



# THE DATASHEET OF Z8F0821HH020SC



**High Performance 8-Bit Microcontrollers**

**Z8 Encore! XP<sup>®</sup> F0822  
Series**

**Product Specification**

PS022517-0508



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# Introduction

This Product Specification provides detailed operating information for Z8 Encore! XP<sup>®</sup> F0822 Series devices within the Z8 Encore! XP Microcontroller (MCU) family of products. Within this document, Z8 Encore! XP<sup>®</sup> F0822 Series is referred as Z8 Encore! XP or the F0822 Series unless specifically stated otherwise.

## About This Manual

Zilog recommends that you read and understand everything in this manual before setting up and using the product. We have designed this Product Specification to be used either as a *how to* procedural manual or a reference guide to important data.

## Intended Audience

This document is written for Zilog customers who are experienced at working with microcontrollers, integrated circuits, or printed circuit assemblies.

## Manual Conventions

The following assumptions and conventions are adopted to provide clarity and ease of use:

### Courier Typeface

Commands, code lines and fragments, bits, equations, hexadecimal addresses, and various executable items are distinguished from general text by the use of the `Courier` typeface. Where the use of the font is not indicated, as in the Index, the name of the entity is presented in upper case.

- **Example:** `FLAGS[1]` is `smrf`.

### Hexadecimal Values

Hexadecimal values are designated by uppercase *H* suffix and appear in the `Courier` typeface.

- **Example:** R1 is set to `F8H`.

### Brackets

The square brackets `[ ]`, indicate a register or bus.

- **Example:** For the register `R1[7:0]`, R1 is an 8-bit register, `R1[7]` is the most significant bit, and `R1[0]` is the least significant bit.

## Braces

The curly braces { }, indicate a single register or bus created by concatenating some combination of smaller registers, buses, or individual bits.

- **Example:** The 12-bit register address {0H, RP[7:4], R1[3:0]} is composed of a 4-bit hexadecimal value (0H) and two 4-bit register values taken from the Register Pointer (RP) and Working Register R1. 0H is the most significant nibble (4-bit value) of the 12-bit register, and R1[3:0] is the least significant nibble of the 12-bit register.

## Parentheses

The parentheses ( ), indicate an indirect register address lookup.

- **Example:** (R1) is the memory location referenced by the address contained in the Working Register R1.

## Parentheses/Bracket Combinations

The parentheses ( ), indicate an indirect register address lookup and the square brackets, [ ], indicate a register or bus.

- **Example:** Assume PC[15:0] contains the value 1234h. (PC [15:0]) then refers to the contents of the memory location at address 1234h.

## Use of the Words *Set*, *Reset* and *Clear*

The word *set* implies that a register bit or a condition contains a logical 1. The words *reset* or *clear* imply that a register bit or a condition contains a logical 0. When either of these terms is followed by a number, the word *logical* cannot be included; however, it is implied.

## Notation for Bits and Similar Registers

A field of bits within a register is designated as: Register[n:n].

- **Example:** ADDR[15:0] refers to bits 15 through bit 0 of the Address.

## Use of the Terms *LSB*, *MSB*, *lsb*, and *msb*

In this document, the terms *LSB* and *MSB*, when appearing in upper case, mean *least significant byte* and *most significant byte*, respectively. The lowercase forms, *lsb* and *msb*, mean *least significant bit* and *most significant bit*, respectively.

## Use of Initial Uppercase Letters

Initial uppercase letters designate settings and conditions in general text.

- **Example 1:** The receiver forces the SCL line to Low.
- **Example 2:** The Master generates a STOP condition to abort the transfer.

## Use of All Uppercase Letters

The use of all uppercase letters designates the names of states, modes, and commands.

- **Example 1:** The bus is considered BUSY after the Start condition.
- **Example 2:** A START command triggers the processing of the initialization sequence.
- **Example 3:** STOP mode.

## Bit Numbering

Bits are numbered from 0 to  $n-1$  where  $n$  indicates the total number of bits. For example, the 8 bits of a register are numbered from 0 to 7.

## Safeguards

It is important that you understand the following safety terms, which are defined here.



**Caution:** *Indicates a procedure or file can become corrupted if you does not follow directions.*

## Abbreviations/Acronyms

This document uses the following abbreviations or acronyms.

| Abbreviations/<br>Acronyms | Expansion                                   |
|----------------------------|---------------------------------------------|
| ADC                        | Analog-to-Digital Converter                 |
| LPO                        | Low-Power Operational Amplifier             |
| SPI                        | Serial Peripheral Interface                 |
| WDT                        | Watchdog Timer                              |
| GPIO                       | General-Purpose Input/Output                |
| OCD                        | On-Chip Debugger                            |
| POR                        | Power-On Reset                              |
| LVD                        | Low-Voltage Detection                       |
| VBO                        | Voltage Brownout                            |
| ISR                        | Interrupt Service Routine                   |
| UART                       | Universal Asynchronous Receiver/Transmitter |
| IrDA                       | Infrared Data Association                   |
| I <sup>2</sup> C           | Inter-Integrated Circuit                    |



| <b>Abbreviations/<br/>Acronyms</b> | <b>Expansion</b>                 |
|------------------------------------|----------------------------------|
| PDIP                               | Plastic Dual Inline Package      |
| SOIC                               | Small Outline Integrated Circuit |
| SSOP                               | Small Shrink Outline Package     |
| PC                                 | Program Counter                  |
| IRQ                                | Interrupt Request                |

# Introduction

Zilog's Z8 Encore! XP<sup>®</sup> MCU product family is a line of Zilog microcontrollers based on the 8-bit eZ8 CPU. Z8 Encore! XP<sup>®</sup> F0822 Series, hereafter referred as Z8 Encore! XP or the 8K Series adds Flash memory to Zilog's extensive line of 8-bit microcontrollers. The Flash in-circuit programming allows faster development time and program changes in the field. The new eZ8 CPU is upward-compatible with the existing Z8<sup>®</sup> instructions. The rich peripheral set of Z8 Encore! XP makes it suitable for a variety of applications including motor control, security systems, home appliances, personal electronic devices, and sensors.

## Features

The features of Z8 Encore! XP MCU product family include:

- 20 MHz eZ8 CPU core
- Up to 8 KB Flash with in-circuit programming capability
- 1 KB Register RAM
- Optional 2- to 5-channel, 10-bit Analog-to-Digital Converter (ADC)
- Full-duplex 9-bit Universal Asynchronous Receiver/Transmitter (UART) with bus transceiver Driver Enable Control
- Inter-Integrated Circuit (I<sup>2</sup>C)
- Serial Peripheral Interface (SPI)
- Infrared Data Association (IrDA)-compliant infrared encoder/decoders
- Two 16-bit timers with Capture, Compare, and PWM capability
- Watchdog Timer (WDT) with internal RC oscillator
- 11 to 19 Input/Output pins depending upon package
- Up to 19 interrupts with configurable priority
- On-Chip Debugger (OCD)
- Voltage Brownout (VBO) protection
- Power-On Reset (POR)
- Crystal oscillator with three power settings and RC oscillator option

- 2.7 V to 3.6 V operating voltage with 5 V-tolerant inputs
- 20-pin and 28-pin packages
- 0 °C to +70 °C standard temperature and -40 °C to +105 °C extended temperature operating ranges

## Part Selection Guide

Table 1 identifies the basic features and package styles available for each device within the Z8 Encore! XP<sup>®</sup> F0822 Series product line.

**Table 1. Z8 Encore! XP<sup>®</sup> F0822 Series Part Selection Guide**

| Part Number | Flash (KB) | RAM (KB) | I/O | 16-bit Timers with PWM | ADC Inputs | UARTs with IrDA | I <sup>2</sup> C | SPI | Package Pin Counts |    |
|-------------|------------|----------|-----|------------------------|------------|-----------------|------------------|-----|--------------------|----|
|             |            |          |     |                        |            |                 |                  |     | 20                 | 28 |
| Z8F0822     | 8          | 1        | 19  | 2                      | 5          | 1               | 1                | 1   |                    | X  |
| Z8F0821     | 8          | 1        | 11  | 2                      | 2          | 1               | 1                |     | X                  |    |
| Z8F0812     | 8          | 1        | 19  | 2                      | 0          | 1               | 1                | 1   |                    | X  |
| Z8F0811     | 8          | 1        | 11  | 2                      | 0          | 1               | 1                |     | X                  |    |
| Z8F0422     | 4          | 1        | 19  | 2                      | 5          | 1               | 1                | 1   |                    | X  |
| Z8F0421     | 4          | 1        | 11  | 2                      | 2          | 1               | 1                |     | X                  |    |
| Z8F0412     | 4          | 1        | 19  | 2                      | 0          | 1               | 1                | 1   |                    | X  |
| Z8F0411     | 4          | 1        | 11  | 2                      | 0          | 1               | 1                |     | X                  |    |

## Block Diagram

Figure 1 displays the block diagram of the architecture of Z8 Encore! XP<sup>®</sup> F0822 Series devices.

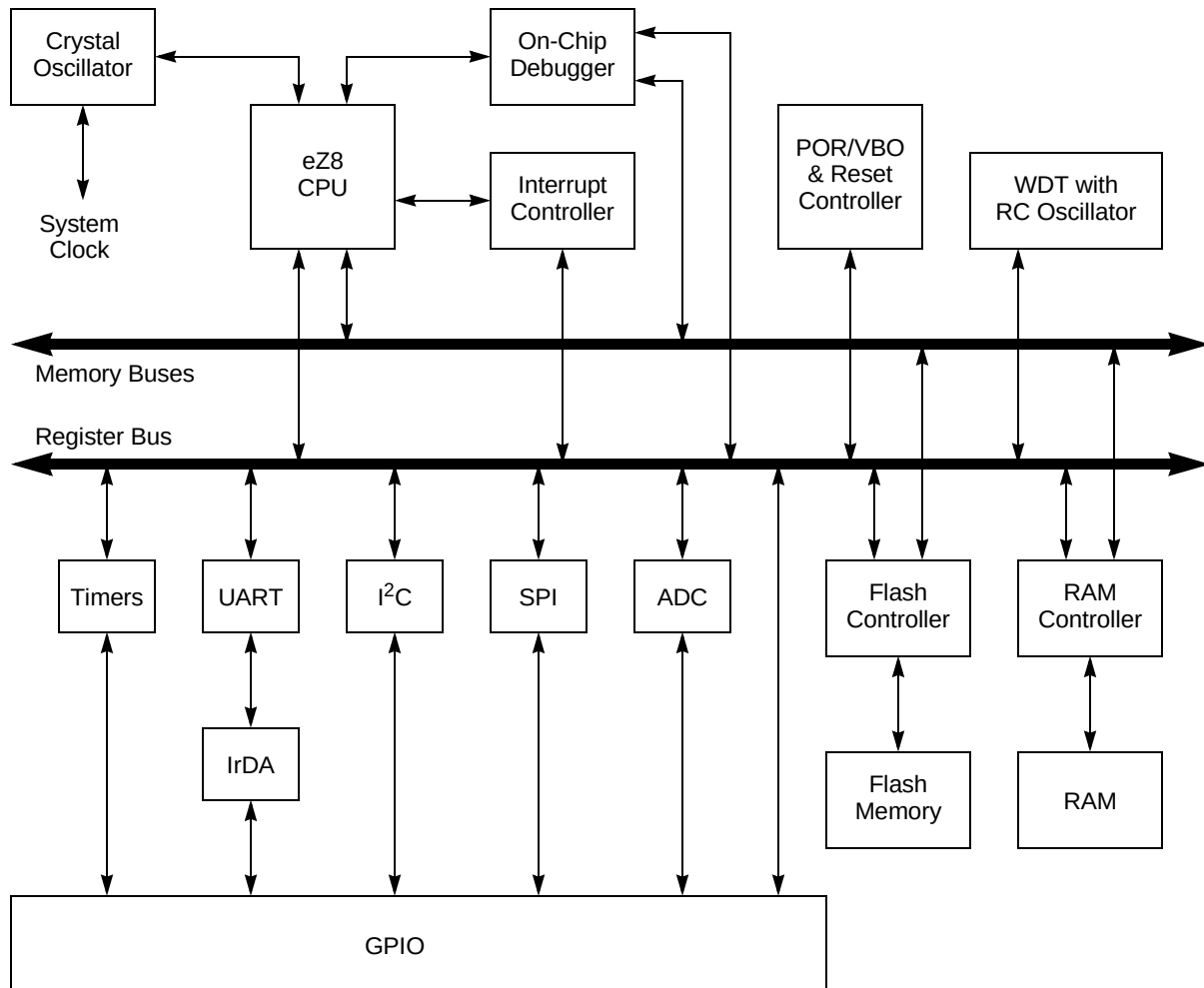


Figure 1. Z8 Encore! XP<sup>®</sup> F0822 Series Block Diagram

## CPU and Peripheral Overview

### eZ8 CPU Features

Zilog's latest eZ8 8-bit CPU, meets the continuing demand for faster and more code-efficient microcontrollers. The eZ8 CPU executes a superset of the original Z8<sup>®</sup> instruction set.

The eZ8 CPU features include:

- Direct register-to-register architecture allows each register to function as an accumulator, improving execution time and decreasing the required Program Memory.
- Software stack allows much greater depth in subroutine calls and interrupts than hardware stacks.
- Compatible with existing Z8® code.
- Expanded internal Register File allows access of up to 4 KB.
- New instructions improve execution efficiency for code developed using higher-level programming languages, including C.
- Pipelined instruction fetch and execution.
- New instructions for improved performance including BIT, BSWAP, BTJ, CPC, LDC, LDCI, LEA, MULT, and SRL.
- New instructions support 12-bit linear addressing of the Register File.
- Up to 10 MIPS operation.
- C-Compiler friendly.
- 2 to 9 clock cycles per instruction.

For more information regarding the eZ8 CPU, refer to *eZ8 CPU Core User Manual (UM0128)* available for download at [www.zilog.com](http://www.zilog.com).

## **General Purpose Input/Output**

Z8 Encore! XP® F0822 Series features 11 to 19 port pins (Ports A–C) for General Purpose Input/Output (GPIO). The number of GPIO pins available is a function of package. Each pin is individually programmable. Ports A and C supports 5 V-tolerant inputs.

## **Flash Controller**

The Flash Controller programs and erases the Flash memory.

## **10-Bit Analog-to-Digital Converter**

The optional Analog-to-Digital Converter (ADC) converts an analog input signal to a 10-bit binary number. The ADC accepts inputs from 2 to 5 different analog input sources.

## **UART**

The Universal Asynchronous Receiver/Transmitter (UART) is full-duplex and capable of handling asynchronous data transfers. The UART supports 8-bit and 9-bit data modes and selectable parity.

## **I<sup>2</sup>C**

The Inter-Integrated Circuit (I<sup>2</sup>C) controller makes the Z8 Encore! XP compatible with the I<sup>2</sup>C protocol. The I<sup>2</sup>C Controller consists of two bidirectional bus lines, a serial data (SDA) line, and a serial clock (SCL) line.

## **Serial Peripheral Interface**

The Serial Peripheral Interface (SPI) allows the Z8 Encore! XP to exchange data between other peripheral devices such as EEPROMs, A/D converters, and ISDN devices. The SPI is a full-duplex, synchronous, and character-oriented channel that supports a four-wire interface.

## **Timers**

Two 16-bit reloadable timers are used for timing/counting events or for motor control operations. These timers provide a 16-bit programmable reload counter and operate in One-Shot, Continuous, Gated, Capture, Compare, Capture and Compare, and PWM modes.

## **Interrupt Controller**

Z8 Encore! XP<sup>®</sup> F0822 Series products support up to 18 interrupts. These interrupts consist of 7 internal peripheral interrupts and 11 GPIO pin interrupt sources. The interrupts have 3 levels of programmable interrupt priority.

## **Reset Controller**

Z8 Encore! XP F0822 Series products are reset using the  $\overline{\text{RESET}}$  pin, POR, WDT, STOP mode exit, or VBO warning signal.

## **On-Chip Debugger**

Z8 Encore! XP F0822 Series products feature an integrated On-Chip Debugger (OCD). The OCD provides a rich-set of debugging capabilities, such as, reading and writing registers, programming the Flash, setting breakpoints, and executing code. A single-pin interface provides communication to the OCD.



# Signal and Pin Descriptions

Z8 Encore! XP<sup>®</sup> F0822 Series products are available in a variety of packages, styles, and pin configurations. This chapter describes the signals and available pin configurations for each of the package styles. For information regarding the physical package specifications, see [Packaging](#) on page 233.

## Available Packages

[Table 2](#) identifies the package styles available for each device within Z8 Encore! XP F0822 Series product line.

**Table 2. Z8 Encore! XP F0822 Series Package Options**

| Part Number | 10-Bit ADC | 20-Pin SSOP and PDIP | 28-Pin SOIC and PDIP |
|-------------|------------|----------------------|----------------------|
| Z8F0822     | Yes        |                      | X                    |
| Z8F0821     | Yes        | X                    |                      |
| Z8F0812     | No         |                      | X                    |
| Z8F0811     | No         | X                    |                      |
| Z8F0422     | Yes        |                      | X                    |
| Z8F0421     | Yes        | X                    |                      |
| Z8F0412     | No         |                      | X                    |
| Z8F0411     | No         | X                    |                      |

## Pin Configurations

[Figure 2](#) through [Figure 5](#) display the pin configurations for all of the packages available in Z8 Encore! XP F0822 Series. See [Table 4](#) for a description of the signals.

► **Note:** *The analog input alternate functions (ANAx) are not available on Z8 Encore! XP<sup>®</sup> F0822 Series devices.*

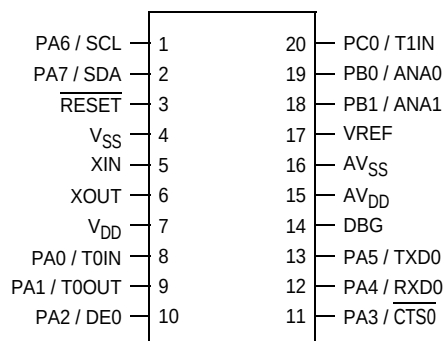


Figure 2. Z8F0821 and Z8F0421 in 20-Pin SSOP and PDIP Packages

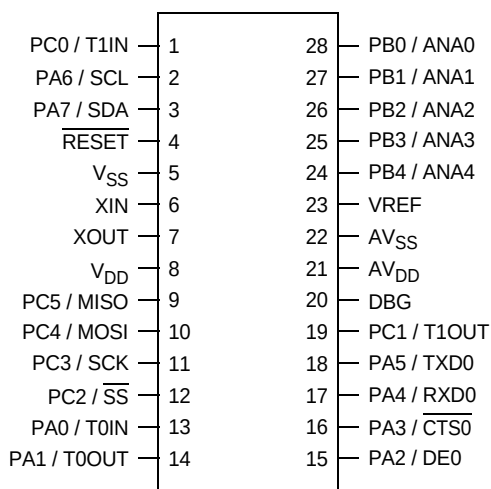


Figure 3. Z8F0822 and Z8F0422 in 28-Pin SOIC and PDIP Packages

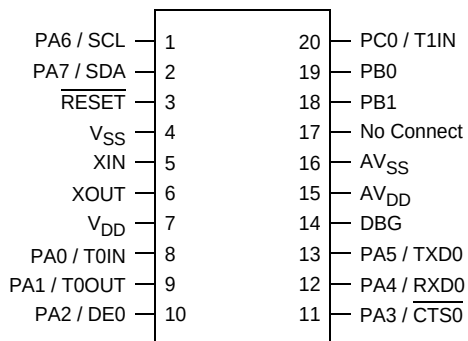


Figure 4. Z8F0811 and Z8F0411 in 20-Pin SSOP and PDIP Packages

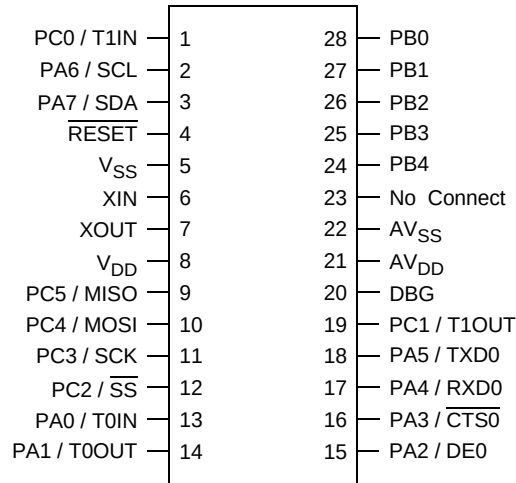


Figure 5. Z8F0812 and Z8F0412 in 28-Pin SOIC and PDIP Packages

## Signal Descriptions

Table 3 describes Z8 Encore! XP<sup>®</sup> F0822 Series signals. See [Pin Configurations](#) on page 7 to determine the signals available for the specific package styles

Table 3. Signal Descriptions

| Signal Mnemonic                      | I/O | Description                                                                                                                                                                                                                                                                   |
|--------------------------------------|-----|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>General-Purpose I/O Ports A-H</b> |     |                                                                                                                                                                                                                                                                               |
| PA[7:0]                              | I/O | <b>Port C</b> —These pins are used for general-purpose I/O and supports 5 V-tolerant inputs.                                                                                                                                                                                  |
| PB[4:0]                              | I/O | <b>Port B</b> —These pins are used for general-purpose I/O.                                                                                                                                                                                                                   |
| PC[5:0]                              | I/O | <b>Port C</b> —These pins are used for general-purpose I/O and support 5 V-tolerant inputs.                                                                                                                                                                                   |
| <b>I<sup>2</sup>C Controller</b>     |     |                                                                                                                                                                                                                                                                               |
| SCL                                  | I/O | <b>Serial Clock</b> —This open-drain pin clocks data transfers in accordance with the I <sup>2</sup> C standard protocol. This pin is multiplexed with a GPIO pin. When the GPIO pin is configured for alternate function to enable the SCL function, this pin is open-drain. |
| SDA                                  | I/O | <b>Serial Data</b> —This open-drain pin transfers data between the I <sup>2</sup> C and a slave. This pin is multiplexed with a GPIO pin. When the GPIO pin is configured for alternate function to enable the SDA function, this pin is open-drain.                          |

Table 3. Signal Descriptions (Continued)

| Signal Mnemonic         | I/O | Description                                                                                                                                                                                                                                                                                                                      |
|-------------------------|-----|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>SPI Controller</b>   |     |                                                                                                                                                                                                                                                                                                                                  |
| $\overline{SS}$         | I/O | <b>Slave Select</b> —This signal can be an output or an input. If the Z8 Encore! XP <sup>®</sup> is the SPI Master, this pin can be configured as the Slave Select output. If the Z8 Encore! XP is the SPI Slave, this pin is the input slave select. It is multiplexed with a GPIO pin.                                         |
| SCK                     | I/O | <b>SPI Serial Clock</b> —The SPI Master supplies this pin. If the Z8 Encore! XP is the SPI Master, this pin is the output. If the Z8 Encore! XP is the SPI Slave, this pin is the input. It is multiplexed with a GPIO pin.                                                                                                      |
| MOSI                    | I/O | <b>Master-Out/Slave-In</b> —This signal is the data output from the SPI Master device and the data input to the SPI Slave device. It is multiplexed with a GPIO pin.                                                                                                                                                             |
| MISO                    | I/O | <b>Master-In/Slave-Out</b> —This pin is the data input to the SPI Master device and the data output from the SPI Slave device. It is multiplexed with a GPIO pin.                                                                                                                                                                |
| <b>UART Controllers</b> |     |                                                                                                                                                                                                                                                                                                                                  |
| TXD0                    | O   | <b>Transmit Data</b> —This signal is the transmit output from the UART and IrDA. The TXD signals are multiplexed with GPIO pins.                                                                                                                                                                                                 |
| RXD0                    | I   | <b>Receive Data</b> —This signal is the receiver input for the UART and IrDA. The RXD signals are multiplexed with GPIO pins.                                                                                                                                                                                                    |
| $\overline{CTS0}$       | I   | <b>Clear To Send</b> —This signal is control inputs for the UART. The $\overline{CTS}$ signals are multiplexed with GPIO pins.                                                                                                                                                                                                   |
| DE0                     | O   | <b>Driver Enable</b> —This signal allows automatic control of external RS-485 drivers. This signal is approximately the inverse of the TXE (Transmit Empty) bit in the UART Status 0 Register. The DE signal can be used to ensure the external RS-485 driver is enabled when data is transmitted by the UART.                   |
| <b>Timers</b>           |     |                                                                                                                                                                                                                                                                                                                                  |
| T0OUT / T1OUT           | O   | <b>Timer Output 0–1</b> —These signals are output pins from the timers. The Timer Output signals are multiplexed with GPIO pins.                                                                                                                                                                                                 |
| T0IN / T1IN             | I   | <b>Timer Input 0–1</b> —These signals are used as the Capture, Gating and Counter inputs. The Timer Input signals are multiplexed with GPIO pins.                                                                                                                                                                                |
| <b>Analog</b>           |     |                                                                                                                                                                                                                                                                                                                                  |
| ANA[4:0]                | I   | <b>Analog Input</b> —These signals are inputs to the Analog-to-Digital Converter (ADC). The ADC analog inputs are multiplexed with GPIO pins.                                                                                                                                                                                    |
| VREF                    | I   | <b>Analog-to-Digital Converter reference voltage input</b> —As an output, the VREF signal is not recommended for use as a reference voltage for external devices. If the ADC is configured to use the internal reference voltage generator, this pin should be left unconnected or capacitively coupled to analog ground (AVSS). |

Table 3. Signal Descriptions (Continued)

| Signal Mnemonic                                                                                                                                                                                                                                                                                                                                                                                                               | I/O | Description                                                                                                                                                                                                                                                                                                                                          |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <b>Oscillators</b>                                                                                                                                                                                                                                                                                                                                                                                                            |     |                                                                                                                                                                                                                                                                                                                                                      |
| XIN                                                                                                                                                                                                                                                                                                                                                                                                                           | I   | <b>External Crystal Input</b> —This is the input pin to the crystal oscillator. A crystal is connected between the external crystal input and the XOUT pin to form the oscillator. In addition, this pin is used with external RC networks or external clock drivers to provide the system clock to the system.                                      |
| XOUT                                                                                                                                                                                                                                                                                                                                                                                                                          | O   | <b>External Crystal Output</b> —This pin is the output of the crystal oscillator. A crystal is connected between external crystal output and the XIN pin to form the oscillator. When the system clock is referred in this manual, it refers to the frequency of the signal at this pin. This pin must be left unconnected when not using a crystal. |
| <b>On-Chip Debugger</b>                                                                                                                                                                                                                                                                                                                                                                                                       |     |                                                                                                                                                                                                                                                                                                                                                      |
| DBG                                                                                                                                                                                                                                                                                                                                                                                                                           | I/O | <b>Debug</b> —This pin is the control and data input and output to and from the OCD. This pin is open-drain.                                                                                                                                                                                                                                         |
|  <b>Caution:</b> <i>For operation of the OCD, all power pins (<math>V_{DD}</math> and <math>AV_{DD}</math>) must be supplied with power and all ground pins (<math>V_{SS}</math> and <math>AV_{SS}</math>) must be properly grounded. The DBG pin is open-drain and must have an external pull-up resistor to ensure proper operation.</i> |     |                                                                                                                                                                                                                                                                                                                                                      |
| <b>Reset</b>                                                                                                                                                                                                                                                                                                                                                                                                                  |     |                                                                                                                                                                                                                                                                                                                                                      |
| RESET                                                                                                                                                                                                                                                                                                                                                                                                                         | I   | <b>RESET</b> —Generates a Reset when asserted (driven Low).                                                                                                                                                                                                                                                                                          |
| <b>Power Supply</b>                                                                                                                                                                                                                                                                                                                                                                                                           |     |                                                                                                                                                                                                                                                                                                                                                      |
| $V_{DD}$                                                                                                                                                                                                                                                                                                                                                                                                                      | I   | Digital Power Supply.                                                                                                                                                                                                                                                                                                                                |
| $AV_{DD}$                                                                                                                                                                                                                                                                                                                                                                                                                     | I   | <b>Analog Power Supply</b> —Must be powered up and grounded to $V_{DD}$ , even if not using analog features.                                                                                                                                                                                                                                         |
| $V_{SS}$                                                                                                                                                                                                                                                                                                                                                                                                                      | I   | Digital Ground.                                                                                                                                                                                                                                                                                                                                      |
| $AV_{SS}$                                                                                                                                                                                                                                                                                                                                                                                                                     | I   | <b>Analog Ground</b> —Must be grounded and connected to $V_{SS}$ , even if not using analog features.                                                                                                                                                                                                                                                |



## Pin Characteristics

Table 4 provides detailed information on the characteristics for each pin available on Z8 Encore! XP<sup>®</sup> F0822 Series products. Table 4 data is sorted alphabetically by the pin symbol mnemonic.

**Table 4. Pin Characteristics**

| Symbol<br>Mnemonic | Direction | Reset<br>Direction | Active Low<br>or<br>Active High | Tri-State<br>Output | Internal<br>Pull-up or<br>Pull-down | Schmitt-Trigger<br>Input | Open Drain<br>Output |
|--------------------|-----------|--------------------|---------------------------------|---------------------|-------------------------------------|--------------------------|----------------------|
| AV <sub>DD</sub>   | N/A       | N/A                | N/A                             | N/A                 | No                                  | No                       | N/A                  |
| AV <sub>SS</sub>   | N/A       | N/A                | N/A                             | N/A                 | No                                  | No                       | N/A                  |
| DBG                | I/O       | I                  | N/A                             | Yes                 | No                                  | Yes                      | Yes                  |
| PA[7:0]            | I/O       | I                  | N/A                             | Yes                 | Programmable<br>Pull-up             | Yes                      | Yes,<br>Programmable |
| PB[4:0]            | I/O       | I                  | N/A                             | Yes                 | Programmable<br>Pull-up             | Yes                      | Yes,<br>Programmable |
| PC[5:0]            | I/O       | I                  | N/A                             | Yes                 | Programmable<br>Pull-up             | Yes                      | Yes,<br>Programmable |
| RESET              | I         | I                  | Low                             | N/A                 | Pull-up                             | Yes                      | N/A                  |
| V <sub>DD</sub>    | N/A       | N/A                | N/A                             | N/A                 | No                                  | No                       | N/A                  |
| VREF               | Analog    | N/A                | N/A                             | N/A                 | No                                  | No                       | N/A                  |
| V <sub>SS</sub>    | N/A       | N/A                | N/A                             | N/A                 | No                                  | No                       | N/A                  |
| XIN                | I         | I                  | N/A                             | N/A                 | No                                  | No                       | N/A                  |
| XOUT               | O         | O                  | N/A                             | No                  | No                                  | No                       | No                   |

# Address Space

The eZ8 CPU accesses three distinct address spaces:

- The [Register File](#) contains addresses for the general-purpose registers and the eZ8 CPU, Peripheral, and GPIO Port Control Registers.
- The [Program Memory](#) contains addresses for all memory locations having executable code and/or data.
- The [Data Memory](#) contains addresses for all memory locations that hold data only.

These three address spaces are covered briefly in the following sections. For more information on the eZ8 CPU and its address space, refer to *eZ8 CPU Core User Manual (UM0128)* available for download at [www.zilog.com](http://www.zilog.com).

## Register File

The Register File address space in the Z8 Encore! XP® is 4 KB (4096 bytes). It is composed of two sections—Control Registers and General-Purpose Registers. When instructions are executed, registers are read from when defined as sources and written to when defined as destinations. The architecture of the eZ8 CPU allows all general-purpose registers to function as accumulators, address pointers, index registers, stack areas, or scratch pad memory.

The upper 256 bytes of the 1 KB Register File address space is reserved for control of the eZ8 CPU, the on-chip peripherals, and the I/O ports. These registers are located at addresses from F00H to FFFH. Some of the addresses within the 256-byte Control Register section is reserved (unavailable). Reading from the reserved Register File addresses returns an undefined value. Writing to reserved Register File addresses is not recommended and can produce unpredictable results.

The on-chip RAM always begins at address 000H in the Register File address space. Z8 Encore! XP F0822 Series contains 1 KB of on-chip RAM. Reading from Register File addresses outside the available RAM addresses (and not within the control register address space) returns an undefined value. Writing to these Register File addresses produces no effect.

## Program Memory

The eZ8 CPU supports 64 KB of Program Memory address space. Z8 Encore! XP® F0822 Series contain 4 KB to 8 KB on-chip Flash in the Program Memory address space, depending on the device. Reading from Program Memory addresses outside the available Flash addresses returns FFH. Writing to unimplemented Program Memory addresses produces no effect. [Table 5](#) describes the Program Memory Maps for Z8 Encore! XP F0822 Series devices.

**Table 5. Z8 Encore! XP<sup>®</sup> F0822 Series Program Memory Maps**

| Program Memory Address (Hex)                                                        | Function                 |
|-------------------------------------------------------------------------------------|--------------------------|
| <b>Z8F082x and Z8F081x Products</b>                                                 |                          |
| 0000-0001                                                                           | Option Bits              |
| 0002-0003                                                                           | Reset Vector             |
| 0004-0005                                                                           | WDT Interrupt Vector     |
| 0006-0007                                                                           | Illegal Instruction Trap |
| 0008-0037                                                                           | Interrupt Vectors*       |
| 0038-1FFF                                                                           | Program Memory           |
| <b>Z8F042x and Z8F041x Products</b>                                                 |                          |
| 0000-0001                                                                           | Option Bits              |
| 0002-0003                                                                           | Reset Vector             |
| 0004-0005                                                                           | WDT Interrupt Vector     |
| 0006-0007                                                                           | Illegal Instruction Trap |
| 0008-0037                                                                           | Interrupt Vectors*       |
| 0038-0FFF                                                                           | Program Memory           |
| Note: *See <a href="#">Table 24</a> on page 57 for a list of the interrupt vectors. |                          |

## Data Memory

Z8 Encore! XP<sup>®</sup> F0822 Series does not use the eZ8 CPU's 64 KB Data Memory address space.

## Information Area

[Table 6](#) describes the Z8 Encore! XP F0822 Series Information Area. This 512 byte Information Area is accessed by setting bit 7 of the Page Select Register to 1. When access is enabled, the Information Area is mapped into the Program Memory and overlays the 512 bytes at addresses FE00H to FFFFH. When the Information Area access is enabled, all reads from these Program Memory addresses return the Information Area data rather than the Program Memory data. Access to the Information Area is read-only.

**Table 6. Information Area Map**

| Program Memory Address (Hex) | Function                                                                                           |
|------------------------------|----------------------------------------------------------------------------------------------------|
| FE00H-FE3FH                  | Reserved                                                                                           |
| FE40H-FE53H                  | <b>Part Number</b><br>20-character ASCII alphanumeric code<br>Left justified and filled with zeros |
| FE54H-FFFFH                  | Reserved                                                                                           |

# Register File Address Map

Table 7 provides the address map for the Register File of the Z8 Encore! XP<sup>®</sup> F0822 Series products. Not all devices and package styles in the F0822 Series support the ADC, the SPI, or all of the GPIO Ports. Consider registers for unimplemented peripherals as Reserved.

