | ADDRESS: 0D8H INITIAL VALUE: 00H |
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| | POL | 16BIT | PWM3E | CAP3 | T3CK1 | T3CK0 | T3CN | T3ST | X:The value "0" or "1" corresponding your operation. |
| | X | 0 | 1 | 0 | X | X | X | X | |

| | | | | | | | | | |
|---------------|---|---|---|---|-------------|---------|-----------|---------|---|
| T3PWHR | - | - | - | - | W | W | W | W | ADDRESS: 0DBH INITIAL VALUE: ---- 0000B Bit Manipulation Not Available X:The value "0" or "1" corresponding your operation. |
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 0 | |
| | - | - | - | - | T3PWHR3 | T3PWHR2 | T3PWHR1 | T3PWHR0 | |
| | - | - | - | - | X | X | X | X | |
| | | | | | Period High | | Duty High | | |

| | | | | | | | | |
|--------------|---|---|---|---|---|---|---|--------------------------------------|
| T3PPR | W | W | W | W | W | W | W | ADDRESS: 0D9H INITIAL VALUE: 0FFH |
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | |
| | | | | | | | | |

| | | | | | | | | |
|--------------|-----|-----|-----|-----|-----|-----|-----|-------------------------------------|
| T3PDR | R/W | R/W | R/W | R/W | R/W | R/W | R/W | ADDRESS: 0DAH INITIAL VALUE: 00H |
| | 7 | 6 | 5 | 4 | 3 | 2 | 1 | |
| | | | | | | | | |

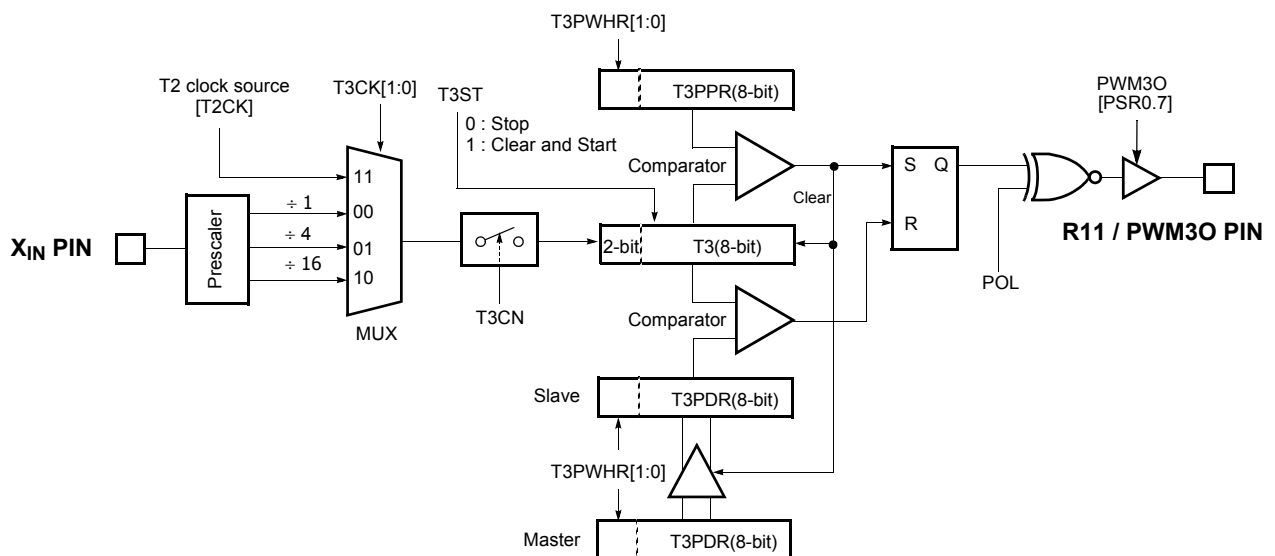


Figure 13-18 PWM3 Mode

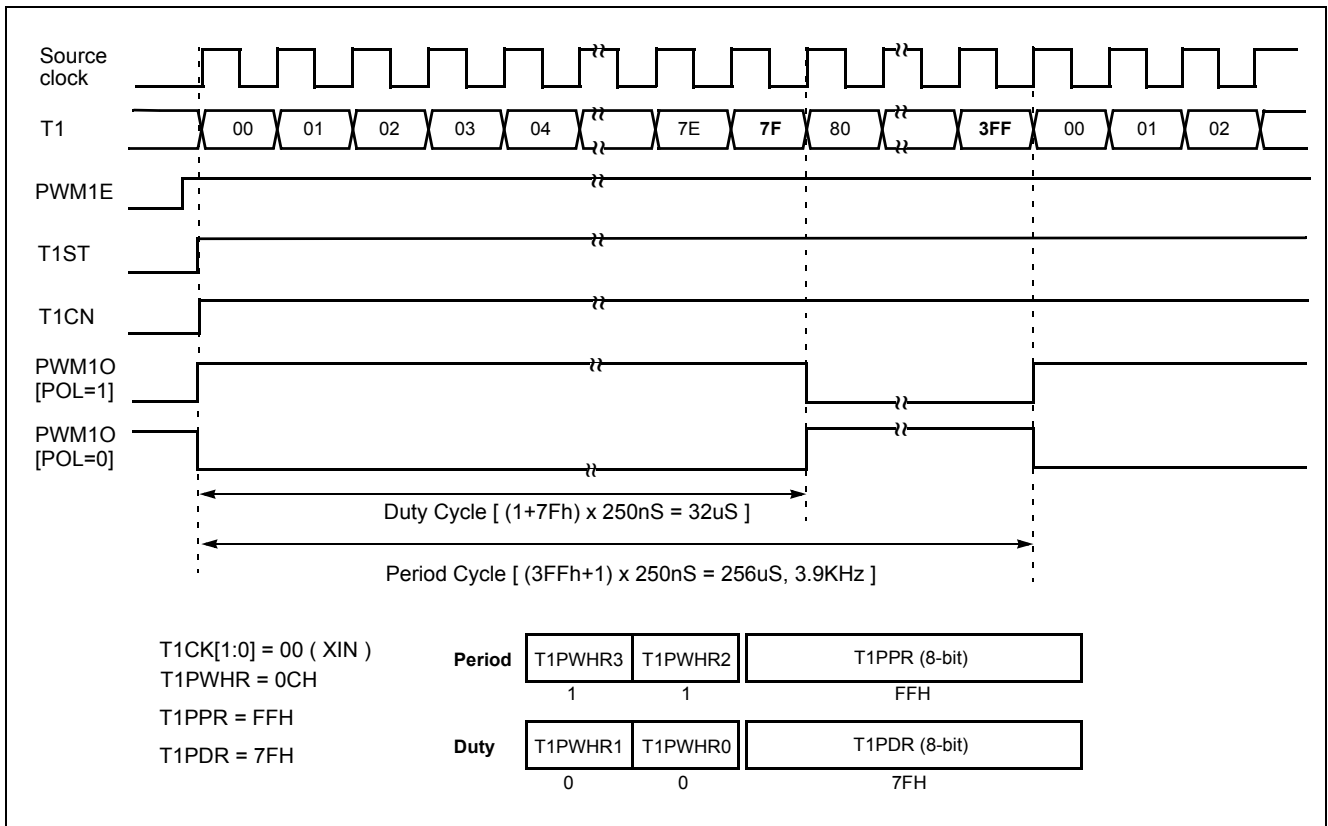


Figure 13-19 Example of PWM1 at 4MHz

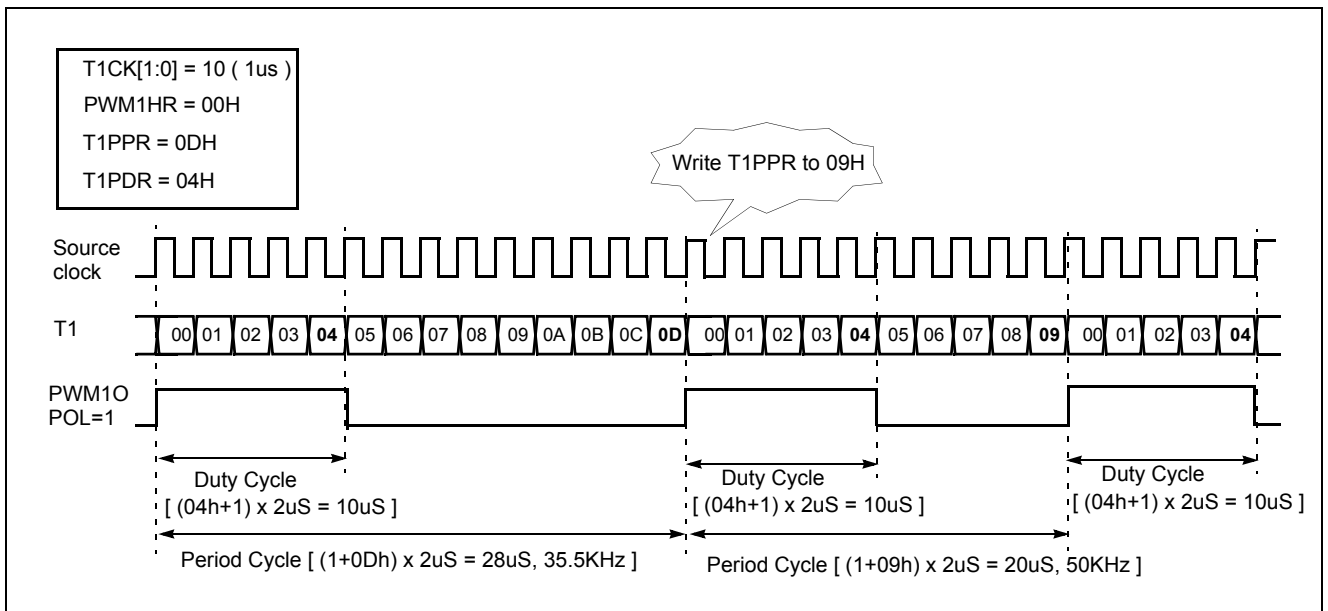


Figure 13-20 Example of Changing the PWM1 Period in Absolute Duty Cycle (@4MHz)

14. ANALOG TO DIGITAL CONVERTER

The analog-to-digital converter (A/D) allows conversion of an analog input signal to a corresponding 10-bit digital value. The A/D module has sixteen analog inputs, which are multiplexed into one sample and hold. The output of the sample and hold is the input into the converter, which generates the result via successive approximation.

The analog reference voltage is selected to V_{DD} or AV_{ref} by setting of the bit $AVREFS$ in $PSR1$ register. If external analog reference AV_{ref} is selected, the analog input channel 0 ($AN0$) should not be selected to use. Because this pin is used to an analog reference of A/D converter.

The A/D module has three registers which are the control register $ADCM$ and A/D result register $ADCRH$ and $ADCRL$. The $ADCRH[7:6]$ is used as ADC clock source selection bits too. The register $ADCM$, shown in Figure 14-4, controls the operation of the A/D converter module. The port pins can be configured as analog inputs or digital I/O.

It is selected for the corresponding channel to be converted by setting $ADS[3:0]$. The A/D port is set to analog input port by $ADEN$ and $ADS[3:0]$ regardless of port I/O direction register. The port unselected by $ADS[3:0]$ operates as normal port.

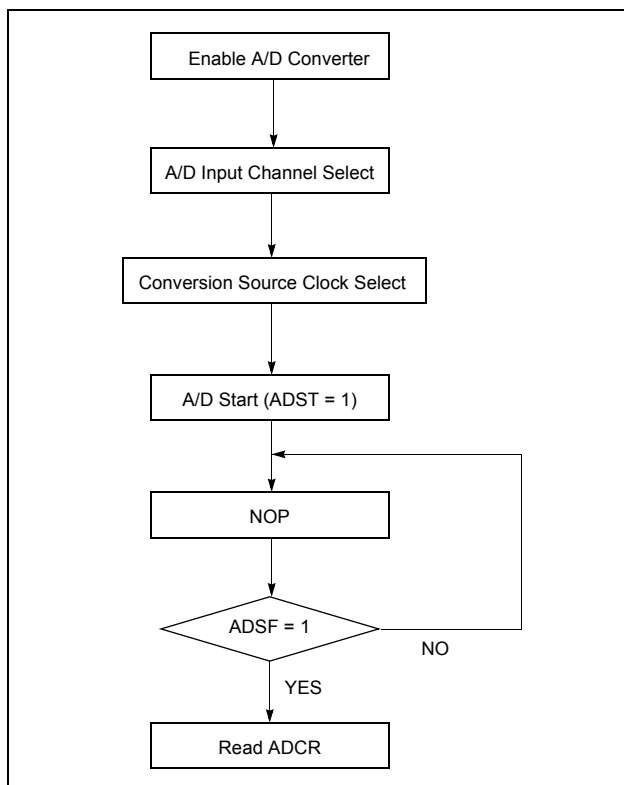


Figure 14-1 A/D Converter Operation Flow

How to Use A/D Converter

The processing of conversion is start when the start bit $ADST$ is

set to “1”. After one cycle, it is cleared by hardware. 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 $ADSF$ is set to “1”, and the A/D interrupt flag $ADCIF$ is set. See Figure 14-1 for operation flow.

The block diagram of the A/D module is shown in Figure 14-3. The A/D status bit $ADSF$ is set automatically when A/D conversion is completed, cleared when A/D conversion is in process. The conversion time takes 13 times of conversion source clock. The conversion source clock should selected for the conversion time being more than $25\mu s$.

A/D Converter Cautions

(1) Input range of $AN0 \sim AN15$

The input voltage of A/D input pins should be within the specification range. In particular, if a voltage above V_{DD} (or AV_{ref}) or below V_{SS} is input (even if within the absolute maximum rating range), the conversion value for that channel can not be indeterminate. The conversion values of the other channels may also be affected.

(2) Noise countermeasures

In order to maintain 10-bit resolution, attention must be paid to noise on pins V_{DD} (or AV_{ref}) and analog input pins ($AN0 \sim AN15$). Since the effect increases in proportion to the output impedance of the analog input source, it is recommended in some cases that a capacitor be connected externally as shown in Figure 14-2 in order to reduce noise. The capacitance is user-selectable and appropriately determined according to the target system.

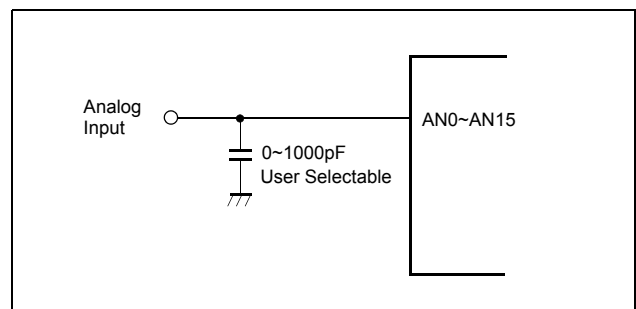


Figure 14-2 Analog Input Pin Connecting Capacitor

(3) I/O operation

The analog input pins $AN0 \sim AN15$ also have function as input/output port pins. When A/D conversion is performed with any pin, be sure not to execute a PORT input instruction with the selected pin while conversion is in progress, as this may reduce the conversion resolution.

Also, if digital pulses are applied to a pin adjacent to the pin in the process of A/D conversion, the expected A/D conversion value

may not be obtainable due to coupling noise. Therefore, avoid applying pulses to pins adjacent to the pin undergoing A/D conversion.

(4) AV_{DD} pin input impedance

A series resistor string of approximately 5KΩ is connected between the AV_{REF} pin and the V_{SS} pin. Therefore, if the output impedance of the analog power source is high, this will result in parallel connection to the series resistor string between the AV_{REF} pin and the V_{SS} pin, and there will be a large analog sup-

ply voltage error

Note: If the AV_{REF} voltage is less than V_{DD} voltage and analog input pins(ANX), shared with various alternate function, are used bidirectional I/O port, the leakage current may flow V_{DD} pin to AV_{REF} pin in output high mode or analog input pins(ANX) to AV_{REF} pin in input high mode.

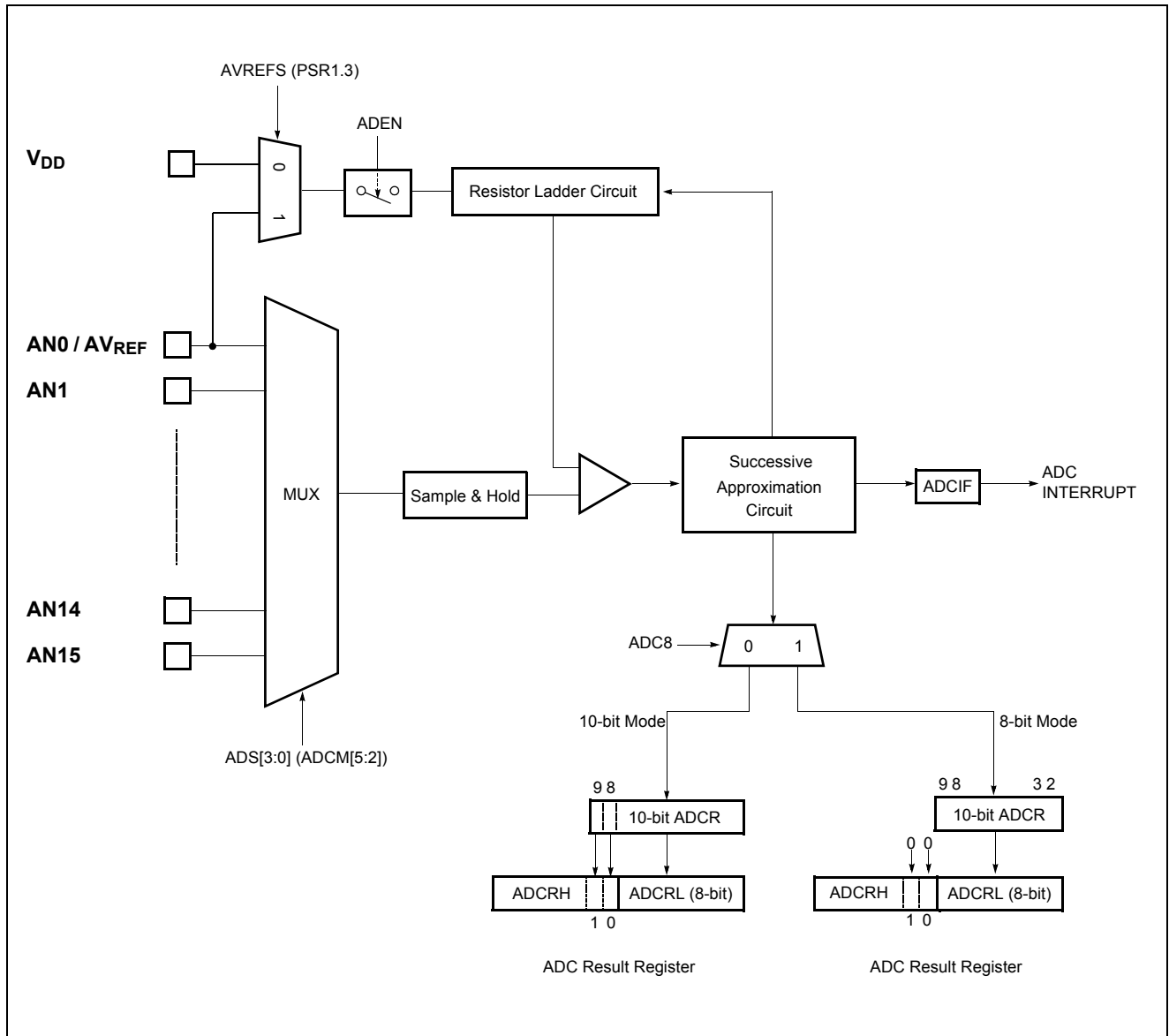


Figure 14-3 A/D Block Diagram

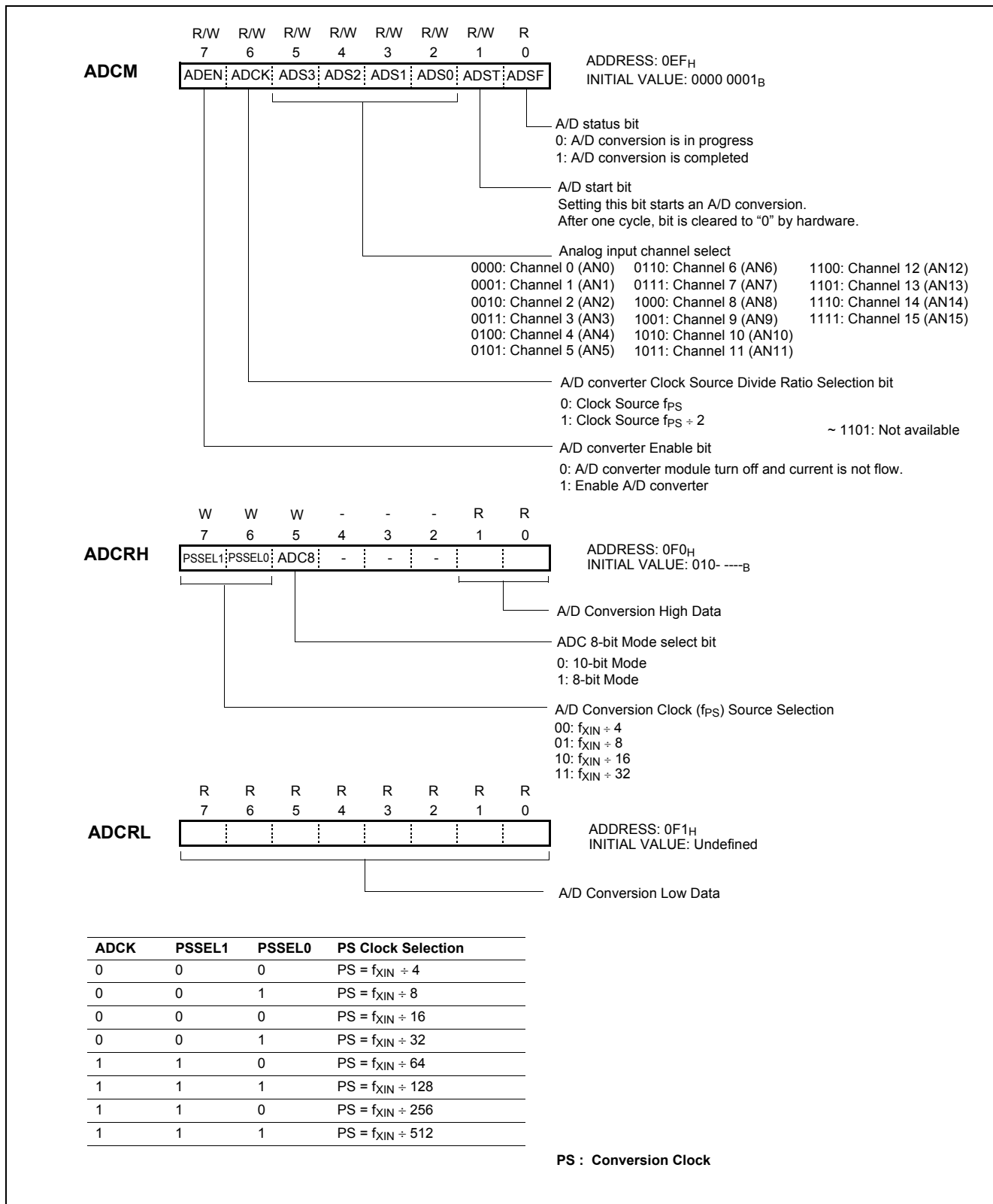


Figure 14-4 A/D Converter Control & Result Register

Serial I/O Mode Register (SIOM) controls serial I/O function. According to SCK1 and SCK0, the internal clock or external clock can be selected.