**Table 7. Register File Address Map**

| Address<br>(Hex)           | Register Description              | Mnemonic | Reset (Hex) | Page No             |
|----------------------------|-----------------------------------|----------|-------------|---------------------|
| <b>General Purpose RAM</b> |                                   |          |             |                     |
| 000-3FF                    | General-Purpose Register File RAM | —        | XX          |                     |
| 400-EFF                    | Reserved                          | —        | XX          |                     |
| <b>Timer 0</b>             |                                   |          |             |                     |
| F00                        | Timer 0 High Byte                 | T0H      | 00          | <a href="#">78</a>  |
| F01                        | Timer 0 Low Byte                  | T0L      | 01          | <a href="#">78</a>  |
| F02                        | Timer 0 Reload High Byte          | T0RH     | FF          | <a href="#">79</a>  |
| F03                        | Timer 0 Reload Low Byte           | T0RL     | FF          | <a href="#">79</a>  |
| F04                        | Timer 0 PWM High Byte             | T0PWMH   | 00          | <a href="#">79</a>  |
| F05                        | Timer 0 PWM Low Byte              | T0PWML   | 00          | <a href="#">79</a>  |
| F06                        | Timer 0 Control 0                 | T0CTL0   | 00          | <a href="#">81</a>  |
| F07                        | Timer 0 Control 1                 | T0CTL1   | 00          | <a href="#">81</a>  |
| <b>Timer 1</b>             |                                   |          |             |                     |
| F08                        | Timer 1 High Byte                 | T1H      | 00          | <a href="#">78</a>  |
| F09                        | Timer 1 Low Byte                  | T1L      | 01          | <a href="#">78</a>  |
| F0A                        | Timer 1 Reload High Byte          | T1RH     | FF          | <a href="#">79</a>  |
| F0B                        | Timer 1 Reload Low Byte           | T1RL     | FF          | <a href="#">79</a>  |
| F0C                        | Timer 1 PWM High Byte             | T1PWMH   | 00          | <a href="#">79</a>  |
| F0D                        | Timer 1 PWM Low Byte              | T1PWML   | 00          | <a href="#">79</a>  |
| F0E                        | Timer 1 Control 0                 | T1CTL0   | 00          | <a href="#">81</a>  |
| F0F                        | Timer 1 Control 1                 | T1CTL1   | 00          | <a href="#">81</a>  |
| F10-F3F                    | Reserved                          | —        | XX          |                     |
| <b>UART 0</b>              |                                   |          |             |                     |
| F40                        | UART0 Transmit Data               | U0TXD    | XX          | <a href="#">100</a> |
|                            | UART0 Receive Data                | U0RXD    | XX          | <a href="#">101</a> |
| F41                        | UART0 Status 0                    | U0STAT0  | 0000011Xb   | <a href="#">101</a> |
| F42                        | UART0 Control 0                   | U0CTL0   | 00          | <a href="#">103</a> |
| F43                        | UART0 Control 1                   | U0CTL1   | 00          | <a href="#">103</a> |
| F44                        | UART0 Status 1                    | U0STAT1  | 00          | <a href="#">101</a> |
| F45                        | UART0 Address Compare Register    | U0ADDR   | 00          | <a href="#">105</a> |
| F46                        | UART0 Baud Rate High Byte         | U0BRH    | FF          | <a href="#">106</a> |
| XX=Undefined               |                                   |          |             |                     |



**Table 7. Register File Address Map (Continued)**

| Address<br>(Hex)                                                               | Register Description                 | Mnemonic | Reset (Hex) | Page No             |
|--------------------------------------------------------------------------------|--------------------------------------|----------|-------------|---------------------|
| F47                                                                            | UART0 Baud Rate Low Byte             | U0BRL    | FF          | <a href="#">106</a> |
| F48-F4F                                                                        | Reserved                             | —        | XX          |                     |
| <b>I<sup>2</sup>C</b>                                                          |                                      |          |             |                     |
| F50                                                                            | I <sup>2</sup> C Data                | I2CDATA  | 00          | <a href="#">139</a> |
| F51                                                                            | I <sup>2</sup> C Status              | I2CSTAT  | 80          | <a href="#">140</a> |
| F52                                                                            | I <sup>2</sup> C Control             | I2CCTL   | 00          | <a href="#">141</a> |
| F53                                                                            | I <sup>2</sup> C Baud Rate High Byte | I2CBRH   | FF          | <a href="#">143</a> |
| F54                                                                            | I <sup>2</sup> C Baud Rate Low Byte  | I2CBRL   | FF          | <a href="#">143</a> |
| F55                                                                            | I <sup>2</sup> C Diagnostic State    | I2CDST   | XX000000b   | <a href="#">143</a> |
| F56                                                                            | I <sup>2</sup> C Diagnostic Control  | I2CDIAG  | 00          | <a href="#">145</a> |
| F57-F5F                                                                        | Reserved                             | —        | XX          |                     |
| <b>Serial Peripheral Interface (SPI) Unavailable in 20-Pin Package Devices</b> |                                      |          |             |                     |
| F60                                                                            | SPI Data                             | SPIDATA  | 01          | <a href="#">121</a> |
| F61                                                                            | SPI Control                          | SPICTL   | 00          | <a href="#">122</a> |
| F62                                                                            | SPI Status                           | SPISTAT  | 00          | <a href="#">123</a> |
| F63                                                                            | SPI Mode                             | SPIMODE  | 00          | <a href="#">124</a> |
| F64                                                                            | SPI Diagnostic State                 | SPIDST   | 00          | <a href="#">125</a> |
| F65                                                                            | Reserved                             | —        | XX          |                     |
| F66                                                                            | SPI Baud Rate High Byte              | SPIBRH   | FF          | <a href="#">125</a> |
| F67                                                                            | SPI Baud Rate Low Byte               | SPIBRL   | FF          | <a href="#">125</a> |
| F68-F6F                                                                        | Reserved                             | —        | XX          |                     |
| <b>Analog-to-Digital Converter (ADC)</b>                                       |                                      |          |             |                     |
| F70                                                                            | ADC Control                          | ADCCTL   | 20          | <a href="#">150</a> |
| F71                                                                            | Reserved                             | —        | XX          |                     |
| F72                                                                            | ADC Data High Byte                   | ADCD_H   | XX          | <a href="#">151</a> |
| F73                                                                            | ADC Data Low Bits                    | ADCD_L   | XX          | <a href="#">151</a> |
| F74-FBF                                                                        | Reserved                             | —        | XX          |                     |
| <b>Interrupt Controller</b>                                                    |                                      |          |             |                     |
| FC0                                                                            | Interrupt Request 0                  | IRQ0     | 00          | <a href="#">61</a>  |
| FC1                                                                            | IRQ0 Enable High Bit                 | IRQ0ENH  | 00          | <a href="#">63</a>  |
| FC2                                                                            | IRQ0 Enable Low Bit                  | IRQ0ENL  | 00          | <a href="#">63</a>  |
| FC3                                                                            | Interrupt Request 1                  | IRQ1     | 00          | <a href="#">62</a>  |
| FC4                                                                            | IRQ1 Enable High Bit                 | IRQ1ENH  | 00          | <a href="#">64</a>  |
| FC5                                                                            | IRQ1 Enable Low Bit                  | IRQ1ENL  | 00          | <a href="#">64</a>  |
| FC6                                                                            | Interrupt Request 2                  | IRQ2     | 00          | <a href="#">63</a>  |
| FC7                                                                            | IRQ2 Enable High Bit                 | IRQ2ENH  | 00          | <a href="#">65</a>  |
| FC8                                                                            | IRQ2 Enable Low Bit                  | IRQ2ENL  | 00          | <a href="#">65</a>  |
| FC9-FCC                                                                        | Reserved                             | —        | XX          |                     |
| FCD                                                                            | Interrupt Edge Select                | IRQES    | 00          | <a href="#">67</a>  |
| XX=Undefined                                                                   |                                      |          |             |                     |



**Table 7. Register File Address Map (Continued)**

| Address (Hex)                  | Register Description                  | Mnemonic | Reset (Hex) | Page No             |
|--------------------------------|---------------------------------------|----------|-------------|---------------------|
| FCE                            | Reserved                              | —        | 00          |                     |
| FCF                            | Interrupt Control                     | IRQCTL   | 00          | <a href="#">67</a>  |
| <b>GPIO Port A</b>             |                                       |          |             |                     |
| FD0                            | Port A Address                        | PAADDR   | 00          | <a href="#">50</a>  |
| FD1                            | Port A Control                        | PACTL    | 00          | <a href="#">51</a>  |
| FD2                            | Port A Input Data                     | PAIN     | XX          | <a href="#">54</a>  |
| FD3                            | Port A Output Data                    | PAOUT    | 00          | <a href="#">55</a>  |
| <b>GPIO Port B</b>             |                                       |          |             |                     |
| FD4                            | Port B Address                        | PBADDR   | 00          | <a href="#">50</a>  |
| FD5                            | Port B Control                        | PBCTL    | 00          | <a href="#">51</a>  |
| FD6                            | Port B Input Data                     | PBIN     | XX          | <a href="#">54</a>  |
| FD7                            | Port B Output Data                    | PBOUT    | 00          | <a href="#">55</a>  |
| <b>GPIO Port C</b>             |                                       |          |             |                     |
| FD8                            | Port C Address                        | PCADDR   | 00          | <a href="#">50</a>  |
| FD9                            | Port C Control                        | PCCTL    | 00          | <a href="#">51</a>  |
| FDA                            | Port C Input Data                     | PCIN     | XX          | <a href="#">54</a>  |
| FDB                            | Port C Output Data                    | PCOUT    | 00          | <a href="#">55</a>  |
| FDC-FEF                        | Reserved                              | —        | XX          |                     |
| <b>Watchdog Timer (WDT)</b>    |                                       |          |             |                     |
| FF0                            | Watchdog Timer Control                | WDTCTL   | XXX00000b   | <a href="#">86</a>  |
| FF1                            | Watchdog Timer Reload Upper Byte      | WDTU     | FF          | <a href="#">87</a>  |
| FF2                            | Watchdog Timer Reload High Byte       | WDTH     | FF          | <a href="#">87</a>  |
| FF3                            | Watchdog Timer Reload Low Byte        | WDTL     | FF          | <a href="#">87</a>  |
| FF4-FF7                        | Reserved                              | —        | XX          |                     |
| <b>Flash Memory Controller</b> |                                       |          |             |                     |
| FF8                            | Flash Control                         | FCTL     | 00          | <a href="#">159</a> |
| FF8                            | Flash Status                          | FSTAT    | 00          | <a href="#">160</a> |
| FF9                            | Page Select                           | FPS      | 00          | <a href="#">160</a> |
| FF9 (if enabled)               | Flash Sector Protect                  | FPROT    | 00          | <a href="#">161</a> |
| FFA                            | Flash Programming Frequency High Byte | FFREQH   | 00          | <a href="#">161</a> |
| FFB                            | Flash Programming Frequency Low Byte  | FFREQL   | 00          | <a href="#">161</a> |
| <b>Read-Only Memory</b>        |                                       |          |             |                     |
| FF8                            | Reserved                              | —        | XX          |                     |
| FF9                            | Page Select                           | RPS      | 00          | <a href="#">160</a> |
| FFA-FFB                        | Reserved                              | —        | XX          |                     |
| <b>eZ8 CPU</b>                 |                                       |          |             |                     |
| XX=Undefined                   |                                       |          |             |                     |



**Table 7. Register File Address Map (Continued)**

| Address<br>(Hex) | Register Description    | Mnemonic | Reset (Hex) | Page No      |
|------------------|-------------------------|----------|-------------|--------------|
| FFC              | Flags                   | —        | XX          | Refer to eZ8 |
| FFD              | Register Pointer        | RP       | XX          | CPU User     |
| FFE              | Stack Pointer High Byte | SPH      | XX          | Manual       |
| FFF              | Stack Pointer Low Byte  | SPL      | XX          |              |
| XX=Undefined     |                         |          |             |              |

## Control Register Summary

### Timer 0 High Byte

T0H (F00H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Timer 0 current count value

### Timer 0 Low Byte

T0L (F01H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Timer 0 current count value

### Timer 0 Reload High Byte

T0RH (F02H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Timer 0 reload value [15:8]

### Timer 0 Reload Low Byte

T0RL (F03H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Timer 0 reload value [7:0]

### Timer 0 PWM High Byte

T0PWMH (F04H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Timer 0 PWM value [15:8]

### Timer 0 Control 0

T0CTL0 (F06H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Reserved  
Cascade Timer  
0 = Timer 0 Input signal is  
GPIO pin  
1 = Timer 0 Input signal is  
Timer 1 out  
Reserved

### Timer 0 Control 1

T0CTL1 (F07H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Timer Mode  
000 = One-Shot mode  
001 = Continuous mode  
010 = Counter mode  
011 = PWM mode  
100 = Capture mode  
101 = Compare mode  
110 = Gated mode  
111 = Capture/Compare  
mode  
Prescale Value  
000 = Divide by 1  
001 = Divide by 2  
010 = Divide by 4  
011 = Divide by 8  
100 = Divide by 16  
101 = Divide by 32  
110 = Divide by 64  
111 = Divide by 128  
Timer Input/Output Polarity  
Operation of this bit is a  
function of  
the current operating mode  
of the timer  
Timer Enable  
0 = Timer is disabled  
1 = Timer is enabled

### Timer 1 High Byte

T1H (F08H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Timer 1 current count value

### Timer 1 Low Byte

T1L (F09H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

Timer 1 current count value

### Timer 1 Reload High Byte

T1RH (F0AH - Read/Write)

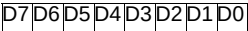
D7 D6 D5 D4 D3 D2 D1 D0

Timer 1 reload value [15:8]



Timer 1 Reload Low Byte

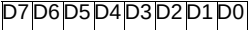
T1RL (F0BH - Read/Write)



Timer 1 reload value [7:0]

Timer 1 PWM High Byte

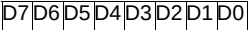
T1PWMH (F0CH - Read/Write)



Timer 1 PWM value [15:8]

Timer 1 PWM Low Byte

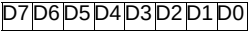
T1PWML (F0DH - Read/Write)



Timer 1 PWM value [7:0]

Timer 1 Control 0

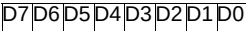
T1CTL0 (F0EH - Read/Write)



Reserved  
Cascade Timer  
0 = Timer 1 Input signal is  
GPIO pin  
1 = Timer 1 Input signal is  
Timer 0 out  
Reserved

Timer 1 Control 1

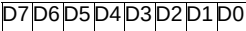
T1CTL1 (F0FH - Read/Write)



Timer Mode  
000 = One-Shot mode  
001 = Continuous mode  
010 = Counter mode  
011 = PWM mode  
100 = Capture mode  
101 = Compare mode  
110 = Gated mode  
111 = Capture/Compare  
mode  
Prescale Value  
000 = Divide by 1  
001 = Divide by 2  
010 = Divide by 4  
011 = Divide by 8  
100 = Divide by 16  
101 = Divide by 32  
110 = Divide by 64  
111 = Divide by 128  
Timer Input/Output Polarity  
Operation of this bit is a  
function of  
the current operating mode  
of the timer  
Timer Enable  
0 = Timer is disabled  
1 = Timer is enabled

UART0 Transmit Data

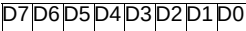
U0TXD (F40H - Write Only)



UART0 transmitter data byte

UART0 Receive Data

U0RXD (F40H - Read Only)

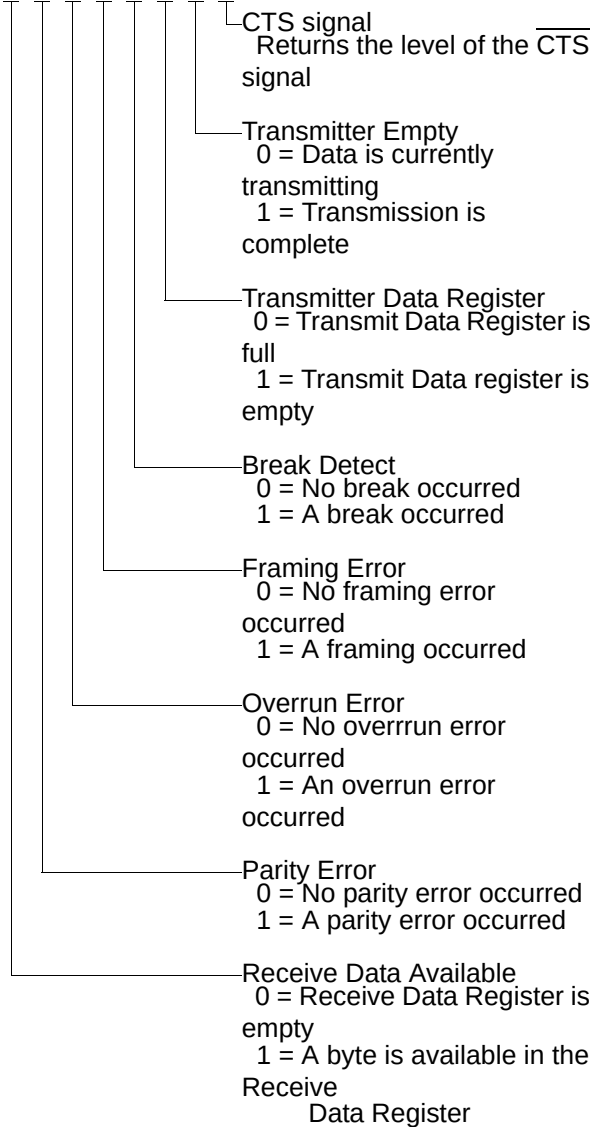


UART0 receiver data byte

#### UART0 Status 0

U0STAT0 (F41H - Read Only)

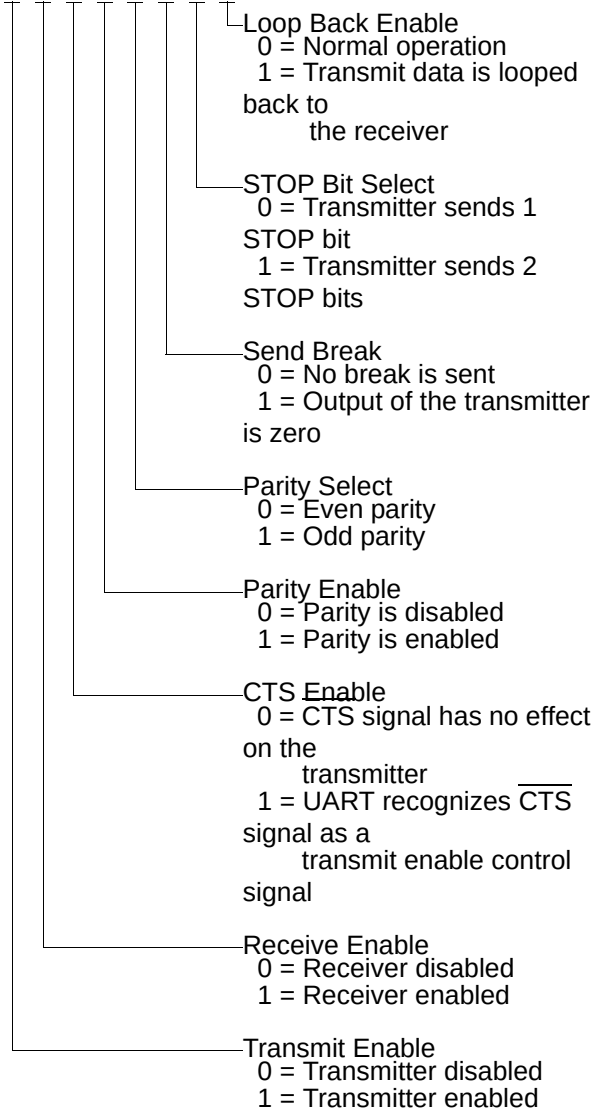
D7 D6 D5 D4 D3 D2 D1 D0



#### UART0 Control 0

U0CTL0 (F42H - Read/Write)

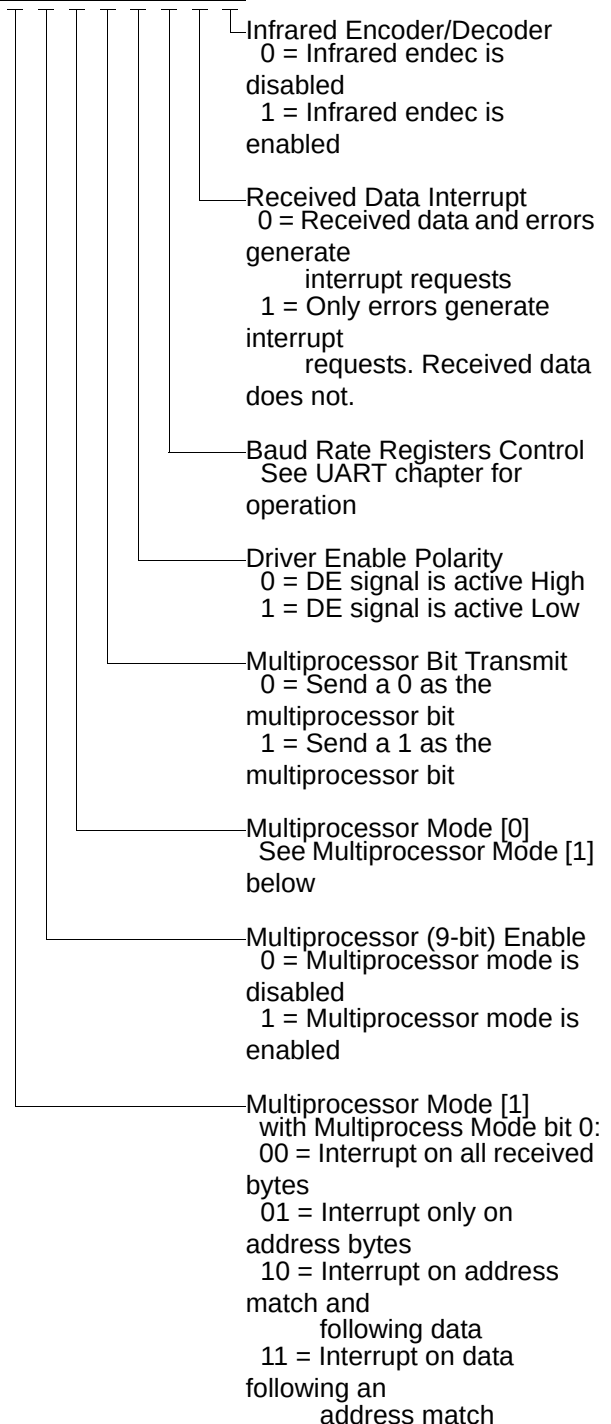
D7 D6 D5 D4 D3 D2 D1 D0



UART0 Control 1

U0CTL1 (F43H - Read/Write)

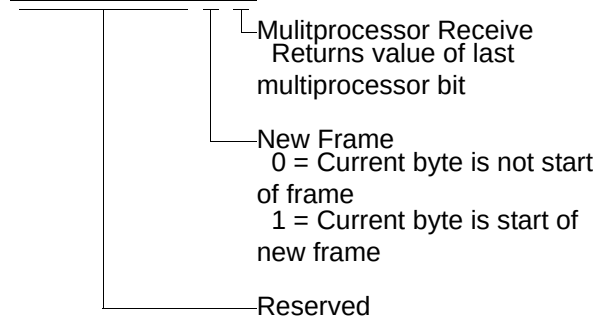
D7 D6 D5 D4 D3 D2 D1 D0



#### UART0 Status 1

U0STAT1 (F44H - Read Only)

D7 D6 D5 D4 D3 D2 D1 D0



#### UART0 Address Compare

U0ADDR (F45H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0



#### UART0 Baud Rate Generator High Byte

U0BRH (F46H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0



#### UART0 Baud Rate Generator Low Byte

U0BRL (F47H - Read/Write)

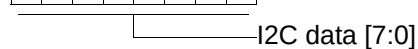
D7 D6 D5 D4 D3 D2 D1 D0



#### I2C Data

I2CDATA (F50H - Read/Write)

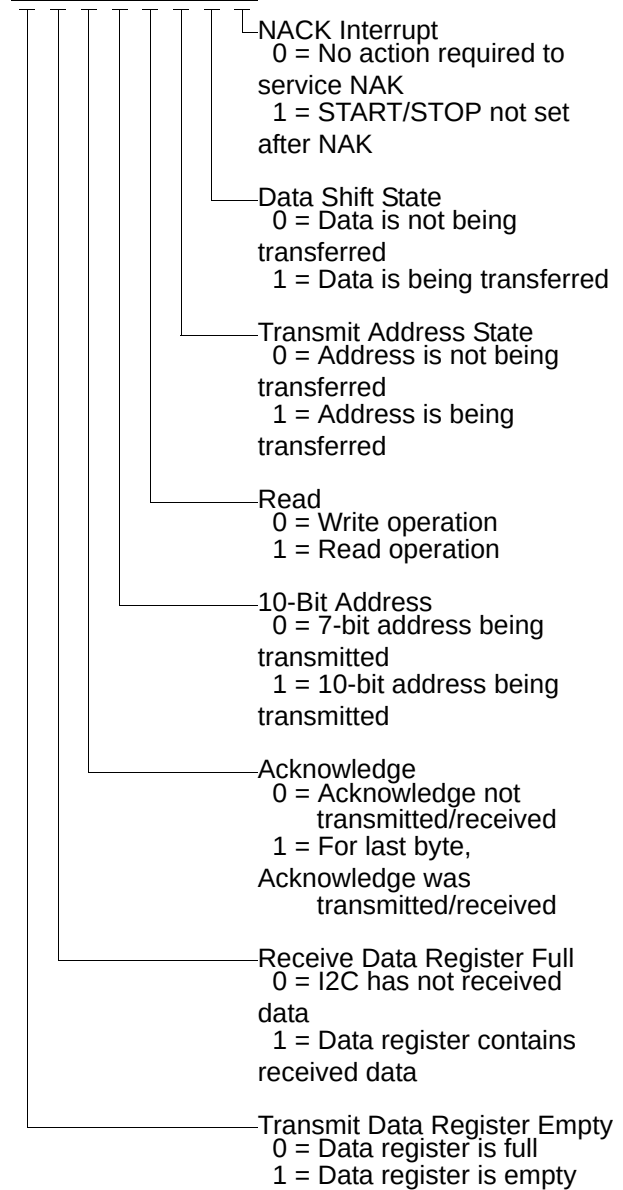
D7 D6 D5 D4 D3 D2 D1 D0

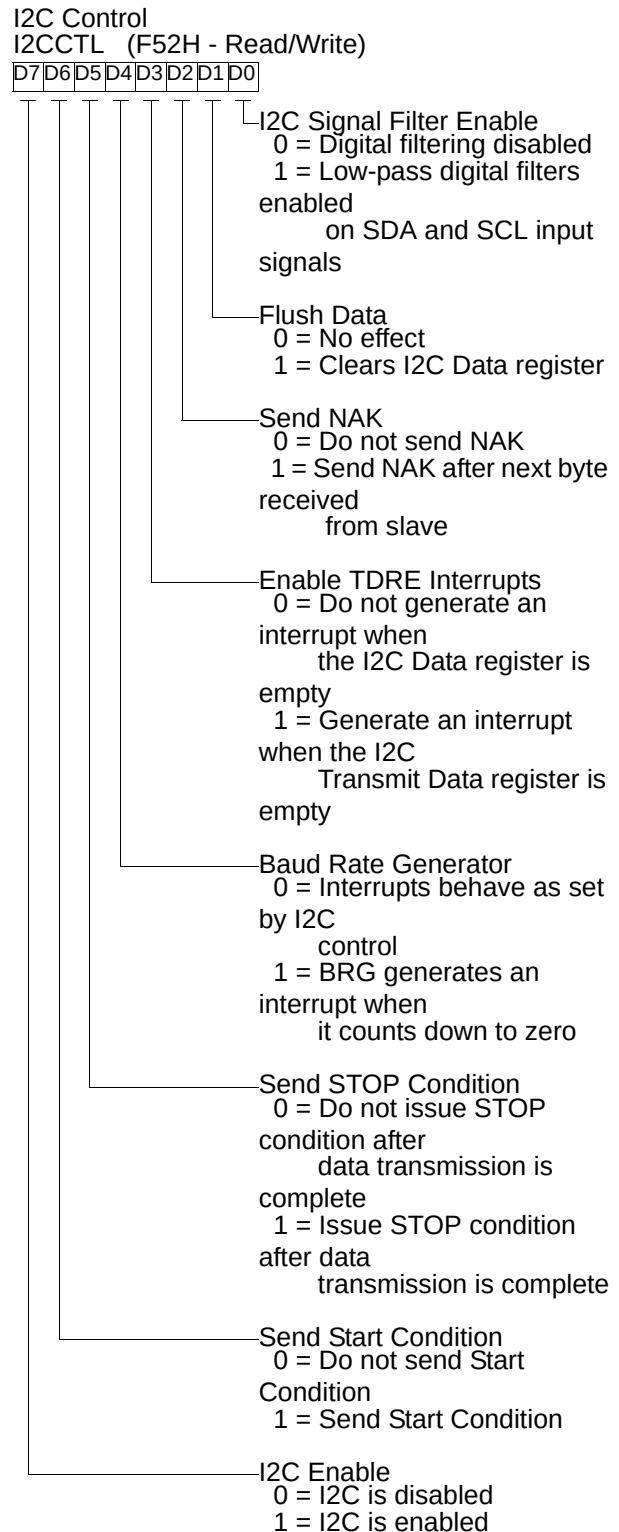


#### I2C Status

I2CSTAT (F51H - Read Only)

D7 D6 D5 D4 D3 D2 D1 D0





### I2C Baud Rate Generator High Byte

I2CBRH (F53H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

I2C Baud Rate divisor [15:8]

### I2C Baud Rate Generator Low Byte

I2CBRL (F54H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

I2C Baud Rate divisor [7:0]

### SPI Data

SPIDATA (F60H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

SPI Data [7:0]

### SPI Control

SPICTL (F61H - Read/Write)

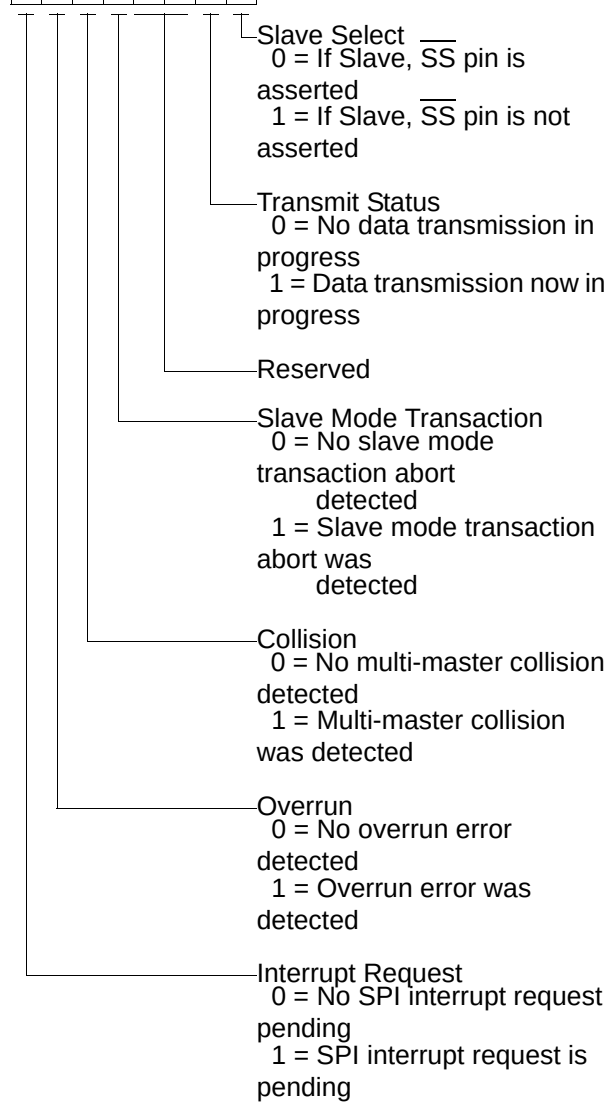
D7 D6 D5 D4 D3 D2 D1 D0

- SPI Enable
  - 0 = SPI disabled
  - 1 = SPI enabled
- Master Mode Enabled
  - 0 = SPI configured in Slave mode
  - 1 = SPI configured in Master mode
- Wire-OR (open-drain) Mode
  - 0 = SPI signals not configured for open-drain
  - 1 = SPI signals (SCK,  $\overline{SS}$ , MISO, and MOSI) configured for open-drain
- Clock Polarity
  - 0 = SCK idles Low
  - 1 = SPI idles High
- Phase Select
  - Sets the phase relationship of the data to the clock.
- BRG Timer Interrupt Request
  - 0 = BRG timer function is disabled
  - 1 = BRG time-out interrupt is enabled
- Start an SPI Interrupt Request
  - 0 = No effect
  - 1 = Generate an SPI interrupt request
- Interrupt Request Enable
  - 0 = SPI interrupt requests are disabled
  - 1 = SPI interrupt requests are enabled

#### SPI Status

##### SPISAT (F62H - Read Only)

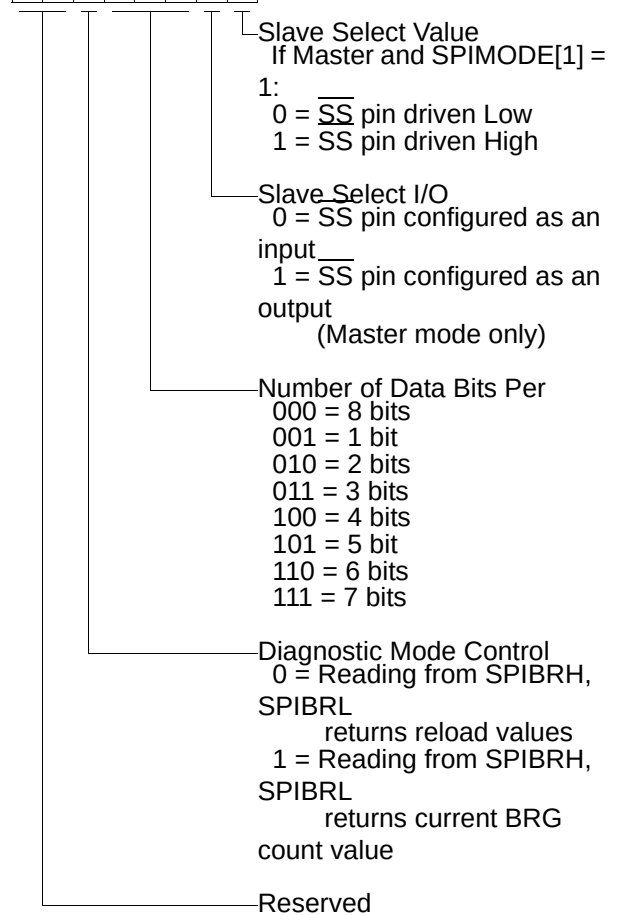
D7 D6 D5 D4 D3 D2 D1 D0

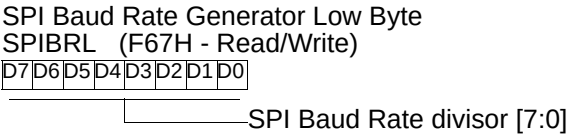
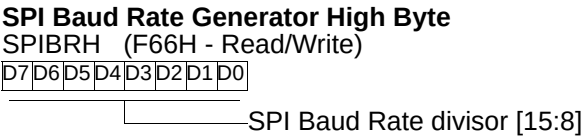
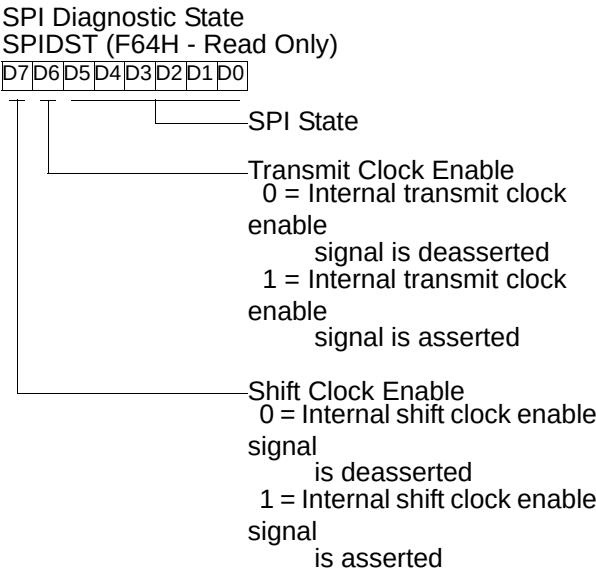