Serial I/O Data Register (SIOR) is an 8-bit shift register. First LSB is send or is received first.

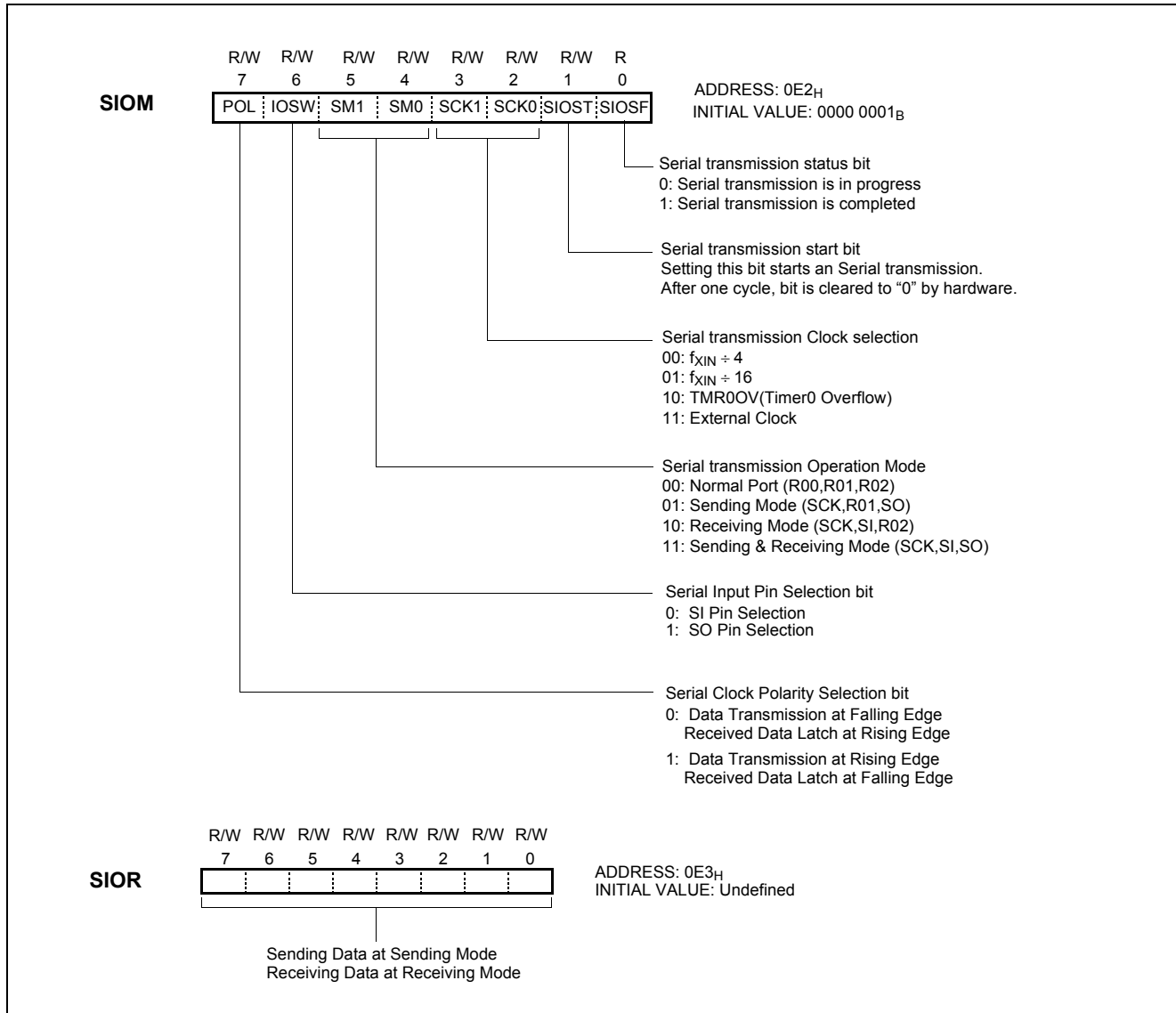


Figure 15-2 SIO Control Register

15.1 Transmission/Receiving Timing

The serial transmission is started by setting SIOST(bit1 of SIOM) to "1". After one cycle of SCK, SIOST and SIOSF (bit 0 of SIOM) is cleared automatically to "0". At the default state of POL bit clear, the serial output data from 8-bit shift register is output at falling edge of SCLK, and input data is latched at rising edge

of SCLK pin (Refer to Figure 15-3). When transmission clock is counted 8 times, serial I/O counter is cleared as '0'. Transmission clock is halted in "H" state and serial I/O interrupt (SIOIF) occurred. SIOSF is set to "1" automatically.

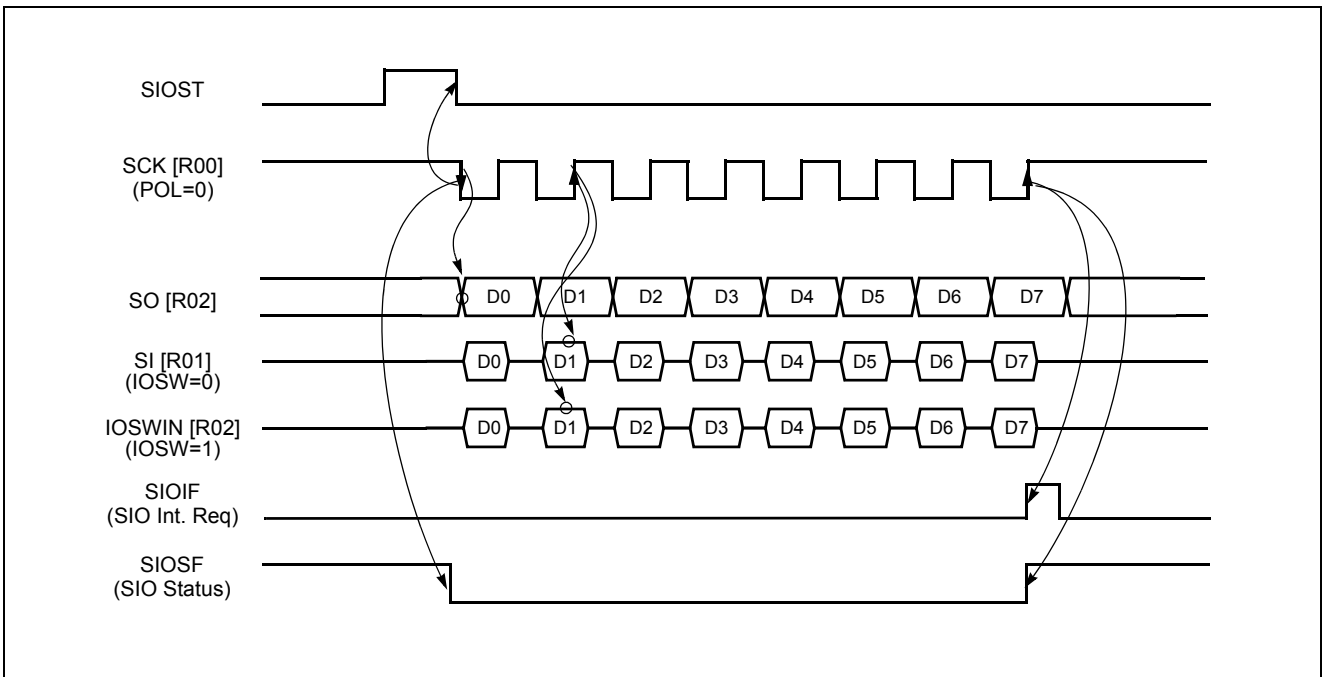


Figure 15-3 Serial I/O Timing Diagram at POL=0

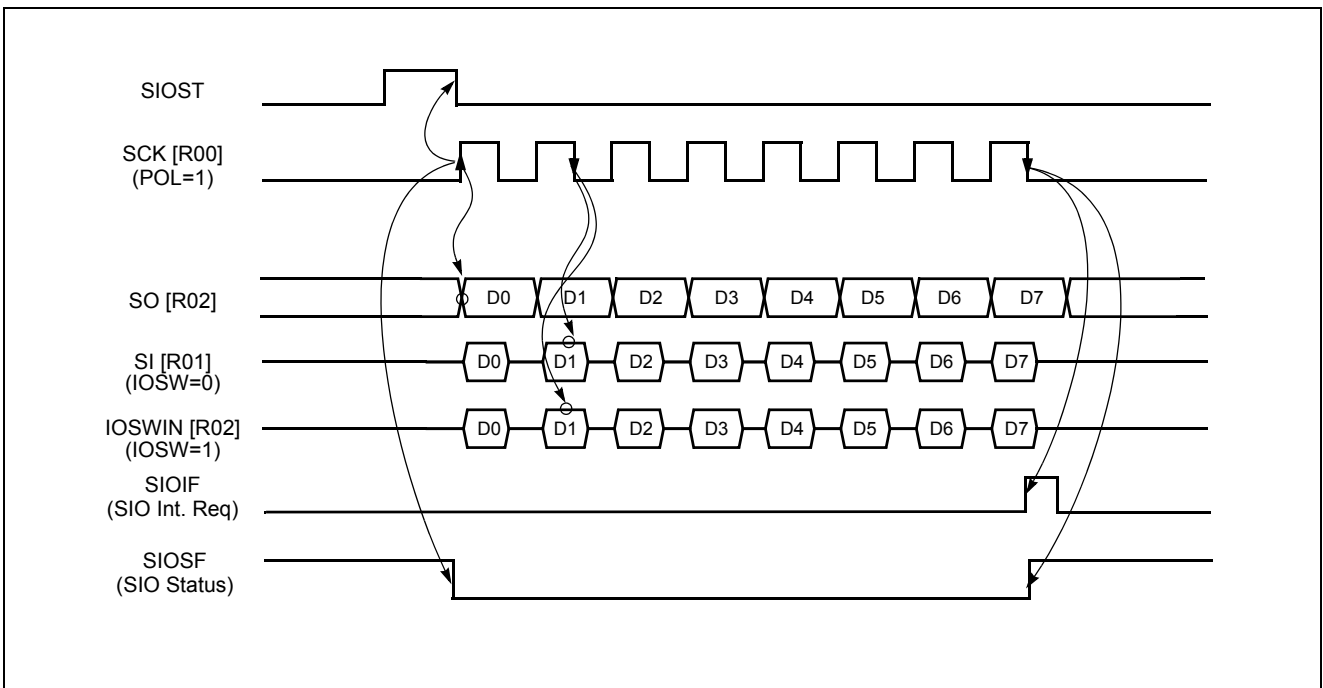


Figure 15-4 Serial I/O Timing Diagram at POL=1

15.2 The usage of Serial I/O

1. Select transmission/receiving mode.
2. In case of sending mode, write data to be send to SIOR.
3. Set SIOST to “1” to start serial transmission.
4. The SIO interrupt is generated at the completion of SIO and SIOIF is set to “1”.
5. In case of receiving mode, the received data is acquired by reading the SIOR.
6. When using polling method, the completion of 1 byte serial communication can be checked by reading SIOST and SIOSF. As shown in example code, wait until SIOST is changed to “0” and then wait the SIOSF is changed to “1” for completion check.

```
LDM  SIOR,#0AAh      ;set tx data
LDM  SIOM,#0011_1100b;set SIO mode
NOP
LDM  SIOM,#0011_1110b;SIO Start
NOP
SIO_WAIT:
NOP
BBS  SIOST,SIO_WAIT  ;wait first edge
BBC  SIOSF,SIO_WAIT  ;wait complete
```

Note: When external clock is used, the frequency should be less than 1MHz and recommended duty is 50%. If both transmission mode is selected and transmission is performed simultaneously, error may be occur.

16. BUZZER FUNCTION

The buzzer driver block consists of 6-bit binary counter, buzzer register BUZR, and clock source selector. It generates square-wave which has very wide range frequency (488Hz ~ 250kHz at $f_{XIN}= 4MHz$) by user software.

A 50% duty pulse can be output to R12 / BUZO pin to use for piezo-electric buzzer drive. Pin R12 is assigned for output port of Buzzer driver by setting the bit 2 of PSR1(address 0F9H) to "1". For PSR1 register, refer to Figure 16-2 .

Example: 5kHz output at 4MHz.

```
LDM BUZR, #0011_0001B
LDM PSR1, #XXXX_X1XXB
```

X means don't care

The bit 0 to 5 of BUZR determines output frequency for buzzer

driving.

Equation of frequency calculation is shown below.

$$f_{BUZ} = \frac{f_{XIN}}{2 \times DivideRatio \times (BUR + 1)}$$

- f_{BUZ} : Buzzer frequency
- f_{XIN} : Oscillator frequency
- Divide Ratio: Prescaler divide ratio by BUCK[1:0]
- BUR: Lower 6-bit value of BUZR. Buzzer period value.

The frequency of output signal is controlled by the buzzer control register BUZR. The bit 0 to bit 5 of BUZR determine output frequency for buzzer driving.

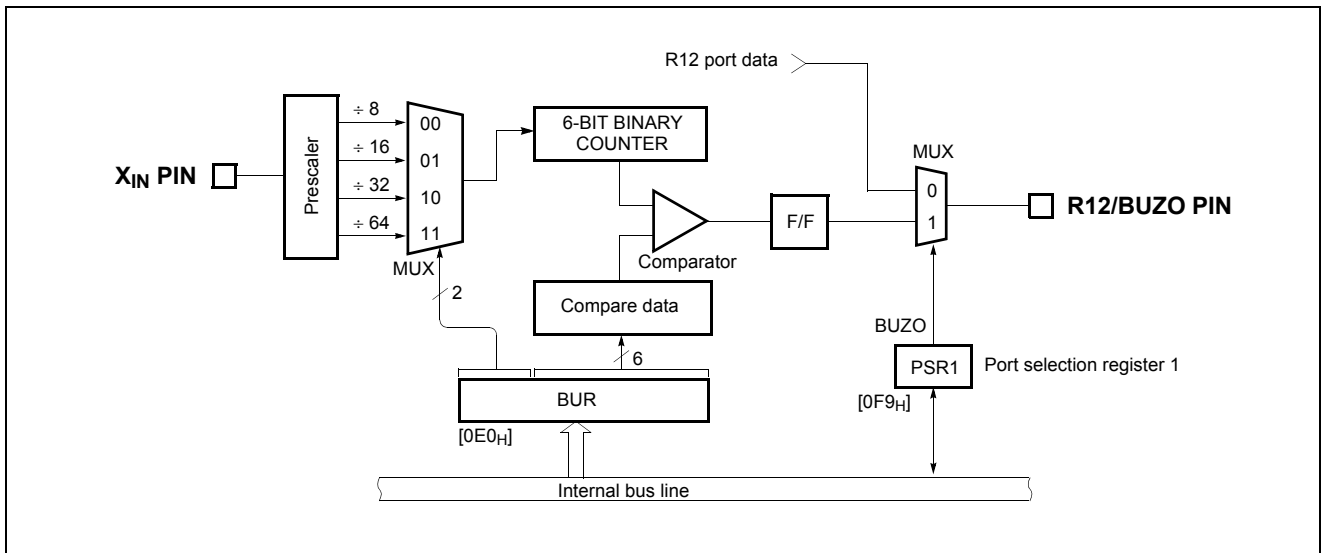


Figure 16-1 Block Diagram of Buzzer Driver

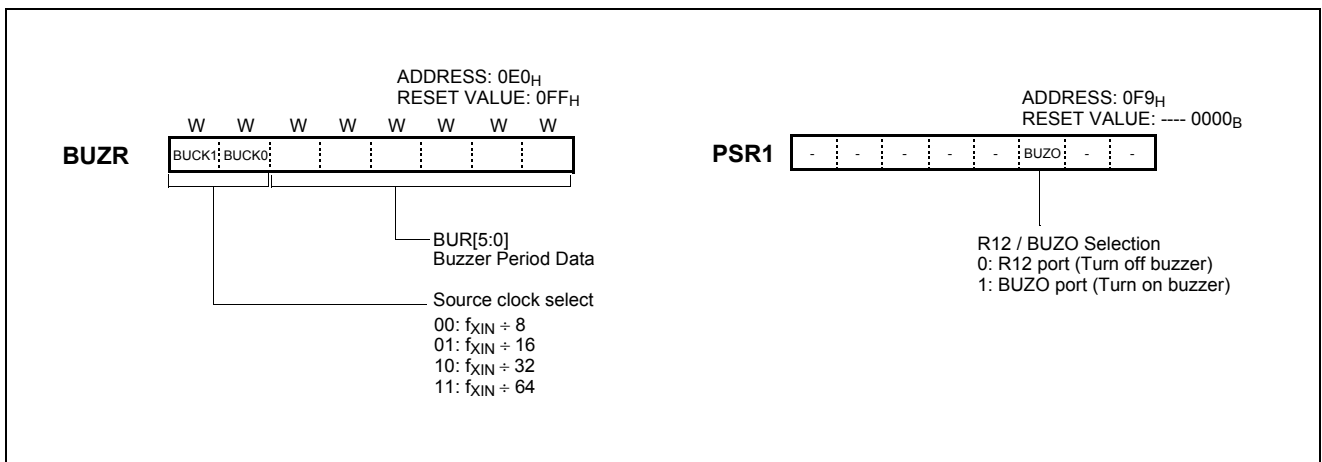


Figure 16-2 Buzzer Register & PSR1

The 6-bit counter is cleared and starts the counting by writing signal at BUZR register. It is incremental from 00_H until it matches 6-bit BUR value.