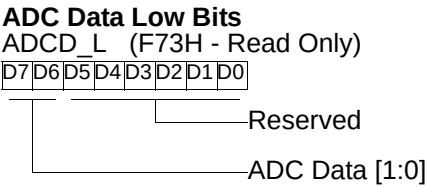
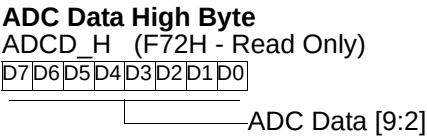
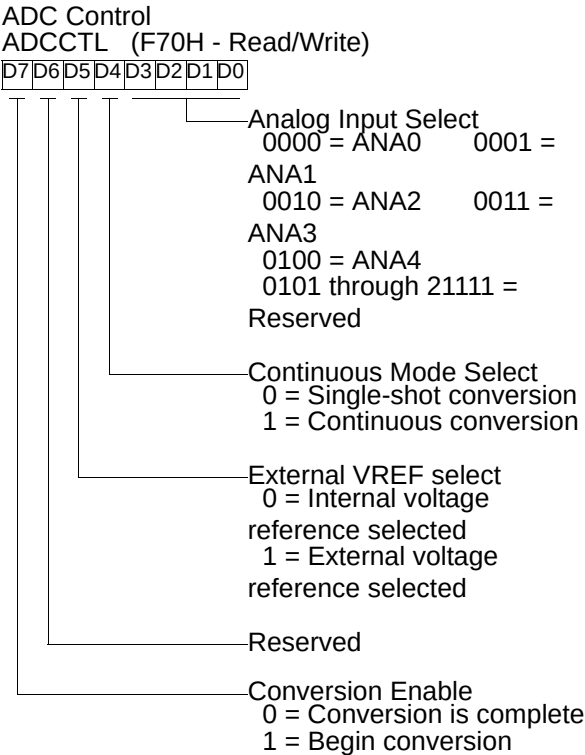
#### SPI Mode

##### SPIMODE (F63H - Read/Write)

D7 D6 D5 D4 D3 D2 D1 D0

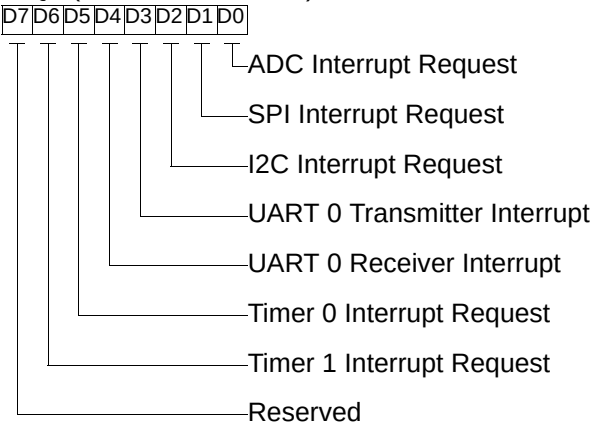






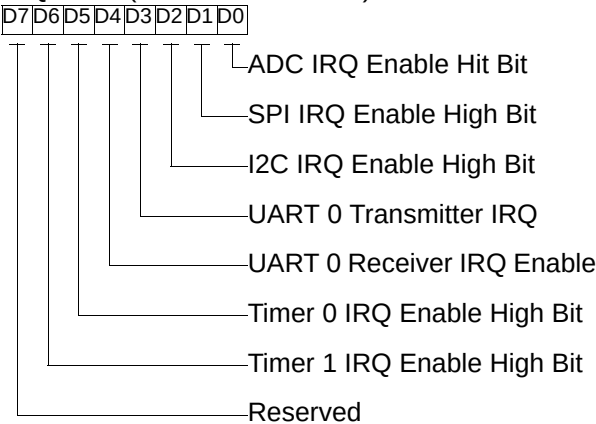


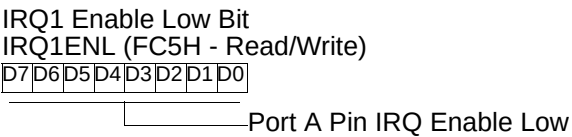
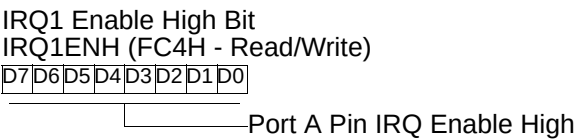
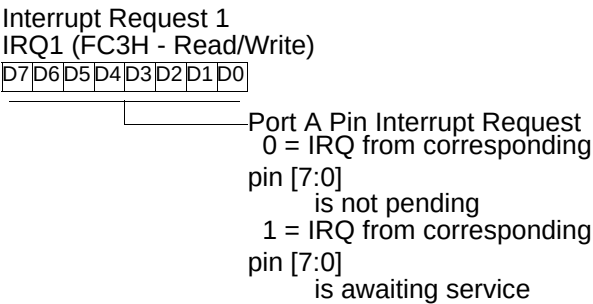
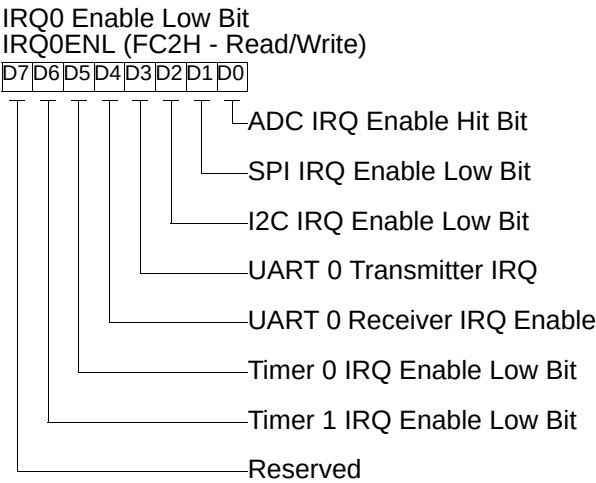
Interrupt Request 0  
IRQ0 (FC0H - Read/Write)

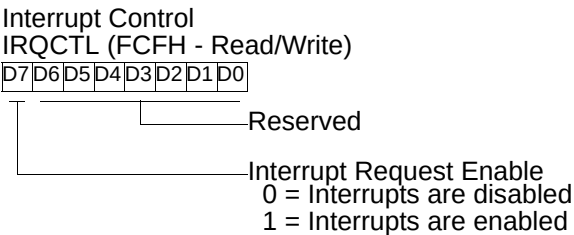
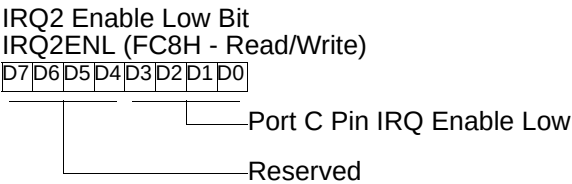
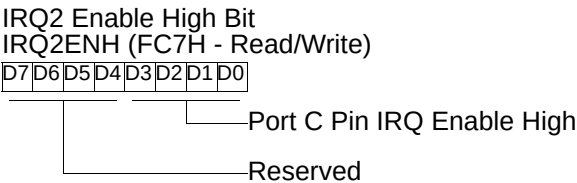
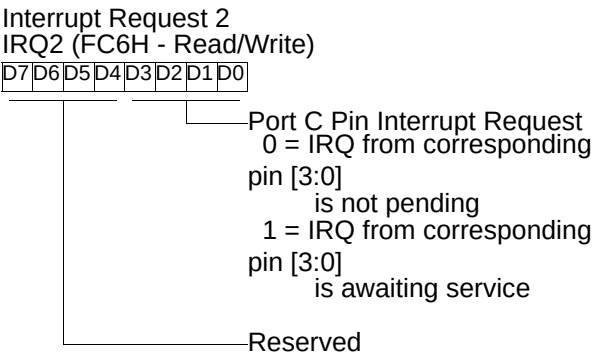


For all of the above  
peripherals:  
0 = Peripheral IRQ is not  
pending  
1 = Peripheral IRQ is  
awaiting service

IRQ0 Enable High Bit  
IRQ0ENH (FC1H - Read/Write)







#### Port A Address

PAADDR (FD0H - Read/Write)

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|

Port A Address[7:0]  
Selects Port Sub-Registers:  
00H = No function  
01H = Data direction  
02H = Alternate function  
03H = Output control (open-drain)  
04H = High drive enable  
05H = STOP mode recovery enable  
06H = Pull-up enable  
07H-FFH = No function

#### Port A Control

PACTL (FD1H - Read/Write)

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|

Port A Control[7:0]  
Provides Access to Port Sub-Registers

#### Port A Input Data

PAIN (FD2H - Read Only)

|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|

Port A Input Data [7:0]

#### Port A Output Data

PAOUT (FD3H - Read/Write)

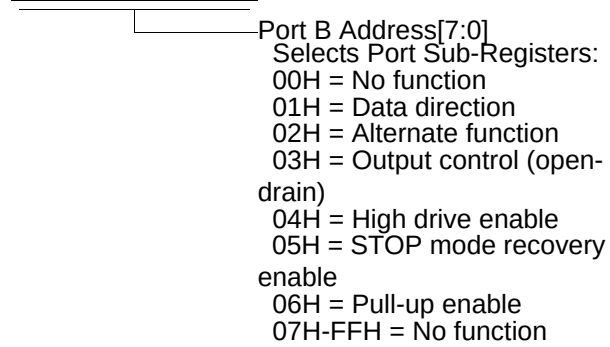
|    |    |    |    |    |    |    |    |
|----|----|----|----|----|----|----|----|
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|

Port A Output Data [7:0]

#### Port B Address

PBADDR (FD4H - Read/Write)

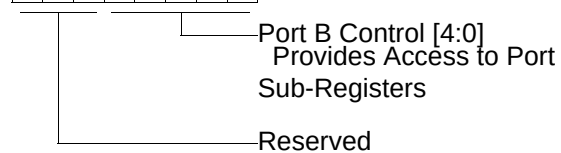
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|
|----|----|----|----|----|----|----|----|



#### Port B Control

PBCTL (FD5H - Read/Write)

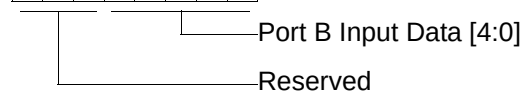
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|
|----|----|----|----|----|----|----|----|



#### Port B Input Data

PBIN (FD6H - Read Only)

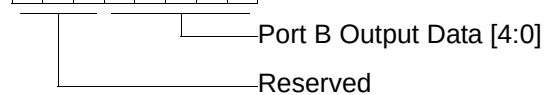
| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|
|----|----|----|----|----|----|----|----|

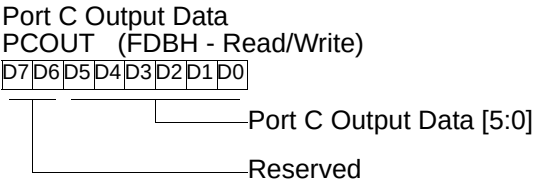
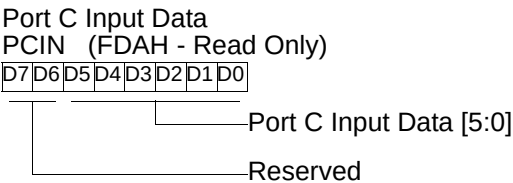
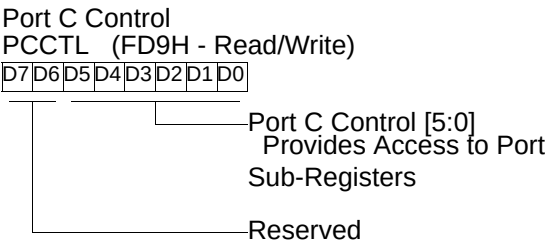
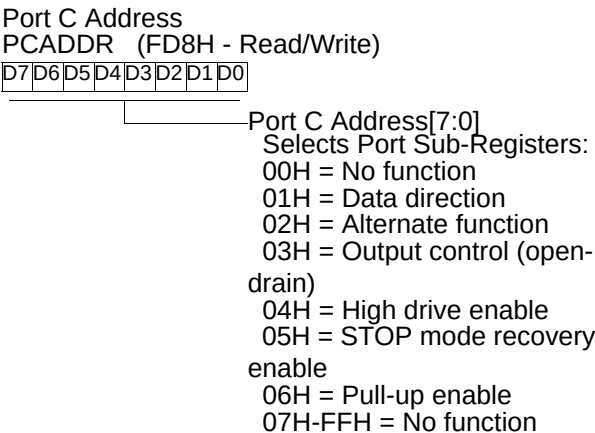


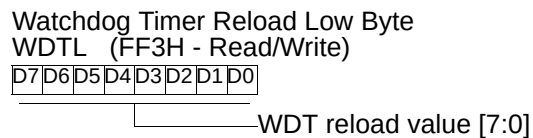
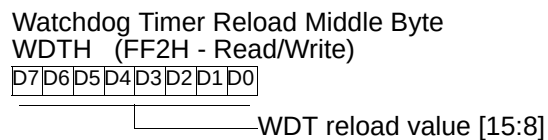
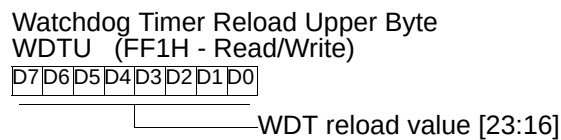
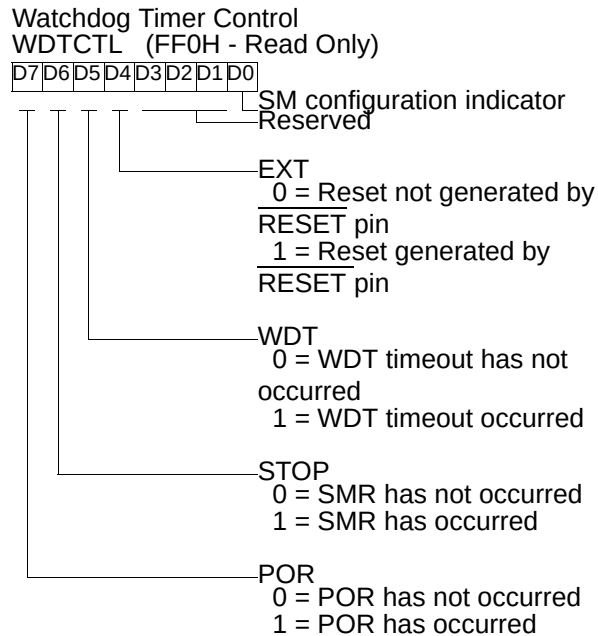
#### Port B Output Data

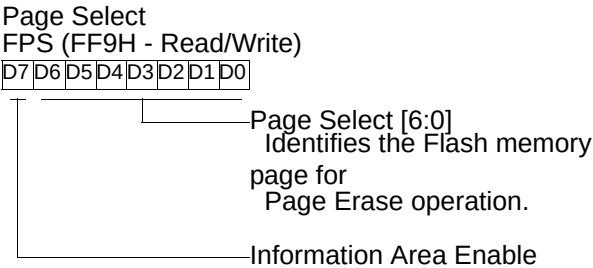
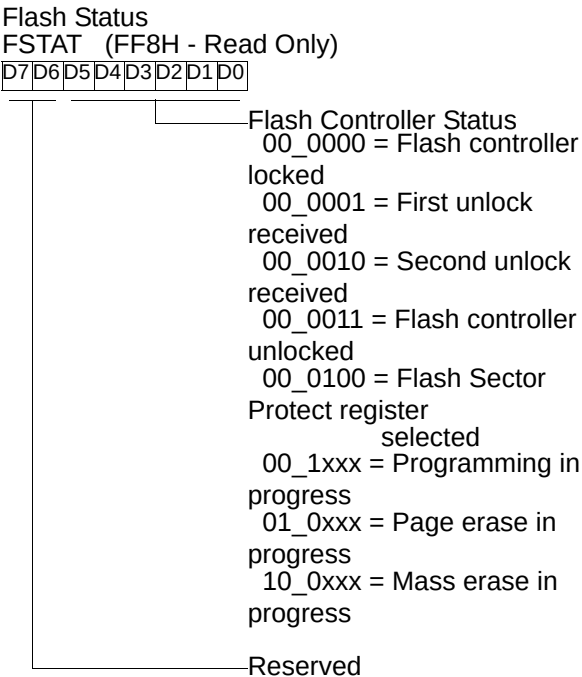
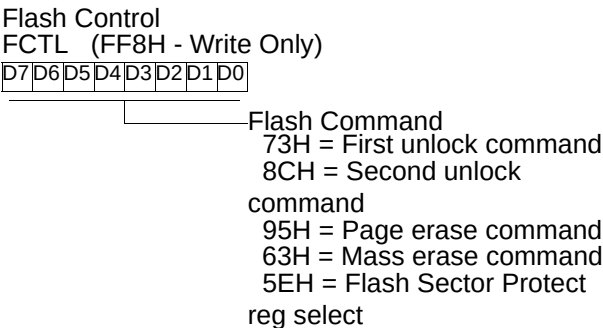
PBOUT (FD7H - Read/Write)

| D7 | D6 | D5 | D4 | D3 | D2 | D1 | D0 |
|----|----|----|----|----|----|----|----|
|----|----|----|----|----|----|----|----|



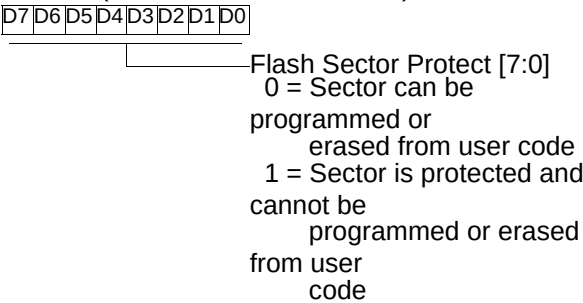








Flash Sector Protect  
FPROT (FF9H - Read/Write to 1's)



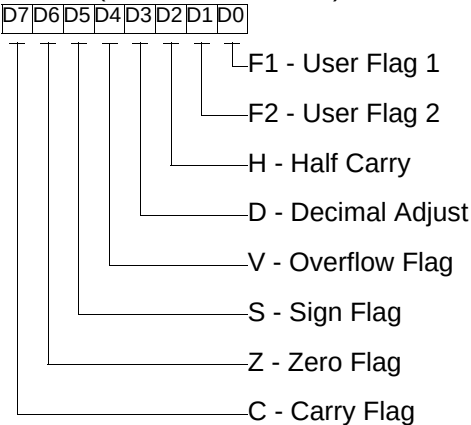
Flash Frequency High Byte  
FFREQH (FFAH - Read/Write)



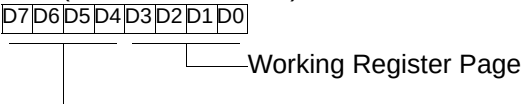
Flash Frequency Low Byte  
FFREQL (FFBH - Read/Write)

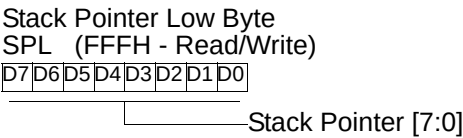
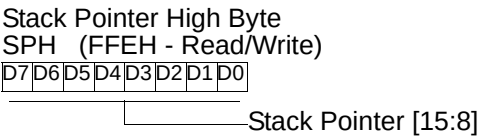
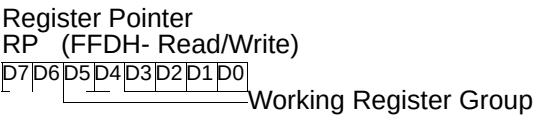


Flags  
FLAGS (FFCH - Read/Write)



Register Pointer  
RP (FFDH- Read/Write)





# Reset and Stop Mode Recovery

The Reset Controller within the Z8 Encore! XP<sup>®</sup> F0822 Series controls Reset and Stop Mode Recovery operation. In typical operation, the following events cause a Reset to occur:

- Power-On Reset (POR)
- Voltage Brownout
- WDT time-out (when configured through the WDT\_RES Option Bit to initiate a Reset)
- External  $\overline{\text{RESET}}$  pin assertion
- On-Chip Debugger initiated Reset (OCDCTL[0] set to 1)

When the Z8 Encore! XP F0822 Series device is in STOP mode, a Stop Mode Recovery is initiated by any of the following events:

- WDT time-out
- GPIO Port input pin transition on an enabled Stop Mode Recovery source
- DBG pin driven Low

## Reset Types

Z8 Encore! XP F0822 Series provides two types of reset operation (System Reset and Stop Mode Recovery). The type of reset is a function of both the current operating mode of the Z8 Encore! XP F0822 Series device and the source of the Reset. [Table 8](#) lists the types of Resets and their operating characteristics.

**Table 8. Reset and Stop Mode Recovery Characteristics and Latency**

| Reset Characteristics and Latency |                                     |       |                                                   |
|-----------------------------------|-------------------------------------|-------|---------------------------------------------------|
| Reset Type                        | Control Registers                   | eZ8   | Reset Latency (Delay)                             |
|                                   |                                     | CPU   |                                                   |
| System Reset                      | Reset (as applicable)               | Reset | 66 WDT Oscillator cycles + 16 System Clock cycles |
| Stop Mode Recovery                | Unaffected, except WDT_CTL register | Reset | 66 WDT Oscillator cycles + 16 System Clock cycles |

## System Reset

During a System Reset, a Z8 Encore! XP® F0822 Series device is held in Reset for 66 cycles of the WDT oscillator followed by 16 cycles of the system clock. At the beginning of Reset, all GPIO pins are configured as inputs. All GPIO programmable pull-ups are disabled.

During Reset, the eZ8 CPU and the on-chip peripherals are idle; however, the on-chip crystal oscillator and WDT oscillator continue to run. The system clock begins operating following the WDT oscillator cycle count. The eZ8 CPU and on-chip peripherals remain idle through all the 16 cycles of the system clock.

Upon Reset, control registers within the Register File which have a defined Reset value are loaded with their reset values. Other control registers (including the Stack Pointer, Register Pointer, and Flags) and general-purpose RAM are undefined following the Reset. The eZ8 CPU fetches the Reset vector at Program Memory addresses 0002H and 0003H and loads that value into the Program Counter. Program execution begins at the Reset vector address.

## Reset Sources

[Table 9](#) lists the reset sources as a function of the operating mode. The text following provides more detailed information on the individual reset sources.

► **Note:** A POR/VBO event always has priority over all other possible reset sources to insure a full system reset occurs.

**Table 9. Reset Sources and Resulting Reset Type**

| Operating Mode       | Reset Source                             | Reset Type                                             |
|----------------------|------------------------------------------|--------------------------------------------------------|
| NORMAL or HALT modes | POR/VBO                                  | System Reset                                           |
|                      | WDT time-out when configured for Reset   | System Reset                                           |
|                      | $\overline{\text{RESET}}$ pin assertion  | System Reset                                           |
|                      | OCD initiated Reset (OCDCTL[0] set to 1) | System Reset except the OCD is unaffected by the reset |
| STOP mode            | POR/ VBO                                 | System Reset                                           |
|                      | $\overline{\text{RESET}}$ pin assertion  | System Reset                                           |
|                      | DBG pin driven Low                       | System Reset                                           |

## Power-On Reset

Each device in the Z8 Encore! XP<sup>®</sup> F0822 Series contains an internal POR circuit. The POR circuit monitors the supply voltage and holds the device in the Reset state until the supply voltage reaches a safe operating level. After the supply voltage exceeds the POR voltage threshold ( $V_{POR}$ ), the POR Counter is enabled and counts 66 cycles of the WDT oscillator. After the POR counter times out, the XTAL Counter is enabled to count a total of 16 system clock pulses. The device is held in the Reset state until both the POR Counter and XTAL counter have timed out. After the Z8 Encore! XP F0822 Series device exits the POR state, the eZ8 CPU fetches the Reset vector. Following POR, the POR status bit in the Watchdog Timer Control Register (WDTCTL) is set to 1.

Figure 6 displays POR operation. See [Electrical Characteristics](#) for POR threshold voltage ( $V_{POR}$ ).

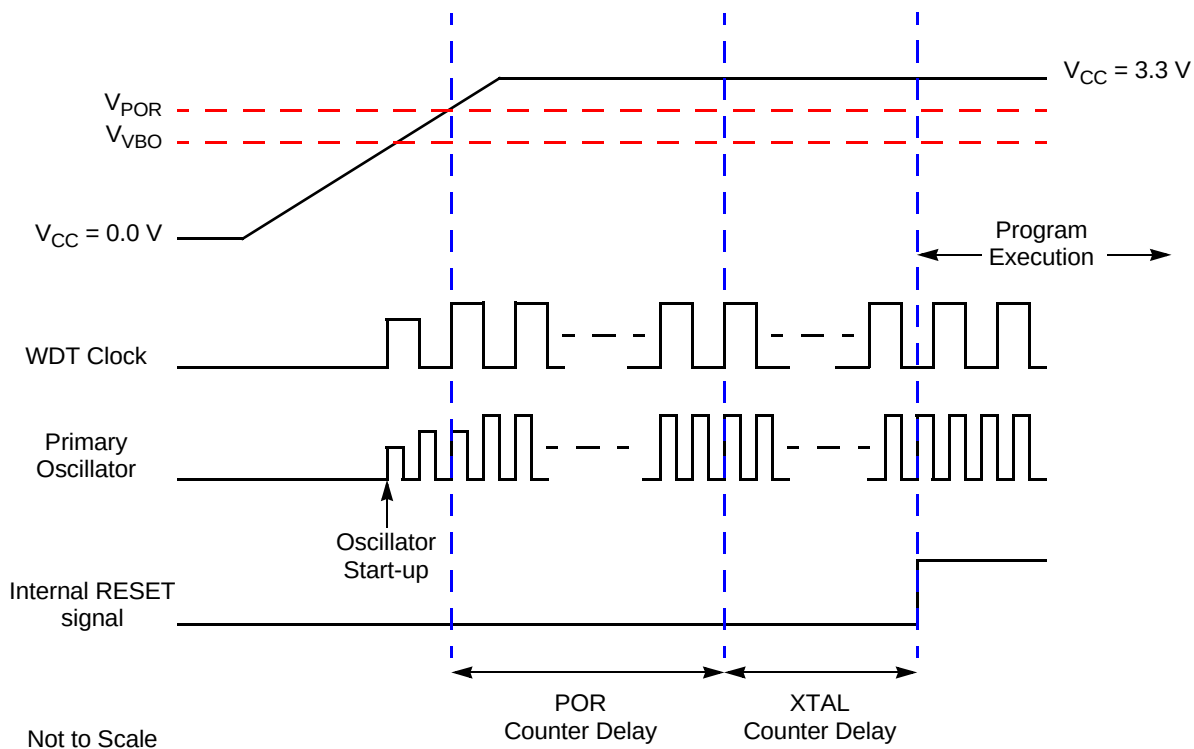


**Figure 6. Power-On Reset Operation**

## Voltage Brownout Reset

The devices in Z8 Encore! XP F0822 Series provide low Voltage Brownout protection. The VBO circuit senses when the supply voltage drops to an unsafe level (below the VBO threshold voltage) and forces the device into the Reset state. While the supply voltage

remains below the POR voltage threshold ( $V_{POR}$ ), the VBO block holds the device in the Reset state.

After the supply voltage again exceeds the POR voltage threshold, the device progresses through a full System Reset sequence as described in the POR section. Following POR, the POR status bit in the Watchdog Timer Control Register (WDTCTL) is set to 1.

Figure 7 displays the VBO operation. See [Electrical Characteristics](#) on page 185 for the VBO and POR threshold voltages ( $V_{VBO}$  and  $V_{POR}$ ).

The VBO circuit can be either enabled or disabled during STOP mode. Operation during STOP mode is set by the VBO\_AO Option Bit. For information on configuring VBO\_AO, see [Option Bits](#) on page 163.

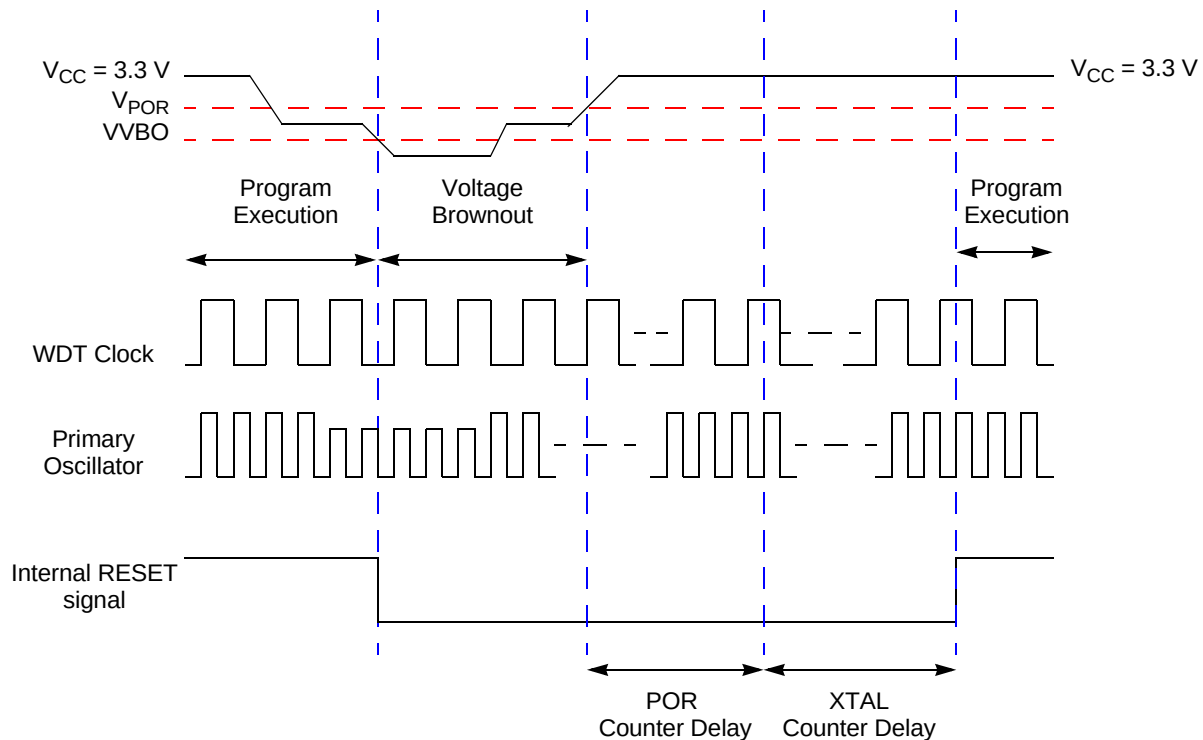


**Figure 7. Voltage Brownout Reset Operation**

### Watchdog Timer Reset

If the device is in NORMAL or HALT mode, WDT initiates a System Reset at time-out, if the WDT\_RES Option Bit is set to 1. This is the default (unprogrammed) setting of the WDT\_RES Option Bit. The WDT status bit in the WDT Control Register is set to signify that the reset was initiated by the WDT.

## External Pin Reset

The  $\overline{\text{RESET}}$  pin contains a Schmitt-triggered input, an internal pull-up, an analog filter, and a digital filter to reject noise. After the  $\overline{\text{RESET}}$  pin is asserted for at least 4 system clock cycles, the device progresses through the System Reset sequence. While the  $\overline{\text{RESET}}$  input pin is asserted Low, Z8 Encore! XP F0822 Series device continues to be held in the Reset state. If the  $\overline{\text{RESET}}$  pin is held Low beyond the System Reset time-out, the device exits the Reset state immediately following  $\overline{\text{RESET}}$  pin deassertion. Following a System Reset initiated by the external  $\overline{\text{RESET}}$  pin, the EXT status bit in the Watchdog Timer Control Register (WDTCTL) is set to 1.

## On-Chip Debugger Initiated Reset

A POR is initiated using the OCD by setting the RST bit in the OCD Control Register. The OCD block is not reset but the rest of the chip goes through a normal system reset. The RST bit automatically clears during the system reset. Following the system reset, the POR bit in the WDT Control Register is set.

## Stop Mode Recovery

STOP mode is entered by execution of a STOP instruction by the eZ8 CPU. For detailed information on STOP mode, see [Low-Power Modes](#) on page 45. During Stop Mode Recovery, the device is held in reset for 66 cycles of the WDT oscillator followed by 16 cycles of the system clock. Stop Mode Recovery only affects the contents of the WDT Control Register and does not affect any other values in the Register File, including the Stack Pointer, Register Pointer, Flags, Peripheral Control Registers, and General-Purpose RAM.

The eZ8 CPU fetches the Reset vector at Program Memory addresses 0002H and 0003H and loads that value into the Program Counter. Program execution begins at the Reset vector address. Following Stop Mode Recovery, the STOP bit in the WDT Control Register is set to 1. [Table 10](#) lists the Stop Mode Recovery sources and resulting actions. The text following provides more detailed information on each of the Stop Mode Recovery sources.

**Table 10. Stop Mode Recovery Sources and Resulting Action**

| Operating Mode | Stop Mode Recovery Source                                                   | Action                                                               |
|----------------|-----------------------------------------------------------------------------|----------------------------------------------------------------------|
| STOP mode      | WDT time-out when configured for Reset                                      | Stop Mode Recovery                                                   |
|                | WDT time-out when configured for interrupt                                  | Stop Mode Recovery followed by interrupt (if interrupts are enabled) |
|                | Data transition on any GPIO Port pin enabled as a Stop Mode Recovery source | Stop Mode Recovery                                                   |

### Stop Mode Recovery Using WDT Time-Out

If the WDT times out during STOP mode, the device undergoes a Stop Mode Recovery sequence. In the WDT Control Register, the WDT and STOP bits are set to 1. If the WDT is configured to generate an interrupt upon time-out and the Z8 Encore! XP<sup>®</sup> F0822 Series device is configured to respond to interrupts, the eZ8 CPU services the WDT interrupt request following the normal Stop Mode Recovery sequence.