When main-frequency is 4MHz, buzzer frequency is shown as below Table 16-1.

| BUR [5:0] | BUR[7:6] | | | | BUR [5:0] | BUR[7:6] | | | |
|--------------|----------|---------|--------|--------|--------------|----------|-------|-------|-------|
| | 00 | 01 | 10 | 11 | | 00 | 01 | 10 | 11 |
| 00 | 250.000 | 125.000 | 62.500 | 31.250 | 20 | 7.576 | 3.788 | 1.894 | 0.947 |
| 01 | 125.000 | 62.500 | 31.250 | 15.625 | 21 | 7.353 | 3.676 | 1.838 | 0.919 |
| 02 | 83.333 | 41.667 | 20.833 | 10.417 | 22 | 7.143 | 3.571 | 1.786 | 0.893 |
| 03 | 62.500 | 31.250 | 15.625 | 7.813 | 23 | 6.944 | 3.472 | 1.736 | 0.868 |
| 04 | 50.000 | 25.000 | 12.500 | 6.250 | 24 | 6.757 | 3.378 | 1.689 | 0.845 |
| 05 | 41.667 | 20.833 | 10.417 | 5.208 | 25 | 6.579 | 3.289 | 1.645 | 0.822 |
| 06 | 35.714 | 17.857 | 8.929 | 4.464 | 26 | 6.410 | 3.205 | 1.603 | 0.801 |
| 07 | 31.250 | 15.625 | 7.813 | 3.906 | 27 | 6.250 | 3.125 | 1.563 | 0.781 |
| 08 | 27.778 | 13.889 | 6.944 | 3.472 | 28 | 6.098 | 3.049 | 1.524 | 0.762 |
| 09 | 25.000 | 12.500 | 6.250 | 3.125 | 29 | 5.952 | 2.976 | 1.488 | 0.744 |
| 0A | 22.727 | 11.364 | 5.682 | 2.841 | 2A | 5.814 | 2.907 | 1.453 | 0.727 |
| 0B | 20.833 | 10.417 | 5.208 | 2.604 | 2B | 5.682 | 2.841 | 1.420 | 0.710 |
| 0C | 19.231 | 9.615 | 4.808 | 2.404 | 2C | 5.556 | 2.778 | 1.389 | 0.694 |
| 0D | 17.857 | 8.929 | 4.464 | 2.232 | 2D | 5.435 | 2.717 | 1.359 | 0.679 |
| 0E | 16.667 | 8.333 | 4.167 | 2.083 | 2E | 5.319 | 2.660 | 1.330 | 0.665 |
| 0F | 15.625 | 7.813 | 3.906 | 1.953 | 2F | 5.208 | 2.604 | 1.302 | 0.651 |
| 10 | 14.706 | 7.353 | 3.676 | 1.838 | 30 | 5.102 | 2.551 | 1.276 | 0.638 |
| 11 | 13.889 | 6.944 | 3.472 | 1.736 | 31 | 5.000 | 2.500 | 1.250 | 0.625 |
| 12 | 13.158 | 6.579 | 3.289 | 1.645 | 32 | 4.902 | 2.451 | 1.225 | 0.613 |
| 13 | 12.500 | 6.250 | 3.125 | 1.563 | 33 | 4.808 | 2.404 | 1.202 | 0.601 |
| 14 | 11.905 | 5.952 | 2.976 | 1.488 | 34 | 4.717 | 2.358 | 1.179 | 0.590 |
| 15 | 11.364 | 5.682 | 2.841 | 1.420 | 35 | 4.630 | 2.315 | 1.157 | 0.579 |
| 16 | 10.870 | 5.435 | 2.717 | 1.359 | 36 | 4.545 | 2.273 | 1.136 | 0.568 |
| 17 | 10.417 | 5.208 | 2.604 | 1.302 | 37 | 4.464 | 2.232 | 1.116 | 0.558 |
| 18 | 10.000 | 5.000 | 2.500 | 1.250 | 38 | 4.386 | 2.193 | 1.096 | 0.548 |
| 19 | 9.615 | 4.808 | 2.404 | 1.202 | 39 | 4.310 | 2.155 | 1.078 | 0.539 |
| 1A | 9.259 | 4.630 | 2.315 | 1.157 | 3A | 4.237 | 2.119 | 1.059 | 0.530 |
| 1B | 8.929 | 4.464 | 2.232 | 1.116 | 3B | 4.167 | 2.083 | 1.042 | 0.521 |
| 1C | 8.621 | 4.310 | 2.155 | 1.078 | 3C | 4.098 | 2.049 | 1.025 | 0.512 |
| 1D | 8.333 | 4.167 | 2.083 | 1.042 | 3D | 4.032 | 2.016 | 1.008 | 0.504 |
| 1E | 8.065 | 4.032 | 2.016 | 1.008 | 3E | 3.968 | 1.984 | 0.992 | 0.496 |
| 1F | 7.813 | 3.906 | 1.953 | 0.977 | 3F | 3.907 | 1.953 | 0.977 | 0.488 |

Table 16-1 buzzer frequency (kHz unit)

17. INTERRUPTS

The MC80F0704/0708/0804/0808 interrupt circuits consist of Interrupt enable register (IENH, IENL), Interrupt request flags of IRQH, IRQL, Priority circuit, and Master enable flag ("I" flag of PSW). Fifteen interrupt sources are provided. The configuration of interrupt circuit is shown in Figure 17-1 and interrupt priority is shown in Table 17-1.

The External Interrupts INT0 ~ INT3 each can be transition-activated (1-to-0 or 0-to-1 transition) by selection IEDS register. The flags that actually generate these interrupts are bit INT0IF, INT1IF, INT2IF and INT3IF in register IRQH. When an external interrupt is generated, the generated flag is cleared by the hardware when the service routine is vectored to only if the interrupt was transition-activated.

The Timer 0 ~ Timer 3 Interrupts are generated by T0IF, T1IF, T2IF and T3IF which is set by a match in their respective timer/counter register.

The Basic Interval Timer Interrupt is generated by BITIF which is set by an overflow in the timer register.

The AD converter Interrupt is generated by ADCIF which is set by finishing the analog to digital conversion.

The Watchdog timer is generated by WDTIF and WTIF which is set by a match in Watchdog timer register.

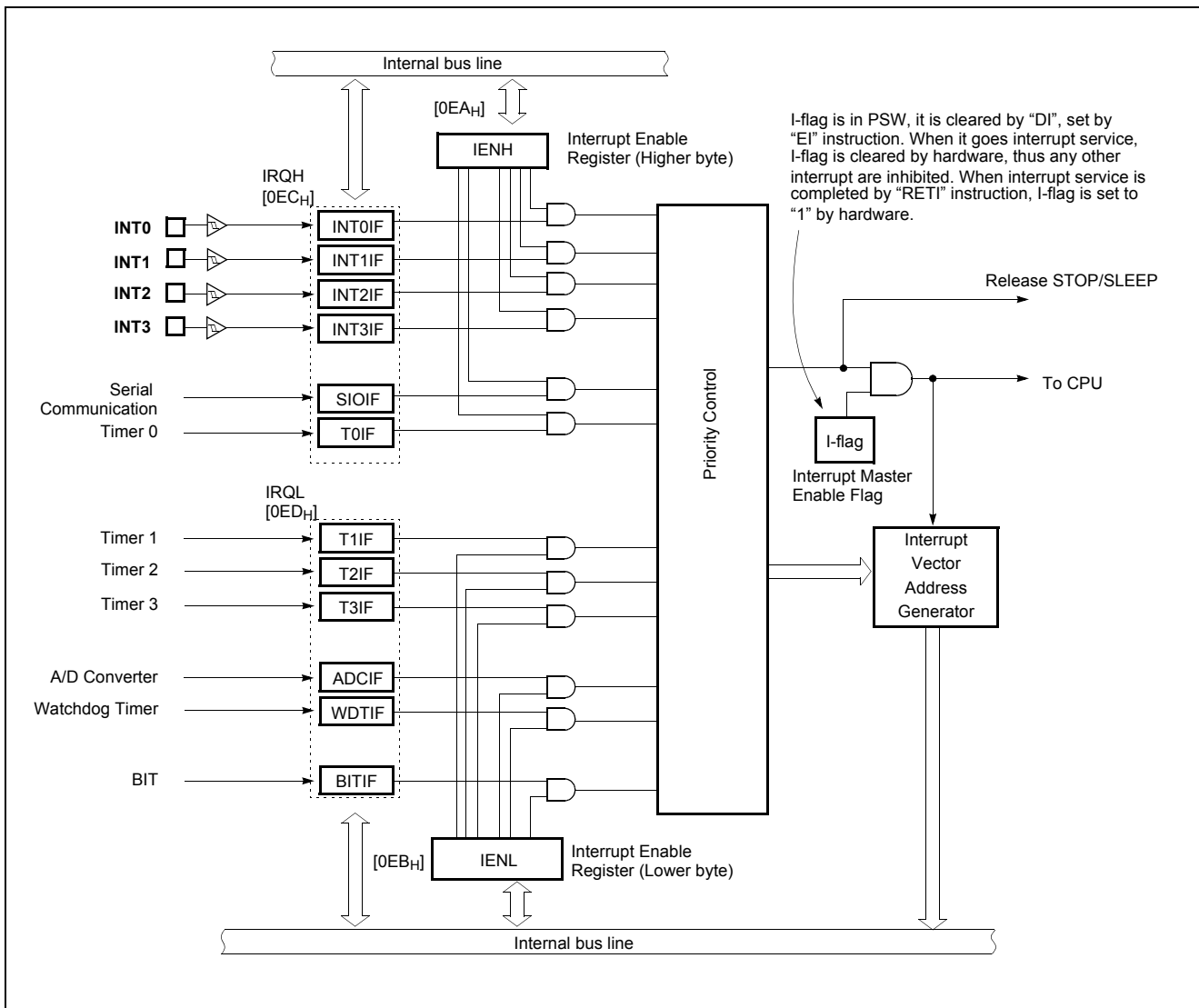


Figure 17-1 Block Diagram of Interrupt

The Basic Interval Timer Interrupt is generated by BITIF which is set by an overflow in the timer counter register.

The SIO interrupt is generated by SIOIF which is set by completion of SIO data reception or transmission.

The interrupts are controlled by the interrupt master enable flag I-flag (bit 2 of PSW on Figure 8-3), the interrupt enable register (IENH, IENL), and the interrupt request flags (in IRQH and IRQL) except Power-on reset and software BRK interrupt. The Table 17-1 shows the Interrupt priority.

Vector addresses are shown in Figure 8-6 . Interrupt enable registers are shown in Figure 17-2 . These registers are composed of interrupt enable flags of each interrupt source and these flags determine whether an interrupt will be accepted or not. When enable flag is "0", a corresponding interrupt source is prohibited. Note that PSW contains also a master enable bit, I-flag, which disables all interrupts at once.

| Reset/Interrupt | Symbol | Priority |
|----------------------|---------|----------|
| Hardware Reset | RESET | 1 |
| External Interrupt 0 | INT0 | 2 |
| External Interrupt 1 | INT1 | 3 |
| External Interrupt 2 | INT2 | 4 |
| External Interrupt 3 | INT3 | 5 |
| Serial Input/Output | SIO | 6 |
| Timer/Counter 0 | Timer 0 | 7 |
| Timer/Counter 1 | Timer 1 | 8 |
| Timer/Counter 2 | Timer 2 | 9 |
| Timer/Counter 3 | Timer 3 | 10 |
| ADC Interrupt | ADC | 11 |
| Watchdog Timer | WDT | 12 |
| Basic Interval Timer | BIT | 13 |

Table 17-1 Interrupt Priority

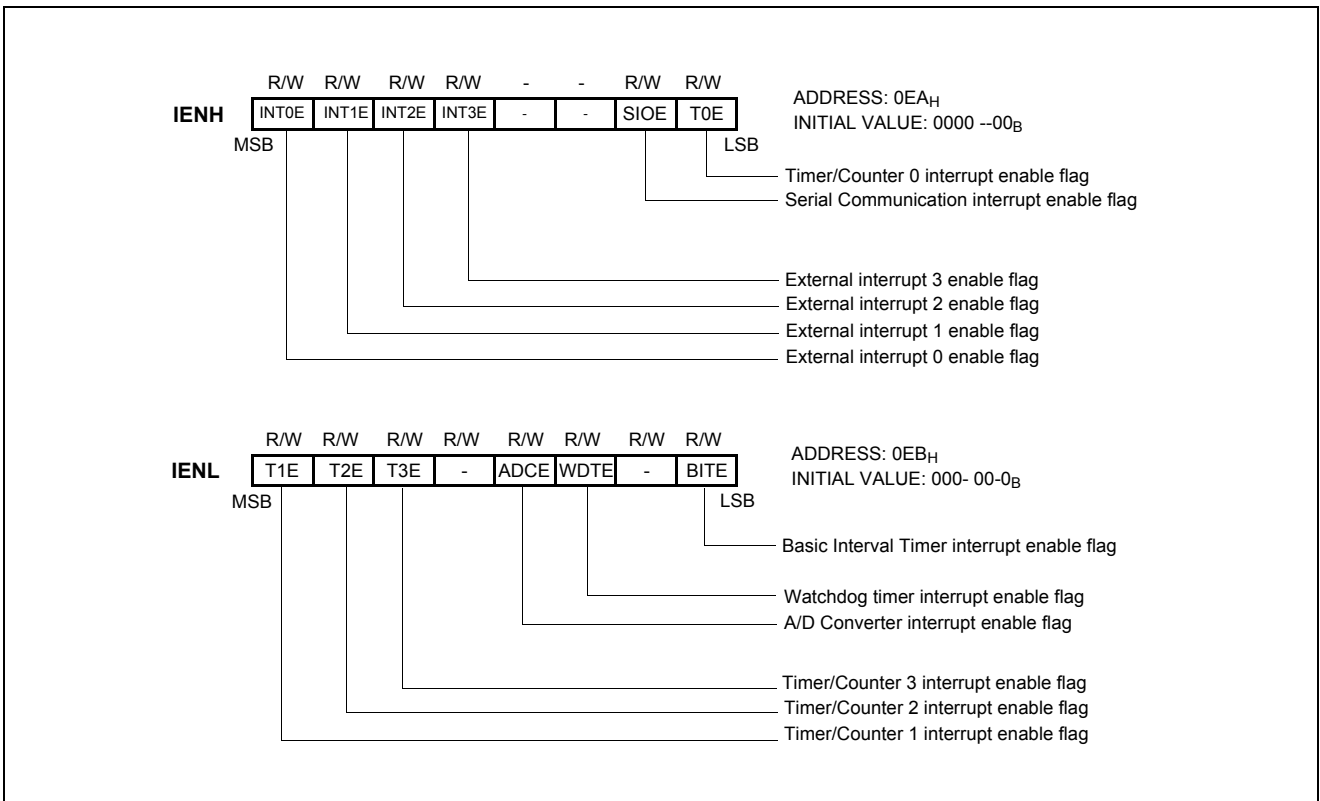


Figure 17-2 Interrupt Enable Flag Register

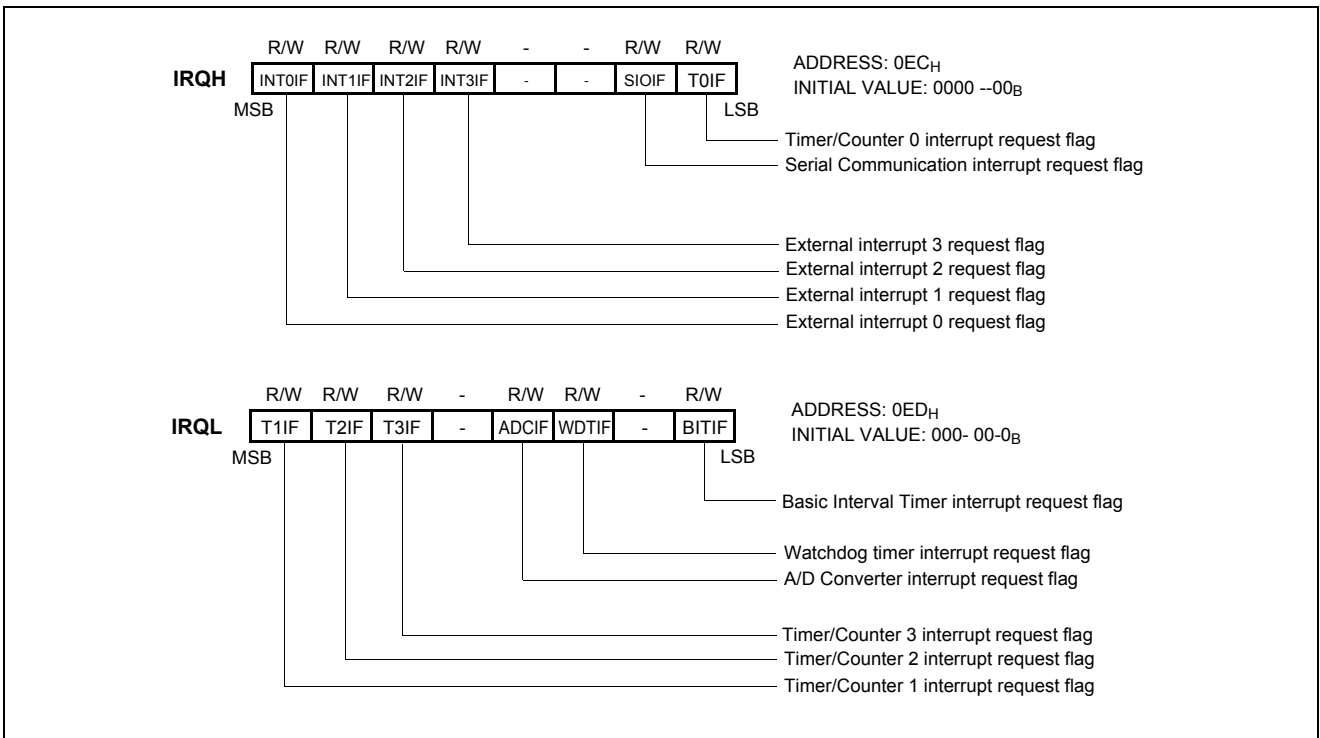


Figure 17-3 Interrupt Request Flag Register

17.1 Interrupt Sequence

An interrupt request is held until the interrupt is accepted or the interrupt latch is cleared to “0” by a reset or an instruction. Interrupt acceptance sequence requires 8 cycles of f_{XIN} ($2\mu s$ at f_{X-}

$f_{IN}=4MHz$) after the completion of the current instruction execution. The interrupt service task is terminated upon execution of an interrupt return instruction [RETI].

Interrupt acceptance

1. The interrupt master enable flag (I-flag) is cleared to “0” to temporarily disable the acceptance of any following maskable interrupts. When a non-maskable interrupt is accepted, the acceptance of any following interrupts is temporarily disabled.
2. The contents of the program counter (return address) and the program status word are saved (pushed) onto the

stack area. The stack pointer decreases 3 times.

3. The entry address of the interrupt service program is read from the vector table address and the entry address is loaded to the program counter.
4. The instruction stored at the entry address of the interrupt service program is executed.

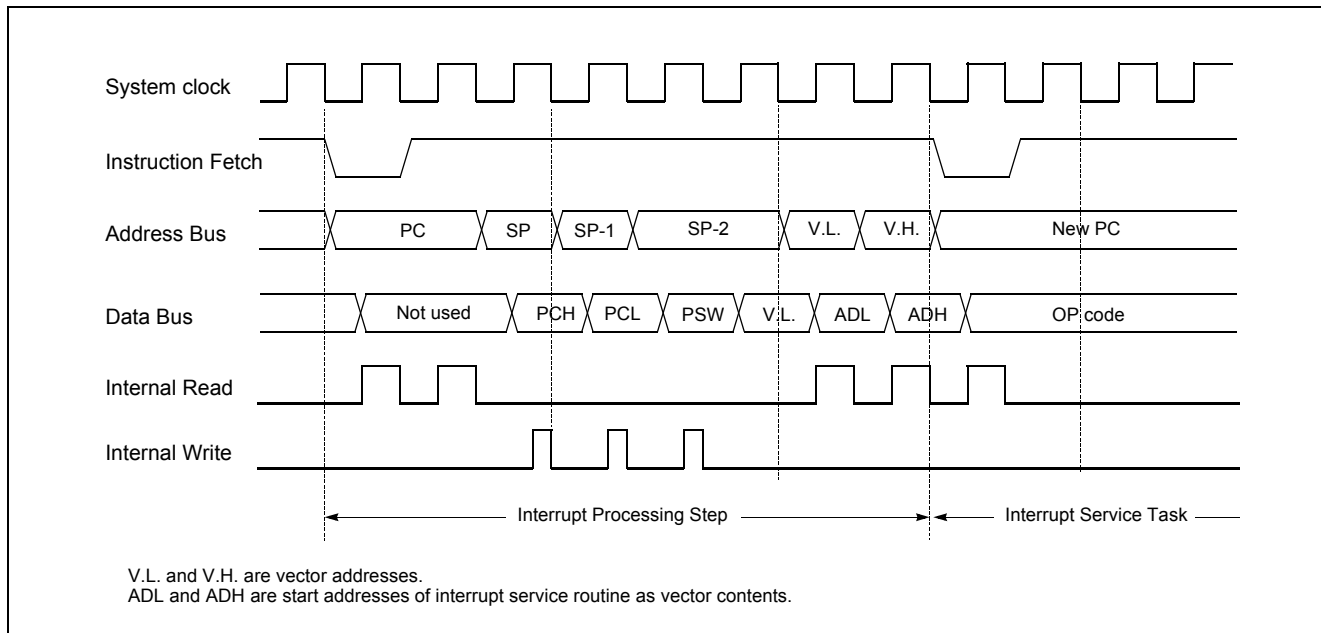
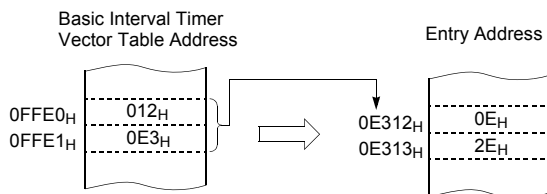


Figure 17-4 Timing chart of Interrupt Acceptance and Interrupt Return Instruction



Correspondence between vector table address for BIT interrupt and the entry address of the interrupt service program.

A interrupt request is not accepted until the I-flag is set to “1” even if a requested interrupt has higher priority than that of the current interrupt being serviced.

When nested interrupt service is required, the I-flag should be set to “1” by “EI” instruction in the interrupt service program. In this case, acceptable interrupt sources are selectively enabled by the individual interrupt enable flags.

Clearing Interrupt Request Flag

The Interrupt Request flag may not cleared itself during interrupt acceptance processing. After interrupt acceptance, it should be

cleared as shown in interrupt service routine.

Note: The MC80F0708 and HMS87C1416B is similar in function, but the interrupt processing method is different. When replacing the HMS87C1416B to MC80F0708, clearing interrupt request flag should be added.

Saving/Restoring General-purpose Register

During interrupt acceptance processing, the program counter and the program status word are automatically saved on the stack, but accumulator and other registers are not saved itself. These registers are saved by the software if necessary. Also, when multiple interrupt services are nested, it is necessary to avoid using the same data memory area for saving registers.

The following method is used to save/restore the general-purpose registers.

Example: Register save using push and pop instructions

```
INTxx: CLR1 INTxxIF ;CLEAR REQUEST.
        PUSH A ;SAVE ACC.
        PUSH X ;SAVE X REG.
        PUSH Y ;SAVE Y REG.
```

17.2 BRK Interrupt

Software interrupt can be invoked by BRK instruction, which has the lowest priority order.

Interrupt vector address of BRK is shared with the vector of TCALL 0 (Refer to Program Memory Section). When BRK interrupt is generated, B-flag of PSW is set to distinguish BRK from TCALL 0.

Each processing step is determined by B-flag as shown in Figure 17-5 .