### Stop Mode Recovery Using a GPIO Port Pin Transition

Each of the GPIO Port pins can be configured as a Stop Mode Recovery input source. On any GPIO pin enabled as a STOP Mode Recover source, a change in the input pin value (from High to Low or from Low to High) initiates Stop Mode Recovery. The GPIO Stop Mode Recovery signals are filtered to reject pulses less than 10 ns (typical) in duration. In the WDT Control Register, the STOP bit is set to 1.

**Caution:**

*In STOP mode, the GPIO Port Input Data Registers (PxIN) are disabled. The Port Input Data Registers record the Port transition only if the signal stays on the Port pin through the end of the Stop Mode Recovery delay. Therefore, short pulses on the Port pin initiates Stop Mode Recovery without being written to the Port Input Data Register or without initiating an interrupt (if enabled for that pin).*

# Low-Power Modes

Z8 Encore! XP<sup>®</sup> F0822 Series products contain power-saving features. The highest level of power reduction is provided by STOP mode. The next level of power reduction is provided by the HALT mode.

## STOP Mode

Execution of the eZ8 CPU's STOP instruction places the device into STOP mode. In STOP mode, the operating characteristics are:

- Primary crystal oscillator is stopped; the XIN pin is driven High and the XOUT pin is driven Low.
- System clock is stopped.
- eZ8 CPU is stopped.
- Program counter (PC) stops incrementing.
- If enabled for operation in STOP Mode, the WDT and its internal RC oscillator continue to operate.
- If enabled for operation in STOP mode through the associated Option Bit, the VBO protection circuit continues to operate.
- All other on-chip peripherals are idle.

To minimize current in STOP mode, WDT must be disabled and all GPIO pins configured as digital inputs must be driven to one of the supply rails ( $V_{CC}$  or GND). The device can be brought out of STOP mode using Stop Mode Recovery. For more information on Stop Mode Recovery, see [Reset and Stop Mode Recovery](#) on page 39.



**Caution:** *STOP Mode must not be used when driving the Z8F082x family devices with an external clock driver source.*

## HALT Mode

Execution of the eZ8 CPU's HALT instruction places the device into HALT mode. In HALT mode, the operating characteristics are:

- Primary crystal oscillator is enabled and continues to operate.
- System clock is enabled and continues to operate.
- eZ8 CPU is stopped.
- Program counter stops incrementing.

- WDT's internal RC oscillator continues to operate.
- If enabled, the WDT continues to operate.
- All other on-chip peripherals continue to operate.

The eZ8 CPU can be brought out of HALT mode by any of the following operations:

- Interrupt
- WDT time-out (interrupt or reset)
- Power-On Reset
- Voltage Brownout reset
- External  $\overline{\text{RESET}}$  pin assertion

To minimize current in HALT mode, all GPIO pins which are configured as inputs must be driven to one of the supply rails ( $V_{CC}$  or GND).

# General-Purpose Input/Output

Z8 Encore! XP<sup>®</sup> F0822 Series products support a maximum of 19 port pins (Ports A–C) for General-Purpose Input/Output (GPIO) operations. Each port consists Control and Data Registers. The GPIO Control Registers are used to determine data direction, open-drain, output drive current, programmable pull-ups, Stop Mode Recovery functionality, and alternate pin functions. Each port pin is individually programmable. Ports A and C support 5 V-tolerant inputs.

## GPIO Port Availability by Device

[Table 11](#) lists the port pins available with each device and package type.

**Table 11. Port Availability by Device and Package Type**

| Devices                            | Package | Port A | Port B | Port C |
|------------------------------------|---------|--------|--------|--------|
| Z8X0821, Z8X0811, Z8X0421, Z8X0411 | 20-pin  | [7:0]  | [1:0]  | [0]    |
| Z8X0822, Z8X0812, Z8X0422, Z8X0412 | 28-pin  | [7:0]  | [4:0]  | [5:0]  |

## Architecture

[Figure 8](#) displays a simplified block diagram of a GPIO port pin. It does not display the ability to accommodate alternate functions, variable port current drive strength, and programmable pull-up.

## GPIO Alternate Functions

Many of the GPIO port pins are used as both general-purpose I/O and to provide access to on-chip peripheral functions such as timers and serial communication devices. The Port A–C Alternate Function sub-registers configure these pins for either general-purpose I/O or alternate function operation. When a pin is configured for alternate function, control of the port-pin direction (input/output) is passed from the Port A–C Data Direction registers to the alternate function assigned to this pin. [Table 12](#) lists the alternate functions associated with each port pin.

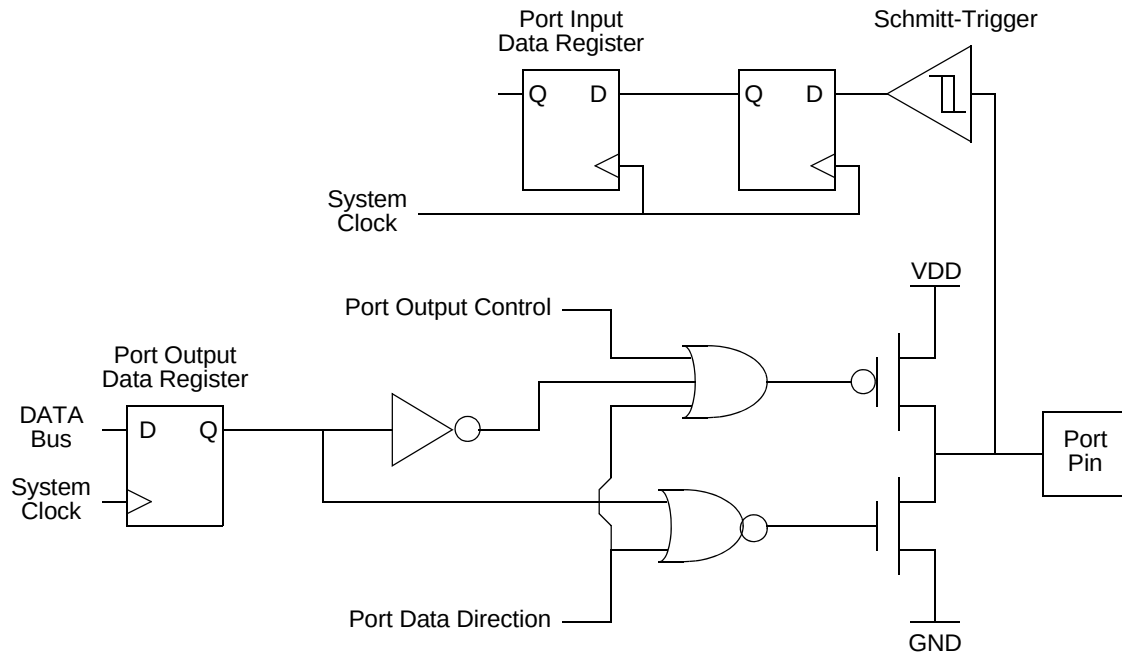


Figure 8. GPIO Port Pin Block Diagram

Table 12. Port Alternate Function Mapping

| Port          | Pin | Mnemonic                 | Alternate Function Description                    |
|---------------|-----|--------------------------|---------------------------------------------------|
| <b>Port A</b> | PA0 | T0IN                     | Timer 0 Input                                     |
|               | PA1 | T0OUT                    | Timer 0 Output                                    |
|               | PA2 | DE                       | UART 0 Driver Enable                              |
|               | PA3 | $\overline{\text{CTS0}}$ | UART 0 Clear to Send                              |
|               | PA4 | RXD0 / IRRX0             | UART 0 / IrDA 0 Receive Data                      |
|               | PA5 | TXD0 / IRTX0             | UART 0 / IrDA 0 Transmit Data                     |
|               | PA6 | SCL                      | I <sup>2</sup> C Clock (automatically open-drain) |
|               | PA7 | SDA                      | I <sup>2</sup> C Data (automatically open-drain)  |
| <b>Port B</b> | PB0 | ANA0                     | ADC Analog Input 0                                |
|               | PB1 | ANA1                     | ADC Analog Input 1                                |
|               | PB2 | ANA2                     | ADC Analog Input 2                                |
|               | PB3 | ANA3                     | ADC Analog Input 3                                |
|               | PB4 | ANA4                     | ADC Analog Input 4                                |

**Table 12. Port Alternate Function Mapping (Continued)**

| Port   | Pin | Mnemonic        | Alternate Function Description |
|--------|-----|-----------------|--------------------------------|
| Port C | PC0 | T1IN            | Timer 1 Input                  |
|        | PC1 | T1OUT           | Timer 1 Output                 |
|        | PC2 | $\overline{SS}$ | SPI Slave Select               |
|        | PC3 | SCK             | SPI Serial Clock               |
|        | PC4 | MOSI            | SPI Master Out Slave In        |
|        | PC5 | MISO            | SPI Master In Slave Out        |

## GPIO Interrupts

Many of GPIO port pins are used as interrupt sources. Some port pins are configured to generate an interrupt request on either the rising edge or falling edge of the pin input signal. Other port pin interrupts generate an interrupt when any edge occurs (both rising and falling). For more details on interrupts using the GPIO pins, see [GPIO Port Pin Block Diagram](#) on page 48.

## GPIO Control Register Definitions

Four registers for each port provide access to GPIO control, input data, and output data. [Table 13](#) lists the GPIO Port Registers and Sub-Registers. Use the Port A–C Address and Control Registers together to provide access to sub-registers for Port configuration and control.

**Table 13. GPIO Port Registers and Sub-Registers**

| Port Register Mnemonic     | Port Register Name                                              |
|----------------------------|-----------------------------------------------------------------|
| PxADDR                     | Port A–C Address Register<br>(selects sub-registers)            |
| PxCTL                      | Port A–C Control Register<br>(provides access to sub-registers) |
| PxIN                       | Port A–C Input Data Register                                    |
| PxOUT                      | Port A–C Output Data Register                                   |
| Port Sub-Register Mnemonic | Port Register Name                                              |
| PxDD                       | Data Direction                                                  |
| PxAF                       | Alternate Function                                              |

**Table 13. GPIO Port Registers and Sub-Registers (Continued)**

| Port Register Mnemonic | Port Register Name               |
|------------------------|----------------------------------|
| PxOC                   | Output Control (Open-Drain)      |
| PxHDE                  | High Drive Enable                |
| PxSMRE                 | Stop Mode Recovery Source Enable |
| PxPUE                  | Pull-up Enable                   |

**Port A–C Address Registers**

The Port A–C Address Registers select the GPIO Port functionality accessible through the Port A–C Control Registers. The Port A–C Address and Control Registers combine to provide access to all GPIO Port control ([Table 14](#)).

**Table 14. Port A–C GPIO Address Registers (PxADDR)**

| BITS  | 7                | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------------------|---|---|---|---|---|---|---|
| FIELD | PADDR[7:0]       |   |   |   |   |   |   |   |
| RESET | 00H              |   |   |   |   |   |   |   |
| R/W   | R/W              |   |   |   |   |   |   |   |
| ADDR  | FD0H, FD4H, FD8H |   |   |   |   |   |   |   |

**PADDR[7:0]—Port Address**

The Port Address selects one of the sub-registers accessible through the Port Control register.

| PADDR[7:0] | Port Control Sub-Register Accessible Using the Port A–C Control Registers      |
|------------|--------------------------------------------------------------------------------|
| 00H        | No function. Provides some protection against accidental Port reconfiguration. |
| 01H        | Data Direction                                                                 |
| 02H        | Alternate Function                                                             |
| 03H        | Output Control (Open-Drain)                                                    |
| 04H        | High Drive Enable                                                              |
| 05H        | Stop Mode Recovery Source Enable                                               |
| 06H        | Pull-up Enable                                                                 |
| 07H–FFH    | No Function                                                                    |

## Port A–C Control Registers

The Port A–C Control Registers set the GPIO port operation. The value in the corresponding Port A–C Address Register determines the control sub-registers accessible using the Port A–C Control Register (Table 15).

**Table 15. Port A–C Control Registers (PxCTL)**

| BITS  | 7                | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------------------|---|---|---|---|---|---|---|
| FIELD | PCTL             |   |   |   |   |   |   |   |
| RESET | 00H              |   |   |   |   |   |   |   |
| R/W   | R/W              |   |   |   |   |   |   |   |
| ADDR  | FD1H, FD5H, FD9H |   |   |   |   |   |   |   |

### PCTL[7:0]—Port Control

The Port Control Register provides access to all sub-registers that configure the GPIO Port operation.

## Port A–C Data Direction Sub-Registers

The Port A–C Data Direction sub-register is accessed through the Port A–C Control register by writing 01H to the Port A–C Address Register (Table 16).

**Table 16. Port A–C Data Direction Sub-Registers**

| BITS  | 7                                                                                     | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-------|---------------------------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|
| FIELD | DD7                                                                                   | DD6 | DD5 | DD4 | DD3 | DD2 | DD1 | DD0 |
| RESET | 1                                                                                     |     |     |     |     |     |     |     |
| R/W   | R/W                                                                                   |     |     |     |     |     |     |     |
| ADDR  | If 01H in Port A–C Address Register, accessible through the Port A–C Control Register |     |     |     |     |     |     |     |

### DD[7:0]—Data Direction

These bits control the direction of the associated port pin. Port Alternate Function operation overrides the Data Direction register setting.

0 = Output. Data in the Port A–C Output Data Register is driven onto the port pin.

1 = Input. The port pin is sampled and the value written into the Port A–C Input Data Register. The output driver is tri-stated.

## Port A–C Alternate Function Sub-Registers

The Port A–C Alternate Function sub-register (Table 17) is accessed through the Port A–C Control Register by writing 02H to the Port A–C Address Register. The Port A–C Alternate Function sub-registers select the alternate functions for the selected

pins. To determine the alternate function associated with each port pin, see [GPIO Port Pin Block Diagram](#) on page 48.



**Caution:** Do not enable alternate function for GPIO port pins which do not have an associated alternate function. Failure to follow this guideline can result in unpredictable operation.

**Table 17. Port A–CA–C Alternate Function Sub-Registers**

| BITS  | 7                                                                                     | 6   | 5   | 4   | 3   | 2   | 1   | 0   |
|-------|---------------------------------------------------------------------------------------|-----|-----|-----|-----|-----|-----|-----|
| FIELD | AF7                                                                                   | AF6 | AF5 | AF4 | AF3 | AF2 | AF1 | AF0 |
| RESET | 0                                                                                     |     |     |     |     |     |     |     |
| R/W   | R/W                                                                                   |     |     |     |     |     |     |     |
| ADDR  | If 02H in Port A–C Address Register, accessible through the Port A–C Control Register |     |     |     |     |     |     |     |

**AF[7:0]—Port Alternate Function enabled**

0 = The port pin is in NORMAL mode and the DDx bit in the Port A–C Data Direction sub-register determines the direction of the pin.

1 = The alternate function is selected. Port pin operation is controlled by the alternate function.

**Port A–C Output Control Sub-Registers**

The Port A–C Output Control sub-register ([Table 18](#)) is accessed through the Port A–C Control Register by writing 03H to the Port A–C Address Register. Setting the bits in the Port A–C Output Control sub-registers to 1 configures the specified port pins for open-drain operation. These sub-registers affect the pins directly and, as a result, alternate functions are also affected.

**Table 18. Port A–C Output Control Sub-Registers**

| BITS  | 7                                                                                     | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|-------|---------------------------------------------------------------------------------------|------|------|------|------|------|------|------|
| FIELD | POC7                                                                                  | POC6 | POC5 | POC4 | POC3 | POC2 | POC1 | POC0 |
| RESET | 0                                                                                     |      |      |      |      |      |      |      |
| R/W   | R/W                                                                                   |      |      |      |      |      |      |      |
| ADDR  | If 03H in Port A–C Address Register, accessible through the Port A–C Control Register |      |      |      |      |      |      |      |

**POC[7:0]—Port Output Control**

These bits function independently of the alternate function bit and always disable the drains if set to 1.

0 = The drains are enabled for any output mode (unless overridden by the

alternate function).

1 = The drain of the associated pin is disabled (open-drain mode).

### Port A–C High Drive Enable Sub-Registers

The Port A–C High Drive Enable sub-register (Table 19) is accessed through the Port A–C Control Register by writing 04H to the Port A–C Address Register. Setting the bits in the Port A–C High Drive Enable sub-registers to 1 configures the specified port pins for high current output drive operation. The Port A–C High Drive Enable sub-register affects the pins directly and, as a result, alternate functions are also affected.

**Table 19. Port A–C High Drive Enable Sub-Registers**

| BITS  | 7                                                                                     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
|-------|---------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| FIELD | PHDE7                                                                                 | PHDE6 | PHDE5 | PHDE4 | PHDE3 | PHDE2 | PHDE1 | PHDE0 |
| RESET | 0                                                                                     |       |       |       |       |       |       |       |
| R/W   | R/W                                                                                   |       |       |       |       |       |       |       |
| ADDR  | If 04H in Port A–C Address Register, accessible through the Port A–C Control Register |       |       |       |       |       |       |       |

#### PHDE[7:0]—Port High Drive Enabled

0 = The Port pin is configured for standard output current drive.

1 = The Port pin is configured for high output current drive.

### Port A–C Stop Mode Recovery Source Enable Sub-Registers

The Port A–C Stop Mode Recovery Source Enable sub-register (Table 20) is accessed through the Port A–C Control Register by writing 05H to the Port A–C Address Register. Setting the bits in the Port A–C Stop Mode Recovery Source Enable sub-registers to 1 configures the specified Port pins as a Stop Mode Recovery source. During STOP Mode, any logic transition on a Port pin enabled as a Stop Mode Recovery source initiates Stop Mode Recovery.

**Table 20. Port A–C Stop Mode Recovery Source Enable Sub-Registers**

| BITS  | 7                                                                                     | 6      | 5      | 4      | 3      | 2      | 1      | 0      |
|-------|---------------------------------------------------------------------------------------|--------|--------|--------|--------|--------|--------|--------|
| FIELD | PSMRE7                                                                                | PSMRE6 | PSMRE5 | PSMRE4 | PSMRE3 | PSMRE2 | PSMRE1 | PSMRE0 |
| RESET | 0                                                                                     |        |        |        |        |        |        |        |
| R/W   | R/W                                                                                   |        |        |        |        |        |        |        |
| ADDR  | If 05H in Port A–C Address Register, accessible through the Port A–C Control Register |        |        |        |        |        |        |        |

#### PSMRE[7:0]—Port Stop Mode Recovery Source Enabled

0 = The port pin is not configured as a Stop Mode Recovery source. Transitions on this pin during STOP mode does not initiate Stop Mode Recovery.

1 = The port pin is configured as a Stop Mode Recovery source. Any logic transition on this pin during STOP mode initiates Stop Mode Recovery.

### Port A–C Pull-up Enable Sub-Registers

The Port A–C Pull-Up Enable sub-register ([Table 21](#)) is accessed through the Port A–C Control Register by writing 06H to the Port A–C Address Register. Setting the bits in the Port A–C Pull-Up Enable sub-registers enables a weak internal resistive pull-up on the specified Port pins.

**Table 21. Port A–C Pull-Up Enable Sub-Registers**

| BITS  | 7                                                                                     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
|-------|---------------------------------------------------------------------------------------|-------|-------|-------|-------|-------|-------|-------|
| FIELD | PPUE7                                                                                 | PPUE6 | PPUE5 | PPUE4 | PPUE3 | PPUE2 | PPUE1 | PPUE0 |
| RESET | 0                                                                                     |       |       |       |       |       |       |       |
| R/W   | R/W                                                                                   |       |       |       |       |       |       |       |
| ADDR  | If 06H in Port A–C Address Register, accessible through the Port A–C Control Register |       |       |       |       |       |       |       |

### PPUE[7:0]—Port Pull-up Enabled

0 = The weak pull-up on the Port pin is disabled.  
1 = The weak pull-up on the Port pin is enabled.

### Port A–C Input Data Registers

Reading from the Port A–C Input Data Registers ([Table 22](#)) returns the sampled values from the corresponding port pins. The Port A–C Input Data Registers are Read-only.

**Table 22. Port A–C Input Data Registers (PxIN)**

| BITS  | 7                | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|-------|------------------|------|------|------|------|------|------|------|
| FIELD | PIN7             | PIN6 | PIN5 | PIN4 | PIN3 | PIN2 | PIN1 | PIN0 |
| RESET | X                |      |      |      |      |      |      |      |
| R/W   | R                |      |      |      |      |      |      |      |
| ADDR  | FD2H, FD6H, FDAH |      |      |      |      |      |      |      |

### PIN[7:0]—Port Input Data

Sampled data from the corresponding port pin input.  
0 = Input data is logical 0 (Low).  
1 = Input data is logical 1 (High).

## Port A–C Output Data Register

The Port A–C Output Data Register ([Table 23](#)) controls the output data to the pins.

**Table 23. Port A–C Output Data Register (PxOUT)**

| BITS  | 7                | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
|-------|------------------|-------|-------|-------|-------|-------|-------|-------|
| FIELD | POUT7            | POUT6 | POUT5 | POUT4 | POUT3 | POUT2 | POUT1 | POUT0 |
| RESET | 0                |       |       |       |       |       |       |       |
| R/W   | R/W              |       |       |       |       |       |       |       |
| ADDR  | FD3H, FD7H, FDBH |       |       |       |       |       |       |       |

### POUT[7:0]—Port Output Data

These bits contain the data to be driven to the port pins. The values are only driven if the corresponding pin is configured as an output and the pin is not configured for alternate function operation.

0 = Drive a logical 0 (Low).

1 = Drive a logical 1 (High). High value is not driven if the drain has been disabled by setting the corresponding Port Output Control Register bit to 1.



# Interrupt Controller

The interrupt controller on Z8 Encore! XP<sup>®</sup> F0822 Series products prioritizes the interrupt requests from the on-chip peripherals and the GPIO port pins. The features of the interrupt controller include the following:

- 19 unique interrupt vectors:
  - 12 GPIO port pin interrupt sources.
  - 7 On-chip peripheral interrupt sources.
- Flexible GPIO interrupts:
  - 8 selectable rising and falling edge GPIO interrupts.
  - 4 dual-edge interrupts.
- Three levels of individually programmable interrupt priority.
- WDT is configured to generate an interrupt.

Interrupt Requests (IRQs) allow peripheral devices to suspend CPU operation in an orderly manner and force the CPU to start an Interrupt Service Routine (ISR). Usually this ISR is involved with the exchange of data, status information, or control information between the CPU and the interrupting peripheral. When the service routine is completed, the CPU returns to the operation from which it was interrupted.

The eZ8 CPU supports both vectored and polled interrupt handling. For polled interrupts, the interrupt control has no effect on operation. For more information on interrupt servicing, refer to *eZ8 CPU Core User Manual (UM0128)* available for download at [www.zilog.com](http://www.zilog.com).

## Interrupt Vector Listing

Table 24 lists all the interrupts available in order of priority. The interrupt vector is stored with the most significant byte (MSB) at the even Program Memory address and the least significant byte (LSB) at the following odd Program Memory address.

**Table 24. Interrupt Vectors in Order of Priority**

| Priority | Program Memory Vector Address | Interrupt Source                                    |
|----------|-------------------------------|-----------------------------------------------------|
| Highest  | 0002H                         | Reset (not an interrupt)                            |
|          | 0004H                         | WDT (see <a href="#">Watchdog Timer</a> on page 83) |
|          | 0006H                         | Illegal Instruction Trap (not an interrupt)         |

**Table 24. Interrupt Vectors in Order of Priority (Continued)**

| Priority      | Program Memory<br>Vector Address | Interrupt Source                      |
|---------------|----------------------------------|---------------------------------------|
|               | 0008H                            | Reserved                              |
|               | 000AH                            | Timer 1                               |
|               | 000CH                            | Timer 0                               |
|               | 000EH                            | UART 0 receiver                       |
|               | 0010H                            | UART 0 transmitter                    |
|               | 0012H                            | I <sup>2</sup> C                      |
|               | 0014H                            | SPI                                   |
|               | 0016H                            | ADC                                   |
|               | 0018H                            | Port A7, rising or falling input edge |
|               | 001AH                            | Port A6, rising or falling input edge |
|               | 001CH                            | Port A5, rising or falling input edge |
|               | 001EH                            | Port A4, rising or falling input edge |
|               | 0020H                            | Port A3, rising or falling input edge |
|               | 0022H                            | Port A2, rising or falling input edge |
|               | 0024H                            | Port A1, rising or falling input edge |
|               | 0026H                            | Port A0, rising or falling input edge |
|               | 0028H                            | Reserved                              |
|               | 002AH                            | Reserved                              |
|               | 002CH                            | Reserved                              |
|               | 002EH                            | Reserved                              |
|               | 0030H                            | Port C3, both input edges             |
|               | 0032H                            | Port C2, both input edges             |
|               | 0034H                            | Port C1, both input edges             |
| <b>Lowest</b> | 0036H                            | Port C0, both input edges             |

## Architecture

Figure 9 displays a block diagram of the interrupt controller.

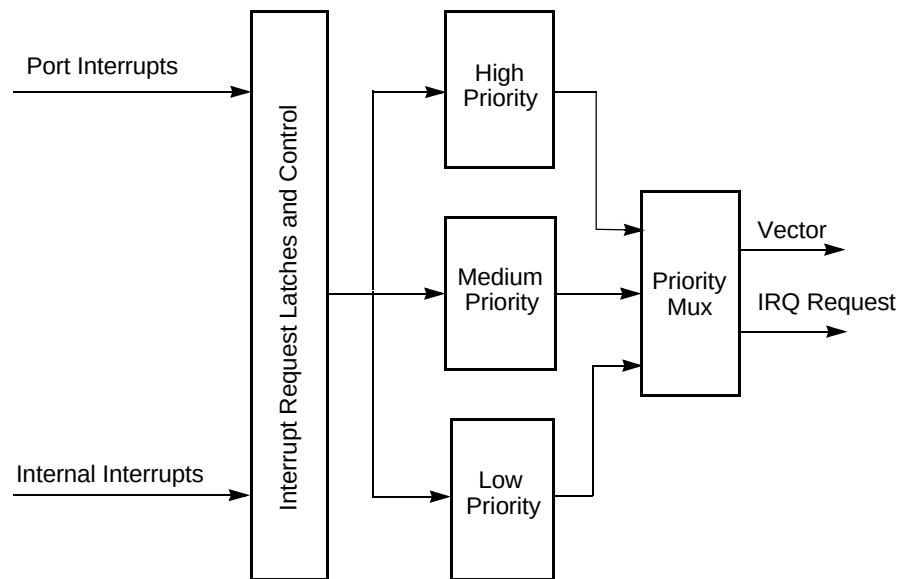


**Figure 9. Interrupt Controller Block Diagram**

## Operation

### Master Interrupt Enable

The master interrupt enable bit (IRQE) in the Interrupt Control Register globally enables and disables interrupts.

Interrupts are globally enabled by any of the following actions:

- Execution of an EI (Enable Interrupt) instruction.
- Execution of an IRET (Return from Interrupt) instruction.
- Writing a 1 to the IRQE bit in the Interrupt Control Register.

Interrupts are globally disabled by any of the following actions:

- Execution of a DI (Disable Interrupt) instruction.
- eZ8 CPU acknowledgement of an interrupt service request from the interrupt controller.
- Writing a 0 to the IRQE bit in the Interrupt Control Register.
- Reset.
- Execution of a Trap instruction.
- Illegal Instruction trap.

## Interrupt Vectors and Priority

The interrupt controller supports three levels of interrupt priority. Level 3 is the highest priority, Level 2 is the second highest priority, and Level 1 is the lowest priority. If all the interrupts were enabled with identical interrupt priority (all as Level 2 interrupts), then interrupt priority would be assigned from highest to lowest as specified in [Table 24](#). Level 3 interrupts always have higher priority than Level 2 interrupts which in turn always have higher priority than Level 1 interrupts. Within each interrupt priority level (Level 1, Level 2, or Level 3), priority is assigned as specified in [Table 24](#). Reset, WDT interrupt (if enabled), and Illegal Instruction Trap always have highest priority.

## Interrupt Assertion

Interrupt sources assert their interrupt requests for only a single system clock period (single pulse). When the interrupt request is acknowledged by the eZ8 CPU, the corresponding bit in the Interrupt Request Register is cleared until the next interrupt occurs. Writing a 0 to the corresponding bit in the Interrupt Request Register likewise clears the interrupt request.



**Caution:** *The following style of coding to clear bits in the Interrupt Request Registers is not recommended. All incoming interrupts received between execution of the first LDX command and the last LDX command is lost.*

**Poor coding style resulting in lost interrupt requests:**

```
LDX r0, IRQ0
AND r0, MASK
LDX IRQ0, r0
```

► **Note:** *To avoid missing interrupts, the following style of coding to clear bits in the Interrupt Request 0 register is recommended:*

**Good coding style that avoids lost interrupt requests:**

```
ANDX IRQ0, MASK
```

## Software Interrupt Assertion

Program code generates interrupts directly. Writing 1 to the desired bit in the Interrupt Request Register triggers an interrupt (assuming that interrupt is enabled). When the interrupt request is acknowledged by the eZ8 CPU, the bit in the Interrupt Request Register is automatically cleared to 0.



**Caution:** *The following style of coding to generate software interrupts by setting bits in the Interrupt Request Registers is not recommended. All incoming interrupts received between execution of the first LDX command and the last LDX command is lost.*

**Poor coding style that resulting in lost interrupt requests:**

```
LDX r0, IRQ0
OR r0, MASK
LDX IRQ0, r0
```

► **Note:** To avoid missing interrupts, the following style of coding to set bits in the Interrupt Request Registers is recommended

**Good coding style that avoids lost interrupt requests:**

```
ORX IRQ0, MASK
```

## Interrupt Control Register Definitions

For all interrupts other than the WDT interrupt, the Interrupt Control Registers enable individual interrupts, set interrupt priorities, and indicate interrupt requests.

### Interrupt Request 0 Register

The Interrupt Request 0 (IRQ0) Register (Table 25) stores the interrupt requests for both vectored and polled interrupts. When a request is presented to the interrupt controller, the corresponding bit in the IRQ0 Register becomes 1. If interrupts are globally enabled (vectored interrupts), the interrupt controller passes an interrupt request to the eZ8 CPU. If interrupts are globally disabled (polled interrupts), the eZ8 CPU reads the IRQ0 Register to determine if any interrupt requests are pending.

**Table 25. Interrupt Request 0 Register (IRQ0)**

| BITS  | 7        | 6   | 5   | 4     | 3     | 2    | 1    | 0    |
|-------|----------|-----|-----|-------|-------|------|------|------|
| FIELD | Reserved | T1I | T0I | U0RXI | U0TXI | I2CI | SPII | ADCI |
| RESET | 0        |     |     |       |       |      |      |      |
| R/W   | R/W      |     |     |       |       |      |      |      |
| ADDR  | FC0H     |     |     |       |       |      |      |      |

**Reserved—Must be 0**

**T1I—Timer 1 Interrupt Request**

0 = No interrupt request is pending for Timer 1.

1 = An interrupt request from Timer 1 is awaiting service.

**T0I—Timer 0 Interrupt Request**

0 = No interrupt request is pending for Timer 0.

1 = An interrupt request from Timer 0 is awaiting service.

**U0RXI—UART 0 Receiver Interrupt Request**

0 = No interrupt request is pending for the UART 0 receiver.

1 = An interrupt request from the UART 0 receiver is awaiting service.

**U0TXI—UART 0 Transmitter Interrupt Request**

0 = No interrupt request is pending for the UART 0 transmitter.

1 = An interrupt request from the UART 0 transmitter is awaiting service.

**I2CI—I<sup>2</sup>C Interrupt Request**0 = No interrupt request is pending for the I<sup>2</sup>C.1 = An interrupt request from the I<sup>2</sup>C is awaiting service.**SPII—SPI Interrupt Request**

0 = No interrupt request is pending for the SPI.

1 = An interrupt request from the SPI is awaiting service.

**ADCI—ADC Interrupt Request**

0 = No interrupt request is pending for the ADC.

1 = An interrupt request from the ADC is awaiting service.

**Interrupt Request 1 Register**

The Interrupt Request 1 (IRQ1) Register (Table 26) stores interrupt requests for both vectored and polled interrupts. When a request is presented to the interrupt controller, the corresponding bit in the IRQ1 register becomes 1. If interrupts are globally enabled (vectored interrupts), the interrupt controller passes an interrupt request to the eZ8 CPU. If interrupts are globally disabled (polled interrupts), the eZ8 CPU reads the IRQ1 Register to determine if any interrupt requests are pending.

**Table 26. Interrupt Request 1 Register (IRQ1)**

| BITS  | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|-------|------|------|------|------|------|------|------|------|
| FIELD | PA7I | PA6I | PA5I | PA4I | PA3I | PA2I | PA1I | PA0I |
| RESET | 0    |      |      |      |      |      |      |      |
| R/W   | R/W  |      |      |      |      |      |      |      |
| ADDR  | FC3H |      |      |      |      |      |      |      |

**PAxI—Port A Pin x Interrupt Request**

0 = No interrupt request is pending for GPIO Port A pin x.

1 = An interrupt request from GPIO Port A pin x is awaiting service.

Where x indicates the specific GPIO Port pin number (0 through 7).

## Interrupt Request 2 Register

The Interrupt Request 2 (IRQ2) Register (Table 27) stores interrupt requests for both vectored and polled interrupts. When a request is presented to the interrupt controller, the corresponding bit in the IRQ2 register becomes 1. If interrupts are globally enabled (vectored interrupts), the interrupt controller passes an interrupt request to the eZ8 CPU. If interrupts are globally disabled (polled interrupts), the eZ8 CPU reads the IRQ2 Register to determine if any interrupt requests are pending.

**Table 27. Interrupt Request 2 Register (IRQ2)**

| BITS  | 7        | 6 | 5 | 4 | 3    | 2    | 1    | 0    |
|-------|----------|---|---|---|------|------|------|------|
| FIELD | Reserved |   |   |   | PC3I | PC2I | PC1I | PC0I |
| RESET | 0        |   |   |   |      |      |      |      |
| R/W   | R/W      |   |   |   |      |      |      |      |
| ADDR  | FC6H     |   |   |   |      |      |      |      |

**Reserved—Must be 0**

### PCxI—Port C Pin x Interrupt Request

0 = No interrupt request is pending for GPIO Port C pin x.

1 = An interrupt request from GPIO Port C pin x is awaiting service.

Where x indicates the specific GPIO Port C pin number (0 through 3).

## IRQ0 Enable High and Low Bit Registers

The IRQ0 Enable High and Low Bit Registers (Table 29 and Table 30) form a priority encoded enabling for interrupts in the Interrupt Request 0 Register. Priority is generated by setting bits in each register. Table 28 describes the priority control for IRQ0.

**Table 28. IRQ0 Enable and Priority Encoding**

| IRQ0ENH[x] | IRQ0ENL[x] | Priority | Description |
|------------|------------|----------|-------------|
| 0          | 0          | Disabled | Disabled    |
| 0          | 1          | Level 1  | Low         |
| 1          | 0          | Level 2  | Nominal     |
| 1          | 1          | Level 3  | High        |

where x indicates the register bits from 0 through 7.

**Table 29. IRQ0 Enable High Bit Register (IRQ0ENH)**

| BITS  | 7        | 6     | 5     | 4      | 3      | 2      | 1      | 0      |
|-------|----------|-------|-------|--------|--------|--------|--------|--------|
| FIELD | Reserved | T1ENH | T0ENH | U0RENH | U0TENH | I2CENH | SPIENH | ADCENH |
| RESET | 0        |       |       |        |        |        |        |        |
| R/W   | R/W      |       |       |        |        |        |        |        |
| ADDR  | FC1H     |       |       |        |        |        |        |        |

**Reserved—Must be 0**

**T1ENH**—Timer 1 Interrupt Request Enable High Bit

**T0ENH**—Timer 0 Interrupt Request Enable High Bit

**U0RENH**—UART 0 Receive Interrupt Request Enable High Bit

**U0TENH**—UART 0 Transmit Interrupt Request Enable High Bit

**I2CENH**—I<sup>2</sup>C Interrupt Request Enable High Bit

**SPIENH**—SPI Interrupt Request Enable High Bit

**ADCENH**—ADC Interrupt Request Enable High Bit

**Table 30. IRQ0 Enable Low Bit Register (IRQ0ENL)**

| BITS  | 7        | 6     | 5     | 4      | 3      | 2      | 1      | 0      |
|-------|----------|-------|-------|--------|--------|--------|--------|--------|
| FIELD | Reserved | T1ENL | T0ENL | U0RENL | U0TENL | I2CENL | SPIENL | ADCENL |
| RESET | 0        |       |       |        |        |        |        |        |
| R/W   | R/W      |       |       |        |        |        |        |        |
| ADDR  | FC2H     |       |       |        |        |        |        |        |

**Reserved—Must be 0**

**T1ENL**—Timer 1 Interrupt Request Enable Low Bit

**T0ENL**—Timer 0 Interrupt Request Enable Low Bit

**U0RENL**—UART 0 Receive Interrupt Request Enable Low Bit

**U0TENL**—UART 0 Transmit Interrupt Request Enable Low Bit

**I2CENL**—I<sup>2</sup>C Interrupt Request Enable Low Bit

**SPIENL**—SPI Interrupt Request Enable Low Bit

**ADCENL**—ADC Interrupt Request Enable Low Bit

## IRQ1 Enable High and Low Bit Registers

Table 31 describes the priority control for IRQ1. The IRQ1 Enable High and Low Bit Registers (Table 32 and Table 33) form a priority encoded enabling for interrupts in the Interrupt Request 1 Register. Priority is generated by setting bits in each register.

**Table 31. IRQ1 Enable and Priority Encoding**

| IRQ1ENH[x] | IRQ1ENL[x] | Priority | Description |
|------------|------------|----------|-------------|
| 0          | 0          | Disabled | Disabled    |
| 0          | 1          | Level 1  | Low         |
| 1          | 0          | Level 2  | Nominal     |
| 1          | 1          | Level 3  | High        |

where x indicates the register bits from 0 through 7.

**Table 32. IRQ1 Enable High Bit Register (IRQ1ENH)**

| BITS  | 7      | 6      | 5      | 4      | 3      | 2      | 1      | 0      |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|
| FIELD | PA7ENH | PA6ENH | PA5ENH | PA4ENH | PA3ENH | PA2ENH | PA1ENH | PA0ENH |
| RESET | 0      |        |        |        |        |        |        |        |
| R/W   | R/W    |        |        |        |        |        |        |        |
| ADDR  | FC4H   |        |        |        |        |        |        |        |

**PAxENH**—Port A Bit[x] Interrupt Request Enable High Bit

**Table 33. IRQ1 Enable Low Bit Register (IRQ1ENL)**

| BITS  | 7      | 6      | 5      | 4      | 3      | 2      | 1      | 0      |
|-------|--------|--------|--------|--------|--------|--------|--------|--------|
| FIELD | PA7ENL | PA6ENL | PA5ENL | PA4ENL | PA3ENL | PA2ENL | PA1ENL | PA0ENL |
| RESET | 0      |        |        |        |        |        |        |        |
| R/W   | R/W    |        |        |        |        |        |        |        |
| ADDR  | FC5H   |        |        |        |        |        |        |        |

**PAxENL**—Port A Bit[x] Interrupt Request Enable Low Bit

## IRQ2 Enable High and Low Bit Registers

[Table 34](#) describes the priority control for IRQ2. The IRQ2 Enable High and Low Bit Registers ([Table 35](#) and [Table 36](#)) form a priority encoded enabling for interrupts in the Interrupt Request 2 register. Priority is generated by setting bits in each register.

**Table 34. IRQ2 Enable and Priority Encoding**

| IRQ2ENH[x] | IRQ2ENL[x] | Priority | Description |
|------------|------------|----------|-------------|
| 0          | 0          | Disabled | Disabled    |
| 0          | 1          | Level 1  | Low         |
| 1          | 0          | Level 2  | Nominal     |
| 1          | 1          | Level 3  | High        |

where x indicates the register bits from 0 through 7.

**Table 35. IRQ2 Enable High Bit Register (IRQ2ENH)**

| BITS  | 7        | 6 | 5 | 4 | 3     | 2     | 1     | 0     |
|-------|----------|---|---|---|-------|-------|-------|-------|
| FIELD | Reserved |   |   |   | C3ENH | C2ENH | C1ENH | C0ENH |
| RESET | 0        |   |   |   |       |       |       |       |
| R/W   | R/W      |   |   |   |       |       |       |       |
| ADDR  | FC7H     |   |   |   |       |       |       |       |

**Reserved—Must be 0.**

**C3ENH**—Port C3 Interrupt Request Enable High Bit

**C2ENH**—Port C2 Interrupt Request Enable High Bit

**C1ENH**—Port C1 Interrupt Request Enable High Bit

**C0ENH**—Port C0 Interrupt Request Enable High Bit

**Table 36. IRQ2 Enable Low Bit Register (IRQ2ENL)**

| BITS  | 7        | 6 | 5 | 4 | 3     | 2     | 1     | 0     |
|-------|----------|---|---|---|-------|-------|-------|-------|
| FIELD | Reserved |   |   |   | C3ENL | C2ENL | C1ENL | C0ENL |
| RESET | 0        |   |   |   |       |       |       |       |
| R/W   | R/W      |   |   |   |       |       |       |       |
| ADDR  | FC8H     |   |   |   |       |       |       |       |

**Reserved—Must be 0.**

**C3ENL**—Port C3 Interrupt Request Enable Low Bit

**C2ENL**—Port C2 Interrupt Request Enable Low Bit

**C1ENL**—Port C1 Interrupt Request Enable Low Bit

**C0ENL**—Port C0 Interrupt Request Enable Low Bit

## Interrupt Edge Select Register

The Interrupt Edge Select (IRQES) register (Table 37) determines whether an interrupt is generated for the rising edge or falling edge on the selected GPIO Port input pin. The minimum pulse width must be greater than 1 system clock to guarantee capture of the edge triggered interrupt. Edge detection for pulses less than 1 system clock are not guaranteed.

**Table 37. Interrupt Edge Select Register (IRQES)**

| BITS  | 7    | 6    | 5    | 4    | 3    | 2    | 1    | 0    |
|-------|------|------|------|------|------|------|------|------|
| FIELD | IES7 | IES6 | IES5 | IES4 | IES3 | IES2 | IES1 | IES0 |
| RESET | 0    |      |      |      |      |      |      |      |
| R/W   | R/W  |      |      |      |      |      |      |      |
| ADDR  | FCDH |      |      |      |      |      |      |      |

### IES<sub>x</sub>—Interrupt Edge Select *x*

0 = An interrupt request is generated on the falling edge of the PAX input.

1 = An interrupt request is generated on the rising edge of the PAX input.

Where *x* indicates the specific GPIO Port pin number (0 through 7).

## Interrupt Control Register

The Interrupt Control (IRQCTL) register (Table 38) contains the master enable bit for all interrupts.

**Table 38. Interrupt Control Register (IRQCTL)**

| BITS  | 7    | 6        | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|----------|---|---|---|---|---|---|
| FIELD | IRQE | Reserved |   |   |   |   |   |   |
| RESET | 0    |          |   |   |   |   |   |   |
| R/W   | R/W  | R        |   |   |   |   |   |   |
| ADDR  | FCFH |          |   |   |   |   |   |   |

### IRQE—Interrupt Request Enable

This bit is set to 1 by execution of an EI (Enable Interrupts) or IRET (Interrupt Return) instruction, or by a direct register write of a 1 to this bit. It is reset to 0 by executing a DI instruction, eZ8 CPU acknowledgement of an interrupt request, Reset or by a direct register write of a 0 to this bit.

0 = Interrupts are disabled.

1 = Interrupts are enabled.

### Reserved—Must be 0



# Timers

Z8 Encore! XP<sup>®</sup> F0822 Series products contain up to two 16-bit reloadable timers that can be used for timing, event counting, or generation of pulse-width modulated signals. The timer features include:

- 16-bit reload counter.
- Programmable prescaler with prescale values from 1 to 128.
- PWM output generation.
- Capture and compare capability.
- External input pin for timer input, clock gating, or capture signal. External input pin signal frequency is limited to a maximum of one-fourth the system clock frequency.
- Timer output pin.
- Timer interrupt.

In addition to the timers described in this chapter, the Baud Rate Generators for any unused UART, SPI, or I<sup>2</sup>C peripherals can also be used to provide basic timing functionality. See the respective serial communication peripheral chapters for information on using the Baud Rate Generators as timers.

## Architecture

[Figure 10](#) displays the architecture of the timers.

## Operation

The timers are 16-bit up-counters. Minimum time-out delay is set by loading the value 0001H into the Timer Reload High and Low Byte registers and setting the prescale value to 1. Maximum time-out delay is set by loading the value 0000H into the Timer Reload High and Low Byte registers and setting the prescale value to 128. If the Timer reaches FFFFH, the timer rolls over to 0000H and continues counting.

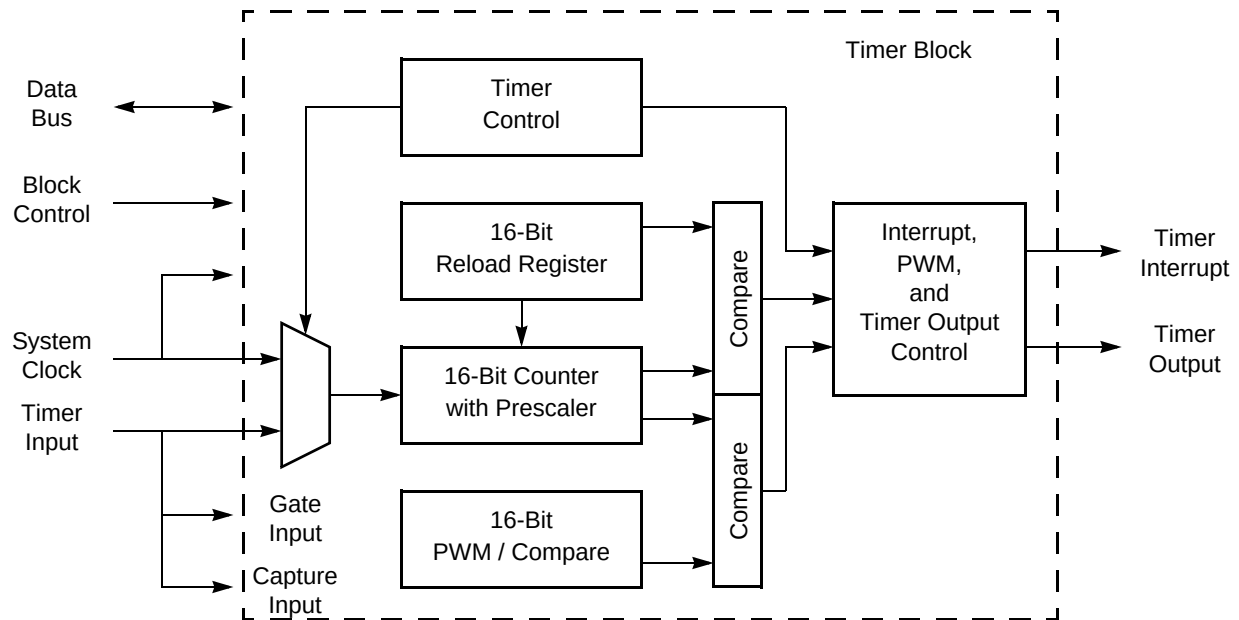


Figure 10. Timer Block Diagram

## Timer Operating Modes

The timers are configured to operate in the following modes:

### ONE-SHOT Mode

In ONE-SHOT mode, the timer counts up to the 16-bit Reload value stored in the Timer Reload High and Low Byte registers. The timer input is the system clock. On reaching the Reload value, the timer generates an interrupt and the count value in the Timer High and Low Byte registers is reset to 0001H. Then, the timer is automatically disabled and stops counting.

Also, if the Timer Output alternate function is enabled, the Timer Output pin changes state for one system clock cycle (from Low to High or vice-versa) on timer Reload. If it is required for the Timer Output to make a permanent state change on One-Shot time-out, first set the TPOL bit in the Timer Control Register to the start value before beginning ONE-SHOT mode. Then, after starting the timer, set TPOL to the opposite bit value.

Follow the steps below for configuring a timer for ONE-SHOT mode and initiating the count:

1. Write to the Timer Control Register to:
  - Disable the timer
  - Configure the timer for ONE-SHOT mode

- Set the prescale value
  - If using the Timer Output alternate function, set the initial output level (High or Low).
2. Write to the Timer High and Low Byte Registers to set the starting count value.
  3. Write to the Timer Reload High and Low Byte Registers to set the Reload value.
  4. If desired, enable the timer interrupt and set the timer interrupt priority by writing to the relevant interrupt registers.
  5. If using the Timer Output function, configure the associated GPIO port pin for the Timer Output alternate function.
  6. Write to the Timer Control Register to enable the timer and initiate counting.

In ONE-SHOT mode, the system clock always provides the timer input. The timer period is given by the following equation:

$$\text{ONE-SHOT Mode Time-Out Period (s)} = \frac{(\text{Reload Value} - \text{Start Value}) \times \text{Prescale}}{\text{System Clock Frequency (Hz)}}$$

### CONTINUOUS Mode

In CONTINUOUS mode, the timer counts up to the 16-bit Reload value stored in the Timer Reload High and Low Byte Registers. The timer input is the system clock. Upon reaching the Reload value, the timer generates an interrupt, the count value in the Timer High and Low Byte Registers is reset to 0001H and counting resumes. Also, if the Timer Output alternate function is enabled, the Timer Output pin changes state (from Low to High or from High to Low) upon timer Reload.

Follow the steps below for configuring a timer for CONTINUOUS mode and initiating the count:

1. Write to the Timer Control Register to:
  - Disable the timer
  - Configure the timer for CONTINUOUS mode
  - Set the prescale value.
  - If using the Timer Output alternate function, set the initial output level (High or Low).
2. Write to the Timer High and Low Byte registers to set the starting count value (usually 0001H). This only affects the first pass in CONTINUOUS mode. After the first timer Reload in CONTINUOUS mode, counting always begins at the reset value of 0001H.
3. Write to the Timer Reload High and Low Byte Registers to set the Reload value.
4. If desired, enable the timer interrupt and set the timer interrupt priority by writing to the relevant interrupt registers.
5. If using the Timer Output function, configure the associated GPIO port pin for the Timer Output alternate function.

6. Write to the Timer Control Register to enable the timer and initiate counting.

In CONTINUOUS mode, the system clock always provides the timer input. The timer period is given by the following equation:

$$\text{CONTINUOUS Mode Time-Out Period (s)} = \frac{\text{Reload Value} \times \text{Prescale}}{\text{System Clock Frequency (Hz)}}$$

If an initial starting value other than 0001H is loaded into the Timer High and Low Byte Registers, the ONE-SHOT mode equation must be used to determine the first time-out period.

### COUNTER Mode

In COUNTER mode, the timer counts input transitions from a GPIO port pin. The timer input is taken from the GPIO Port pin Timer Input alternate function. The TPOL bit in the Timer Control Register selects whether the count occurs on the rising edge or the falling edge of the Timer Input signal. In COUNTER mode, the prescaler is disabled.



**Caution:** *The input frequency of the Timer Input signal must not exceed one-fourth system clock frequency.*

Upon reaching the Reload value stored in the Timer Reload High and Low Byte Registers, the timer generates an interrupt, the count value in the Timer High and Low Byte Registers is reset to 0001H and counting resumes. Also, if the Timer Output alternate function is enabled, the Timer Output pin changes state (from Low to High or from High to Low) at timer Reload.

Follow the steps below for configuring a timer for COUNTER mode and initiating the count:

1. Write to the Timer Control Register to:
  - Disable the timer
  - Configure the timer for COUNTER mode.
  - Select either the rising edge or falling edge of the Timer Input signal for the count. This also sets the initial logic level (High or Low) for the Timer Output alternate function. However, the Timer Output function does not have to be enabled.
2. Write to the Timer High and Low Byte Registers to set the starting count value. This only affects the first pass in COUNTER mode. After the first timer Reload in COUNTER mode, counting always begins at the reset value of 0001H. Generally, in COUNTER mode the Timer High and Low Byte Registers must be written with the value 0001H.
3. Write to the Timer Reload High and Low Byte Registers to set the Reload value.

4. If required, enable the timer interrupt and set the timer interrupt priority by writing to the relevant interrupt registers.
5. Configure the associated GPIO port pin for the Timer Input alternate function.
6. If using the Timer Output function, configure the associated GPIO port pin for the Timer Output alternate function.
7. Write to the Timer Control Register to enable the timer.

In COUNTER mode, the number of Timer Input transitions since the timer start is given by the following equation:

$$\text{COUNTER Mode Timer Input Transitions} = \text{Current Count Value} - \text{Start Value}$$

### PWM Mode

In PWM mode, the timer outputs a Pulse-Width Modulator output signal through a GPIO port pin. The timer input is the system clock. The timer first counts up to the 16-bit PWM match value stored in the Timer PWM High and Low Byte Registers. When the timer count value matches the PWM value, the Timer Output toggles. The timer continues counting until it reaches the Reload value stored in the Timer Reload High and Low Byte registers. Upon reaching the Reload value, the timer generates an interrupt, the count value in the Timer High and Low Byte Registers is reset to 0001H and counting resumes.

If the TPOL bit in the Timer Control Register is set to 1, the Timer Output signal begins as a High (1) and then transitions to a Low (0) when the timer value matches the PWM value. The Timer Output signal returns to a High (1) after the timer reaches the Reload value and is reset to 0001H.

If the TPOL bit in the Timer Control Register is set to 0, the Timer Output signal begins as a Low (0) and then transitions to a High (1) when the timer value matches the PWM value. The Timer Output signal returns to a Low (0) after the timer reaches the Reload value and is reset to 0001H.

Follow the steps below for configuring a timer for PWM mode and initiating the PWM operation:

1. Write to the Timer Control Register to:
  - Disable the timer
  - Configure the timer for PWM mode.
  - Set the prescale value.
  - Set the initial logic level (High or Low) and PWM High/Low transition for the Timer Output alternate function.
2. Write to the Timer High and Low Byte Registers to set the starting count value (typically 0001H). This only affects the first pass in PWM mode. After the first timer reset in PWM mode, counting always begins at the reset value of 0001H.

3. Write to the PWM High and Low Byte registers to set the PWM value.
4. Write to the Timer Reload High and Low Byte Registers to set the Reload value (PWM period). The Reload value must be greater than the PWM value.
5. If required, enable the timer interrupt and set the timer interrupt priority by writing to the relevant interrupt registers.
6. Configure the associated GPIO port pin for the Timer Output alternate function.
7. Write to the Timer Control Register to enable the timer and initiate counting.

The PWM period is given by the following equation.

$$\text{PWM Period (s)} = \frac{\text{Reload Value} \times \text{Prescale}}{\text{System Clock Frequency (Hz)}}$$

If an initial starting value other than 0001H is loaded into the Timer High and Low Byte Registers, the ONE-SHOT mode equation is used to determine the first PWM time-out period.

If TPOL is set to 0, the ratio of the PWM output High time to the total period is given by

$$\text{PWM Output High Time Ratio (\%)} = \frac{\text{Reload Value} - \text{PWM Value}}{\text{Reload Value}} \times 100$$

If TPOL is set to 1, the ratio of the PWM output High time to the total period is given by

$$\text{PWM Output High Time Ratio (\%)} = \frac{\text{PWM Value}}{\text{Reload Value}} \times 100$$

### CAPTURE Mode

In CAPTURE mode, the current timer count value is recorded when the desired external Timer Input transition occurs. The Capture count value is written to the Timer PWM High and Low Byte Registers. The timer input is the system clock. The TPOL bit in the Timer Control Register determines if the Capture occurs on a rising edge or a falling edge of the Timer Input signal. When the Capture event occurs, an interrupt is generated and the timer continues counting.

The timer continues counting up to the 16-bit Reload value stored in the Timer Reload High and Low Byte registers. Upon reaching the Reload value, the timer generates an interrupt and continues counting.

Follow the steps below for configuring a timer for CAPTURE mode and initiating the count:

1. Write to the Timer Control Register to:
  - Disable the timer

- Configure the timer for CAPTURE mode
  - Set the prescale value
  - Set the Capture edge (rising or falling) for the Timer Input
2. Write to the Timer High and Low Byte Registers to set the starting count value (typically 0001H).
  3. Write to the Timer Reload High and Low Byte Registers to set the Reload value.
  4. Clear the Timer PWM High and Low Byte Registers to 0000H. This allows user software to determine if interrupts were generated by either a capture event or a reload. If the PWM High and Low Byte Registers still contains 0000H after the interrupt, then the interrupt was generated by a Reload.
  5. If required, enable the timer interrupt and set the timer interrupt priority by writing to the relevant interrupt registers.
  6. Configure the associated GPIO port pin for the Timer Input alternate function.
  7. Write to the Timer Control Register to enable the timer and initiate counting.

In CAPTURE mode, the elapsed time from timer start to Capture event is calculated using the following equation:

$$\text{Capture Elapsed Time (s)} = \frac{(\text{Capture Value} - \text{Start Value}) \times \text{Prescale}}{\text{System Clock Frequency (Hz)}}$$

### COMPARE Mode

In COMPARE mode, the timer counts up to the 16-bit maximum Compare value stored in the Timer Reload High and Low Byte Registers. The timer input is the system clock. Upon reaching the Compare value, the timer generates an interrupt and counting continues (the timer value is not reset to 0001H). Also, if the Timer Output alternate function is enabled, the Timer Output pin changes state (from Low to High or from High to Low) upon Compare.

If the Timer reaches FFFFH, the timer rolls over to 0000H and continue counting.

Follow the steps below for configuring a timer for COMPARE mode and initiating the count:

1. Write to the Timer Control Register to:
  - Disable the timer
  - Configure the timer for COMPARE mode
  - Set the prescale value
  - Set the initial logic level (High or Low) for the Timer Output alternate function, if required
2. Write to the Timer High and Low Byte registers to set the starting count value
3. Write to the Timer Reload High and Low Byte registers to set the Compare value

4. If required, enable the timer interrupt and set the timer interrupt priority by writing to the relevant interrupt registers
5. If using the Timer Output function, configure the associated GPIO port pin for the Timer Output alternate function
6. Write to the Timer Control Register to enable the timer and initiate counting

In COMPARE mode, the system clock always provides the timer input. The Compare time is calculated by the following equation:

$$\text{Compare Mode Time (s)} = \frac{(\text{Compare Value} - \text{Start Value}) \times \text{Prescale}}{\text{System Clock Frequency (Hz)}}$$

### GATED Mode

In GATED mode, the timer counts only when the Timer Input signal is in its active state (asserted), as determined by the TPOL bit in the Timer Control Register. When the Timer Input signal is asserted, counting begins. A timer interrupt is generated when the Timer Input signal is deasserted or a timer reload occurs. To determine if a Timer Input signal deassertion generated the interrupt, read the associated GPIO input value and compare to the value stored in the TPOL bit.

The timer counts up to the 16-bit Reload value stored in the Timer Reload High and Low Byte Registers. The timer input is the system clock. When reaching the Reload value, the timer generates an interrupt, the count value in the Timer High and Low Byte Registers is reset to 0001H and counting resumes (assuming the Timer Input signal is still asserted). Also, if the Timer Output alternate function is enabled, the Timer Output pin changes state (from Low to High or from High to Low) at timer reset.

Follow the steps below for configuring a timer for GATED mode and initiating the count:

1. Write to the Timer Control Register to:
  - Disable the timer
  - Configure the timer for GATED mode
  - Set the prescale value
2. Write to the Timer High and Low Byte Registers to set the starting count value. This only affects the first pass in GATED mode. After the first timer reset in GATED mode, counting always begins at the reset value of 0001H
3. Write to the Timer Reload High and Low Byte Registers to set the Reload value
4. If desired, enable the timer interrupt and set the timer interrupt priority by writing to the relevant interrupt registers
5. Configure the associated GPIO port pin for the Timer Input alternate function
6. Write to the Timer Control Register to enable the timer
7. Assert the Timer Input signal to initiate the counting

## CAPTURE/COMPARE Mode

In CAPTURE/COMPARE mode, the timer begins counting on the *first* external Timer Input transition. The required transition (rising edge or falling edge) is set by the TPOL bit in the Timer Control Register. The timer input is the system clock.

Every subsequent desired transition (after the first) of the Timer Input signal captures the current count value. The Capture value is written to the Timer PWM High and Low Byte Registers. When the Capture event occurs, an interrupt is generated, the count value in the Timer High and Low Byte Registers is reset to 0001H and counting resumes.

If no Capture event occurs, the timer counts up to the 16-bit Compare value stored in the Timer Reload High and Low Byte registers. Upon reaching the Compare value, the timer generates an interrupt, the count value in the Timer High and Low Byte Registers is reset to 0001H and counting resumes.

Follow the steps below for configuring a timer for CAPTURE/COMPARE mode and initiating the count:

1. Write to the Timer Control Register to:
  - Disable the timer
  - Configure the timer for CAPTURE/COMPARE mode
  - Set the prescale value
  - Set the Capture edge (rising or falling) for the Timer Input
2. Write to the Timer High and Low Byte registers to set the starting count value (typically 0001H)
3. Write to the Timer Reload High and Low Byte registers to set the Compare value
4. If desired, enable the timer interrupt and set the timer interrupt priority by writing to the relevant interrupt registers
5. Configure the associated GPIO port pin for the Timer Input alternate function
6. Write to the Timer Control Register to enable the timer
7. Counting begins on the first appropriate transition of the Timer Input signal.  
No interrupt is generated by this first edge

In CAPTURE/COMPARE mode, the elapsed time from timer start to Capture event is calculated using the following equation:

$$\text{Capture Elapsed Time (s)} = \frac{(\text{Capture Value} - \text{Start Value}) \times \text{Prescale}}{\text{System Clock Frequency (Hz)}}$$

## Reading the Timer Count Values

The current count value in the timers can be read while counting (enabled). This capability has no effect on timer operation. When the timer is enabled and the Timer High Byte

Register is read, the contents of the Timer Low Byte Register are placed in a holding register. A subsequent read from the Timer Low Byte Register returns the value in the holding register. This operation allows accurate reads of the full 16-bit timer count value while enabled. When the timers are not enabled, a read from the Timer Low Byte Register returns the actual value in the counter.

### Timer Output Signal Operation

Timer Output is a GPIO port pin alternate function. Generally, the Timer Output is toggled every time the counter is reloaded.

## Timer Control Register Definitions

### Timer 0–1 High and Low Byte Registers

The Timer 0–1 High and Low Byte (TxH and TxL) Registers ([Table 39](#)) contain the current 16-bit timer count value. When the timer is enabled, a read from TxH causes the value in TxL to be stored in a temporary holding register. A read from TMRL always returns this temporary register when the timers are enabled. When the timer is disabled, reads from the TMRL reads the register directly.

Writing to the Timer High and Low Byte Registers while the timer is enabled is not recommended. There are no temporary holding registers available for write operations, so simultaneous 16-bit writes are not possible. If either the Timer High or Low Byte Registers are written during counting, the 8-bit written value is placed in the counter (High or Low Byte) at the next clock edge. The counter continues counting from the new value.

**Table 39. Timer 0–1 High Byte Register (TxH)**

| BITS  | 7          | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------------|---|---|---|---|---|---|---|
| FIELD | TH         |   |   |   |   |   |   |   |
| RESET | 0          |   |   |   |   |   |   |   |
| R/W   | R/W        |   |   |   |   |   |   |   |
| ADDR  | F00H, F08H |   |   |   |   |   |   |   |

**Table 40. Timer 0–1 Low Byte Register (TxL)**

| BITS  | 7          | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------------|---|---|---|---|---|---|---|
| FIELD | TL         |   |   |   |   |   |   |   |
| RESET | 0          |   |   |   |   |   |   | 1 |
| R/W   | R/W        |   |   |   |   |   |   |   |
| ADDR  | F01H, F09H |   |   |   |   |   |   |   |

**TH and TL—Timer High and Low Bytes**

These 2 bytes, {TMRH[7:0], TMRL[7:0]}, contain the current 16-bit timer count value.

**Timer Reload High and Low Byte Registers**

The Timer 0–1 Reload High and Low Byte (TxRH and TxRL) Registers ([Table 41](#)) store a 16-bit reload value, {TRH[7:0], TRL[7:0]}. Values written to the Timer Reload High Byte register are stored in a temporary holding register. When a write to the Timer Reload Low Byte Register occurs, the temporary holding register value is written to the Timer High Byte Register. This operation allows simultaneous updates of the 16-bit Timer Reload value.

In COMPARE mode, the Timer Reload High and Low Byte Registers store the 16-bit Compare value.

**Table 41. Timer 0–1 Reload High Byte Register (TxRH)**

| BITS  | 7          | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------------|---|---|---|---|---|---|---|
| FIELD | TRH        |   |   |   |   |   |   |   |
| RESET | 1          |   |   |   |   |   |   |   |
| R/W   | R/W        |   |   |   |   |   |   |   |
| ADDR  | F02H, F0AH |   |   |   |   |   |   |   |

**Table 42. Timer 0–1 Reload Low Byte Register (TxRL)**

| BITS  | 7          | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------------|---|---|---|---|---|---|---|
| FIELD | TRL        |   |   |   |   |   |   |   |
| RESET | 1          |   |   |   |   |   |   |   |
| R/W   | R/W        |   |   |   |   |   |   |   |
| ADDR  | F03H, F0BH |   |   |   |   |   |   |   |

**TRH and TRL—Timer Reload Register High and Low**

These two bytes form the 16-bit Reload value, {TRH[7:0], TRL[7:0]}. This value sets the maximum count value which initiates a timer reload to 0001H. In COMPARE mode, these two bytes form the 16-bit Compare value.

**Timer 0–1 PWM High and Low Byte Registers**

The Timer 0–1 PWM High and Low Byte (TxPWMH and TxPWML) registers ([Table 43](#) and [Table 44](#)) are used for Pulse-Width Modulator (PWM) operations. These registers also store the Capture values for the CAPTURE and CAPTURE/COMPARE modes.

**Table 43. Timer 0–1 PWM High Byte Register (TxPWMH)**

| BITS  | 7          | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------------|---|---|---|---|---|---|---|
| FIELD | PWMH       |   |   |   |   |   |   |   |
| RESET | 0          |   |   |   |   |   |   |   |
| R/W   | R/W        |   |   |   |   |   |   |   |
| ADDR  | F04H, F0CH |   |   |   |   |   |   |   |

**Table 44. Timer 0–1 PWM Low Byte Register (TxPWML)**

| BITS  | 7          | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------------|---|---|---|---|---|---|---|
| FIELD | PWML       |   |   |   |   |   |   |   |
| RESET | 0          |   |   |   |   |   |   |   |
| R/W   | R/W        |   |   |   |   |   |   |   |
| ADDR  | F05H, F0DH |   |   |   |   |   |   |   |

#### **PWMH and PWML—Pulse-Width Modulator High and Low Bytes**

These two bytes, {PWMH[7:0], PWML[7:0]}, form a 16-bit value that is compared to the current 16-bit timer count. When a match occurs, the PWM output changes state. The PWM output value is set by the TPOL bit in the Timer Control Register (TxCTL) register.

The TxPWMH and TxPWML registers also store the 16-bit captured timer value when operating in CAPTURE or CAPTURE/COMPARE modes.

### **Timer 0–3 Control 0 Registers**

The Timer 0–3 Control 0 (TxCTL0) registers ([Table 45](#)) allow cascading of the Timers.

**Table 45. Timer 0–3 Control 0 Register (TxCTL0)**

| BITS  | 7                      | 6 | 5 | 4   | 3        | 2 | 1 | 0 |
|-------|------------------------|---|---|-----|----------|---|---|---|
| FIELD | Reserved               |   |   | CSC | Reserved |   |   |   |
| RESET | 0                      |   |   |     |          |   |   |   |
| R/W   | R/W                    |   |   |     |          |   |   |   |
| ADDR  | F06H, F0EH, F16H, F1EH |   |   |     |          |   |   |   |

#### **CSC—Cascade Timers**

0 = Timer Input signal comes from the pin.

1 = For Timer 0, input signal is connected to Timer 1 output.

For Timer 1, input signal is connected to Timer 0 output.

## Timer 0–1 Control 1 Registers

The Timer 0–1 Control (TxCTL) registers enable/disable the timers, set the prescaler value, and determine the timer operating mode.

**Table 46. Timer 0–1 Control Register (TxCTL)**

| BITS  | 7          | 6    | 5    | 4 | 3 | 2     | 1 | 0 |
|-------|------------|------|------|---|---|-------|---|---|
| FIELD | TEN        | TPOL | PRES |   |   | TMODE |   |   |
| RESET | 0          |      |      |   |   |       |   |   |
| R/W   | R/W        |      |      |   |   |       |   |   |
| ADDR  | F07H, F0FH |      |      |   |   |       |   |   |

### **TEN—Timer Enable**

0 = Timer is disabled.

1 = Timer enabled to count.

### **TPOL—Timer Input/Output Polarity**

Operation of this bit is a function of the current operating mode of the timer.

### **ONE-SHOT Mode**

When the timer is disabled, the Timer Output signal is set to the value of this bit.

When the timer is enabled, the Timer Output signal is complemented upon timer Reload.

### **CONTINUOUS Mode**

When the timer is disabled, the Timer Output signal is set to the value of this bit. When the timer is enabled, the Timer Output signal is complemented upon timer Reload.

### **COUNTER Mode**

If the timer is enabled the Timer Output signal is complemented after timer reload.

0 = Count occurs on the rising edge of the Timer Input signal.

1 = Count occurs on the falling edge of the Timer Input signal.

### **PWM Mode**

0 = Timer Output is forced Low (0) when the timer is disabled. When enabled, the Timer Output is forced High (1) upon PWM count match and forced Low (0) upon Reload.

1 = Timer Output is forced High (1) when the timer is disabled. When enabled, the Timer Output is forced Low (0) upon PWM count match and forced High (1) upon Reload.

### **CAPTURE Mode**

0 = Count is captured on the rising edge of the Timer Input signal.