17.3 Multi Interrupt

If two requests of different priority levels are received simultaneously, the request of higher priority level is serviced. If requests of the interrupt are received at the same time simultaneously, an internal polling sequence determines by hard-

Example: Clearing Interrupt Request Flag

```
T1_INT: CLR1 T1IF ;CLEAR T1 REQUEST
        [interrupt processing]
        RETI ;RETURN
```

```
[interrupt processing]
POP Y ;RESTORE Y REG.
POP X ;RESTORE X REG.
POP A ;RESTORE ACC.
RETI ;RETURN
```

General-purpose register save/restore using push and pop instructions;

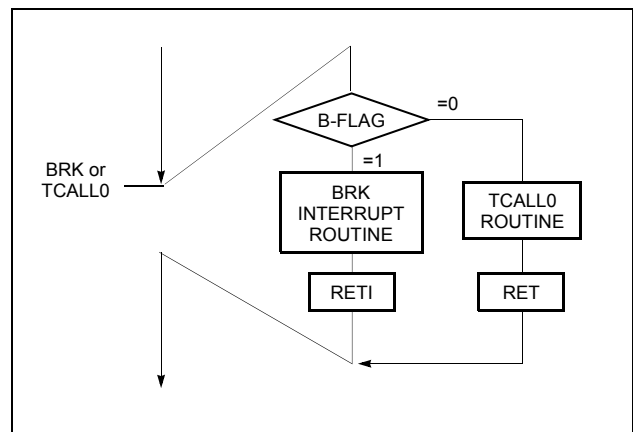
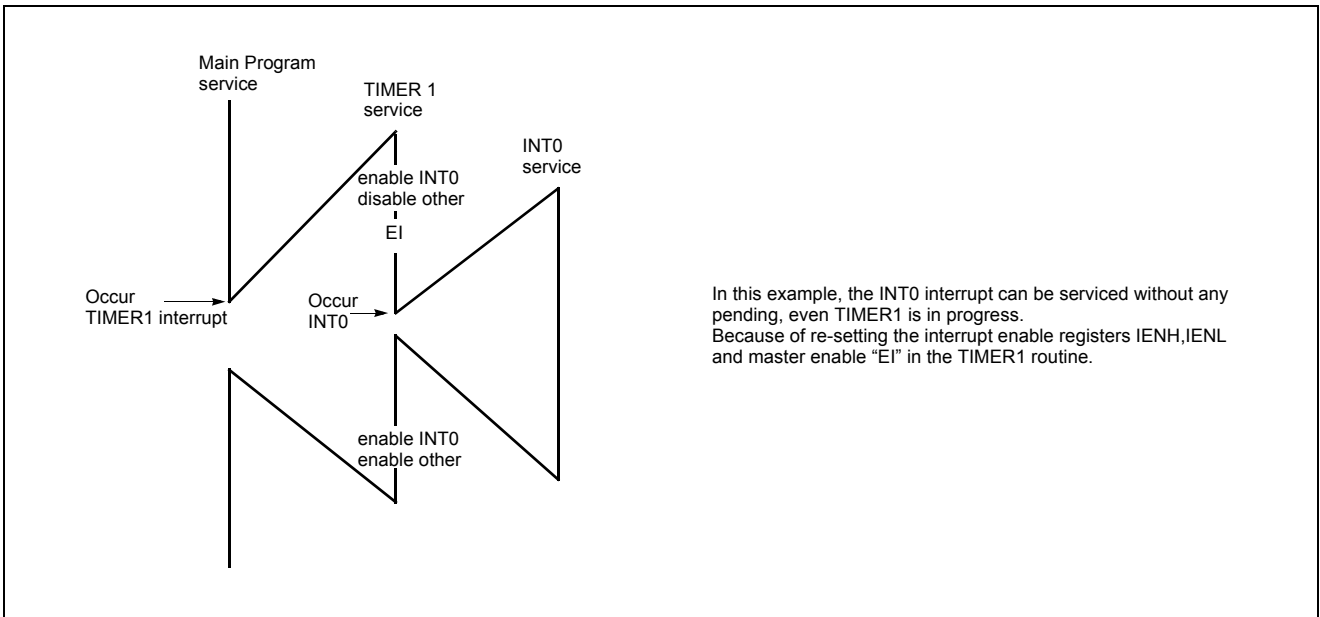


Figure 17-5 Execution of BRK/TCALL0

ware which request is serviced. However, multiple processing through software for special features is possible. Generally when an interrupt is accepted, the I-flag is cleared to disable any further interrupt. But as user sets I-flag in interrupt routine, some further

interrupt can be serviced even if certain interrupt is in progress.



In this example, the INTO interrupt can be serviced without any pending, even TIMER1 is in progress. Because of re-setting the interrupt enable registers IENH,IENL and master enable "EI" in the TIMER1 routine.

Figure 17-6 Execution of Multi Interrupt

Example: During Timer1 interrupt is in progress, INTO interrupt serviced without any suspend.

| | | | | | |
|---------|------|------------|------------------------|------|-------------------------------------|
| TIMER1: | CLR1 | T1IF | ; Clear Timer1 Request | : | |
| | PUSH | A | | : | |
| | PUSH | X | | : | |
| | PUSH | Y | | : | |
| | LDM | IENH, #80H | ; Enable INT0 only | LDM | IENH, #0FFH ; Enable all interrupts |
| | LDM | IENL, #0 | ; Disable other int. | LDM | IENL, #0FFH |
| | EI | | ; Enable Interrupt | POP | Y |
| | : | | | POP | X |
| | : | | | POP | A |
| | : | | | RETI | |

17.4 External Interrupt

The external interrupt on INT0, INT1, INT2 and INT3 pins are edge triggered depending on the edge selection register IEDS (address 0EEH) as shown in Figure 17-7.

The edge detection of external interrupt has three transition activated mode: rising edge, falling edge, and both edge.

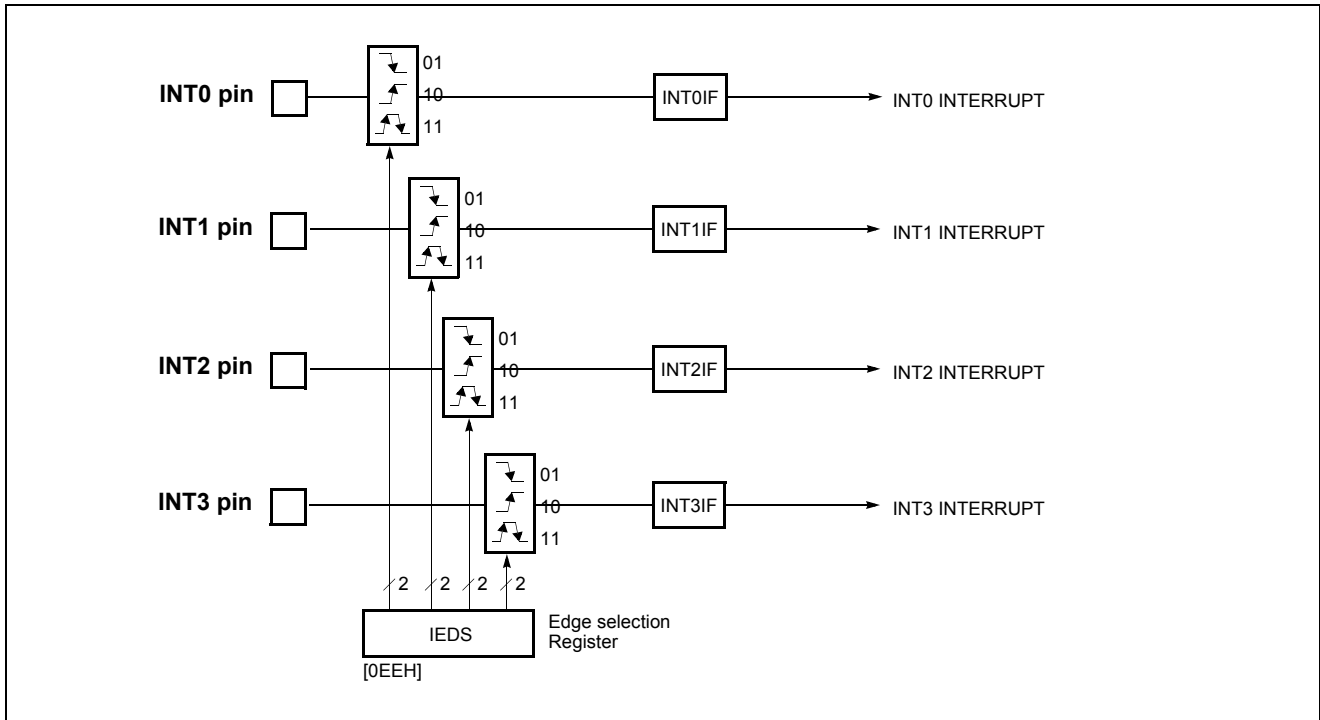


Figure 17-7 External Interrupt Block Diagram

INT0 ~ INT3 are multiplexed with general I/O ports (R11, R12, R03, R00). To use as an external interrupt pin, the bit of port selection register PSR0 should be set to “1” correspondingly.

Example: To use as an INT0 and INT2

```

;**** Set external interrupt port as pull-up state.
LDM PU1, #0000_0101B
;**** Set port as an external interrupt port
LDM PSR0, #0000_0101B
;**** Set Falling-edge Detection
LDM IEDS, #0001_0001B

```

Response Time

The INT0 ~ INT3 edge are latched into INT0IF ~ INT3IF at every machine cycle. The values are not actually polled by the circuitry until the next machine cycle. If a request is active and conditions are right for it to be acknowledged, a hardware subroutine call to the requested service routine will be the next instruction to be executed. The DIV itself takes twelve cycles. Thus, a minimum of twelve complete machine cycles elapse between activation of an external interrupt request and the beginning of execution of the first instruction of the service routine.

Figure 17-8 shows interrupt response timings.

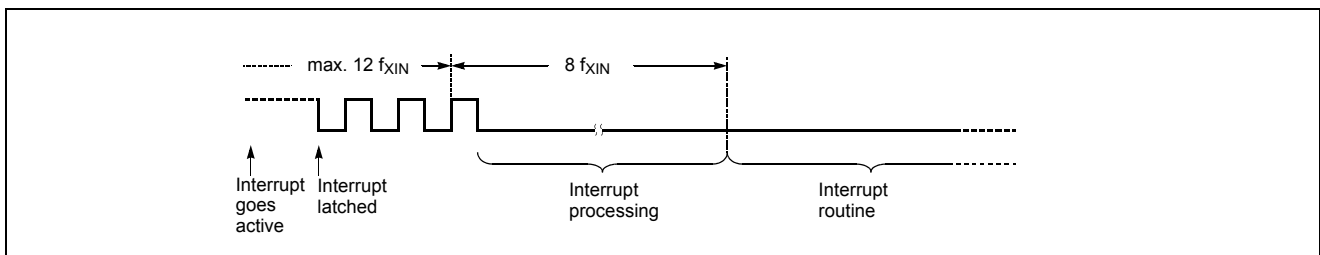


Figure 17-8 Interrupt Response Timing Diagram

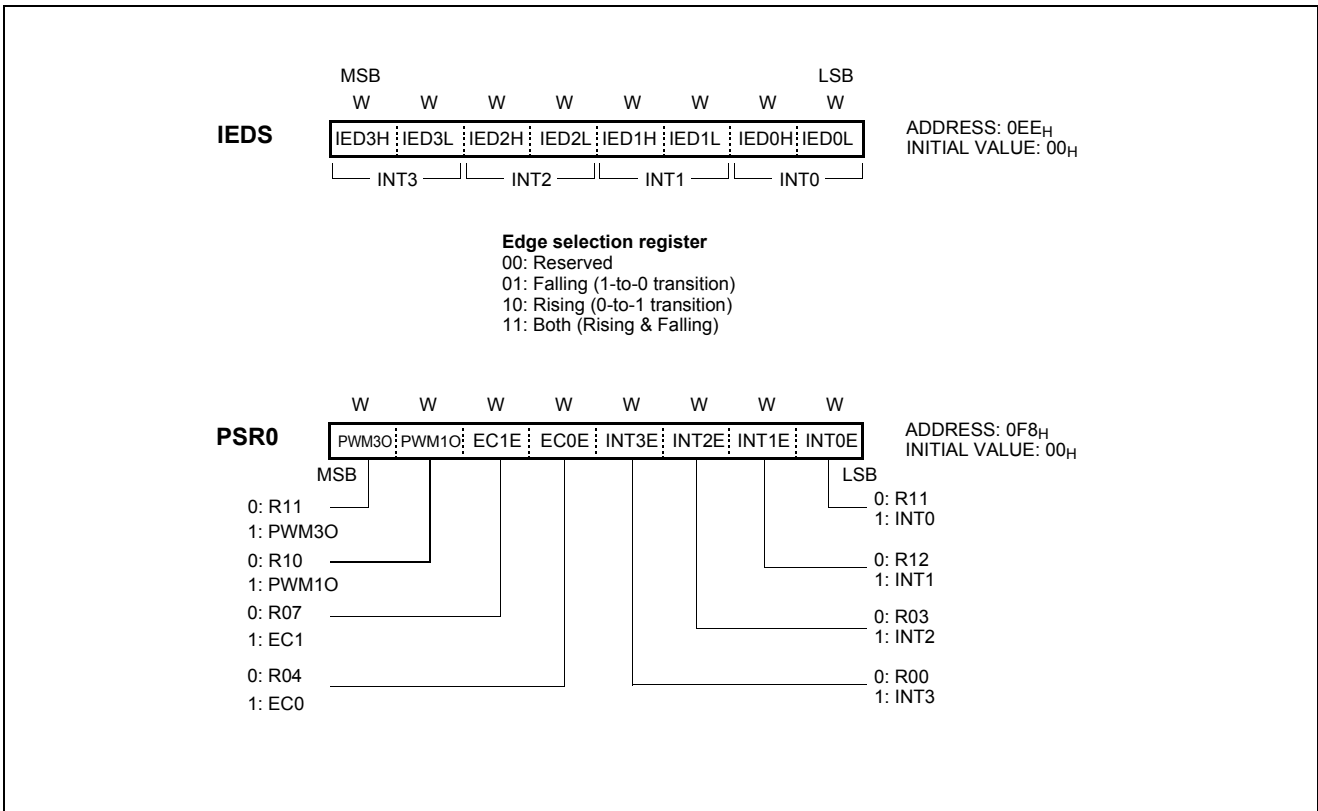


Figure 17-9 IEDS register and Port Selection Register PSR0

18. POWER SAVING OPERATION

The MC80F0704/0708/0804/0808 has two power-down modes. In power-down mode, power consumption is reduced considerably. For applications where power consumption is a critical factor, device provides two kinds of power saving func-

tions, STOP mode and SLEEP mode. Table 18-1 shows the status of each Power Saving Mode. SLEEP mode is entered by the SSCR register to “0Fh”, and STOP mode is entered by STOP instruction after the SSCR register to “5Ah”.

18.1 Sleep Mode

In this mode, the internal oscillation circuits remain active. Oscillation continues and peripherals are operate normally but CPU stops. Movement of all peripherals is shown in Table 18-1. SLEEP mode is entered by setting the SSCR register to “0Fh”. It

is released by Reset or interrupt. To be released by interrupt, interrupt should be enabled before SLEEP mode.

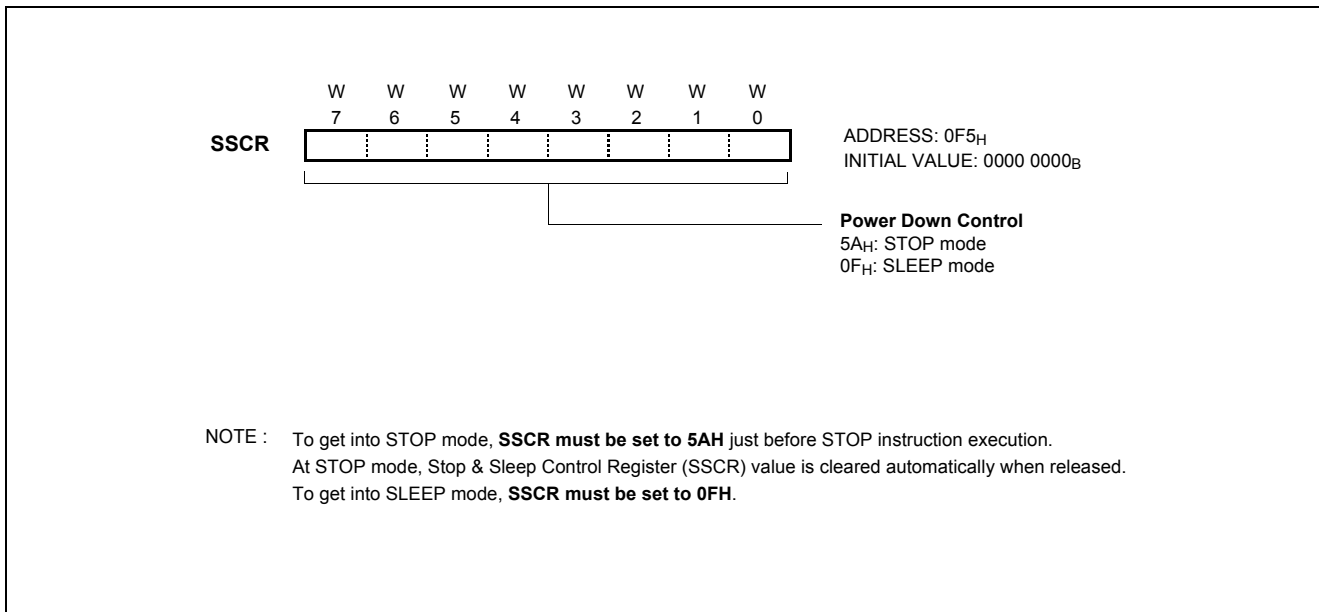


Figure 18-1 STOP and SLEEP Control Register

Release the SLEEP mode

The exit from SLEEP mode is hardware reset or all interrupts. Reset re-defines all the Control registers but does not change the on-chip RAM. Interrupts allow both on-chip RAM and Control registers to retain their values.

If I-flag = 1, the normal interrupt response takes place. If I-flag = 0, the chip will resume execution starting with the instruction following the SLEEP instruction. It will not vector to interrupt service routine. (refer to Figure 18-4)

When exit from SLEEP mode by reset, enough oscillation stabilizing time is required to normal operation. Figure 18-3 shows the timing diagram. When released from the SLEEP mode, the Basic interval timer is activated on wake-up. It is increased from 00H until FFH. The count overflow is set to start normal operation. Therefore, before SLEEP 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. By interrupts, exit from SLEEP mode is shown in Figure 18-2. By reset, exit from SLEEP mode is shown in Figure 18-3.

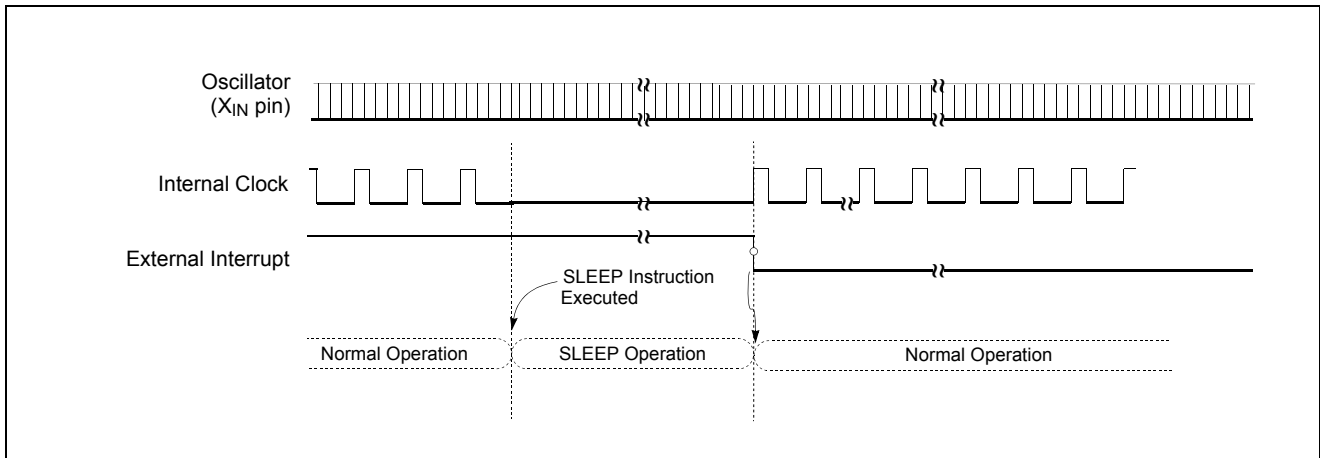


Figure 18-2 SLEEP Mode Release Timing by External Interrupt

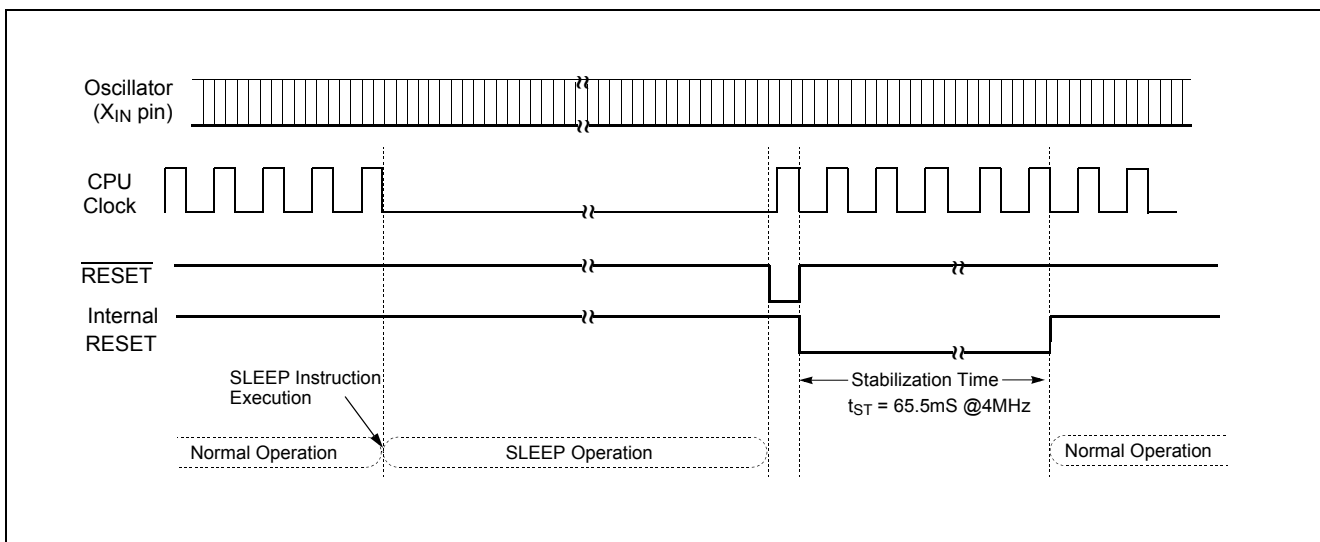


Figure 18-3 Timing of SLEEP Mode Release by Reset

18.2 Stop Mode

In the Stop mode, the main oscillator, system clock and peripheral clock is stopped, but RC-oscillated watchdog timer continue to operate. With the clock frozen, all functions are stopped, but the on-chip RAM and Control registers are held. The port pins out the values held by their respective port data register, port direction registers. Oscillator stops and the systems internal operations are all held up.