1 = Count is captured on the falling edge of the Timer Input signal.

### **COMPARE Mode**

When the timer is disabled, the Timer Output signal is set to the value of this bit. When the timer is enabled, the Timer Output signal is complemented upon timer Reload.

### **GATED Mode**

0 = Timer counts when the Timer Input signal is High (1) and interrupts are generated on the falling edge of the Timer Input.

1 = Timer counts when the Timer Input signal is Low (0) and interrupts are generated on the rising edge of the Timer Input.

### **CAPTURE/COMPARE Mode**

0 = Counting is started on the first rising edge of the Timer Input signal. The current count is captured on subsequent rising edges of the Timer Input signal.

1 = Counting is started on the first falling edge of the Timer Input signal. The current count is captured on subsequent falling edges of the Timer Input signal.

### **PRES—Prescale value**

The timer input clock is divided by  $2^{\text{PRES}}$ , where PRES is set from 0 to 7. The prescaler is reset each time the Timer is disabled. This insures proper clock division each time the Timer is restarted.

000 = Divide by 1

001 = Divide by 2

010 = Divide by 4

011 = Divide by 8

100 = Divide by 16

101 = Divide by 32

110 = Divide by 64

111 = Divide by 128

### **TMODE—Timer Mode**

000 = ONE-SHOT mode

001 = CONTINUOUS mode

010 = COUNTER mode

011 = PWM mode

100 = CAPTURE mode

101 = COMPARE mode

110 = GATED mode

111 = CAPTURE/COMPARE mode

# Watchdog Timer

Watchdog Timer (WDT) protects against corrupt or unreliable software, power faults, and other system-level problems which can place the Z8 Encore! XP® F0822 Series device into unsuitable operating states. It includes the following features:

- On-chip RC oscillator.
- A selectable time-out response—Reset or Interrupt.
- 24-bit programmable time-out value.

## Operation

WDT is a retriggerable one-shot timer that resets or interrupts the Z8 Encore! XP F0822 Series device when the WDT reaches its terminal count. It uses its own dedicated on-chip RC oscillator as its clock source. The WDT has only two modes of operation—ON and OFF. When enabled, it always counts and must be refreshed to prevent a time-out. An enable is performed by executing the WDT instruction or by setting the WDT\_AO Option Bit. The WDT\_AO bit enables the WDT to operate all the time, even if a WDT instruction has not been executed.

The WDT is a 24-bit reloadable downcounter that uses three 8-bit registers in the eZ8 CPU register space to set the reload value. The nominal WDT time-out period is given by the following equation:

$$\text{WDT Time-out Period (ms)} = \frac{\text{WDT Reload Value}}{10}$$

where the WDT reload value is the decimal value of the 24-bit value given by {WDTU[7:0], WDTM[7:0], WDTL[7:0]} and the typical Watchdog Timer RC oscillator frequency is 10 kHz. WDT cannot be refreshed once it reaches 000002H. The WDT Reload Value must not be set to values below 000004H. [Table 47](#) provides information on approximate time-out delays for minimum and maximum WDT reload values.

**Table 47. Watchdog Timer Approximate Time-Out Delays**

| WDT Reload Value | WDT Reload Value | Approximate Time-Out Delay<br>(with 10 kHz typical WDT Oscillator Frequency) |                        |
|------------------|------------------|------------------------------------------------------------------------------|------------------------|
| (Hex)            | (Decimal)        | Typical                                                                      | Description            |
| 000004           | 4                | 400 μs                                                                       | Minimum time-out delay |
| FFFFFF           | 16,777,215       | 1677.5 s                                                                     | Maximum time-out delay |

## Watchdog Timer Refresh

When first enabled, the WDT is loaded with the value in the WDT Reload registers. The WDT then counts down to 000000H unless a WDT instruction is executed by the eZ8 CPU. Execution of the WDT instruction causes the downcounter to be reloaded with the WDT Reload value stored in the WDT Reload registers. Counting resumes following the reload operation.

When Z8 Encore! XP<sup>®</sup> F0822 Series device is operating in DEBUG Mode (using the OCD), the WDT is continuously refreshed to prevent spurious WDT time-outs.

## Watchdog Timer Time-Out Response

The WDT times out when the counter reaches 000000H. A WDT time-out generates either an Interrupt or a Reset. The WDT\_RES Option Bit determines the time-out response of the WDT. For information regarding programming of the WDT\_RES Option Bit, see [Option Bits](#) on page 163.

### WDT Interrupt in Normal Operation

If configured to generate an interrupt when a time-out occurs, the WDT issues an interrupt request to the interrupt controller and sets the WDT Status Bit in the WDT Control Register. If interrupts are enabled, the eZ8 CPU responds to the interrupt request by fetching the WDT interrupt vector and executing the code from the vector address. After time-out and interrupt generation, the WDT counter rolls over to its maximum value of FFFFFFFH and continues counting. The WDT counter is not automatically returned to its Reload Value.

### WDT Reset in STOP Mode

If enabled in STOP mode and configured to generate a Reset when a time-out occurs and the device is in STOP mode, the WDT initiates a Stop Mode Recovery. Both the WDT status bit and the STOP bit in the WDT Control Register is set to 1 following the WDT time-out in STOP mode. For more information, see [Reset and Stop Mode Recovery](#) on page 39. Default operation is for the WDT and its RC oscillator to be enabled during STOP mode.

To minimize power consumption in STOP mode, the WDT and its RC oscillator is disabled in STOP mode. The following sequence configures the WDT to be disabled when the Z8F082x family device enters STOP mode following execution of a STOP instruction:

1. Write 55H to the Watchdog Timer Control Register (WDTCTL).
2. Write AAH to the Watchdog Timer Control Register (WDTCTL).
3. Write 81H to the Watchdog Timer Control Register (WDTCTL) to configure the WDT and its oscillator to be disabled during STOP mode. Alternatively, write 00H to the WDTCTL as the third step in this sequence to reconfigure the WDT and its oscillator to be enabled during STOP mode. This sequence only affects WDT operation in STOP mode.

### WDT Reset in Normal Operation

If configured to generate a Reset when a time-out occurs, the WDT forces the device into the Reset state. The WDT status bit in the WDT Control Register is set to 1. For more information on Reset, see [Reset and Stop Mode Recovery](#) on page 39.

### WDT Reset in STOP Mode

If enabled in STOP mode and configured to generate a Reset when a time-out occurs and the device is in STOP mode, the WDT initiates a Stop Mode Recovery. Both the WDT status bit and the STOP bit in the WDT Control Register is set to 1 following WDT time-out in STOP mode. For more information on Reset, see [Reset and Stop Mode Recovery](#) on page 39. Default operation is for the WDT and its RC oscillator to be enabled during STOP mode.

### WDT RC Disable in STOP Mode

To minimize power consumption in STOP mode, the WDT and its RC oscillator can be disabled in STOP mode. The following sequence configures the WDT to be disabled when the Z8F082x family device enters STOP mode following execution of a STOP instruction:

1. Write 55H to the Watchdog Timer Control Register (WDTCTL).
2. Write AAH to the Watchdog Timer Control Register (WDTCTL).
3. Write 81H to the Watchdog Timer Control Register (WDTCTL) to configure the WDT and its oscillator to be disabled during STOP mode. Alternatively, write 00H to the Watchdog Timer Control Register (WDTCTL) as the third step in this sequence to reconfigure the WDT and its oscillator to be enabled during STOP mode. This sequence only affects WDT operation in STOP mode.

### Watchdog Timer Reload Unlock Sequence

Writing the unlock sequence to the WDTCTL address unlocks the three Watchdog Timer Reload Byte Registers (WDTU, WDTM, and WDTL) to allow changes to the time-out period. These write operations to the WDTCTL address produce no effect on the bits in the WDTCTL. The locking mechanism prevents spurious writes to the Reload Registers. The following sequence is required to unlock the Watchdog Timer Reload Byte Registers (WDTU, WDTM, and WDTL) for write access.

1. Write 55H to the Watchdog Timer Control Register (WDTCTL).
2. Write AAH to the Watchdog Timer Control Register (WDTCTL).
3. Write the Watchdog Timer Reload Upper Byte Register (WDTU).
4. Write the Watchdog Timer Reload High Byte Register (WDTM).
5. Write the Watchdog Timer Reload Low Byte Register (WDTL).

All three Watchdog Timer Reload Registers must be written in this order. There must be no other register writes between each of these operations. If a register write occurs, the lock state machine resets and no further writes occur unless the sequence is restarted. The value in the Watchdog Timer Reload Registers is loaded into the counter when the WDT is first enabled and every time a WDT instruction is executed.

## Watchdog Timer Control Register Definitions

### Watchdog Timer Control Register

The Watchdog Timer Control Register (WDTCTL), detailed in [Table 48](#), is a Read-Only Register that indicates the source of the most recent Reset event, a Stop Mode Recovery event, and a WDT time-out. Reading this register resets the upper four bits to 0.

Writing the 55H, AAH unlock sequence to the Watchdog Timer Control Register (WDTCTL) address unlocks the three Watchdog Timer Reload Byte registers (WDTU, WDTL, and WDTL) to allow changes to the time-out period. These write operations to the WDTCTL address produce no effect on the bits in the WDTCTL. The locking mechanism prevents spurious writes to the Reload registers.

**Table 48. Watchdog Timer Control Register (WDTCTL)**

| BITS  | 7                      | 6    | 5   | 4   | 3        | 2 | 1 | 0 |
|-------|------------------------|------|-----|-----|----------|---|---|---|
| FIELD | POR                    | STOP | WDT | EXT | Reserved |   |   |   |
| RESET | See descriptions below |      |     | 0   |          |   |   |   |
| R/W   | R                      |      |     |     |          |   |   |   |
| ADDR  | FF0H                   |      |     |     |          |   |   |   |

| Reset or Stop Mode Recovery Event                   | POR | STOP | WDT | EXT |
|-----------------------------------------------------|-----|------|-----|-----|
| Power-On Reset                                      | 1   | 0    | 0   | 0   |
| Reset through RESET pin assertion                   | 0   | 0    | 0   | 1   |
| Reset through WDT time-out                          | 0   | 0    | 1   | 0   |
| Reset through the OCD (OCTCTL[1] set to 1)          | 1   | 0    | 0   | 0   |
| Reset from STOP Mode through the DBG Pin driven Low | 1   | 0    | 0   | 0   |
| Stop Mode Recovery through GPIO pin transition      | 0   | 1    | 0   | 0   |
| Stop Mode Recovery through WDT time-out             | 0   | 1    | 1   | 0   |

#### POR—Power-On Reset Indicator

If this bit is set to 1, a POR event occurred. This bit is reset to 0, if a WDT time-out or Stop Mode Recovery occurs. This bit is also reset to 0, when the register is read.

**STOP—Stop Mode Recovery Indicator**

If this bit is set to 1, a Stop Mode Recovery occurred. If the STOP and WDT bits are both set to 1, the Stop Mode Recovery occurred due to a WDT time-out. If the STOP bit is 1 and the WDT bit is 0, the Stop Mode Recovery was not caused by a WDT time-out. This bit is reset by a POR or a WDT time-out that occurred while not in STOP mode. Reading this register also resets this bit.

**WDT—Watchdog Timer Time-Out Indicator**

If this bit is set to 1, a WDT time-out occurred. A POR resets this pin. A Stop Mode Recovery due a change in an input pin also resets this bit. Reading this register resets this bit.

**EXT—External Reset Indicator**

If this bit is set to 1, a Reset initiated by the external  $\overline{\text{RESET}}$  pin occurred. A POR or a Stop Mode Recovery from a change in an input pin resets this bit. Reading this register resets this bit.

**Reserved**

These bits are reserved and must be 0.

**Watchdog Timer Reload Upper, High and Low Byte Registers**

The Watchdog Timer Reload Upper, High and Low Byte (WDTU, WDTL, WDTL) Registers (Table 49 through Table 51) form the 24-bit reload value that is loaded into the WDT, when a WDT instruction executes. The 24-bit reload value is {WDTU[7:0], WDTL[7:0], WDTL[7:0]}. Writing to these registers sets the required Reload Value. Reading from these registers returns the current WDT count value.



**Caution:** The 24-bit WDT Reload Value must not be set to a value less than 000004H.

**Table 49. Watchdog Timer Reload Upper Byte Register (WDTU)**

| BITS                                                                                | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------------------------------------------------------------------------------|------|---|---|---|---|---|---|---|
| FIELD                                                                               | WDTU |   |   |   |   |   |   |   |
| RESET                                                                               | 1    |   |   |   |   |   |   |   |
| R/W                                                                                 | R/W* |   |   |   |   |   |   |   |
| ADDR                                                                                | FF1H |   |   |   |   |   |   |   |
| R/W*—Read returns the current WDT count value. Write sets the desired Reload Value. |      |   |   |   |   |   |   |   |

**WDTU—WDT Reload Upper Byte**

Most significant byte (MSB), Bits[23:16], of the 24-bit WDT reload value.

**Table 50. Watchdog Timer Reload High Byte Register (WDTH)**

| BITS                                                                                | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------------------------------------------------------------------------------|------|---|---|---|---|---|---|---|
| FIELD                                                                               | WDTH |   |   |   |   |   |   |   |
| RESET                                                                               | 1    |   |   |   |   |   |   |   |
| R/W                                                                                 | R/W* |   |   |   |   |   |   |   |
| ADDR                                                                                | FF2H |   |   |   |   |   |   |   |
| R/W*—Read returns the current WDT count value. Write sets the desired Reload Value. |      |   |   |   |   |   |   |   |

**WDTH—WDT Reload High Byte**

Middle byte, Bits[15:8], of the 24-bit WDT reload value.

**Table 51. Watchdog Timer Reload Low Byte Register (WDTL)**

| BITS                                                                                | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------------------------------------------------------------------------------------|------|---|---|---|---|---|---|---|
| FIELD                                                                               | WDTL |   |   |   |   |   |   |   |
| RESET                                                                               | 1    |   |   |   |   |   |   |   |
| R/W                                                                                 | R/W* |   |   |   |   |   |   |   |
| ADDR                                                                                | FF3H |   |   |   |   |   |   |   |
| R/W*—Read returns the current WDT count value. Write sets the desired Reload Value. |      |   |   |   |   |   |   |   |

**WDTL—WDT Reload Low**

Least significant byte (LSB), Bits[7:0], of the 24-bit WDT reload value.

# Universal Asynchronous Receiver/Transmitter

The Universal Asynchronous Receiver/Transmitter (UART) is a full-duplex communication channel capable of handling asynchronous data transfers. The UART uses a single 8-bit data mode with selectable parity. Features of the UART include:

- 8-bit asynchronous data transfer
- Selectable even- and odd-parity generation and checking
- Option of one or two STOP bits
- Separate transmit and receive interrupts
- Framing, parity, overrun, and break detection
- Separate transmit and receive enables
- 16-bit Baud Rate Generator
- Selectable Multiprocessor (9-bit) mode with three configurable interrupt schemes
- BRG timer mode
- Driver Enable output for external bus transceivers

## Architecture

The UART consists of three primary functional blocks: Transmitter, Receiver, and Baud Rate Generator. The UART's transmitter and receiver functions independently, but use the same baud rate and data format. [Figure11](#) on page 90 displays the UART architecture.

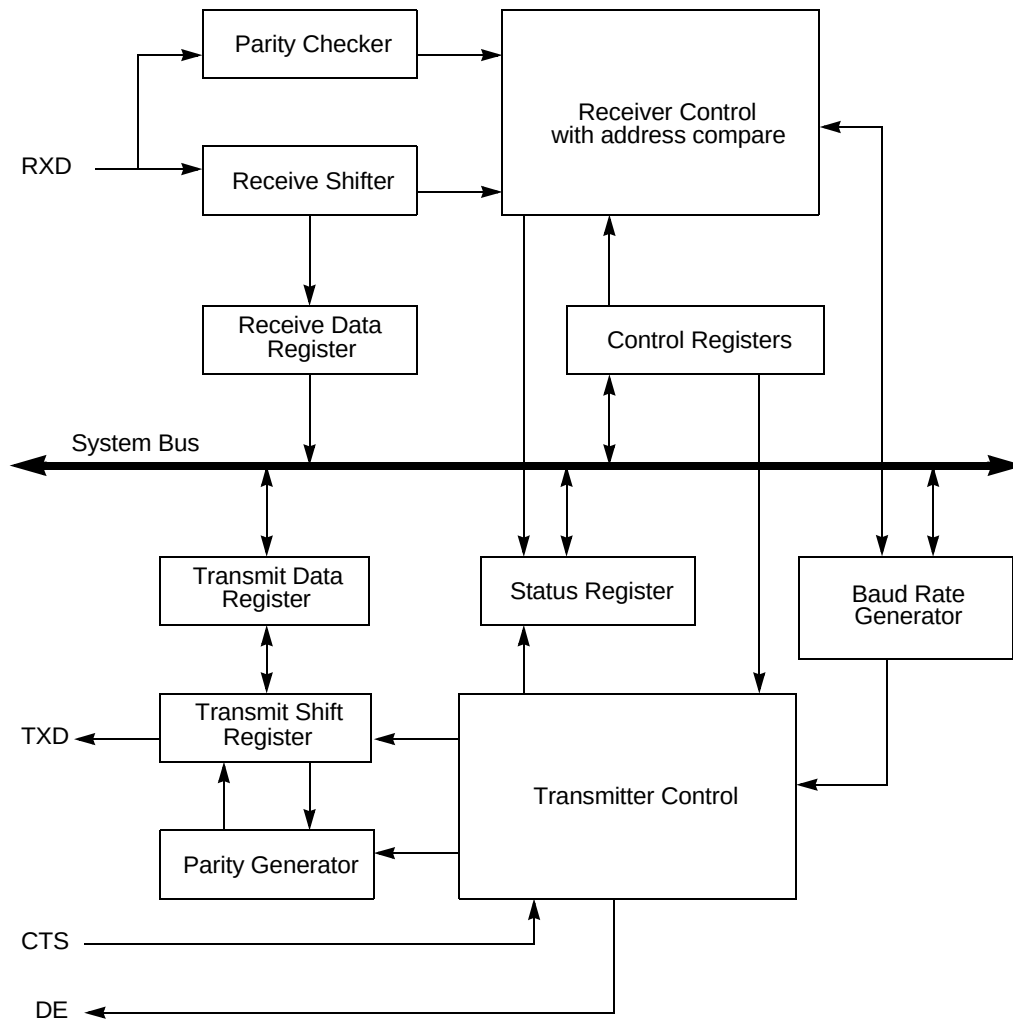


Figure 11. UART Block Diagram

## Operation

### Data Format

The UART always transmits and receives data in an 8-bit data format, least-significant bit first. An even or odd parity bit is optionally added to the data stream. Each character begins with an active Low *START* bit and ends with either 1 or 2 active High *STOP* bits. [Figure12](#) on page 91 and [Figure13](#) on page 91 display the asynchronous data format used by the UART without parity and with parity, respectively.

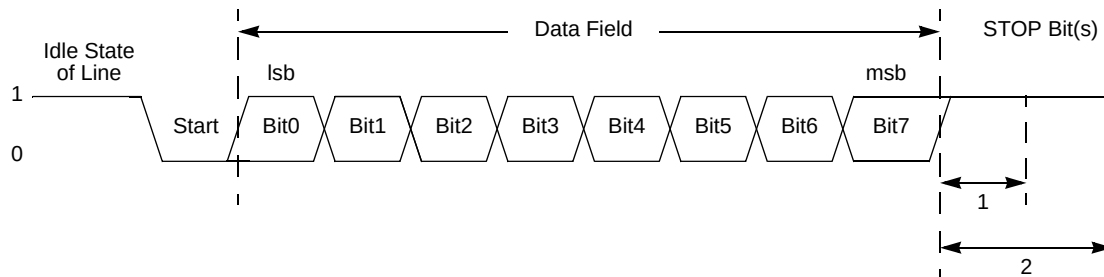


**Figure 12. UART Asynchronous Data Format without Parity**

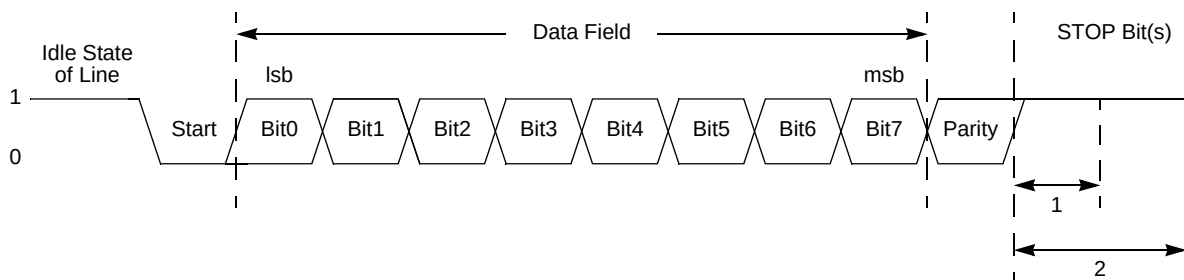


**Figure 13. UART Asynchronous Data Format with Parity**

### Transmitting Data using Polled Method

Follow the steps below to transmit data using polled method of operation:

1. Write to the UART Baud Rate High Byte and Low Byte registers to set the required baud rate.
2. Enable the UART pin functions by configuring the associated GPIO Port pins for alternate function operation.
3. If MULTIPROCESSOR mode is required, write to the UART Control 1 Register to enable multiprocessor (9-bit) mode functions.
  - Set the Multiprocessor Mode Select ( $\overline{\text{MPEN}}$ ) to enable MULTIPROCESSOR mode.
4. Write to the UART Control 0 Register to:
  - Set the transmit enable bit ( $\text{TEN}$ ) to enable the UART for data transmission
  - If parity is required, and MULTIPROCESSOR mode is not enabled, set the parity enable bit ( $\text{PEN}$ ) and select either even or odd parity ( $\text{PSEL}$ ).
  - Set or clear the  $\text{CTSE}$  bit to enable or disable control from the remote receiver using the  $\overline{\text{CTS}}$  pin.

5. Check the TDRE bit in the UART Status 0 Register to determine if the Transmit Data Register is empty (indicated by a 1). If empty, continue to [step 6](#). If the Transmit Data Register is full (indicated by a 0), continue to monitor the TDRE bit until the Transmit Data Register becomes available to receive new data.
6. Write the UART Control 1 Register to select the outgoing address bit:
  - Set the Multiprocessor Bit Transmitter (MPBT) if sending an address byte, clear it if sending a data byte.
7. Write data byte to the UART Transmit Data Register. The transmitter automatically transfers data to the Transmit Shift Register and then transmits the data.
8. If required, and multiprocessor mode is enabled, make any changes to the Multiprocessor Bit Transmitter (MPBT) value.
9. To transmit additional bytes, return to [step 5](#).

### Transmitting Data Using Interrupt-Driven Method

The UART Transmitter interrupt indicates the availability of the Transmit Data Register to accept new data for transmission. Follow the below steps to configure the UART for interrupt-driven data transmission:

1. Write to the UART Baud Rate High and Low Byte Registers to set the required baud rate.
2. Enable the UART pin functions by configuring the associated GPIO Port pins for alternate function operation.
3. Execute a DI instruction to disable interrupts.
4. Write to the Interrupt Control Registers to enable the UART Transmitter interrupt and set the required priority.
5. If MULTIPROCESSOR mode is required, write to the UART Control 1 Register to enable Multiprocessor (9-bit) mode functions:
  - Set the Multiprocessor Mode Select (MPEN) to enable MULTIPROCESSOR mode.
6. Write to the UART Control 0 Register to:
  - Set the transmit enable (TEN) bit to enable the UART for data transmission
  - Enable parity, if required, and if MULTIPROCESSOR mode is not enabled, and select either even or odd parity.
  - Set or clear the CTSE bit to enable or disable control from the remote receiver through the CTS pin.
7. Execute an EI instruction to enable interrupts.

The UART is now configured for interrupt-driven data transmission. Because the UART Transmit Data Register is empty, an interrupt is generated immediately. When the UART Transmit Interrupt is detected, the associated ISR performs the following:

1. Write the UART Control 1 Register to select the outgoing address bit:
  - Set the Multiprocessor Bit Transmitter (MPBT) if sending an address byte, clear it if sending a data byte.
2. Write the data byte to the UART Transmit Data Register. The transmitter automatically transfers data to the Transmit Shift Register and then transmits the data.
3. Clear the UART Transmit Interrupt bit in the applicable Interrupt Request Register.
4. Execute the `IRET` instruction to return from the ISR and waits for the Transmit Data Register to again become empty.

### Receiving Data using the Polled Method

Follow the steps below to configure the UART for polled data reception:

1. Write to the UART Baud Rate High and Low Byte Registers to set the required baud rate.
2. Enable the UART pin functions by configuring the associated GPIO Port pins for alternate function operation.
3. Write to the UART Control 1 Register to enable Multiprocessor mode functions, if desired.
4. Write to the UART Control 0 Register to:
  - Set the receive enable bit (`REN`) to enable the UART for data reception
  - Enable parity, if required, and if `MULTIPROCESSOR` mode is not enabled, and select either even or odd parity.
5. Check the `RDA` bit in the UART Status 0 Register to determine if the Receive Data Register contains a valid data byte (indicated by 1). If `RDA` is set to 1 to indicate available data, continue to [step 6](#). If the Receive Data Register is empty (indicated by a 0), continue to monitor the `RDA` bit awaiting reception of the valid data.
6. Read data from the UART Receive Data Register. If operating in Multiprocessor (9-bit) mode, further actions may be required depending on the Multiprocessor Mode bits `MPMD[1:0]`.
7. Return to [step 5](#) to receive additional data.

## **Receiving Data Using Interrupt-Driven Method**

The UART Receiver interrupt indicates the availability of new data (as well as error conditions). Follow the steps below to configure the UART receiver for interrupt-driven operation:

1. Write to the UART Baud Rate High and Low Byte Registers to set the required baud rate.
2. Enable the UART pin functions by configuring the associated GPIO Port pins for alternate function operation.
3. Execute a `DI` instruction to disable interrupts.
4. Write to the Interrupt Control Registers to enable the UART Receiver interrupt and set the required priority.
5. Clear the UART Receiver interrupt in the applicable Interrupt Request Register.
6. Write to the UART Control 1 Register to enable MULTIPROCESSOR (9-bit) mode functions, if desired.
  - Set the Multiprocessor Mode Select (`MPEN`) to enable MULTIPROCESSOR mode.
  - Set the Multiprocessor Mode Bits, `MPMD [1 : 0]` , to select the required address matching scheme.
  - Configure the UART to interrupt on received data and errors or errors only (interrupt on errors only is unlikely to be useful for Z8 Encore! XP devices without a DMA block)
7. Write the device address to the Address Compare Register (automatic multiprocessor modes only).
8. Write to the UART Control 0 Register to:
  - Set the receive enable bit (`REN`) to enable the UART for data reception
  - Enable parity, if required, and if MULTIPROCESSOR mode is not enabled, and select either even or odd parity.
9. Execute an `EI` instruction to enable interrupts.

The UART is now configured for interrupt-driven data reception. When the UART Receiver Interrupt is detected, the associated ISR performs the following:

1. Check the UART Status 0 Register to determine the source of the interrupt-error, break, or received data.
2. If the interrupt was due to data available, read the data from the UART Receive Data Register. If operating in MULTIPROCESSOR (9-bit) mode, further actions may be required depending on the Multiprocessor Mode bits `MPMD[1:0]`.
3. Clear the UART Receiver Interrupt in the applicable Interrupt Request Register.
4. Execute the `IRET` instruction to return from the ISR and await more data.

## Clear To Send Operation

The CTS pin, if enabled by the CTSE bit of the UART Control 0 register, performs flow control on the outgoing transmit datastream. The Clear To Send (CTS) input pin is sampled one system clock before beginning any new character transmission. To delay transmission of the next data character, an external receiver must deassert CTS at least one system clock cycle before a new data transmission begins. For multiple character transmissions, this would be done during STOP bit transmission. If CTS deasserts in the middle of a character transmission, the current character is sent completely.

## Multiprocessor (9-bit) Mode

The UART has a MULTIPROCESSOR (9-bit) mode that uses an extra (9th) bit for selective communication when a number of processors share a common UART bus. In MULTIPROCESSOR mode (also referred to as 9-bit mode), the multiprocessor bit is transmitted following the 8-bits of data and immediately preceding the STOP bit(s) as displayed in Figure 14. The character format is as displayed in Figure 14.

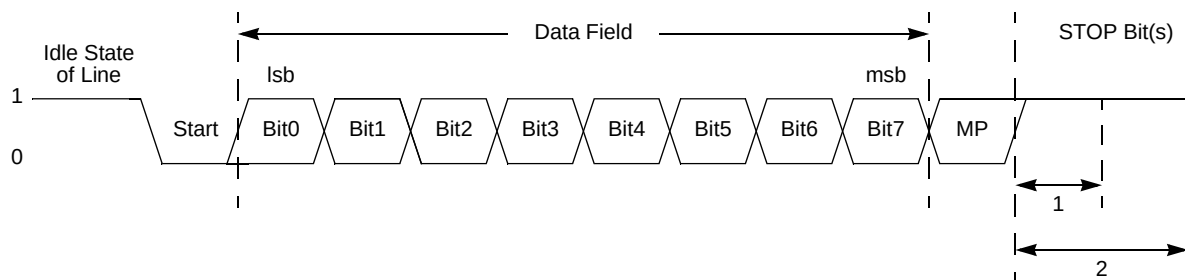


Figure 14. UART Asynchronous MULTIPROCESSOR Mode Data Format

In MULTIPROCESSOR (9-bit) mode, the Parity bit location (9th bit) becomes the Multiprocessor control bit. The UART Control 1 and Status 1 Registers provide Multiprocessor (9-bit) mode control and status information. If an automatic address matching scheme is enabled, the UART Address Compare Register holds the network address of the device.

## MULTIPROCESSOR (9-bit) Mode Receive Interrupts

When multiprocessor mode is enabled, the UART only processes frames addressed to it. The determination of whether a frame of data is addressed to the UART can be made in hardware, software, or combination of the two depending on the multiprocessor configuration bits. In general, the address compare feature reduces the load on the CPU, because it does not need to access the UART when it receives data directed to other devices on the

multi-node network. The following MULTIPROCESSOR modes are available in hardware:

- Interrupt on all address bytes.
- Interrupt on matched address bytes and correctly framed data bytes.
- Interrupt only on correctly framed data bytes.

These modes are selected with `MPMD[1:0]` in the UART Control 1 Register. For all MULTIPROCESSOR modes, bit `MPEN` of the UART Control 1 Register must be set to 1.

The first scheme is enabled by writing `01b` to `MPMD[1:0]`. In this mode, all incoming address bytes cause an interrupt, while data bytes never cause an interrupt. The ISR must manually check the address byte that caused triggered the interrupt. If it matches the UART address, the software should clear `MPMD[0]`. At this point, each new incoming byte interrupts the CPU. The software is then responsible for determining the end-of-frame. It checks for the end-of-frame by reading the `MPRX` bit of the UART Status 1 Register for each incoming byte. If `MPRX=1`, then a new frame begins. If the address of this new frame is different from the UART's address, then `MPMD[0]` must be set to 1 causing the UART interrupts to go inactive until the next address byte. If the new frame's address matches the UART's address, then the data in the new frame should be processed as well.

The second scheme is enabled by setting `MPMD[1:0]` to `10b` and writing the UART's address into the UART Address Compare Register. This mode introduces more hardware control, interrupting only on frames that match the UART's address. When an incoming address byte does not match the UART's address, it is ignored. All successive data bytes in this frame are also ignored. When a matching address byte occurs, an interrupt is issued and further interrupts occur on each successive data byte. The first data byte in the frame contains the `NEWFRM=1` in the UART Status 1 Register. When the next address byte occurs, the hardware compares it to the UART's address. If there is a match, the interrupts continue and the `NEWFRM` bit is set for the first byte of the new frame. If there is no match, then the UART ignores all incoming bytes until the next address match.

The third scheme is enabled by setting `MPMD[1:0]` to `11b` and by writing the UART's address into the UART Address Compare Register. This mode is identical to the second scheme, except that there are no interrupts on address bytes. The first data byte of each frame is still accompanied by a `NEWFRM` assertion.

## External Driver Enable

The UART provides a Driver Enable (DE) signal for off-chip bus transceivers. This feature reduces the software overhead associated with using a GPIO pin to control the transceiver when communicating on a multi-transceiver bus, such as RS-485.

Driver Enable is an active High signal that envelopes the entire transmitted data frame including parity and STOP bits as displayed in [Figure15](#) on page 97. The Driver Enable signal asserts when a byte is written to the UART Transmit Data Register. The Driver

Enable signal asserts at least one UART bit period and no greater than two UART bit periods before the Start bit is transmitted. This format allows a setup time to enable the transceiver. The Driver Enable signal deasserts one system clock period after the last STOP bit is transmitted. This one system clock delay allows both time for data to clear the transceiver before disabling it, as well as the ability to determine if another character follows the current character. In the event of back to back characters (new data must be written to the Transmit Data Register before the previous character is completely transmitted) the DE signal is not deasserted between characters. The DEPOL bit in the UART Control Register 1 sets the polarity of the Driver Enable signal.

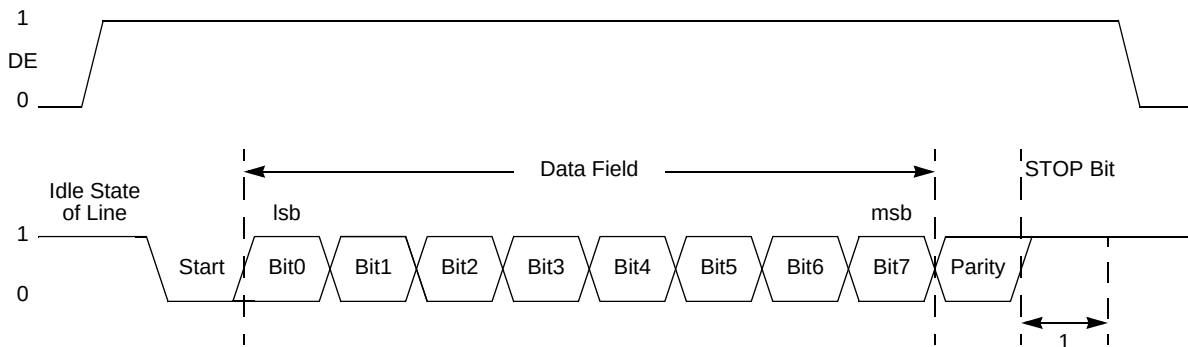


**Figure 15. UART Driver Enable Signal Timing (with 1 STOP Bit and Parity)**

The Driver Enable to Start bit setup time is calculated as follows:

$$\left( \frac{1}{\text{Baud Rate (Hz)}} \right) \leq \text{DE to Start Bit Setup Time (s)} \leq \left( \frac{2}{\text{Baud Rate (Hz)}} \right)$$

## UART Interrupts

The UART features separate interrupts for the transmitter and the receiver. In addition, when the UART primary functionality is disabled, the BRG also functions as a basic timer with interrupt capability.