- The states of the RAM, registers, and latches valid immediately before the system is put in the STOP state are all held.
- The program counter stop the address of the instruction to be executed after the instruction "STOP" which starts the STOP operating mode.

Note: The Stop mode is activated by execution of STOP instruction after setting the SSCR to "5AH". (This register should be written by byte operation. If this register is set by bit manipulation instruction, for example "set1" or "clr1" instruction, it may be undesired operation)

In the Stop mode of operation, V_{DD} can be reduced to minimize power consumption. Care must be taken, however, to ensure that V_{DD} is not reduced before the Stop mode is invoked, and that V_{DD} is restored to its normal operating level, before the Stop mode is terminated.

The reset should not be activated before V_{DD} is restored to its normal operating level, and must be held active long enough to allow the oscillator to restart and stabilize.

Note: After STOP instruction, at least two or more NOP instruction should be written.

```
Ex) LDM CKCLR,#0FH ;more than 20ms
     LDM SSCR,#5AH
     STOP
     NOP ;for stabilization time
     NOP ;for stabilization time
```

In the STOP operation, the dissipation of the power associated with the oscillator and the internal hardware is lowered; however,

the power dissipation associated with the pin interface (depending on the external circuitry and program) is not directly determined by the hardware operation of the STOP feature. This point should be little current flows when the input level is stable at the power voltage level (V_{DD}/V_{SS}); however, when the input level gets higher than the power voltage level (by approximately 0.3 to 0.5V), a current begins to flow. Therefore, if cutting off the output transistor at an I/O port puts the pin signal into the high-impedance state, a current flow across the ports input transistor, requiring to fix the level by pull-up or other means.

| Peripheral | STOP Mode | SLEEP Mode |
|----------------------|--|----------------------------------|
| CPU | Stop | Stop |
| RAM | Retain | Retain |
| Basic Interval Timer | Halted | Operates Continuously |
| Watchdog Timer | Stop (Only operates in RC-WDT mode) | Stop |
| Timer/Counter | Halted (Only when the event counter mode is enabled, timer operates normally) | Operates Continuously |
| Buzzer, ADC | Stop | Stop |
| SIO | Only operate with external clock | Only operate with external clock |
| Oscillator | Stop ($X_{IN}=L, X_{OUT}=H$) | Oscillation |
| I/O Ports | Retain | Retain |
| Control Registers | Retain | Retain |
| Internal Circuit | Stop mode | Sleep mode |
| Prescaler | Retain | Active |
| Address Data Bus | Retain | Retain |
| Release Source | Reset, Timer(EO,1), SIO (ext. clock), Watchdog Timer (RC-WDT mode), External Interrupt | Reset, All Interrupts |

Table 18-1 Peripheral Operation During Power Saving Mode

Release the STOP mode

The source for exit from STOP mode is hardware reset, external interrupt, Timer(EO,1), WDT, SIO. When releasing from the STOP mode by the SIO(ext.clock), the SIOR has dummy data and the SIOST bit should be cleared after release from the STOP mode.

Reset re-defines all the Control registers but does not change the on-chip RAM. External interrupts allow both on-chip RAM and Control registers to retain their values.

If I-flag = 1, the normal interrupt response takes place. If I-flag = 0, the chip will resume execution starting with the instruction following the STOP instruction. It will not vector to interrupt service

routine. (refer to Figure 18-4)

When exit from Stop mode by external interrupt, enough oscillation stabilizing time is required to normal operation. Figure 18-5 shows the timing diagram. When released from the Stop mode, the Basic interval timer is activated on wake-up. It is increased from 00_H until FF_H. The count overflow is set to start normal operation. 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.

By reset, exit from Stop mode is shown in Figure 18-6 .

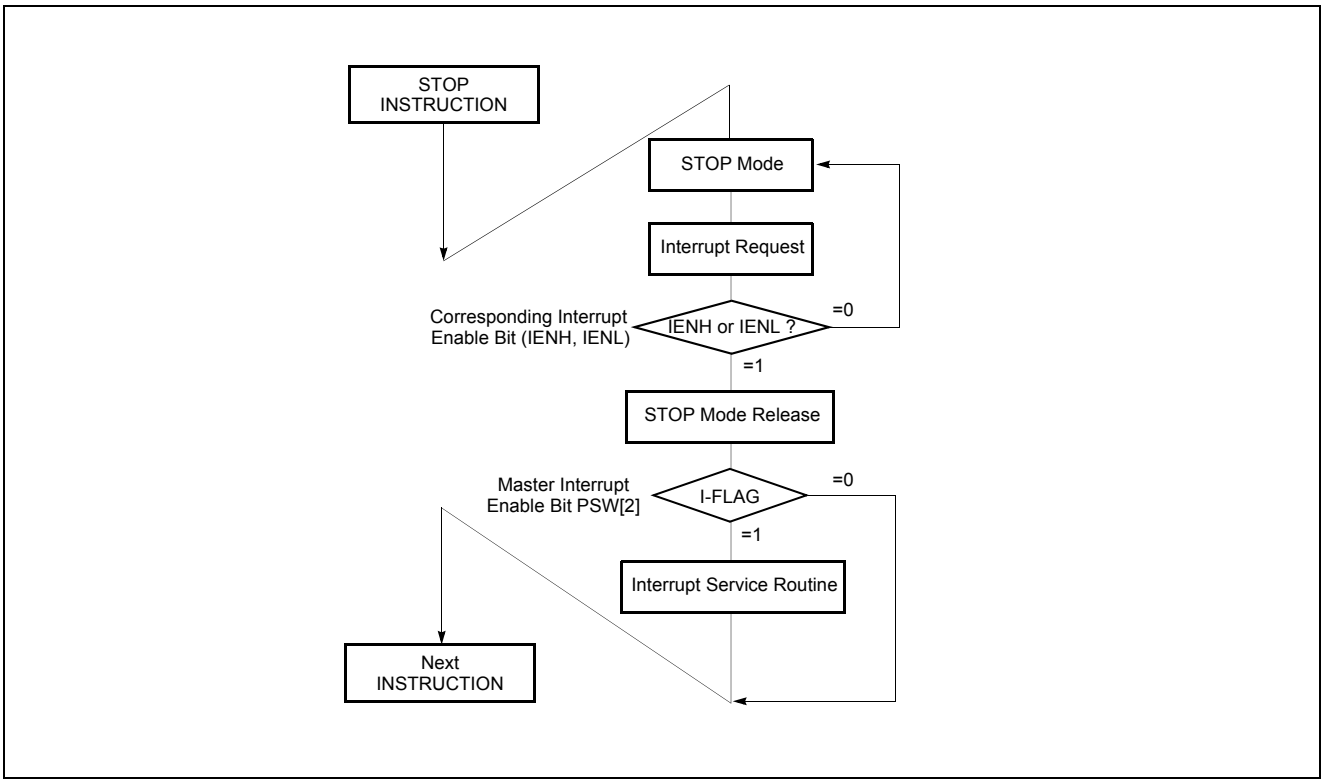


Figure 18-4 STOP Releasing Flow by Interrupts

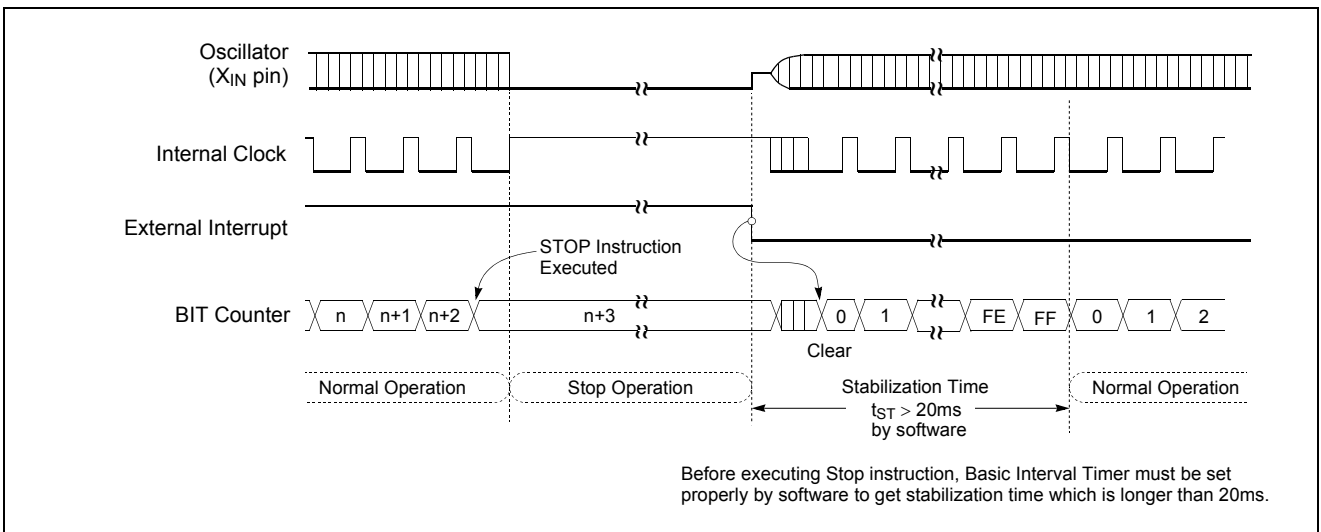


Figure 18-5 STOP Mode Release Timing by External Interrupt

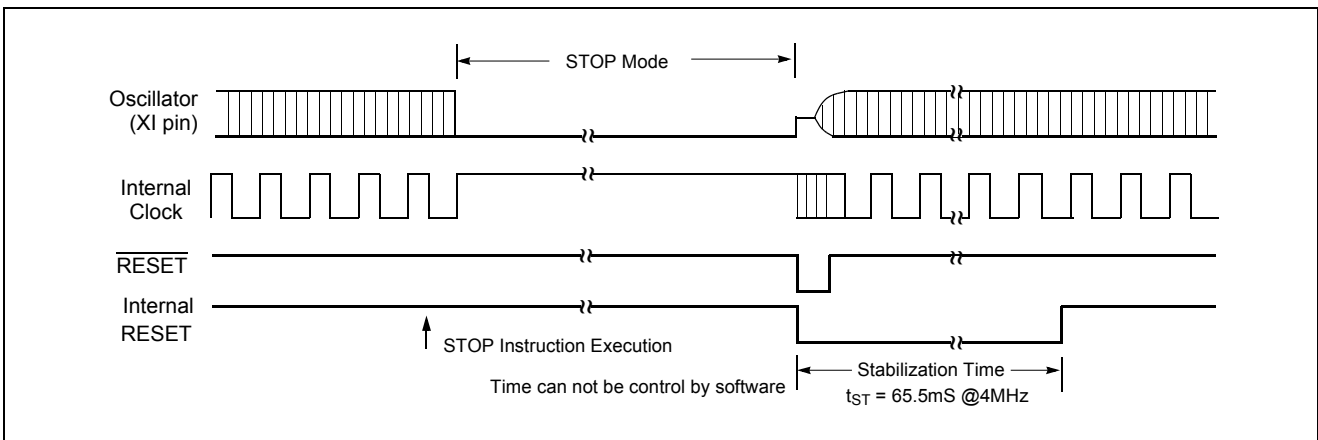


Figure 18-6 Timing of STOP Mode Release by Reset

18.3 Stop Mode at Internal RC-Oscillated Watchdog Timer Mode

In the Internal RC-Oscillated Watchdog Timer mode, the on-chip oscillator is stopped. But internal RC oscillation circuit is oscillated in this mode. The on-chip RAM and Control registers are held. The port pins out the values held by their respective port data register, port direction registers.

The Internal RC-Oscillated Watchdog Timer mode is activated by execution of STOP instruction after setting the bit RCWDT of CKCTLR to "1". (This register should be written by byte operation. If this register is set by bit manipulation instruction, for example "set1" or "clr1" instruction, it may be undesired operation)

Note: Caution: After STOP instruction, at least two or more NOP instruction should be written

```
Ex) LDM WDTR,#1111_1111B
     LDM CKCTLR,#0010_1110B
     LDM SSCR,#0101_1010B
     STOP
     NOP ;for stabilization time
     NOP ;for stabilization time
```

The exit from Internal RC-Oscillated Watchdog Timer mode is hardware reset or external interrupt or watchdog timer interrupt

(at RC-watchdog timer mode). Reset re-defines all the Control registers but does not change the on-chip RAM. External interrupts allow both on-chip RAM and Control registers to retain their values.

If I-flag = 1, the normal interrupt response takes place. In this case, if the bit WDTON of CKCTLR is set to "0" and the bit WDTE of IENH is set to "1", the device will execute the watchdog timer interrupt service routine(Figure 8-6). However, if the bit WDTON of CKCTLR is set to "1", the device will generate the internal Reset signal and execute the reset processing(Figure 18-8). If I-flag = 0, the chip will resume execution starting with the instruction following the STOP instruction. It will not vector to interrupt service routine.(refer to Figure 18-4)

When exit from Stop mode at Internal RC-Oscillated Watchdog Timer mode by external interrupt, the oscillation stabilization time is required to normal operation. Figure 18-7 shows the timing diagram. When release the Internal RC-Oscillated Watchdog Timer mode, the basic interval timer is activated on wake-up. It is increased from 00_H until FF_H. The count overflow is set to start normal operation. 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. By reset, exit from internal RC-Oscillated Watchdog Timer mode is shown in Figure 18-8 .

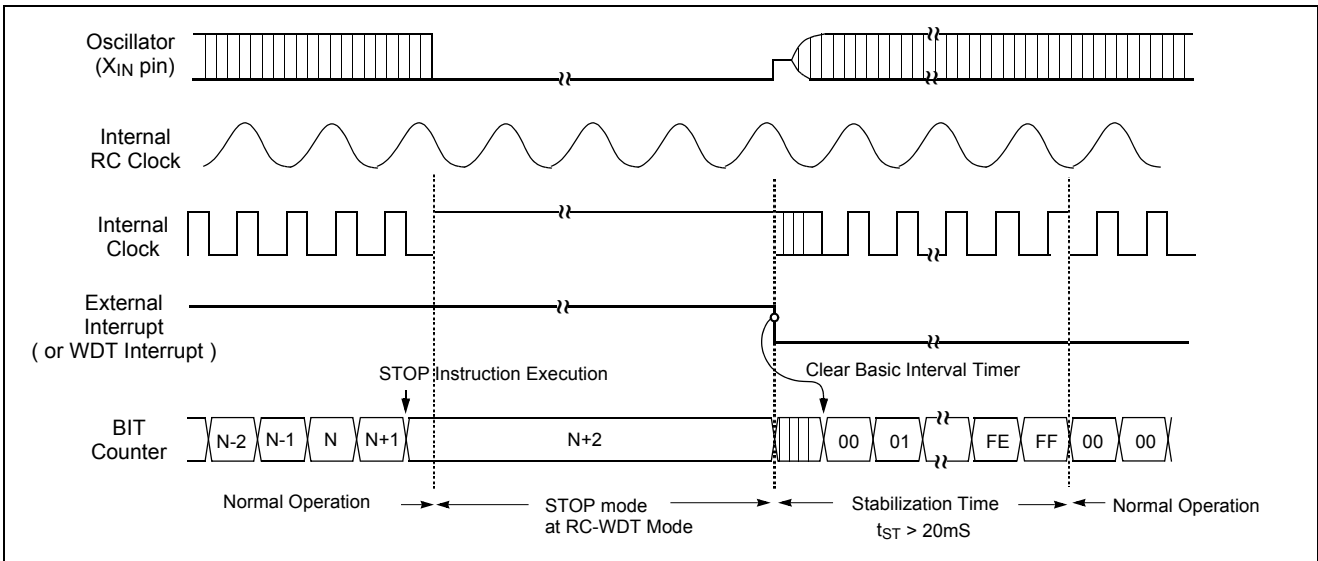


Figure 18-7 Stop Mode Release at Internal RC-WDT Mode by External Interrupt or WDT Interrupt

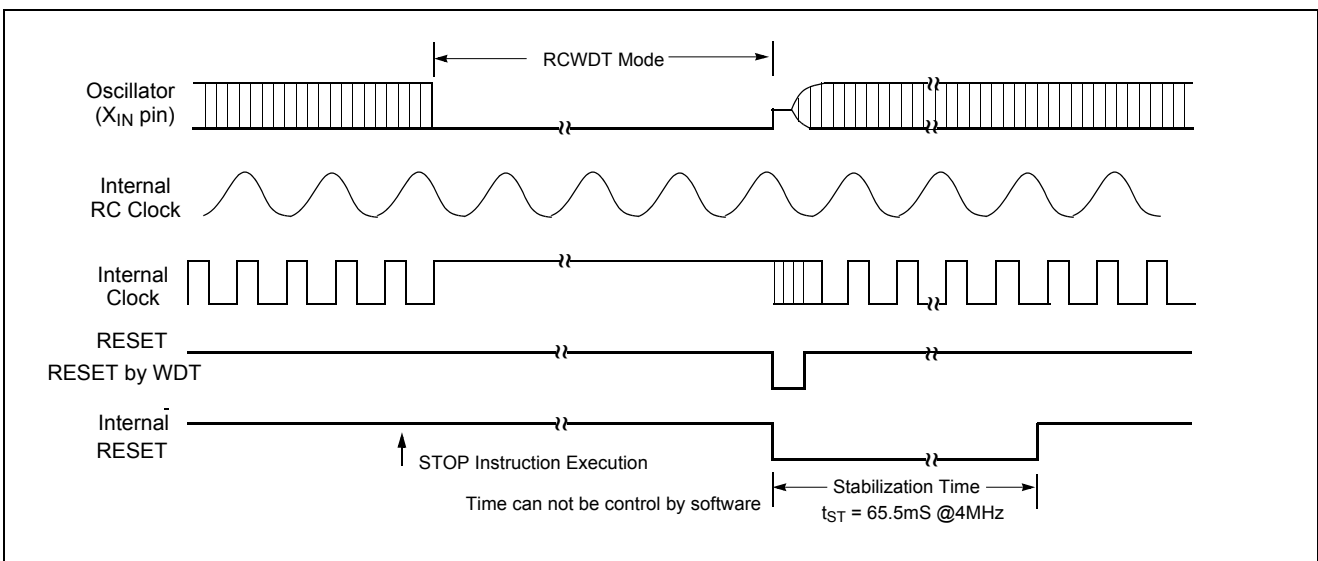


Figure 18-8 Internal RC-WDT Mode Releasing by Reset

18.4 Minimizing Current Consumption

The Stop mode is designed to reduce power consumption. To minimize current drawn during Stop mode, the user should turn-

off output drivers that are sourcing or sinking current, if it is practical.

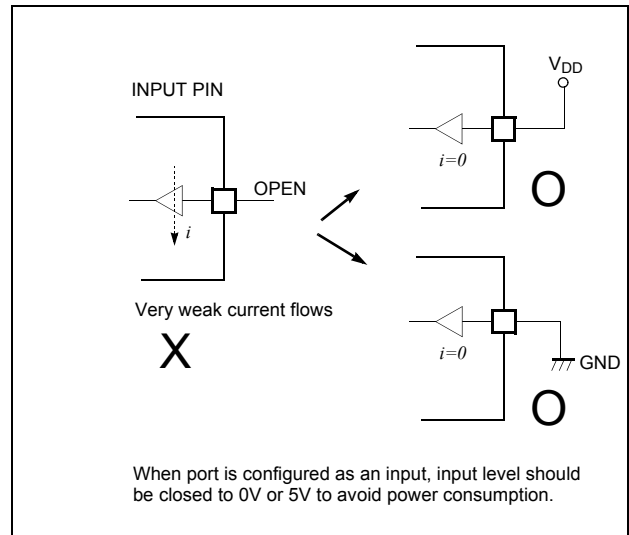
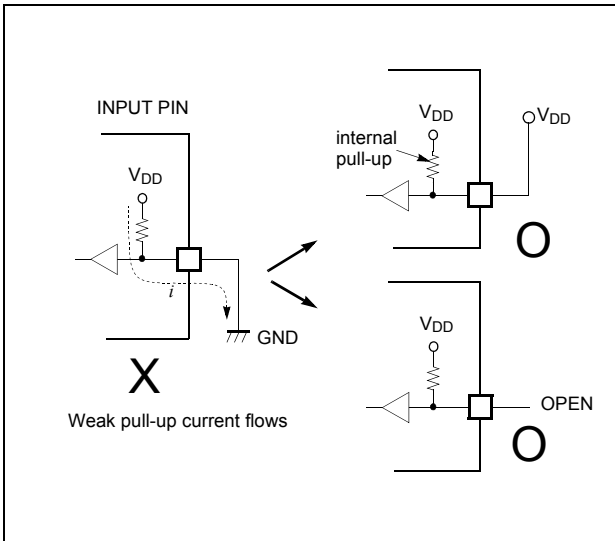


Figure 18-9 Application Example of Unused Input Port

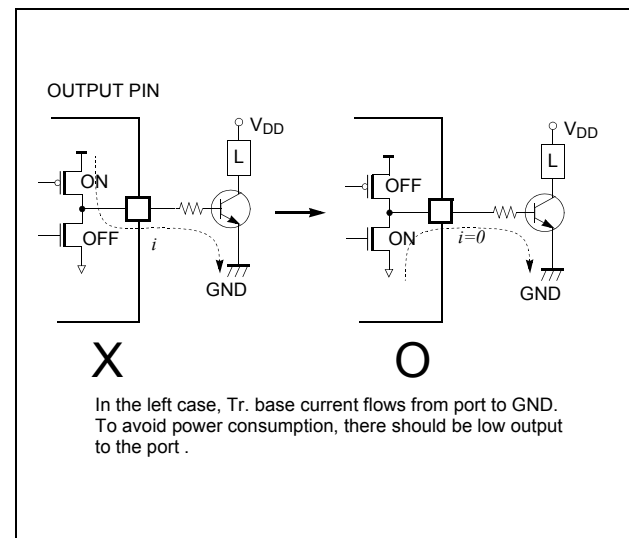
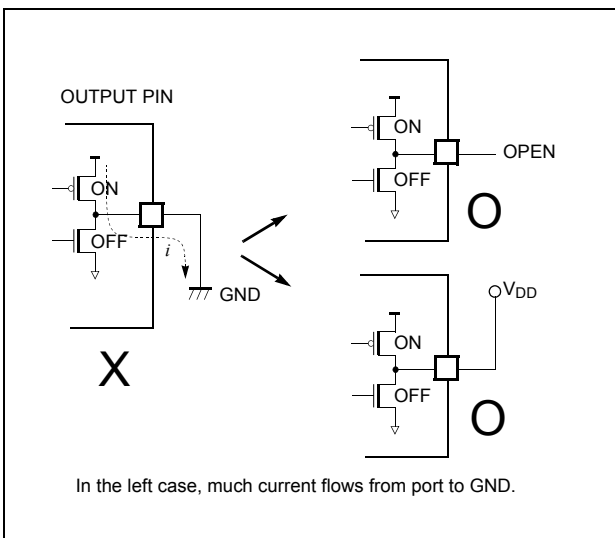


Figure 18-10 Application Example of Unused Output Port

Note: In the STOP operation, the power dissipation associated with the oscillator and the internal hardware is lowered; however, the power dissipation associated with the pin interface (depending on the external circuitry and program) is not directly determined by the hardware operation of the STOP feature. This point should be little current flows when the input level is stable at the power voltage level (V_{DD}/V_{SS}); however, when the input level becomes higher than the power voltage level (by approximately 0.3V), a current begins to flow. Therefore, if cutting off the output transistor at an I/O port puts the pin signal into the high-impedance state, a current flow across the ports input transistor, requiring it to fix the level by

pull-up or other means.

It should be set properly in order that current flow through port doesn't exist.

First consider the port setting to input mode. Be sure that there is no current flow after considering its relationship with external circuit. In input mode, the pin impedance viewing from external MCU is very high that the current doesn't flow.

But input voltage level should be V_{SS} or V_{DD} . Be careful that if unspecified voltage, i.e. if uncertain voltage level (not V_{SS} or

V_{DD}) is applied to input pin, there can be little current (max. 1mA at around 2V) flow.

If it is not appropriate to set as an input mode, then set to output mode considering there is no current flow. The port setting to High or Low is decided by considering its relationship with exter-

nal circuit. For example, if there is external pull-up resistor then it is set to output mode, i.e. to High, and if there is external pull-down register, it is set to low.

19. RESET

The MC80F0704/0708/0804/0808 supports various kinds of reset as below.

- Power-On Reset (POR)
- $\overline{\text{RESET}}$ (external reset circuitry)
- Watchdog Timer Timeout Reset
- Power-Fail Detection (PFD) Reset
- Address Fail Reset

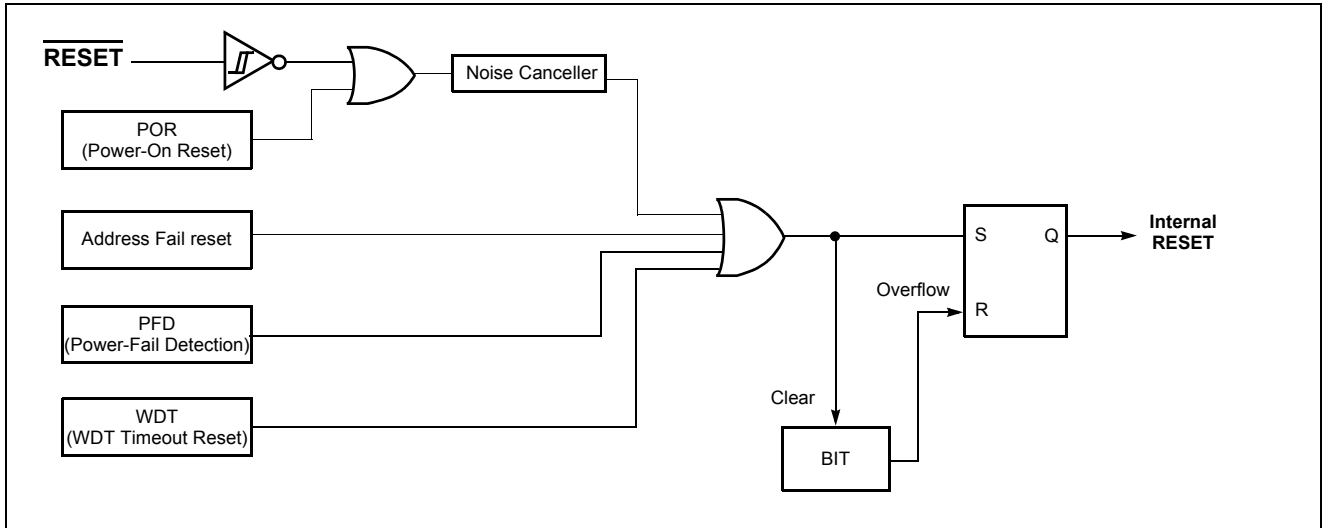


Figure 19-1 RESET Block Diagram

The on-chip POR circuit holds down the device in RESET until V_{DD} has reached a high enough level for proper operation. It will eliminate external components such as reset IC or external resistor and capacitor for external reset circuit. In addition that the $\overline{\text{RESET}}$ pin can be used to normal input port R35 by setting “POR”

and “R35EN” bit Configuration Area(20FFH) in the Flash programming. When the device starts normal operation, its operating parameters (voltage, frequency, temperature...etc) must be met.

.Table 19-1 shows on-chip hardware initialization by reset action.

| On-chip Hardware | Initial Value |
|-------------------------|---|
| Program counter (PC) | (FFFF _H) - (FFFE _H) |
| RAM page register (RPR) | 0 |
| G-flag (G) | 0 |
| Operation mode | Main-frequency clock |

| On-chip Hardware | Initial Value |
|---------------------|-------------------------------|
| Peripheral clock | Off |
| Watchdog timer | Disable |
| Control registers | Refer to Table 8-1 on page 30 |
| Power fail detector | Disable |

Table 19-1 Initializing Internal Status by Reset Action

The reset input is the $\overline{\text{RESET}}$ pin, which is the input to a Schmitt Trigger. A reset is accomplished by holding the $\overline{\text{RESET}}$ pin low for at least 8 oscillator periods, within the operating voltage range and oscillation stable, it is applied, and the internal state is initialized. After reset, 65.5ms (at 4 MHz) add with 7 oscillator periods are required to start execution as shown in Figure 19-3 .

Internal RAM is not affected by reset. When V_{DD} is turned on, the RAM content is indeterminate. Therefore, this RAM should be initialized before read or tested it.

When the $\overline{\text{RESET}}$ pin input goes to high, the reset operation is released and the program execution starts at the vector address stored at addresses FFFE_H - FFFF_H.

A connection for simple power-on-reset is shown in Figure 19-2 .

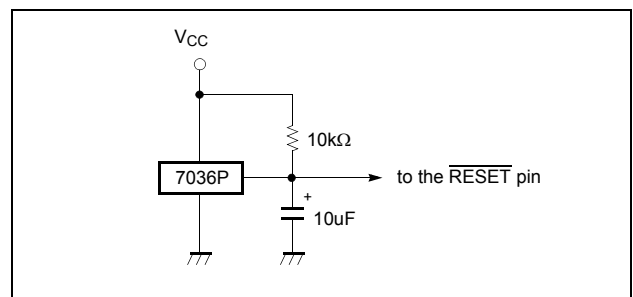


Figure 19-2 Simple Power-on-Reset Circuit

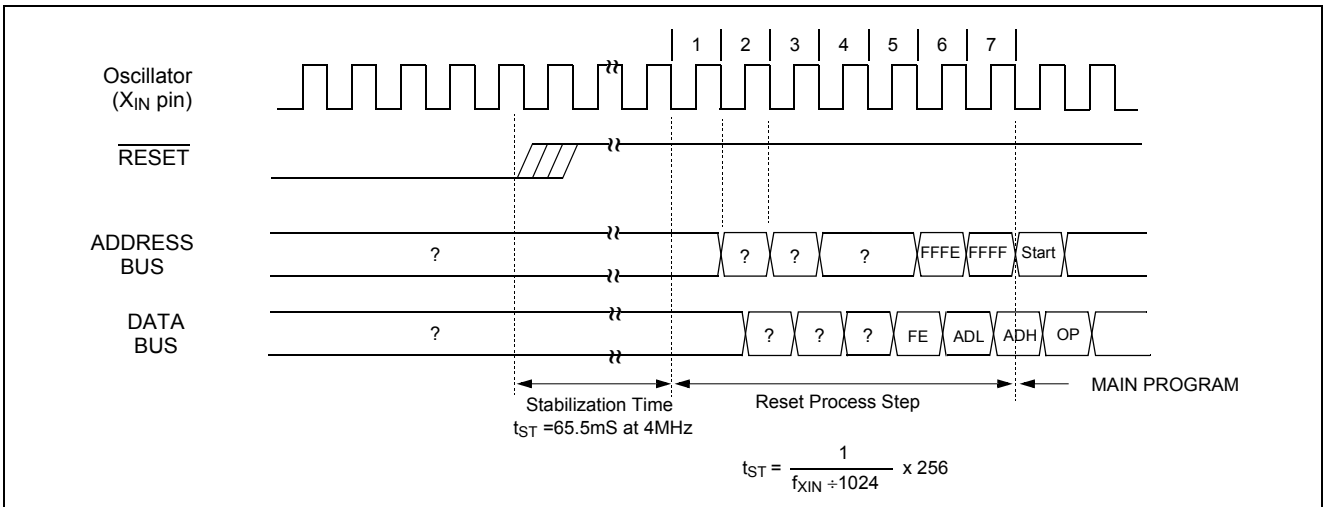


Figure 19-3 Timing Diagram after Reset

The Address Fail Reset is the function to reset the system by checking code access of abnormal and unwished address caused by erroneous program code itself or external noise, which could not be returned to normal operation and would become malfunction state. If the CPU tries to fetch the instruction from ineffective

code area or RAM area, the address fail reset is occurred. Please refer to Figure 11-2 for setting address fail option.

20. POWER FAIL PROCESSOR

The MC80F0704/0708/0804/0808 has an on-chip power fail detection circuitry to immunize against power noise. A configuration register, PFDR, can enable or disable the power fail detect circuitry. Whenever V_{DD} falls close to or below power fail voltage for 100ns, the power fail situation may reset or freeze MCU according to PFDM bit of PFDR. Refer to “Figure 20-1 Power

Fail Voltage Detector Register” on page 97.

In the in-circuit emulator, power fail function is not implemented and user can not experiment with it. Therefore, after final development of user program, this function may be experimented or evaluated.

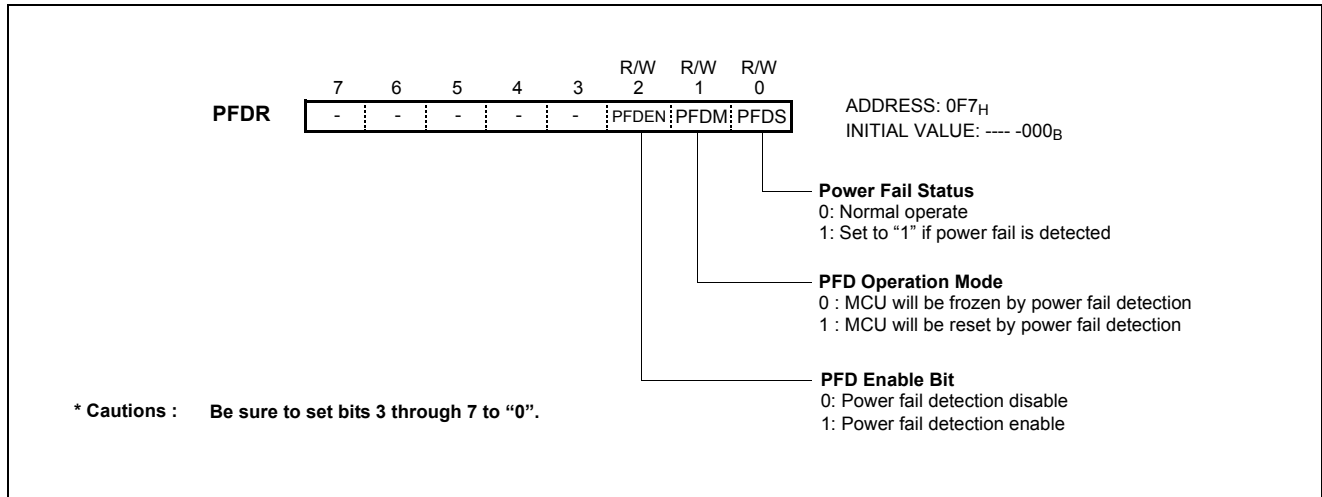


Figure 20-1 Power Fail Voltage Detector Register

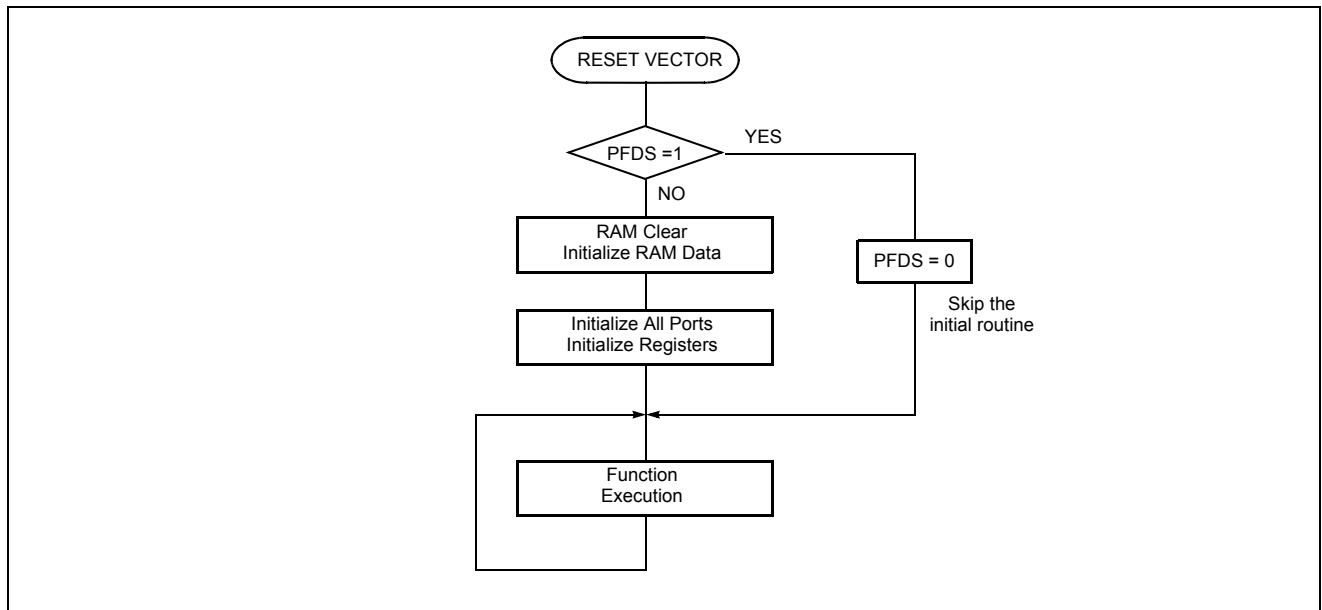


Figure 20-2 Example S/W of Reset flow by Power fail

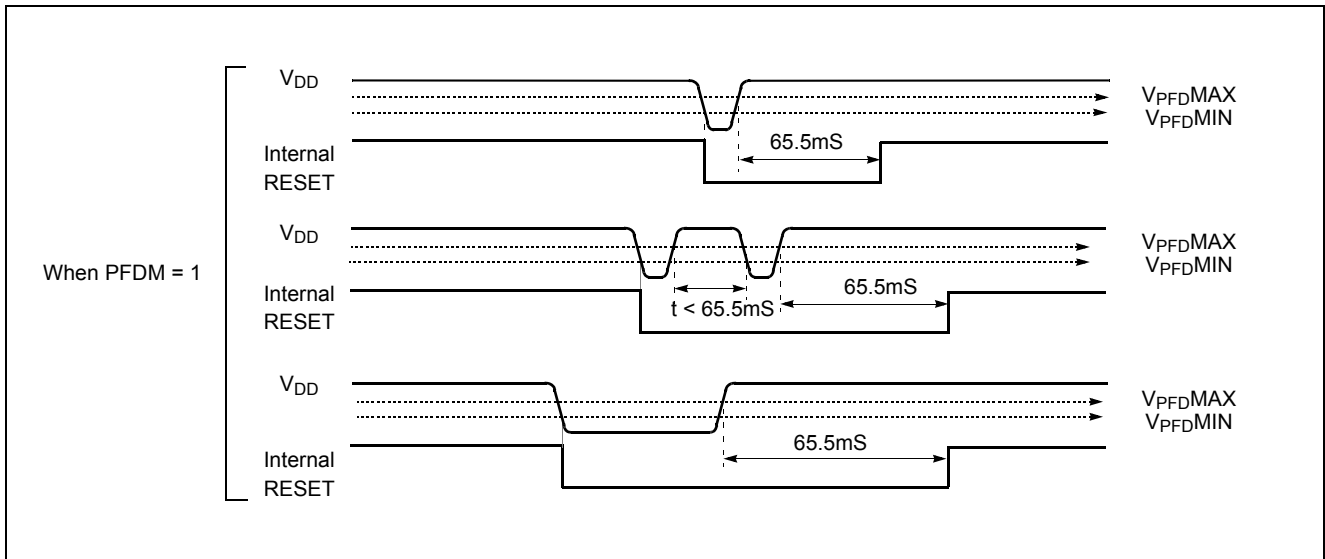


Figure 20-3 Power Fail Processor Situations (at 4MHz operation)

21. COUNTERMEASURE OF NOISE

21.1 Oscillation Noise Protector

The Oscillation Noise Protector (ONP) is used to supply stable internal system clock by excluding the noise which could be entered into oscillator and recovery the oscillation fail. This function could be enabled or disabled by the “ONP” bit of the Device configuration area (20FF_H) for the MC80F0704/0708/0804/0808, “ONP” option bits MASK option.

The ONP function is like below.

- Recovery the oscillation wave crushed or loss caused

by high frequency noise.

- Change system clock to the internal oscillation clock when the high frequency noise is continuing.
- Change system clock to the internal oscillation clock when the X_{IN}/X_{OUT} is shorted or opened, the main oscillation is stopped except by stop instruction and the low frequency noise is entered.