### Transmitter Interrupts

The transmitter generates a single interrupt when the Transmit Data Register Empty bit (TDRE) is set to 1. This indicates that the transmitter is ready to accept new data for transmission. The TDRE interrupt occurs after the Transmit shift register has shifted the first bit of data out. At this point, the Transmit Data Register can be written with the next character to send. This provides 7 bit periods of latency to load the Transmit Data Register before the Transmit shift register completes shifting the current character. Writing to the UART Transmit Data Register clears the TDRE bit to 0.

## Receiver Interrupts

The receiver generates an interrupt when any of the following occurs:

- A data byte is received and is available in the UART Receive Data Register. This interrupt can be disabled independent of the other receiver interrupt sources. The received data interrupt occurs once the receive character is received and placed in the Receive Data Register. Software must respond to this received data available condition before the next character is completely received to avoid an overrun error. In MULTIPROCESSOR mode (MPEN = 1), the receive data interrupts are dependent on the multiprocessor configuration and the most recent address byte
- A break is received
- An overrun is detected
- A data framing error is detected

## UART Overrun Errors

When an overrun error condition occurs the UART prevents overwriting of the valid data currently in the Receive Data Register. The break detect and overrun status bits are not displayed until the valid data is read.

After the valid data has been read, the UART Status 0 Register is updated to indicate the overrun condition (and Break Detect, if applicable). The RDA bit is set to 1 to indicate that the Receive Data Register contains a data byte. However, because the overrun error occurred, this byte cannot contain valid data and should be ignored. The BRKD bit indicates if the overrun was caused by a break condition on the line. After reading the status byte indicating an overrun error, the Receive Data Register must be read again to clear the error bits in the UART Status 0 Register. Updates to the Receive Data Register occur only when the next data word is received.

## UART Data and Error Handling Procedure

[Figure16](#) on page 99 displays the recommended procedure for UART receiver ISRs.

## Baud Rate Generator Interrupts

If the BRG interrupt enable is set, the UART Receiver interrupt asserts when the UART Baud Rate Generator reloads. This action allows the BRG to function as an additional counter if the UART functionality is not employed.

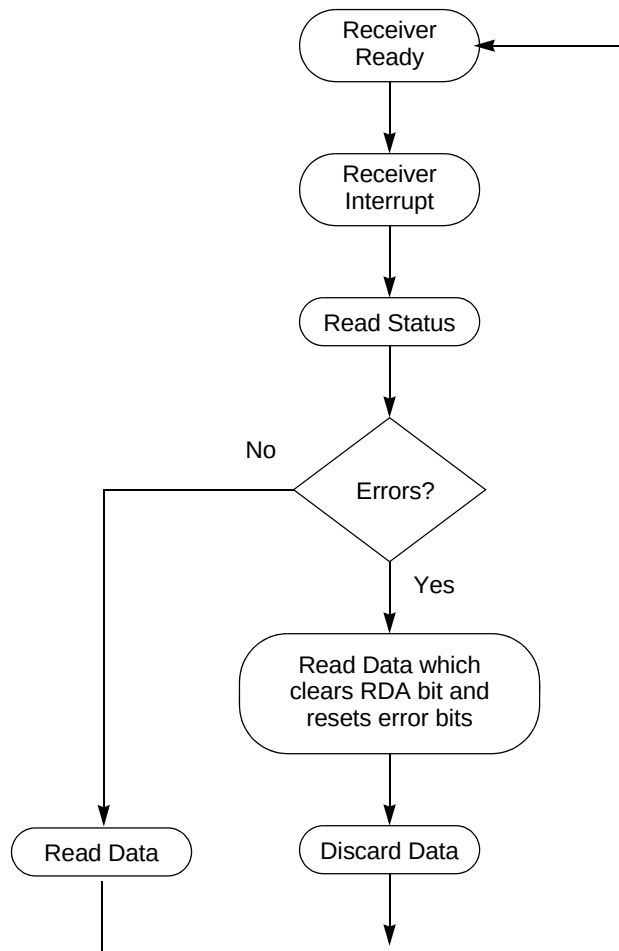


Figure 16. UART Receiver Interrupt Service Routine Flow

## UART Baud Rate Generator

The UART Baud Rate Generator creates a lower frequency baud rate clock for data transmission. The input to the BRG is the system clock. The UART Baud Rate High and Low Byte Registers combine to create a 16-bit baud rate divisor value (BRG[15:0]) that sets the data transmission rate (baud rate) of the UART. The UART data rate is calculated using the following equation:

$$\text{UART Data Rate (bits/s)} = \frac{\text{System Clock Frequency (Hz)}}{16 \times \text{UART Baud Rate Divisor Value}}$$

When the UART is disabled, the BRG functions as a basic 16-bit timer with interrupt on time-out. Follow the steps below to configure the BRG as a timer with interrupt on time-out:

1. Disable the UART by clearing the REN and TEN bits in the UART Control 0 Register to 0.
2. Load the desired 16-bit count value into the UART Baud Rate High and Low Byte Registers.
3. Enable the BRG timer function and associated interrupt by setting the BKGCTL bit in the UART Control 1 Register to 1.

When configured as a general-purpose timer, the interrupt interval is calculated using the following equation:

$$\text{Interrupt Interval (s)} = \text{System Clock Period (s)} \times \text{BRG}[15:0]$$

## UART Control Register Definitions

The UART Control Registers support the UART and the associated Infrared Encoder/Decoders. See [Infrared Encoder/Decoder](#) on page 109 for more information on the infrared operation.

### UART Transmit Data Register

Data bytes written to the UART Transmit Data Register ([Table 52](#)) are shifted out on the TXD<sub>x</sub> pin. The Write-only UART Transmit Data Register shares a Register File address with the Read-only UART Receive Data Register.

**Table 52. UART Transmit Data Register (U0TXD)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | TXD  |   |   |   |   |   |   |   |
| RESET | X    | X | X | X | X | X | X | X |
| R/W   | W    | W | W | W | W | W | W | W |
| ADDR  | F40H |   |   |   |   |   |   |   |

#### TXD—Transmit Data

UART transmitter data byte to be shifted out through the TXD<sub>x</sub> pin.

## UART Receive Data Register

Data bytes received through the RXD<sub>x</sub> pin are stored in the UART Receive Data Register (Table 53). The Read-only UART Receive Data Register shares a Register File address with the Write-only UART Transmit Data Register.

**Table 53. UART Receive Data Register (U0RXD)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | RXD  |   |   |   |   |   |   |   |
| RESET | X    |   |   |   |   |   |   |   |
| R/W   | R    |   |   |   |   |   |   |   |
| ADDR  | F40H |   |   |   |   |   |   |   |

### RXD—Receive Data

UART receiver data byte from the RXD<sub>x</sub> pin

## UART Status 0 Register

The UART Status 0 and Status 1 registers (Table 54 and Table 55 on page 102) identify the current UART operating configuration and status.

**Table 54. UART Status 0 Register (U0STAT0)**

| BITS  | 7    | 6  | 5  | 4  | 3    | 2    | 1   | 0   |
|-------|------|----|----|----|------|------|-----|-----|
| FIELD | RDA  | PE | OE | FE | BRKD | TDRE | TXE | CTS |
| RESET | 0    |    |    |    |      | 1    |     | X   |
| R/W   | R    |    |    |    |      |      |     |     |
| ADDR  | F41H |    |    |    |      |      |     |     |

### RDA—Receive Data Available

This bit indicates that the UART Receive Data Register has received data. Reading the UART Receive Data Register clears this bit.

0 = The UART Receive Data Register is empty.

1 = There is a byte in the UART Receive Data Register.

### PE—Parity Error

This bit indicates that a parity error has occurred. Reading the UART Receive Data Register clears this bit.

0 = No parity error has occurred.

1 = A parity error has occurred.

### OE—Overrun Error

This bit indicates that an overrun error has occurred. An overrun occurs when new data is received and the UART Receive Data Register has not been read. If the RDA bit is reset to

0, then reading the UART Receive Data Register clears this bit.

0 = No overrun error occurred.

1 = An overrun error occurred.

#### **FE—Framing Error**

This bit indicates that a framing error (no STOP bit following data reception) was detected. Reading the UART Receive Data Register clears this bit.

0 = No framing error occurred.

1 = A framing error occurred.

#### **BRKD—Break Detect**

This bit indicates that a break occurred. If the data bits, parity/multiprocessor bit, and STOP bit(s) are all zeros then this bit is set to 1. Reading the UART Receive Data Register clears this bit.

0 = No break occurred.

1 = A break occurred.

#### **TDRE—Transmitter Data Register Empty**

This bit indicates that the UART Transmit Data Register is empty and ready for additional data. Writing to the UART Transmit Data Register resets this bit.

0 = Do not write to the UART Transmit Data Register.

1 = The UART Transmit Data Register is ready to receive an additional byte to be transmitted.

#### **TXE—Transmitter Empty**

This bit indicates that the transmit shift register is empty and character transmission is finished.

0 = Data is currently transmitting.

1 = Transmission is complete.

#### **CTS— $\overline{\text{CTS}}$ Signal**

When this bit is read it returns the level of the  $\overline{\text{CTS}}$  signal.

### **UART Status 1 Register**

This register contains multiprocessor control and status bits.

**Table 55. UART Status 1 Register (U0STAT1)**

| BITS  | 7        | 6 | 5 | 4 | 3   | 2 | 1      | 0    |
|-------|----------|---|---|---|-----|---|--------|------|
| FIELD | Reserved |   |   |   |     |   | NEWFRM | MPRX |
| RESET | 0        |   |   |   |     |   |        |      |
| R/W   | R        |   |   |   | R/W |   | R      |      |
| ADDR  | F44H     |   |   |   |     |   |        |      |

**Reserved—Must be 0**

**NEWFRM**—Status bit denoting the start of a new frame. Reading the UART Receive Data Register resets this bit to 0.

0 = The current byte is not the first data byte of a new frame.

1 = The current byte is the first data byte of a new frame.

**MPRX—Multiprocessor Receive**

Returns the value of the last multiprocessor bit received. Reading from the UART Receive Data Register resets this bit to 0.

**UART Control 0 and Control 1 Registers**

The UART Control 0 and Control 1 registers (Table 56 and Table 57 on page 104) configure the properties of the UART's transmit and receive operations. The UART Control Registers must not be written while the UART is enabled.

**Table 56. UART Control 0 Register (U0CTL0)**

| BITS  | 7    | 6   | 5    | 4   | 3    | 2    | 1    | 0    |
|-------|------|-----|------|-----|------|------|------|------|
| FIELD | TEN  | REN | CTSE | PEN | PSEL | SBRK | STOP | LBEN |
| RESET | 0    |     |      |     |      |      |      |      |
| R/W   | R/W  |     |      |     |      |      |      |      |
| ADDR  | F42H |     |      |     |      |      |      |      |

**TEN—Transmit Enable**

This bit enables or disables the transmitter. The enable is also controlled by the  $\overline{\text{CTS}}$  signal and the CTSE bit. If the  $\overline{\text{CTS}}$  signal is low and the CTSE bit is 1, the transmitter is enabled.

0 = Transmitter disabled.

1 = Transmitter enabled.

**REN—Receive Enable**

This bit enables or disables the receiver.

0 = Receiver disabled.

1 = Receiver enabled.

**CTSE—CTS Enable**

0 = The  $\overline{\text{CTS}}$  signal has no effect on the transmitter.

1 = The UART recognizes the  $\overline{\text{CTS}}$  signal as an enable control from the transmitter.

**PEN—Parity Enable**

This bit enables or disables parity. Even or odd is determined by the PSEL bit. This bit is overridden by the MPEN bit.

0 = Parity is disabled.

1 = The transmitter sends data with an additional parity bit and the receiver receives an additional parity bit.

**PSEL—Parity Select**

0 = Even parity is transmitted and expected on all received data.

1 = Odd parity is transmitted and expected on all received data.

**SBRK—Send Break**

This bit pauses or breaks data transmission by forcing the Transmit data output to 0.

Sending a break interrupts any transmission in progress, so ensure that the transmitter has finished sending data before setting this bit. The UART does not automatically generate a STOP Bit when SBRK is deasserted. Software must time the duration of the Break and the duration of any STOP Bit time desired following the Break.

0 = No break is sent.

1 = The output of the transmitter is zero.

**STOP—STOP Bit Select**

0 = The transmitter sends one stop bit.

1 = The transmitter sends two stop bits.

**LBEN—Loop Back Enable**

0 = Normal operation.

1 = All transmitted data is looped back to the receiver.

**Table 57. UART Control 1 Register (U0CTL1)**

| BITS  | 7       | 6    | 5       | 4    | 3     | 2      | 1      | 0    |
|-------|---------|------|---------|------|-------|--------|--------|------|
| FIELD | MPMD[1] | MPEN | MPMD[0] | MPBT | DEPOL | BRGCTL | RDAIRQ | IREN |
| RESET | 0       |      |         |      |       |        |        |      |
| R/W   | R/W     |      |         |      |       |        |        |      |
| ADDR  | F43H    |      |         |      |       |        |        |      |

**MPMD[1:0]—Multiprocessor Mode**

If Multiprocessor (9-bit) mode is enabled,

00 = The UART generates an interrupt request on all received bytes (data and address).

01 = The UART generates an interrupt request only on received address bytes.

10 = The UART generates an interrupt request when a received address byte matches the value stored in the Address Compare Register and on all successive data bytes until an address mismatch occurs.

11 = The UART generates an interrupt request on all received data bytes for which the most recent address byte matched the value in the Address Compare Register.

**MPEN—Multiprocessor (9-bit) Enable**

This bit is used to enable Multiprocessor (9-bit) mode.

0 = Disable Multiprocessor (9-bit) mode.

1 = Enable Multiprocessor (9-bit) mode.

#### **MPBT—Multiprocessor Bit Transmit**

This bit is applicable only when Multiprocessor (9-bit) mode is enabled.

0 = Send a 0 in the multiprocessor bit location of the data stream (9th bit).

1 = Send a 1 in the multiprocessor bit location of the data stream (9th bit).

#### **DEPOL—Driver Enable Polarity**

0 = DE signal is Active High.

1 = DE signal is Active Low.

#### **BRGCTL—Baud Rate Control**

This bit causes different UART behavior depending on whether the UART receiver is enabled (REN = 1 in the UART Control 0 Register).

When the UART receiver is not enabled, this bit determines whether the BRG will issue interrupts.

0 = Reads from the Baud Rate High and Low Byte registers return the BRG Reload Value

1 = The BRG generates a receive interrupt when it counts down to zero. Reads from the Baud Rate High and Low Byte registers return the current BRG count value.

When the UART receiver is enabled, this bit allows reads from the Baud Rate Registers to return the BRG count value instead of the Reload Value.

0 = Reads from the Baud Rate High and Low Byte registers return the BRG Reload Value.

1 = Reads from the Baud Rate High and Low Byte registers return the current BRG count value. Unlike the Timers, there is no mechanism to latch the High Byte when the Low Byte is read.

#### **RDAIRQ—Receive Data Interrupt Enable**

0 = Received data and receiver errors generates an interrupt request to the Interrupt Controller.

1 = Received data does not generate an interrupt request to the Interrupt Controller. Only receiver errors generate an interrupt request.

#### **IREN—Infrared Encoder/Decoder Enable**

0 = Infrared Encoder/Decoder is disabled. UART operates normally operation.

1 = Infrared Encoder/Decoder is enabled. The UART transmits and receives data through the Infrared Encoder/Decoder.

### **UART Address Compare Register**

The UART Address Compare register stores the multi-node network address of the UART. When the MPMD[1] bit of UART Control Register 0 is set, all incoming address bytes will be compared to the value stored in the Address Compare register. Receive interrupts and RDA assertions will only occur in the event of a match.

**Table 58. UART Address Compare Register (U0ADDR)**

| BITS  | 7         | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|-----------|---|---|---|---|---|---|---|
| FIELD | COMP_ADDR |   |   |   |   |   |   |   |
| RESET | 0         |   |   |   |   |   |   |   |
| R/W   | R/W       |   |   |   |   |   |   |   |
| ADDR  | F45H      |   |   |   |   |   |   |   |

**COMP\_ADDR—Compare Address**

This 8-bit value is compared to the incoming address bytes.

**UART Baud Rate High and Low Byte Registers**

The UART Baud Rate High and Low Byte registers ([Table 59](#) and [Table 60](#)) combine to create a 16-bit baud rate divisor value (BRG[15:0]) that sets the data transmission rate (baud rate) of the UART.

**Table 59. UART Baud Rate High Byte Register (U0BRH)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | BRH  |   |   |   |   |   |   |   |
| RESET | 1    |   |   |   |   |   |   |   |
| R/W   | R/W  |   |   |   |   |   |   |   |
| ADDR  | F46H |   |   |   |   |   |   |   |

**Table 60. UART Baud Rate Low Byte Register (U0BRL)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | BRL  |   |   |   |   |   |   |   |
| RESET | 1    |   |   |   |   |   |   |   |
| R/W   | R/W  |   |   |   |   |   |   |   |
| ADDR  | F47H |   |   |   |   |   |   |   |

The UART data rate is calculated using the following equation:

$$\text{UART Baud Rate (bits/s)} = \frac{\text{System Clock Frequency (Hz)}}{16 \times \text{UART Baud Rate Divisor Value}}$$

For a given UART data rate, the integer baud rate divisor value is calculated using the following equation:

$$\text{UART Baud Rate Divisor Value (BRG)} = \text{Round}\left(\frac{\text{System Clock Frequency (Hz)}}{16 \times \text{UART Data Rate (bits/s)}}\right)$$

The baud rate error relative to the desired baud rate is calculated using the following equation:

$$\text{UART Baud Rate Error (\%)} = 100 \times \left( \frac{\text{Actual Data Rate} - \text{Desired Data Rate}}{\text{Desired Data Rate}} \right)$$

For reliable communication, the UART baud rate error must never exceed 5 percent. [Table 61](#) provides information on data rate errors for popular baud rates and commonly used crystal oscillator frequencies.

**Table 61. UART Baud Rates**

| 10.0 MHz System Clock |             |             |        | 5.5296 MHz System Clock |             |             |       |
|-----------------------|-------------|-------------|--------|-------------------------|-------------|-------------|-------|
| Desired Rate          | BRG Divisor | Actual Rate | Error  | Desired Rate            | BRG Divisor | Actual Rate | Error |
| (kHz)                 | (Decimal)   | (kHz)       | (%)    | (kHz)                   | (Decimal)   | (kHz)       | (%)   |
| 1250.0                | N/A         | N/A         | N/A    | 1250.0                  | N/A         | N/A         | N/A   |
| 625.0                 | 1           | 625.0       | 0.00   | 625.0                   | N/A         | N/A         | N/A   |
| 250.0                 | 3           | 208.33      | -16.67 | 250.0                   | 1           | 345.6       | 38.24 |
| 115.2                 | 5           | 125.0       | 8.51   | 115.2                   | 3           | 115.2       | 0.00  |
| 57.6                  | 11          | 56.8        | -1.36  | 57.6                    | 6           | 57.6        | 0.00  |
| 38.4                  | 16          | 39.1        | 1.73   | 38.4                    | 9           | 38.4        | 0.00  |
| 19.2                  | 33          | 18.9        | 0.16   | 19.2                    | 18          | 19.2        | 0.00  |
| 9.60                  | 65          | 9.62        | 0.16   | 9.60                    | 36          | 9.60        | 0.00  |
| 4.80                  | 130         | 4.81        | 0.16   | 4.80                    | 72          | 4.80        | 0.00  |
| 2.40                  | 260         | 2.40        | -0.03  | 2.40                    | 144         | 2.40        | 0.00  |
| 1.20                  | 521         | 1.20        | -0.03  | 1.20                    | 288         | 1.20        | 0.00  |
| 0.60                  | 1042        | 0.60        | -0.03  | 0.60                    | 576         | 0.60        | 0.00  |
| 0.30                  | 2083        | 0.30        | 0.2    | 0.30                    | 1152        | 0.30        | 0.00  |

**Table 61. UART Baud Rates (Continued)**

| 3.579545 MHz System Clock |             |             |        | 1.8432 MHz System Clock |             |             |       |
|---------------------------|-------------|-------------|--------|-------------------------|-------------|-------------|-------|
| Desired Rate              | BRG Divisor | Actual Rate | Error  | Desired Rate            | BRG Divisor | Actual Rate | Error |
| (kHz)                     | (Decimal)   | (kHz)       | (%)    | (kHz)                   | (Decimal)   | (kHz)       | (%)   |
| 1250.0                    | N/A         | N/A         | N/A    | 1250.0                  | N/A         | N/A         | N/A   |
| 625.0                     | N/A         | N/A         | N/A    | 625.0                   | N/A         | N/A         | N/A   |
| 250.0                     | 1           | 223.72      | -10.51 | 250.0                   | N/A         | N/A         | N/A   |
| 115.2                     | 2           | 111.9       | -2.90  | 115.2                   | 1           | 115.2       | 0.00  |
| 57.6                      | 4           | 55.9        | -2.90  | 57.6                    | 2           | 57.6        | 0.00  |
| 38.4                      | 6           | 37.3        | -2.90  | 38.4                    | 3           | 38.4        | 0.00  |
| 19.2                      | 12          | 18.6        | -2.90  | 19.2                    | 6           | 19.2        | 0.00  |
| 9.60                      | 23          | 9.73        | 1.32   | 9.60                    | 12          | 9.60        | 0.00  |
| 4.80                      | 47          | 4.76        | -0.83  | 4.80                    | 24          | 4.80        | 0.00  |
| 2.40                      | 93          | 2.41        | 0.23   | 2.40                    | 48          | 2.40        | 0.00  |
| 1.20                      | 186         | 1.20        | 0.23   | 1.20                    | 96          | 1.20        | 0.00  |
| 0.60                      | 373         | 0.60        | -0.04  | 0.60                    | 192         | 0.60        | 0.00  |
| 0.30                      | 746         | 0.30        | -0.04  | 0.30                    | 384         | 0.30        | 0.00  |

# Infrared Encoder/Decoder

Z8 Encore! XP<sup>®</sup> F0822 Series products contain a fully-functional, high-performance UART to Infrared Encoder/Decoder (Endec). The Infrared Endec is integrated with an on-chip UART to allow easy communication between the Z8 Encore! XP and IrDA Physical Layer Specification, v1.3-compliant infrared transceivers. Infrared communication provides secure, reliable, low-cost, point-to-point communication between PCs, PDAs, cell phones, printers, and other infrared enabled devices.

## Architecture

Figure 17 displays the architecture of the Infrared Endec.

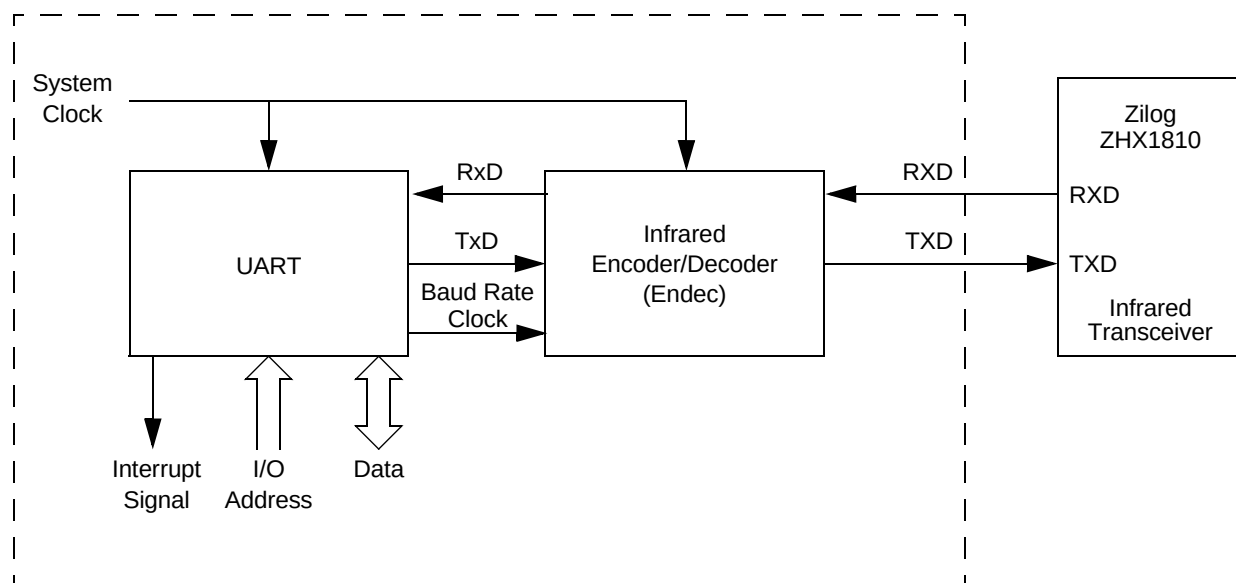


**Figure 17. Infrared Data Communication System Block Diagram**

## Operation

When the Infrared Endec is enabled, the transmit data from the associated on-chip UART is encoded as digital signals in accordance with the IrDA standard and output to the infrared transceiver through the TXD pin. Similarly, data received from the infrared transceiver is passed to the Infrared Endec through the RXD pin, decoded by the Infrared Endec, and then passed to the UART. Communication is half-duplex, which means simultaneous data transmission and reception is not allowed.

The baud rate is set by the UART's Baud Rate Generator and supports IrDA standard baud rates from 9600 baud to 115.2 Kbaud. Higher baud rates are possible, but do not meet IrDA specifications. The UART must be enabled to use the Infrared Endec. The Infrared Endec data rate is calculated using the following equation.

$$\text{Infrared Data Rate (bits/s)} = \frac{\text{System Clock Frequency (Hz)}}{16 \times \text{UART Baud Rate Divisor Value}}$$

### Transmitting IrDA Data

The data to be transmitted using the infrared transceiver is first sent to the UART. The UART's transmit signal (TXD) and baud rate clock are used by the IrDA to generate the modulation signal (IR\_TXD) that drives the infrared transceiver. Each UART/Infrared data bit is 16-clocks wide. If the data to be transmitted is 1, the IR\_TXD signal remains low for the full 16-clock period. If the data to be transmitted is 0, a 3-clock high pulse is output following a 7-clock low period. After the 3-clock high pulse, a 6-clock low pulse is output to complete the full 16-clock data period. [Figure 18](#) displays IrDA data transmission. When the Infrared Endec is enabled, the UART's TXD signal is internal to the Z8 Encore! XP® F0822 Series products while the IR\_TXD signal is output through the TXD pin.

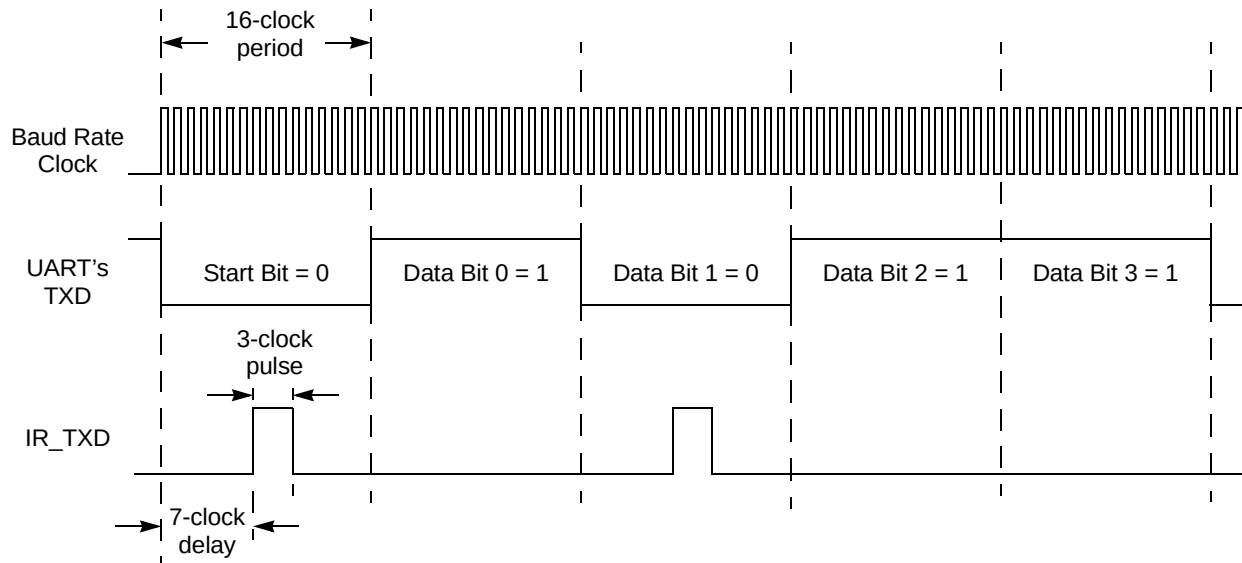


Figure 18. Infrared Data Transmission

## Receiving IrDA Data

Data received from the infrared transceiver through the IR\_RXD signal through the RXD pin is decoded by the Infrared Endec and passed to the UART. The UART's baud rate clock is used by the Infrared Endec to generate the demodulated signal (RXD) that drives the UART. Each UART/Infrared data bit is 16-clocks wide. Figure 19 displays data reception. When the Infrared Endec is enabled, the UART's RXD signal is internal to the Z8 Encore! XP® F0822 Series products while the IR\_RXD signal is received through the RXD pin.

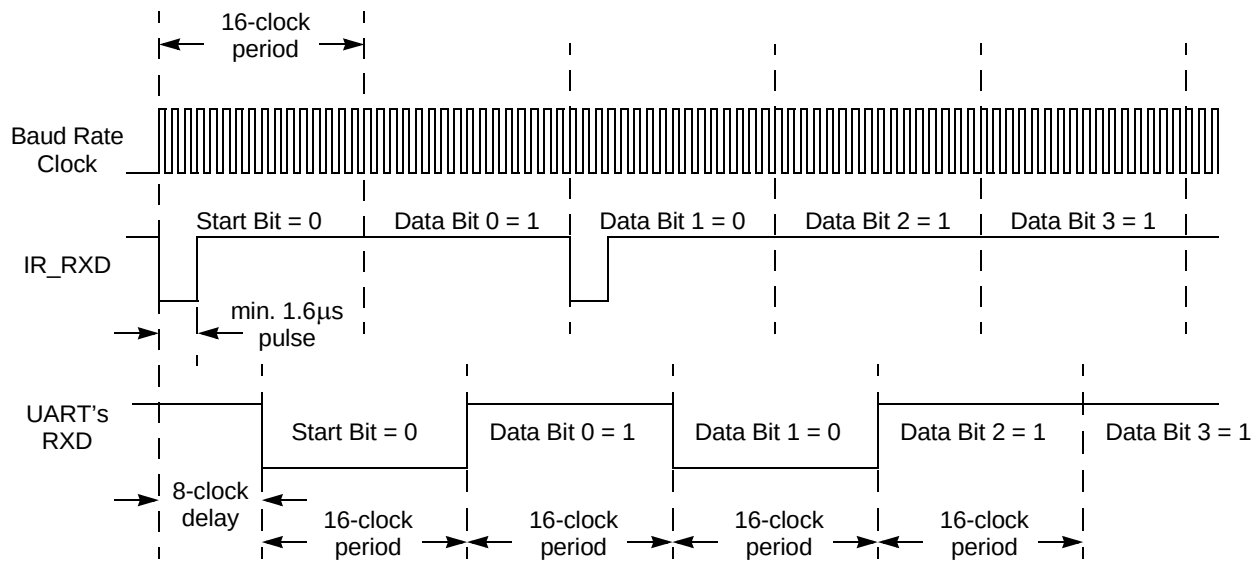


**Figure 19. Infrared Data Reception**



**Caution:** The system clock frequency must be at least 1.0 MHz to ensure proper reception of the 1.6 μs minimum width pulses allowed by the IrDA standard.

## Endec Receiver Synchronization

The IrDA receiver uses a local baud rate clock counter (0 to 15 clock periods) to generate an input stream for the UART and to create a sampling window for detection of incoming pulses. The generated UART input (UART RXD) is delayed by 8 baud rate clock periods with respect to the incoming IrDA data stream. When a falling edge in the input data stream is detected, the Endec counter is reset. When the count reaches a value of 8, the UART RXD value is updated to reflect the value of the decoded data. When the count reaches 12 baud clock periods, the sampling window for the next incoming pulse opens. The window remains open until the count again reaches 8 (or in other words 24 baud clock periods since the previous pulse was detected). This gives the Endec a sampling window

of minus four baud rate clocks to plus eight baud rate clocks around the expected time of an incoming pulse. If an incoming pulse is detected inside this window this process is repeated. If the incoming data is a logical 1 (no pulse), the Endec returns to the initial state and waits for the next falling edge. As each falling edge is detected, the Endec clock counter is reset, resynchronizing the Endec to the incoming signal. This procedure allows the Endec to tolerate jitter and baud rate errors in the incoming data stream. Resynchronizing the Endec does not alter the operation of the UART, which ultimately receives the data. The UART is only synchronized to the incoming data stream when a Start bit is received.

## Infrared Endec Control Register Definitions

All Infrared Endec configuration and status information is set by the UART control registers as defined in [UART Control Register Definitions](#) on page 100.



**Caution:** *To prevent spurious signals during IrDA data transmission, set the `IREN` bit in the UART Control 1 register to 1 to enable the Infrared Endec before enabling the GPIO Port alternate function for the corresponding pin.*

# Serial Peripheral Interface

The Serial Peripheral Interface (SPI) is a synchronous interface allowing several SPI-type devices to be interconnected. SPI-compatible devices include EEPROMs, Analog-to-Digital Converters, and ISDN devices. Features of the SPI include:

- Full-duplex, synchronous, and character-oriented communication
- Four-wire interface
- Data transfers rates up to a maximum of one-half the system clock frequency
- Error detection
- Dedicated Baud Rate Generator

The SPI is not available in 20-pin package devices.

## Architecture

The SPI is configured as either a Master (in single or multi-master systems) or a Slave as displayed in [Figure 20](#) through [Figure 22](#).