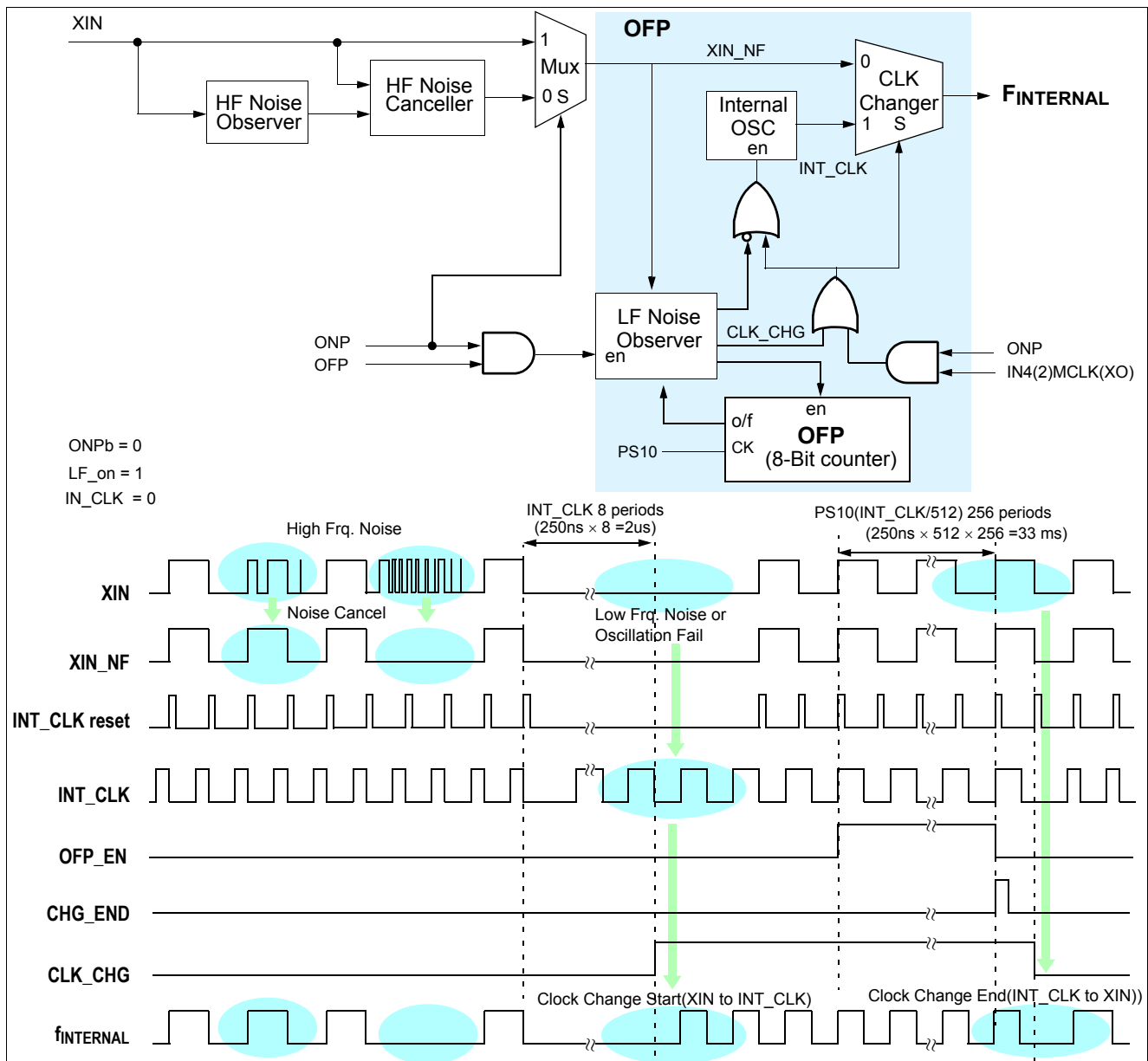


Figure 21-1 Block Diagram of ONP & OFF and Respective Wave Forms

21.2 Oscillation Fail Processor

The oscillation fail processor (OFP) can change the clock source from external to internal oscillator when the oscillation fail occurred. This function could be enabled or disabled by the “OFP” bit of the Device Configuration Area (MASK option for MC80F0704/0708/0804/0808).

And this function can recover the external clock source when the external clock is recovered to normal state.

IN4(2)MCLK/CLKXO(XO) Option

The “IN4MCLK(XO)”, “IN2MCLK(XO)” bit of the Device

Configuration Area (MASK option for MC80F0704/0708/0804/0808 enables the function to operate the device by using the internal oscillator clock in ONP block as system clock. There is no need to connect the X-tal, resonator, RC and R externally. The user only to connect the X_{IN} pin to V_{DD}. After selecting the this option, the period of internal oscillator clock could be checked by X_{OUT} outputting clock divided the internal oscillator clock by 4.

22. Device Configuration Area

The Device Configuration Area can be programmed or left un-programmed to select device configuration such as POR, ONP, CLK option and security bit. This area is not accessible during normal execution but is readable and writable during FLASH program / verify mode.

Note: The Configuration Option may not be read exactly when VDD rising time is very slow. It is recommended to adjust the VDD rising time faster than 40ms/V (200ms from 0V to 5V).

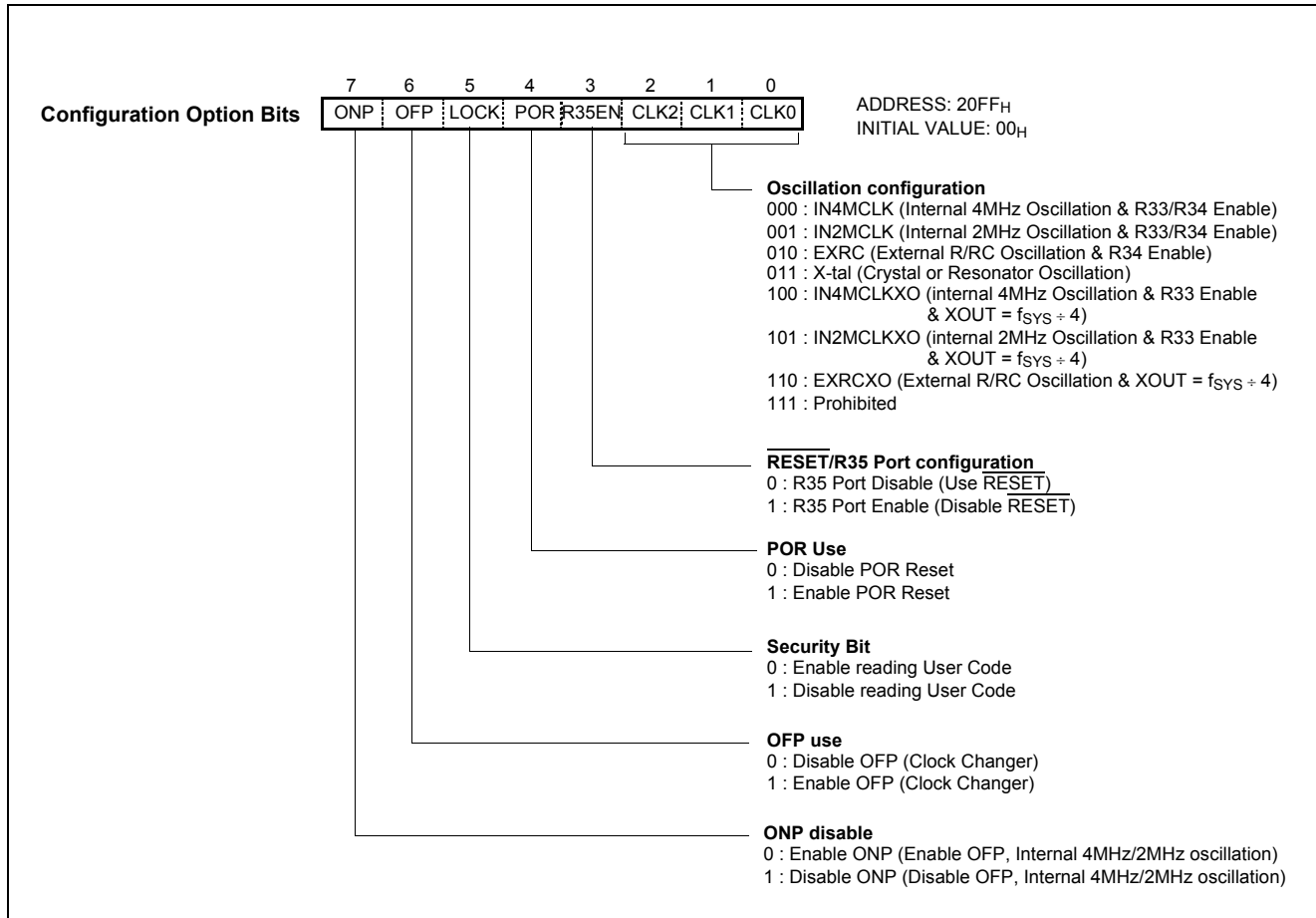
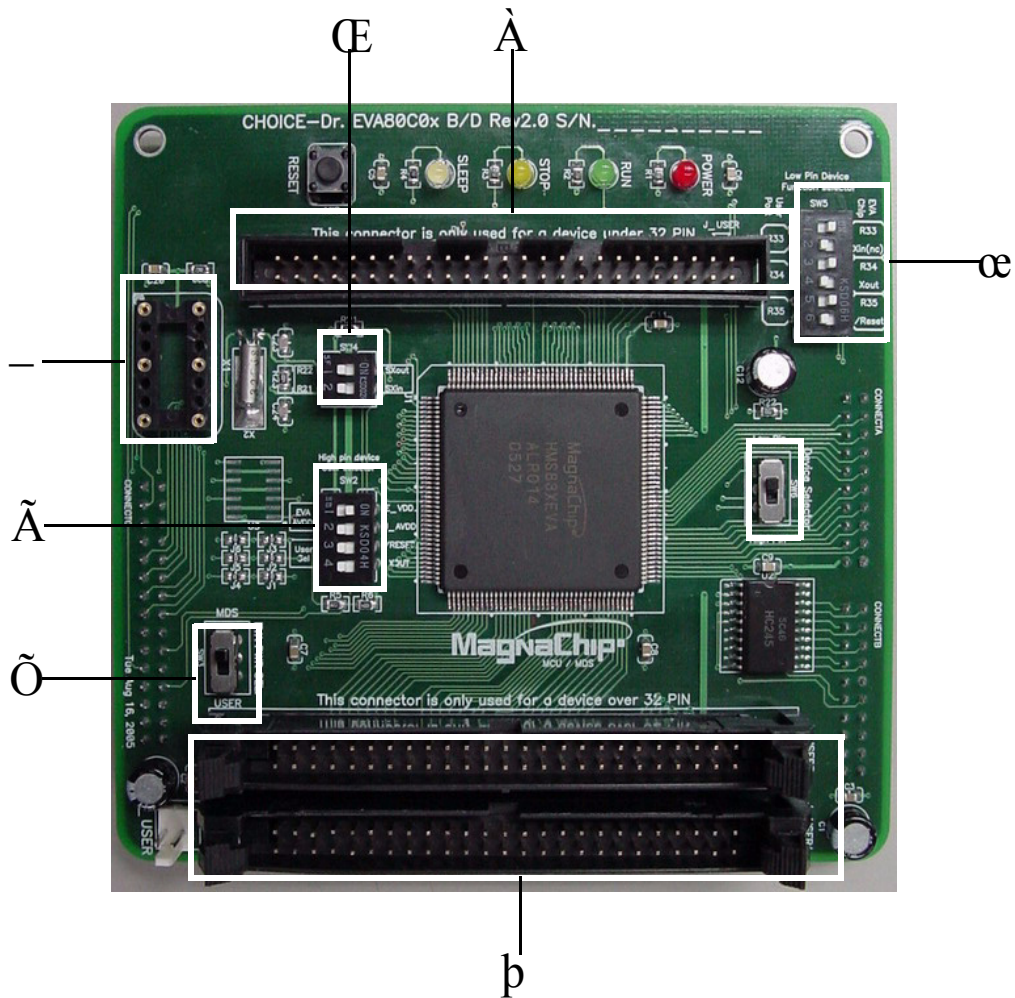


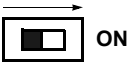


Figure 22-1 Device Configuration Area


23. Emulator EVA. Board Setting



DIP Switch and VR Setting configuration

Before execute the user program, keep in your mind the below

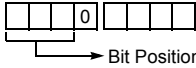
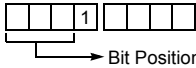
| DIP S/W | Description | ON/OFF Setting |
|-----------------|---|---|
| b | - This connector is only used for a device over 32 PIN. | For the MC80F0224/MC80F0448 |
| A | - This connector is only used for a device under 32 PIN. | For the MC80F0708/0808. |
| Ã SW2 | 1  ON Eva. select switch | Must be OFF position. ON : For the MC80F0224/MC80F0448. OFF : For the MC80F0708/0808. |
| | 2 3  Use Eva. V _{DD} Use User's AV _{DD} AV _{DD} pin select switch | These switches select the AV _{DD} source. ON & OFF : Use Eva. V _{DD} OFF & ON : Use User AV _{DD} |
| | 4 This switch select the /Reset source. | Normally OFF . EVA. chip can be reset by external user target board. ON : Reset is available by either user target system board or Emulator RESET switch. OFF : Reset the MCU by Emulator RESET switch. Does not work from user target board. |
| | 5 This switch select the Xout signal on/off. | Normally OFF . MCU XOUT pin is disconnected internally in the Emulator. Some circumstance user may connect this circuit. ON : Output XOUT signal OFF : Disconnect circuit |
| | This switch select Eva. B/D Power supply source. | |
| Õ SW3 | 1  Use MDS Power Use User's Power | Normally MDS . This switch select Eva. B/D Power supply source. |
| Ɖ SW4 | 1 This switch select the R22 or SX _{OUT} . 2 This switch select the R21 or SX _{IN} . | These switches select the Normal I/O port(off) or Sub-Clock (on). It is reserved for the MC80F0448. ON : SX _{OUT} , SX _{IN} OFF : R22, R21 Don't care (MC80F0224/MC80F0448). |

| DIP S/W | | Description | ON/OFF Setting |
|--|--------|--|--|
|  SW5 | 1 2 | These switches select the R33 or X _{IN} | This switch select the Normal I/O port (on&off) or special function select(off&on). It is reserved for the MC80F0708/0808. ON & OFF : R33,R34,R35 Port selected. OFF & ON : X _{OUT} , X _{IN} , /Reset selected. Don't care (MC80F0224/MC80F0448). |
| | 3 4 | These switches select the R34 or X _{OUT} | |
| | 5 6 | These switches select the R35 or /Reset | |
| — | - | This is External oscillation socket(CAN Type. OSC) | This is for External Clock (CAN Type. OSC). |

APPENDIX

A. INSTRUCTION

A.1 Terminology List

| Terminology | Description |
|-------------|---|
| A | Accumulator |
| X | X - register |
| Y | Y - register |
| PSW | Program Status Word |
| #imm | 8-bit Immediate data |
| dp | Direct Page Offset Address |
| !abs | Absolute Address |
| [] | Indirect expression |
| {} | Register Indirect expression |
| { }+ | Register Indirect expression, after that, Register auto-increment |
| .bit | Bit Position |
| A.bit | Bit Position of Accumulator |
| dp.bit | Bit Position of Direct Page Memory |
| M.bit | Bit Position of Memory Data (000H~0FFFH) |
| rel | Relative Addressing Data |
| upage | U-page (0FF00H~0FFFFH) Offset Address |
| n | Table CALL Number (0~15) |
| + | Addition |
| x |  Upper Nibble Expression in Opcode |
| y |  Upper Nibble Expression in Opcode |
| - | Subtraction |
| x | Multiplication |
| / | Division |
| () | Contents Expression |
| ^ | AND |
| ∨ | OR |
| ⊕ | Exclusive OR |
| ~ | NOT |
| ← | Assignment / Transfer / Shift Left |
| → | Shift Right |
| ↔ | Exchange |
| = | Equal |
| ≠ | Not Equal |

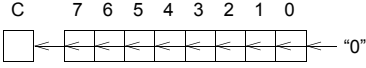
A.2 Instruction Map

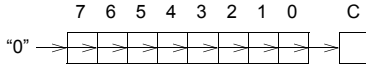
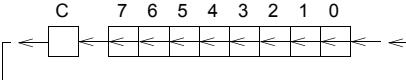
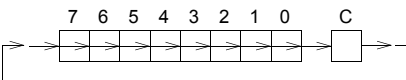
| LOW HIGH | 0000 00 | 00001 01 | 00010 02 | 00011 03 | 00100 04 | 00101 05 | 00110 06 | 00111 07 | 01000 08 | 01001 09 | 01010 0A | 01011 0B | 01100 0C | 01101 0D | 01110 0E | 01111 0F |
|----------|---------|----------------|------------------|-------------------|----------------|-----------|-------------|-------------|----------|-----------|-------------|---------------|------------|--------------|-------------|----------------|
| 000 | - | SET1 dp.bit | BBS A.bit,rel | BBS dp.bit,rel | ADC #imm | ADC dp | ADC dp+X | ADC !abs | ASL A | ASL dp | TCALL 0 | SETA1 .bit | BIT dp | POP A | PUSH A | BRK |
| 001 | CLRC | " | " | " | SBC #imm | SBC dp | SBC dp+X | SBC !abs | ROL A | ROL dp | TCALL 2 | CLRA1 .bit | COM dp | POP X | PUSH X | BRA rel |
| 010 | CLRG | " | " | " | CMP #imm | CMP dp | CMP dp+X | CMP !abs | LSR A | LSR dp | TCALL 4 | NOT1 M.bit | TST dp | POP Y | PUSH Y | PCALL Upage |
| 011 | DI | " | " | " | OR #imm | OR dp | OR dp+X | OR !abs | ROR A | ROR dp | TCALL 6 | OR1 OR1B | CMPX dp | POP PSW | PUSH PSW | RET |
| 100 | CLRV | " | " | " | AND #imm | AND dp | AND dp+X | AND !abs | INC A | INC dp | TCALL 8 | AND1 AND1B | CMPY dp | CBNE dp+X | TXSP | INC X |
| 101 | SETC | " | " | " | EOR #imm | EOR dp | EOR dp+X | EOR !abs | DEC A | DEC dp | TCALL 10 | EOR1 EOR1B | DBNE dp | XMA dp+X | TSPX | DEC X |
| 110 | SETG | " | " | " | LDA #imm | LDA dp | LDA dp+X | LDA !abs | TXA | LDY dp | TCALL 12 | LDC LDCB | LDX dp | LDX dp+Y | XCN | DAS (N/A) |
| 111 | EI | " | " | " | LDM dp,#imm | STA dp | STA dp+X | STA !abs | TAX | STY dp | TCALL 14 | STC M.bit | STX dp | STX dp+Y | XAX | STOP |

| LOW HIGH | 10000 10 | 10001 11 | 10010 12 | 10011 13 | 10100 14 | 10101 15 | 10110 16 | 10111 17 | 11000 18 | 11001 19 | 11010 1A | 11011 1B | 11100 1C | 11101 1D | 11110 1E | 11111 1F |
|----------|------------|----------------|------------------|-------------------|------------|---------------|---------------|---------------|-------------|-------------|-------------|--------------|---------------|------------|--------------|---------------|
| 000 | BPL rel | CLR1 dp.bit | BBC A.bit,rel | BBC dp.bit,rel | ADC {X} | ADC !abs+Y | ADC [dp+X] | ADC [dp]+Y | ASL !abs | ASL dp+X | TCALL 1 | JMP !abs | BIT !abs | ADDW dp | LDX #imm | JMP [!abs] |
| 001 | BVC rel | " | " | " | SBC {X} | SBC !abs+Y | SBC [dp+X] | SBC [dp]+Y | ROL !abs | ROL dp+X | TCALL 3 | CALL !abs | TEST !abs | SUBW dp | LDY #imm | JMP [dp] |
| 010 | BCC rel | " | " | " | CMP {X} | CMP !abs+Y | CMP [dp+X] | CMP [dp]+Y | LSR !abs | LSR dp+X | TCALL 5 | MUL | TCLR1 !abs | CMPW dp | CMPX #imm | CALL [dp] |
| 011 | BNE rel | " | " | " | OR {X} | OR !abs+Y | OR [dp+X] | OR [dp]+Y | ROR !abs | ROR dp+X | TCALL 7 | DBNE Y | CMPX !abs | LDYA dp | CMPY #imm | RETI |
| 100 | BMI rel | " | " | " | AND {X} | AND !abs+Y | AND [dp+X] | AND [dp]+Y | INC !abs | INC dp+X | TCALL 9 | DIV | CMPY !abs | INCW dp | INC Y | TAY |
| 101 | BVS rel | " | " | " | EOR {X} | EOR !abs+Y | EOR [dp+X] | EOR [dp]+Y | DEC !abs | DEC dp+X | TCALL 11 | XMA {X} | XMA dp | DECW dp | DEC Y | TYA |
| 110 | BCS rel | " | " | " | LDA {X} | LDA !abs+Y | LDA [dp+X] | LDA [dp]+Y | LDY !abs | LDY dp+X | TCALL 13 | LDA {X}+ | LDX !abs | STYA dp | XAY | DAA (N/A) |
| 111 | BEQ rel | " | " | " | STA {X} | STA !abs+Y | STA [dp+X] | STA [dp]+Y | STY !abs | STY dp+X | TCALL 15 | STA {X}+ | STX !abs | CBNE dp | XYX | NOP |

A.3 Instruction Set

Arithmetic / Logic Operation

| NO. | MNEMONIC | OP CODE | BYTE NO | CYCLE NO | OPERATION | FLAG NVGBHIZC |
|-----|----------------|---------|---------|----------|---|---------------|
| 1 | ADC #imm | 04 | 2 | 2 | Add with carry. $A \leftarrow (A) + (M) + C$ | NV--H-ZC |
| 2 | ADC dp | 05 | 2 | 3 | | |
| 3 | ADC dp + X | 06 | 2 | 4 | | |
| 4 | ADC !abs | 07 | 3 | 4 | | |
| 5 | ADC !abs + Y | 15 | 3 | 5 | | |
| 6 | ADC [dp + X] | 16 | 2 | 6 | | |
| 7 | ADC [dp] + Y | 17 | 2 | 6 | | |
| 8 | ADC { X } | 14 | 1 | 3 | | |
| 9 | AND #imm | 84 | 2 | 2 | Logical AND $A \leftarrow (A) \wedge (M)$ | N-----Z- |
| 10 | AND dp | 85 | 2 | 3 | | |
| 11 | AND dp + X | 86 | 2 | 4 | | |
| 12 | AND !abs | 87 | 3 | 4 | | |
| 13 | AND !abs + Y | 95 | 3 | 5 | | |
| 14 | AND [dp + X] | 96 | 2 | 6 | | |
| 15 | AND [dp] + Y | 97 | 2 | 6 | | |
| 16 | AND { X } | 94 | 1 | 3 | | |
| 17 | ASL A | 08 | 1 | 2 | Arithmetic shift left  | N-----ZC |
| 18 | ASL dp | 09 | 2 | 4 | | |
| 19 | ASL dp + X | 19 | 2 | 5 | | |
| 20 | ASL !abs | 18 | 3 | 5 | | |
| 21 | CMP #imm | 44 | 2 | 2 | Compare accumulator contents with memory contents $(A) - (M)$ | N-----ZC |
| 22 | CMP dp | 45 | 2 | 3 | | |
| 23 | CMP dp + X | 46 | 2 | 4 | | |
| 24 | CMP !abs | 47 | 3 | 4 | | |
| 25 | CMP !abs + Y | 55 | 3 | 5 | | |
| 26 | CMP [dp + X] | 56 | 2 | 6 | | |
| 27 | CMP [dp] + Y | 57 | 2 | 6 | | |
| 28 | CMP { X } | 54 | 1 | 3 | | |
| 29 | CMPX #imm | 5E | 2 | 2 | Compare X contents with memory contents $(X) - (M)$ | N-----ZC |
| 30 | CMPX dp | 6C | 2 | 3 | | |
| 31 | CMPX !abs | 7C | 3 | 4 | | |
| 32 | CMPY #imm | 7E | 2 | 2 | Compare Y contents with memory contents $(Y) - (M)$ | N-----ZC |
| 33 | CMPY dp | 8C | 2 | 3 | | |
| 34 | CMPY !abs | 9C | 3 | 4 | | |
| 35 | COM dp | 2C | 2 | 4 | 1'S Complement : $(dp) \leftarrow \sim(dp)$ | N-----Z- |
| 36 | DAA | - | - | - | Unsupported | - |
| 37 | DAS | - | - | - | Unsupported | - |
| 38 | DEC A | A8 | 1 | 2 | Decrement $M \leftarrow (M) - 1$ | N-----Z- |
| 39 | DEC dp | A9 | 2 | 4 | | |
| 40 | DEC dp + X | B9 | 2 | 5 | | |
| 41 | DEC !abs | B8 | 3 | 5 | | |
| 42 | DEC X | AF | 1 | 2 | | |
| 43 | DEC Y | BE | 1 | 2 | | |
| 44 | DIV | 9B | 1 | 12 | Divide : YA / X Q: A, R: Y | NV--H-Z- |

| NO. | MNEMONIC | OP CODE | BYTE NO | CYCLE NO | OPERATION | FLAG NVGBHIZC | |
|-----|----------------|---------|---------|----------|--|------------------|----------|
| 45 | EOR #imm | A4 | 2 | 2 | Exclusive OR $A \leftarrow (A) \oplus (M)$ | N-----Z- | |
| 46 | EOR dp | A5 | 2 | 3 | | | |
| 47 | EOR dp + X | A6 | 2 | 4 | | | |
| 48 | EOR !abs | A7 | 3 | 4 | | | |
| 49 | EOR !abs + Y | B5 | 3 | 5 | | | |
| 50 | EOR [dp + X] | B6 | 2 | 6 | | | |
| 51 | EOR [dp] + Y | B7 | 2 | 6 | | | |
| 52 | EOR { X } | B4 | 1 | 3 | Increment $M \leftarrow (M) + 1$ | N-----Z- | |
| 53 | INC A | 88 | 1 | 2 | | | |
| 54 | INC dp | 89 | 2 | 4 | | | |
| 55 | INC dp + X | 99 | 2 | 5 | | | |
| 56 | INC !abs | 98 | 3 | 5 | Logical shift right  | N-----ZC | |
| 59 | LSR A | 48 | 1 | 2 | | | |
| 60 | LSR dp | 49 | 2 | 4 | | | |
| 61 | LSR dp + X | 59 | 2 | 5 | Multiply : $YA \leftarrow Y \times A$ | N-----Z- | |
| 62 | LSR !abs | 58 | 3 | 5 | | | |
| 63 | MUL | 5B | 1 | 9 | Logical OR $A \leftarrow (A) \vee (M)$ | N-----Z- | |
| 64 | OR #imm | 64 | 2 | 2 | | | |
| 65 | OR dp | 65 | 2 | 3 | | | |
| 66 | OR dp + X | 66 | 2 | 4 | | | |
| 67 | OR !abs | 67 | 3 | 4 | | | |
| 68 | OR !abs + Y | 75 | 3 | 5 | | | |
| 69 | OR [dp + X] | 76 | 2 | 6 | Rotate left through carry  | N-----ZC | |
| 72 | ROL A | 28 | 1 | 2 | | | |
| 73 | ROL dp | 29 | 2 | 4 | | | |
| 74 | ROL dp + X | 39 | 2 | 5 | Rotate right through carry  | N-----ZC | |
| 75 | ROL !abs | 38 | 3 | 5 | | | |
| 76 | ROR A | 68 | 1 | 2 | Subtract with carry $A \leftarrow (A) - (M) - \sim(C)$ | NV--HZC | |
| 77 | ROR dp | 69 | 2 | 4 | | | |
| 78 | ROR dp + X | 79 | 2 | 5 | | | |
| 79 | ROR !abs | 78 | 3 | 5 | Test memory contents for negative or zero (dp) - 00 _H | | N-----Z- |
| 80 | SBC #imm | 24 | 2 | 2 | | | |
| 81 | SBC dp | 25 | 2 | 3 | | | |
| 82 | SBC dp + X | 26 | 2 | 4 | | | |
| 83 | SBC !abs | 27 | 3 | 4 | | | |
| 84 | SBC !abs + Y | 35 | 3 | 5 | Exchange nibbles within the accumulator $A_7 \sim A_4 \leftrightarrow A_3 \sim A_0$ | N-----Z- | |
| 85 | SBC [dp + X] | 36 | 2 | 6 | | | |
| 86 | SBC [dp] + Y | 37 | 2 | 6 | | | |
| 87 | SBC { X } | 34 | 1 | 3 | | | |
| 88 | TST dp | 4C | 2 | 3 | | | |
| 89 | XCN | CE | 1 | 5 | | | |

Register / Memory Operation

| NO. | MNEMONIC | OP CODE | BYTE NO | CYCLE NO | OPERATION | FLAG NVGBHIZC |
|-----|----------------|---------|---------|----------|--|---------------|
| 1 | LDA #imm | C4 | 2 | 2 | Load accumulator $A \leftarrow (M)$ | N-----Z- |
| 2 | LDA dp | C5 | 2 | 3 | | |
| 3 | LDA dp + X | C6 | 2 | 4 | | |
| 4 | LDA !abs | C7 | 3 | 4 | | |
| 5 | LDA !abs + Y | D5 | 3 | 5 | | |
| 6 | LDA [dp + X] | D6 | 2 | 6 | | |
| 7 | LDA [dp] + Y | D7 | 2 | 6 | | |
| 8 | LDA { X } | D4 | 1 | 3 | | |
| 9 | LDA { X }+ | DB | 1 | 4 | | |
| 10 | LDM dp,#imm | E4 | 3 | 5 | Load memory with immediate data : $(M) \leftarrow \text{imm}$ | ----- |
| 11 | LDX #imm | 1E | 2 | 2 | Load X-register $X \leftarrow (M)$ | N-----Z- |
| 12 | LDX dp | CC | 2 | 3 | | |
| 13 | LDX dp + Y | CD | 2 | 4 | | |
| 14 | LDX !abs | DC | 3 | 4 | | |
| 15 | LDY #imm | 3E | 2 | 2 | Load Y-register $Y \leftarrow (M)$ | N-----Z- |
| 16 | LDY dp | C9 | 2 | 3 | | |
| 17 | LDY dp + X | D9 | 2 | 4 | | |
| 18 | LDY !abs | D8 | 3 | 4 | | |
| 19 | STA dp | E5 | 2 | 4 | Store accumulator contents in memory $(M) \leftarrow A$ | ----- |
| 20 | STA dp + X | E6 | 2 | 5 | | |
| 21 | STA !abs | E7 | 3 | 5 | | |
| 22 | STA !abs + Y | F5 | 3 | 6 | | |
| 23 | STA [dp + X] | F6 | 2 | 7 | | |
| 24 | STA [dp] + Y | F7 | 2 | 7 | | |
| 25 | STA { X } | F4 | 1 | 4 | | |
| 26 | STA { X }+ | FB | 1 | 4 | X- register auto-increment : $(M) \leftarrow A$, $X \leftarrow X + 1$ | |
| 27 | STX dp | EC | 2 | 4 | Store X-register contents in memory $(M) \leftarrow X$ | ----- |
| 28 | STX dp + Y | ED | 2 | 5 | | |
| 29 | STX !abs | FC | 3 | 5 | | |
| 30 | STY dp | E9 | 2 | 4 | Store Y-register contents in memory $(M) \leftarrow Y$ | ----- |
| 31 | STY dp + X | F9 | 2 | 5 | | |
| 32 | STY !abs | F8 | 3 | 5 | | |
| 33 | TAX | E8 | 1 | 2 | Transfer accumulator contents to X-register : $X \leftarrow A$ | N-----Z- |
| 34 | TAY | 9F | 1 | 2 | Transfer accumulator contents to Y-register : $Y \leftarrow A$ | N-----Z- |
| 35 | TSPX | AE | 1 | 2 | Transfer stack-pointer contents to X-register : $X \leftarrow \text{sp}$ | N-----Z- |
| 36 | TXA | C8 | 1 | 2 | Transfer X-register contents to accumulator: $A \leftarrow X$ | N-----Z- |
| 37 | TXSP | 8E | 1 | 2 | Transfer X-register contents to stack-pointer: $\text{sp} \leftarrow X$ | N-----Z- |
| 38 | TYA | BF | 1 | 2 | Transfer Y-register contents to accumulator: $A \leftarrow Y$ | N-----Z- |
| 39 | XAX | EE | 1 | 4 | Exchange X-register contents with accumulator : $X \leftrightarrow A$ | ----- |
| 40 | XAY | DE | 1 | 4 | Exchange Y-register contents with accumulator : $Y \leftrightarrow A$ | ----- |
| 41 | XMA dp | BC | 2 | 5 | Exchange memory contents with accumulator $(M) \leftrightarrow A$ | N-----Z- |
| 42 | XMA dp+X | AD | 2 | 6 | | |
| 43 | XMA {X} | BB | 1 | 5 | | |
| 44 | XYX | FE | 1 | 4 | | |

16-BIT Operation

| NO. | MNEMONIC | OP CODE | BYTE NO | CYCLE NO | OPERATION | FLAG NVGBHIZC |
|-----|----------|---------|---------|----------|--|---------------|
| 1 | ADDW dp | 1D | 2 | 5 | 16-Bits add without carry $YA \leftarrow (YA) + (dp + 1)(dp)$ | NV--H-ZC |
| 2 | CMPW dp | 5D | 2 | 4 | Compare YA contents with memory pair contents : $(YA) - (dp+1)(dp)$ | N-----ZC |
| 3 | DECW dp | BD | 2 | 6 | Decrement memory pair $(dp+1)(dp) \leftarrow (dp+1)(dp) - 1$ | N-----Z- |
| 4 | INCW dp | 9D | 2 | 6 | Increment memory pair $(dp+1)(dp) \leftarrow (dp+1)(dp) + 1$ | N-----Z- |
| 5 | LDYA dp | 7D | 2 | 5 | Load YA $YA \leftarrow (dp + 1)(dp)$ | N-----Z- |
| 6 | STYA dp | DD | 2 | 5 | Store YA $(dp + 1)(dp) \leftarrow YA$ | ----- |
| 7 | SUBW dp | 3D | 2 | 5 | 16-Bits subtract without carry $YA \leftarrow (YA) - (dp + 1)(dp)$ | NV--H-ZC |

Bit Manipulation

| NO. | MNEMONIC | OP CODE | BYTE NO | CYCLE NO | OPERATION | FLAG NVGBHIZC |
|-----|-------------|---------|---------|----------|--|---------------|
| 1 | AND1 M.bit | 8B | 3 | 4 | Bit AND C-flag : $C \leftarrow (C) \wedge (M.bit)$ | -----C |
| 2 | AND1B M.bit | 8B | 3 | 4 | Bit AND C-flag and NOT : $C \leftarrow (C) \wedge \sim(M.bit)$ | -----C |
| 3 | BIT dp | 0C | 2 | 4 | Bit test A with memory : | MM----Z- |
| 4 | BIT labs | 1C | 3 | 5 | $Z \leftarrow (A) \wedge (M), N \leftarrow (M_7), V \leftarrow (M_6)$ | |
| 5 | CLR1 dp.bit | y1 | 2 | 4 | Clear bit : $(M.bit) \leftarrow "0"$ | ----- |
| 6 | CLRA1 A.bit | 2B | 2 | 2 | Clear A bit : $(A.bit) \leftarrow "0"$ | ----- |
| 7 | CLRC | 20 | 1 | 2 | Clear C-flag : $C \leftarrow "0"$ | -----0 |
| 8 | CLRG | 40 | 1 | 2 | Clear G-flag : $G \leftarrow "0"$ | --0----- |
| 9 | CLRV | 80 | 1 | 2 | Clear V-flag : $V \leftarrow "0"$ | -0--0--- |
| 10 | EOR1 M.bit | AB | 3 | 5 | Bit exclusive-OR C-flag : $C \leftarrow (C) \oplus (M.bit)$ | -----C |
| 11 | EOR1B M.bit | AB | 3 | 5 | Bit exclusive-OR C-flag and NOT : $C \leftarrow (C) \oplus \sim(M.bit)$ | -----C |
| 12 | LDC M.bit | CB | 3 | 4 | Load C-flag : $C \leftarrow (M.bit)$ | -----C |
| 13 | LDCB M.bit | CB | 3 | 4 | Load C-flag with NOT : $C \leftarrow \sim(M.bit)$ | -----C |
| 14 | NOT1 M.bit | 4B | 3 | 5 | Bit complement : $(M.bit) \leftarrow \sim(M.bit)$ | ----- |
| 15 | OR1 M.bit | 6B | 3 | 5 | Bit OR C-flag : $C \leftarrow (C) \vee (M.bit)$ | -----C |
| 16 | OR1B M.bit | 6B | 3 | 5 | Bit OR C-flag and NOT : $C \leftarrow (C) \vee \sim(M.bit)$ | -----C |
| 17 | SET1 dp.bit | x1 | 2 | 4 | Set bit : $(M.bit) \leftarrow "1"$ | ----- |
| 18 | SETA1 A.bit | 0B | 2 | 2 | Set A bit : $(A.bit) \leftarrow "1"$ | ----- |
| 19 | SETC | A0 | 1 | 2 | Set C-flag : $C \leftarrow "1"$ | -----1 |
| 20 | SETG | C0 | 1 | 2 | Set G-flag : $G \leftarrow "1"$ | --1----- |
| 21 | STC M.bit | EB | 3 | 6 | Store C-flag : $(M.bit) \leftarrow C$ | ----- |
| 22 | TCLR1 labs | 5C | 3 | 6 | Test and clear bits with A : $A - (M), (M) \leftarrow (M) \wedge \sim(A)$ | N-----Z- |
| 23 | TSET1 labs | 3C | 3 | 6 | Test and set bits with A : $A - (M), (M) \leftarrow (M) \vee (A)$ | N-----Z- |

Branch / Jump Operation

| NO. | MNEMONIC | OP CODE | BYTE NO | CYCLE NO | OPERATION | FLAG NVGBHIZC |
|-----|----------------|---------|---------|----------|--|---------------|
| 1 | BBC A.bit,rel | y2 | 2 | 4/6 | Branch if bit clear : | ----- |
| 2 | BBC dp.bit,rel | y3 | 3 | 5/7 | if (bit) = 0 , then $pc \leftarrow (pc) + rel$ | ----- |
| 3 | BBS A.bit,rel | x2 | 2 | 4/6 | Branch if bit set : | ----- |
| 4 | BBS dp.bit,rel | x3 | 3 | 5/7 | if (bit) = 1 , then $pc \leftarrow (pc) + rel$ | ----- |
| 5 | BCC rel | 50 | 2 | 2/4 | Branch if carry bit clear if (C) = 0 , then $pc \leftarrow (pc) + rel$ | ----- |
| 6 | BCS rel | D0 | 2 | 2/4 | Branch if carry bit set if (C) = 1 , then $pc \leftarrow (pc) + rel$ | ----- |
| 7 | BEQ rel | F0 | 2 | 2/4 | Branch if equal if (Z) = 1 , then $pc \leftarrow (pc) + rel$ | ----- |
| 8 | BMI rel | 90 | 2 | 2/4 | Branch if minus if (N) = 1 , then $pc \leftarrow (pc) + rel$ | ----- |
| 9 | BNE rel | 70 | 2 | 2/4 | Branch if not equal if (Z) = 0 , then $pc \leftarrow (pc) + rel$ | ----- |
| 10 | BPL rel | 10 | 2 | 2/4 | Branch if minus if (N) = 0 , then $pc \leftarrow (pc) + rel$ | ----- |
| 11 | BRA rel | 2F | 2 | 4 | Branch always $pc \leftarrow (pc) + rel$ | ----- |
| 12 | BVC rel | 30 | 2 | 2/4 | Branch if overflow bit clear if (V) = 0 , then $pc \leftarrow (pc) + rel$ | ----- |
| 13 | BVS rel | B0 | 2 | 2/4 | Branch if overflow bit set if (V) = 1 , then $pc \leftarrow (pc) + rel$ | ----- |
| 14 | CALL !abs | 3B | 3 | 8 | Subroutine call | ----- |
| 15 | CALL [dp] | 5F | 2 | 8 | $M(sp) \leftarrow (pc_H)$, $sp \leftarrow sp - 1$, $M(sp) \leftarrow (pc_L)$, $sp \leftarrow sp - 1$, if !abs, $pc \leftarrow abs$; if [dp], $pc_L \leftarrow (dp)$, $pc_H \leftarrow (dp+1)$. | ----- |
| 16 | CBNE dp,rel | FD | 3 | 5/7 | Compare and branch if not equal : | ----- |
| 17 | CBNE dp+X,rel | 8D | 3 | 6/8 | if (A) \neq (M) , then $pc \leftarrow (pc) + rel$. | ----- |
| 18 | DBNE dp,rel | AC | 3 | 5/7 | Decrement and branch if not equal : | ----- |
| 19 | DBNE Y,rel | 7B | 2 | 4/6 | if (M) \neq 0 , then $pc \leftarrow (pc) + rel$. | ----- |
| 20 | JMP !abs | 1B | 3 | 3 | Unconditional jump $pc \leftarrow$ jump address | ----- |
| 21 | JMP [!abs] | 1F | 3 | 5 | | |
| 22 | JMP [dp] | 3F | 2 | 4 | | |
| 23 | PCALL upage | 4F | 2 | 6 | U-page call $M(sp) \leftarrow (pc_H)$, $sp \leftarrow sp - 1$, $M(sp) \leftarrow (pc_L)$, $sp \leftarrow sp - 1$, $pc_L \leftarrow (upage)$, $pc_H \leftarrow "OFFH"$. | ----- |
| 24 | TCALL n | nA | 1 | 8 | Table call : $(sp) \leftarrow (pc_H)$, $sp \leftarrow sp - 1$, $M(sp) \leftarrow (pc_L)$, $sp \leftarrow sp - 1$, $pc_L \leftarrow (Table\ vector\ L)$, $pc_H \leftarrow (Table\ vector\ H)$ | ----- |

Control Operation & Etc.

| NO. | MNEMONIC | OP CODE | BYTE NO | CYCLE NO | OPERATION | FLAG NVGBHIZC |
|-----|----------|---------|---------|----------|--|------------------|
| 1 | BRK | 0F | 1 | 8 | Software interrupt : $B \leftarrow "1"$, $M(sp) \leftarrow (pc_H)$, $sp \leftarrow sp-1$, $M(s) \leftarrow (pc_L)$, $sp \leftarrow sp - 1$, $M(sp) \leftarrow (PSW)$, $sp \leftarrow sp - 1$, $pc_L \leftarrow (0FFDE_H)$, $pc_H \leftarrow (0FFDF_H)$. | ---1-0-- |
| 2 | DI | 60 | 1 | 3 | Disable interrupts : $I \leftarrow "0"$ | -----0-- |
| 3 | EI | E0 | 1 | 3 | Enable interrupts : $I \leftarrow "1"$ | -----1-- |
| 4 | NOP | FF | 1 | 2 | No operation | ----- |
| 5 | POP A | 0D | 1 | 4 | $sp \leftarrow sp + 1$, $A \leftarrow M(sp)$ $sp \leftarrow sp + 1$, $X \leftarrow M(sp)$ $sp \leftarrow sp + 1$, $Y \leftarrow M(sp)$ $sp \leftarrow sp + 1$, $PSW \leftarrow M(sp)$ | ----- |
| 6 | POP X | 2D | 1 | 4 | | |
| 7 | POP Y | 4D | 1 | 4 | | |
| 8 | POP PSW | 6D | 1 | 4 | | |
| 9 | PUSH A | 0E | 1 | 4 | $M(sp) \leftarrow A$, $sp \leftarrow sp - 1$ $M(sp) \leftarrow X$, $sp \leftarrow sp - 1$ $M(sp) \leftarrow Y$, $sp \leftarrow sp - 1$ $M(sp) \leftarrow PSW$, $sp \leftarrow sp - 1$ | ----- |
| 10 | PUSH X | 2E | 1 | 4 | | |
| 11 | PUSH Y | 4E | 1 | 4 | | |
| 12 | PUSH PSW | 6E | 1 | 4 | | |
| 13 | RET | 6F | 1 | 5 | Return from subroutine $sp \leftarrow sp + 1$, $pc_L \leftarrow M(sp)$, $sp \leftarrow sp + 1$, $pc_H \leftarrow M(sp)$ | ----- |
| 14 | RETI | 7F | 1 | 6 | Return from interrupt $sp \leftarrow sp + 1$, $PSW \leftarrow M(sp)$, $sp \leftarrow sp + 1$, $pc_L \leftarrow M(sp)$, $sp \leftarrow sp + 1$, $pc_H \leftarrow M(sp)$ | restored |
| 15 | STOP | EF | 1 | 3 | Stop mode (halt CPU, stop oscillator) | ----- |