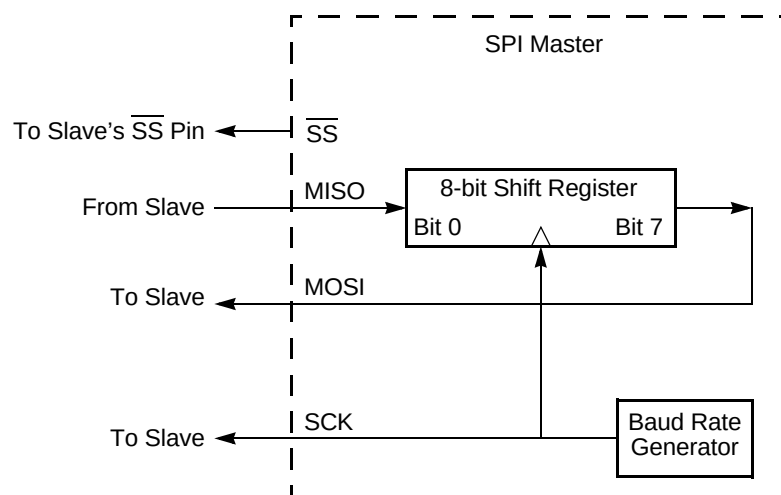


**Figure 20. SPI Configured as a Master in a Single Master, Single Slave System**

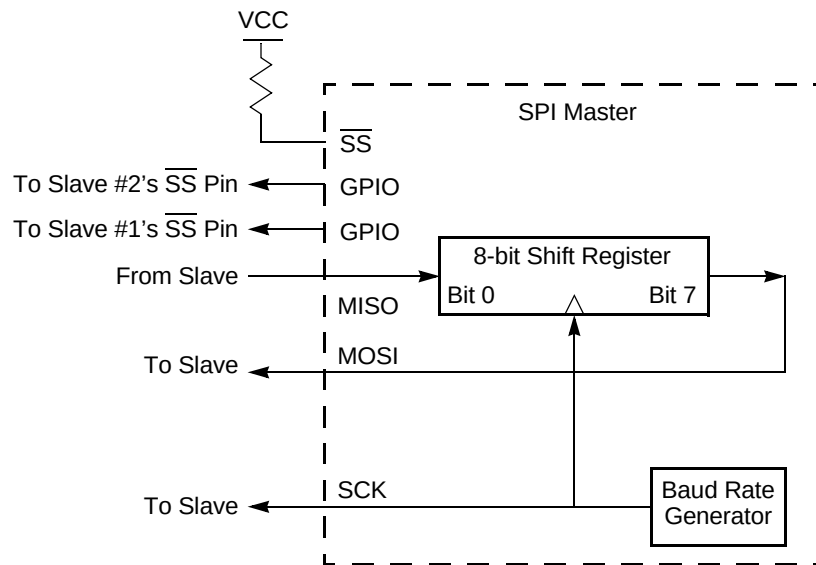


**Figure 21. SPI Configured as a Master in a Single Master, Multiple Slave System**

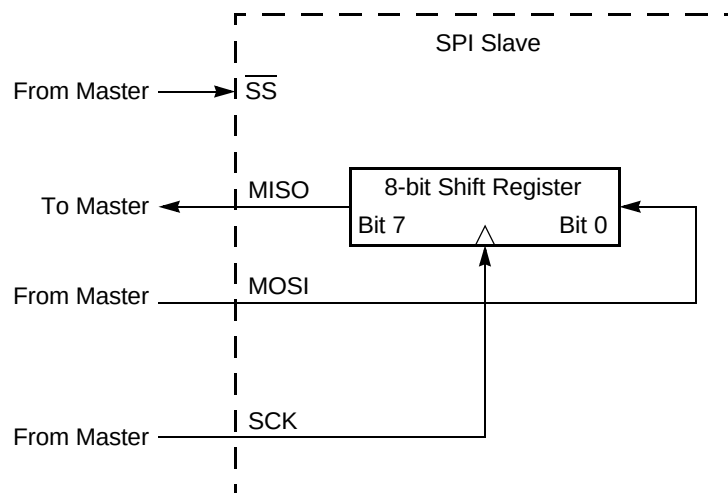


**Figure 22. SPI Configured as a Slave**

## Operation

The SPI is a full-duplex, synchronous, and character-oriented channel that supports a four-wire interface (serial clock, transmit, receive and Slave select). The SPI block consists of a transmit/receive shift register, a Baud Rate (clock) Generator and a control unit.

During an SPI transfer, data is sent and received simultaneously by both the Master and the Slave SPI devices. Separate signals are required for data and the serial clock. When an SPI transfer occurs, a multi-bit (typically 8-bit) character is shifted out one data pin and an multi-bit character is simultaneously shifted in on a second data pin. An 8-bit shift register in the Master and another 8-bit shift register in the Slave are connected as a circular buffer. The SPI shift register is single-buffered in the transmit and receive directions. New data to be transmitted cannot be written into the shift register until the previous transmission is complete and receive data (if valid) has been read.

## SPI Signals

The four basic SPI signals are:

- MISO (Master-In, Slave-Out)
- MOSI (Master-Out, Slave-In)
- SCK (Serial Clock)
- $\overline{SS}$  (Slave Select)

The following sections discuss these SPI signals. Each signal is described in both Master and Slave modes.

### Master-In/Slave-Out

The Master-In/Slave-Out (MISO) pin is configured as an input in a Master device and as an output in a Slave device. It is one of the two lines that transfer serial data, with the most significant bit sent first. The MISO pin of a Slave device is placed in a high-impedance state if the Slave is not selected. When the SPI is not enabled, this signal is in a high-impedance state.

### Master-Out/Slave-In

The Master-Out/Slave-In (MOSI) pin is configured as an output in a Master device and as an input in a Slave device. It is one of the two lines that transfer serial data, with the most significant bit sent first. When the SPI is not enabled, this signal is in a high-impedance state.

### Serial Clock

The Serial Clock (SCK) synchronizes data movement both in and out of the device through its MOSI and MISO pins. In MASTER mode, the SPI's Baud Rate Generator creates the serial clock. The Master drives the serial clock out its own SCK pin to the Slave's SCK pin. When the SPI is configured as a Slave, the SCK pin is an input and the clock signal from the Master synchronizes the data transfer between the Master and Slave devices. Slave devices ignore the SCK signal, unless the  $\overline{SS}$  pin is asserted. When configured as a slave, the SPI block requires a minimum SCK period of greater than or equal to 8 times the system (XIN) clock period.

The Master and Slave are each capable of exchanging a character of data during a sequence of NUMBITS clock cycles (see NUMBITS field in the SPIMODE Register). In both Master and Slave SPI devices, data is shifted on one edge of the SCK and is sampled on the opposite edge where data is stable. Edge polarity is determined by the SPI phase and polarity control.

### Slave Select

The active Low Slave Select ( $\overline{SS}$ ) input signal selects a Slave SPI device.  $\overline{SS}$  must be Low prior to all data communication to and from the Slave device.  $\overline{SS}$  must stay Low for the full duration of each character transferred. The  $\overline{SS}$  signal can stay Low during the transfer of multiple characters or can deassert between each character.

When the SPI is configured as the only Master in an SPI system, the  $\overline{SS}$  pin is set as either an input or an output. For communication between the Z8 Encore! XP F0822 Series device's SPI Master and external Slave devices, the  $\overline{SS}$  signal, as an output, asserts the  $\overline{SS}$  input pin on one of the Slave devices. Other GPIO output pins can also be employed to select external SPI Slave devices.

When the SPI is configured as one Master in a multi-master SPI system, the  $\overline{SS}$  pin should be set as an input. The  $\overline{SS}$  input signal on the Master must be High. If the  $\overline{SS}$  signal goes Low (indicating another Master is driving the SPI bus), a Collision error flag is set in the SPI Status Register.

### SPI Clock Phase and Polarity Control

The SPI supports four combinations of serial clock phase and polarity using two bits in the SPI Control Register. The clock polarity bit, CLKPOL, selects an active high or active low clock and has no effect on the transfer format. Table 62 lists the SPI Clock Phase and Polarity Operation parameters. The clock phase bit, PHASE, selects one of two fundamentally different transfer formats. For proper data transmission, the clock phase and polarity must be identical for the SPI Master and the SPI Slave. The Master always places data on the MOSI line a half-cycle before the receive clock edge (SCK signal), in order for the Slave to latch the data.

**Table 62. SPI Clock Phase (PHASE) and Clock Polarity (CLKPOL) Operation**

| PHASE | CLKPOL | SCK Transmit Edge | SCK Receive Edge | SCK Idle State |
|-------|--------|-------------------|------------------|----------------|
| 0     | 0      | Falling           | Rising           | Low            |
| 0     | 1      | Rising            | Falling          | High           |
| 1     | 0      | Rising            | Falling          | Low            |
| 1     | 1      | Falling           | Rising           | High           |

### Transfer Format PHASE is 0

Figure 23 displays the timing diagram for an SPI transfer in which PHASE is cleared to 0. The two SCK waveforms show polarity with CLKPOL reset to 0 and with CLKPOL set to one. The diagram can be interpreted as either a Master or Slave timing diagram since the SCK Master-In/Slave-Out (MISO) and Master-Out/Slave-In (MOSI) pins are directly connected between the Master and the Slave.

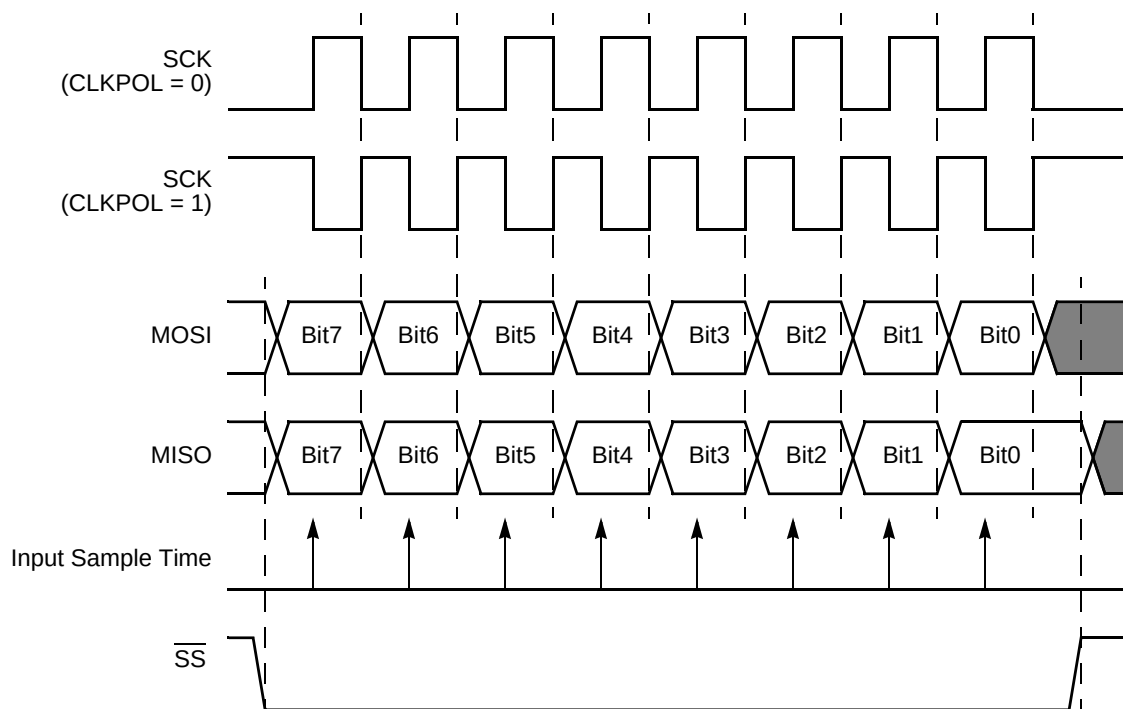


Figure 23. SPI Timing When PHASE is 0

### Transfer Format PHASE is 1

Figure 24 displays the timing diagram for an SPI transfer in which PHASE is one. Two waveforms are depicted for SCK, one for CLKPOL reset to 0 and another for CLKPOL set to 1.

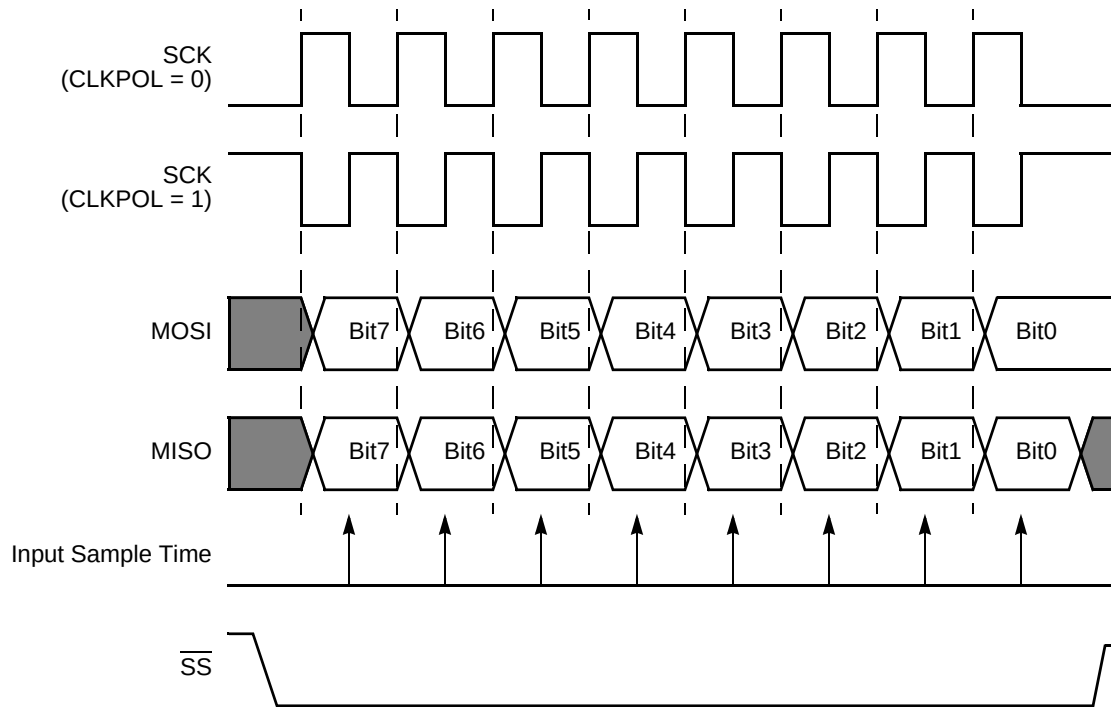


Figure 24. SPI Timing When PHASE is 1

## Multi-Master Operation

In a multi-master SPI system, all SCK pins are tied together, all MOSI pins are tied together and all MISO pins are tied together. All SPI pins must then be configured in OPEN-DRAIN mode to prevent bus contention. At any one time, only one SPI device is configured as the Master and all other SPI devices on the bus are configured as Slaves. The Master enables a single Slave by asserting the  $\overline{SS}$  pin on that Slave only. Then, the single Master drives data out its SCK and MOSI pins to the SCK and MOSI pins on the Slaves (including those which are not enabled). The enabled Slave drives data out its MISO pin to the MISO Master pin.

For a Master device operating in a multi-master system, if the  $\overline{SS}$  pin is configured as an input and is driven Low by another Master, the COL bit is set to 1 in the SPI Status Register. The COL bit indicates the occurrence of a multi-master collision (mode fault error condition).

## Slave Operation

The SPI block is configured for SLAVE mode operation by setting the SPIEN bit to 1 and the MMEN bit to 0 in the SPICTL Register and setting the SSIO bit to 0 in the SPIMODE Register. The IRQE, PHASE, CLKPOL, and WOR bits in the SPICTL Register and the

NUMBITS field in the SPIMODE Register must be set to be consistent with the other SPI devices. The STR bit in the SPICTL Register can be used if desired to force a “startup” interrupt. The BIRQ bit in the SPICTL Register and the SSV bit in the SPIMODE Register is not used in SLAVE mode. The SPI Baud Rate Generator is not used in SLAVE mode so the SPIBRH and SPIBRL Registers need not be initialized.

If the slave has data to send to the master, the data must be written to the SPIDAT Register before the transaction starts (first edge of SCK when  $\overline{SS}$  is asserted). If the SPIDAT Register is not written prior to the slave transaction, the MISO pin outputs whatever value is currently in the SPIDAT Register.

Due to the delay resulting from synchronization of the SPI input signals to the internal system clock, the maximum SPICLK baud rate that can be supported in SLAVE mode is the system clock frequency (XIN) divided by 8. This rate is controlled by the SPI Master.

## Error Detection

The SPI contains error detection logic to support SPI communication protocols and recognize when communication errors have occurred. The SPI Status Register indicates when a data transmission error has been detected.

### Overrun (Write Collision)

An overrun error (write collision) indicates a write to the SPI Data Register was attempted while a data transfer is in progress (in either Master or Slave modes). An overrun sets the OVR bit in the SPI Status Register to 1. Writing a 1 to OVR clears this error flag. The data register is not altered when a write occurs while data transfer is in progress.

### Mode Fault (Multi-Master Collision)

A mode fault indicates when more than one Master is trying to communicate at the same time (a multi-master collision). The mode fault is detected when the enabled Master's  $\overline{SS}$  pin is asserted. A mode fault sets the COL bit in the SPI Status Register to 1. Writing a 1 to COL clears this error Flag.

### SLAVE Mode Abort

In SLAVE mode, if the  $\overline{SS}$  pin deasserts before all bits in a character have been transferred, the transaction aborts. When this condition occurs the ABT bit is set in the SPISTAT Register as well as the IRQ bit (indicating the transaction is complete). The next time  $\overline{SS}$  asserts, the MISO pin outputs SPIDAT[7], regardless of where the previous transaction left off. Writing a 1 to ABT clears this error flag.

## SPI Interrupts

When SPI interrupts are enabled, the SPI generates an interrupt after character transmission/reception completes in both Master and Slave modes. A character is defined to be 1 through 8 bits by the NUMBITS field in the SPI Mode Register. In SLAVE mode it is not

necessary for  $\overline{SS}$  to deassert between characters to generate the interrupt. The SPI in SLAVE mode also generates an interrupt if the  $\overline{SS}$  signal deasserts prior to transfer of all the bits in a character (see description of Slave Abort Error). Writing a 1 to the  $IRQ$  bit in the SPI Status Register clears the pending SPI interrupt request. The  $IRQ$  bit must be cleared to 0 by the ISR to generate future interrupts. To start the transfer process, an SPI interrupt can be forced by software writing a 1 to the  $STR$  bit in the  $SPICTL$  Register.

If the SPI is disabled, an SPI interrupt can be generated by a BRG time-out. This timer function must be enabled by setting the  $BIRQ$  bit in the  $SPICTL$  Register. This BRG time-out does not set the  $IRQ$  bit in the  $SPISTAT$  Register, just the SPI interrupt bit in the interrupt controller.

### SPI Baud Rate Generator

In SPI MASTER mode, the BRG creates a lower frequency serial clock ( $SCK$ ) for data transmission synchronization between the Master and the external Slave. The input to the BRG is the system clock. The SPI Baud Rate High and Low Byte Registers combine to form a 16-bit reload value,  $BRG[15:0]$ , for the SPI Baud Rate Generator. The SPI baud rate is calculated using the following equation:

$$\text{SPI Baud Rate (bits/s)} = \frac{\text{System Clock Frequency (Hz)}}{2 \times BRG[15:0]}$$

Minimum baud rate is obtained by setting  $BRG[15:0]$  to 0000H for a clock divisor value of ( $2 \times 65536 = 131072$ ).

When the SPI is disabled, BRG functions as a basic 16-bit timer with interrupt on time-out. Follow the steps below to configure BRG as a timer with interrupt on time-out:

1. Disable the SPI by clearing the  $SP1EN$  bit in the SPI Control Register to 0.
2. Load the desired 16-bit count value into the SPI Baud Rate High and Low Byte registers.
3. Enable BRG timer function and associated interrupt by setting the  $BIRQ$  bit in the SPI Control Register to 1.

When configured as a general-purpose timer, the interrupt interval is calculated using the following equation:

$$\text{Interrupt Interval (s)} = \text{System Clock Period (s)} \times BRG[15:0]$$

## SPI Control Register Definitions

### SPI Data Register

The SPI Data Register stores both the outgoing (transmit) data and the incoming (receive) data. Reads from the SPI Data Register always return the current contents of the 8-bit Shift Register. Data is shifted out starting with bit 7. The last bit received resides in bit position 0.

With the SPI configured as a Master, writing a data byte to this register initiates the data transmission. With the SPI configured as a Slave, writing a data byte to this register loads the shift register in preparation for the next data transfer with the external Master. In either the Master or Slave modes, if a transmission is already in progress, writes to this register are ignored and the Overrun error Flag, OVR, is set in the SPI Status Register.

When the character length is less than 8 bits (as set by the NUMBITS field in the SPI Mode Register), the transmit character must be left justified in the SPI Data Register. A received character of less than 8 bits is right justified (last bit received is in bit position 0). For example, if the SPI is configured for 4-bit characters, the transmit characters must be written to SPIDATA[7:4] and the received characters are read from SPIDATA[3:0].

**Table 63. SPI Data Register (SPIDATA)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | DATA |   |   |   |   |   |   |   |
| RESET | X    |   |   |   |   |   |   |   |
| R/W   | R/W  |   |   |   |   |   |   |   |
| ADDR  | F60H |   |   |   |   |   |   |   |

**DATA—Data**

Transmit and/or receive data.

## SPI Control Register

The SPI Control Register configures the SPI for transmit and receive operations.

**Table 64. SPI Control Register (SPICTL)**

| BITS  | 7    | 6   | 5    | 4     | 3      | 2   | 1    | 0     |
|-------|------|-----|------|-------|--------|-----|------|-------|
| FIELD | IRQE | STR | BIRQ | PHASE | CLKPOL | WOR | MMEN | SPIEN |
| RESET | 0    |     |      |       |        |     |      |       |
| R/W   | R/W  |     |      |       |        |     |      |       |
| ADDR  | F61H |     |      |       |        |     |      |       |

### IRQE—Interrupt Request Enable

0 = SPI interrupts are disabled. No interrupt requests are sent to the Interrupt Controller.  
1 = SPI interrupts are enabled. Interrupt requests are sent to the Interrupt Controller.

### STR—Start an SPI Interrupt Request

0 = No effect.  
1 = Setting this bit to 1 also sets the **IRQ** bit in the SPI Status Register to 1. Setting this bit forces the SPI to send an interrupt request to the Interrupt Control. This bit can be used by software for a function similar to transmit buffer empty in a UART.  
Writing a 1 to the **IRQ** bit in the SPI Status Register clears this bit to 0.

### BIRQ—BRG Timer Interrupt Request

If the SPI is enabled, this bit has no effect. If the SPI is disabled:  
0 = BRG timer function is disabled.  
1 = BRG timer function and time-out interrupt are enabled.

### PHASE—Phase Select

Sets the phase relationship of the data to the clock. For more information on operation of the **PHASE** bit, see [SPI Clock Phase and Polarity Control](#) on page 116.

### CLKPOL—Clock Polarity

0 = SCK idles Low (0).  
1 = SCK idle High (1).

### WOR—Wire-OR (Open-Drain) Mode Enabled

0 = SPI signal pins not configured for open-drain.  
1 = All four SPI signal pins (SCK,  $\overline{SS}$ , MISO, MOSI) configured for open-drain function. This setting is typically used for multi-master and/or multi-slave configurations.

### MMEN—SPI MASTER Mode Enable

0 = SPI configured in SLAVE mode.  
1 = SPI configured in MASTER mode.

### SPIEN—SPI Enable

0 = SPI disabled.  
1 = SPI enabled.

## SPI Status Register

The SPI Status Register indicates the current state of the SPI. All bits revert to their reset state if the `SPIEN` bit in the `SPICTL` Register equals 0.

**Table 65. SPI Status Register (SPISTAT)**

| BITS                                                 | 7    | 6   | 5   | 4   | 3        | 2 | 1    | 0    |
|------------------------------------------------------|------|-----|-----|-----|----------|---|------|------|
| FIELD                                                | IRQ  | OVR | COL | ABT | Reserved |   | TXST | SLAS |
| RESET                                                | 0    |     |     |     |          |   |      | 1    |
| R/W                                                  | R/W* |     |     |     | R        |   |      |      |
| ADDR                                                 | F62H |     |     |     |          |   |      |      |
| R/W* = Read access. Write a 1 to clear the bit to 0. |      |     |     |     |          |   |      |      |

### IRQ—Interrupt Request

If `SPIEN` = 1, this bit is set if the `STR` bit in the `SPICTL` Register is set, or upon completion of an SPI Master or Slave transaction. This bit does not set if `SPIEN` = 0 and the SPI Baud Rate Generator is used as a timer to generate the SPI interrupt.

0 = No SPI interrupt request pending.

1 = SPI interrupt request is pending.

### OVR—Overflow

0 = An overrun error has not occurred.

1 = An overrun error has been detected.

### COL—Collision

0 = A multi-master collision (mode fault) has not occurred.

1 = A multi-master collision (mode fault) has been detected.

### ABT—SLAVE mode transaction abort

This bit is set if the SPI is configured in SLAVE mode, a transaction is occurring and  $\overline{SS}$  deasserts before all bits of a character have been transferred as defined by the `NUMBITS` field of the `SPIMODE` Register. The `IRQ` bit also sets, indicating the transaction has completed.

0 = A SLAVE mode transaction abort has not occurred.

1 = A SLAVE mode transaction abort has been detected.

### Reserved—Must be 0

### TXST—Transmit Status

0 = No data transmission currently in progress.

1 = Data transmission currently in progress.

### SLAS—Slave Select

If SPI enabled as a Slave

0 =  $\overline{SS}$  input pin is asserted (Low)

1 =  $\overline{SS}$  input is not asserted (High).

If SPI enabled as a Master, this bit is not applicable.

## SPI Mode Register

The SPI Mode Register configures the character bit width and the direction and value of the  $\overline{SS}$  pin.

**Table 66. SPI Mode Register (SPIMODE)**

| BITS  | 7        | 6 | 5    | 4            | 3 | 2 | 1    | 0   |
|-------|----------|---|------|--------------|---|---|------|-----|
| FIELD | Reserved |   | DIAG | NUMBITS[2:0] |   |   | SSIO | SSV |
| RESET | 0        |   |      |              |   |   |      |     |
| R/W   | R        |   | R/W  |              |   |   |      |     |
| ADDR  | F63H     |   |      |              |   |   |      |     |

**Reserved—Must be 0**

### DIAG—Diagnostic Mode Control bit

This bit is for SPI diagnostics. Setting this bit allows the BRG value to be read using the SPIBRH and SPIBRL Register locations.

0 = Reading SPIBRH, SPIBRL returns the value in the SPIBRH and SPIBRL Registers

1 = Reading SPIBRH returns bits [15:8] of the SPI Baud Rate Generator; and reading SPIBRL returns bits [7:0] of the SPI Baud Rate Counter. The Baud Rate Counter High and Low byte values are not buffered.



**Caution:** Take precautions if you are reading the values while BRG is counting.

### NUMBITS[2:0]—Number of Data Bits Per Character to Transfer

This field contains the number of bits to shift for each character transfer. See the SPI Data Register description for information on valid bit positions when the character length is less than 8-bits.

000 = 8 bits

001 = 1 bit

010 = 2 bits

011 = 3 bits

100 = 4 bits

101 = 5 bits

110 = 6 bits

111 = 7 bits

### SSIO—Slave Select I/O

0 =  $\overline{SS}$  pin configured as an input.

1 =  $\overline{SS}$  pin configured as an output (MASTER mode only).

### SSV—Slave Select Value

If SSIO = 1 and SPI configured as a Master:

0 =  $\overline{SS}$  pin driven Low (0).

1 =  $\overline{SS}$  pin driven High (1).

This bit has no effect if  $SSIO = 0$  or SPI configured as a Slave

## SPI Diagnostic State Register

The SPI Diagnostic State Register provides observability of internal state. This is a read only register used for SPI diagnostics.

**Table 67. SPI Diagnostic State Register (SPIDST)**

| BITS  | 7     | 6     | 5        | 4 | 3 | 2 | 1 | 0 |
|-------|-------|-------|----------|---|---|---|---|---|
| FIELD | SCKEN | TCKEN | SPISTATE |   |   |   |   |   |
| RESET | 0     |       |          |   |   |   |   |   |
| R/W   | R     |       |          |   |   |   |   |   |
| ADDR  | F64H  |       |          |   |   |   |   |   |

### SCKEN–Shift Clock Enable

0 = The internal Shift Clock Enable signal is deasserted

1 = The internal Shift Clock Enable signal is asserted (shift register is updates on next system clock)

### TCKEN–Transmit Clock Enable

0 = The internal Transmit Clock Enable signal is deasserted.

1 = The internal Transmit Clock Enable signal is asserted. When this is asserted the serial data out is updated on the next system clock (MOSI or MISO).

### SPISTATE–SPI State Machine

Defines the current state of the internal SPI State Machine.

## SPI Baud Rate High and Low Byte Registers

The SPI Baud Rate High and Low Byte Registers combine to form a 16-bit reload value, BRG[15:0], for the SPI Baud Rate Generator. When configured as a general purpose timer, the interrupt interval is calculated using the following equation:

$$\text{Interrupt Interval (s)} = \text{System Clock Period (s)} \times \text{BRG}[15:0]$$

**Table 68. SPI Baud Rate High Byte Register (SPIBRH)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | BRH  |   |   |   |   |   |   |   |
| RESET | 1    |   |   |   |   |   |   |   |
| R/W   | R/W  |   |   |   |   |   |   |   |
| ADDR  | F66H |   |   |   |   |   |   |   |



**BRH = SPI Baud Rate High Byte**  
Most significant byte, BRG[15:8], of the SPI Baud Rate Generator’s reload value.

Table 69. SPI Baud Rate Low Byte Register (SPIBRL)

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | BRL  |   |   |   |   |   |   |   |
| RESET | 1    |   |   |   |   |   |   |   |
| R/W   | R/W  |   |   |   |   |   |   |   |
| ADDR  | F67H |   |   |   |   |   |   |   |

**BRL = SPI Baud Rate Low Byte**  
Least significant byte, BRG[7:0], of the SPI Baud Rate Generator’s reload value.

# I<sup>2</sup>C Controller

The I<sup>2</sup>C Controller makes the F0822 Series products bus-compatible with the I<sup>2</sup>C protocol. The I<sup>2</sup>C Controller consists of two bidirectional bus lines—a serial data signal (SDA) and a serial clock signal (SCL). Features of the I<sup>2</sup>C Controller include:

- Transmit and Receive Operation in MASTER mode.
- Maximum data rate of 400 kbit/s.
- 7-bit and 10-bit addressing modes for Slaves.
- Unrestricted number of data bytes transmitted per transfer.

The I<sup>2</sup>C Controller in the F0822 Series products does not operate in Slave mode.

## Architecture

Figure 25 displays the architecture of the I<sup>2</sup>C Controller.

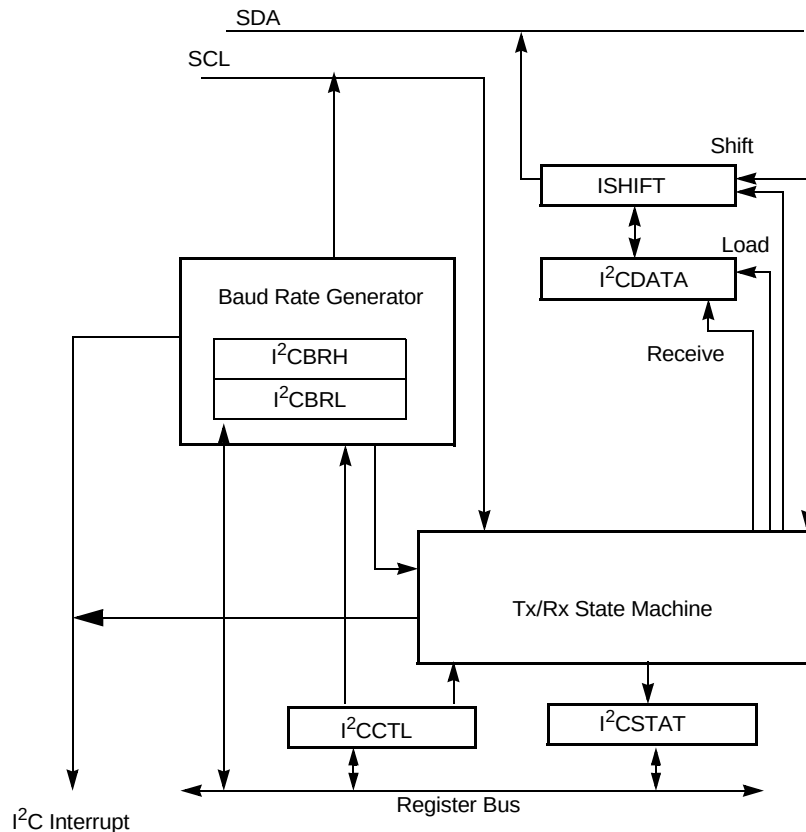


Figure 25. I<sup>2</sup>C Controller Block Diagram

## Operation

The I<sup>2</sup>C Controller operates in MASTER mode to transmit and receive data. Only a single master is supported. Arbitration between two masters must be accomplished in software. I<sup>2</sup>C supports the following operations:

- Master transmits to a 7-bit Slave
- Master transmits to a 10-bit Slave
- Master receives from a 7-bit Slave
- Master receives from a 10-bit Slave

## SDA and SCL Signals

I<sup>2</sup>C sends all addresses, data and acknowledge signals over the SDA line, most-significant bit first. SCL is the common clock for the I<sup>2</sup>C Controller. When the SDA and SCL pin alternate functions are selected for their respective GPIO ports, the pins are automatically configured for open-drain operation.

The master (I<sup>2</sup>C) is responsible for driving the SCL clock signal, although the clock signal becomes skewed by a slow slave device. During the low period of the clock, the slave pulls the SCL signal Low to suspend the transaction. The master releases the clock at the end of the low period and notices that the clock remains low instead of returning to a high level. When the slave releases the clock, the I<sup>2</sup>C Controller continues the transaction. All data is transferred in bytes and there is no limit to the amount of data transferred in one operation. When transmitting data or acknowledging read data from the slave, the SDA signal changes in the middle of the low period of SCL and is sampled in the middle of the high period of SCL.

## I<sup>2</sup>C Interrupts

The I<sup>2</sup>C Controller contains four sources of interrupts—Transmit, Receive, Not Acknowledge, and Baud Rate Generator. These four interrupt sources are combined into a single interrupt request signal to the interrupt controller. The Transmit Interrupt is enabled by the IEN and TXI bits of the control register. The Receive and Not Acknowledge interrupts are enabled by the IEN bit of the control register. BRG interrupt is enabled by the BIRQ and IEN bits of the control register.

Not Acknowledge interrupts occur when a Not Acknowledge condition is received from the slave or sent by the I<sup>2</sup>C Controller and neither the *START* or *STOP* bit is set. The Not Acknowledge event sets the NCKI bit of the I<sup>2</sup>C Status Register and can only be cleared by setting the *START* or *STOP* bit in the I<sup>2</sup>C Control Register. When this interrupt occurs, the I<sup>2</sup>C Controller waits until either the *STOP* or *START* bit is set before performing any action. In an ISR, the NCKI bit should always be checked prior to servicing transmit or receive interrupt conditions because it indicates the transaction is being terminated.

Receive interrupts occur when a byte of data has been received by the I<sup>2</sup>C Controller (Master reading data from Slave). This procedure sets the RDRF bit of the I<sup>2</sup>C Status Register. The RDRF bit is cleared by reading the I<sup>2</sup>C Data Register. The RDRF bit is set during the acknowledge phase. The I<sup>2</sup>C Controller pauses after the acknowledge phase until the receive interrupt is cleared before performing any other action.

Transmit interrupts occur when the TDRE bit of the I<sup>2</sup>C Status register sets and the TXI bit in the I<sup>2</sup>C Control Register is set. Transmit interrupts occur under the following conditions when the Transmit Data Register is empty:

- The I<sup>2</sup>C Controller is enabled
- The first bit of the byte of an address is shifting out and the RD bit of the I<sup>2</sup>C Status register is deasserted.
- The first bit of a 10-bit address shifts out.
- The first bit of write data shifts out.

► **Note:** *Writing to the I<sup>2</sup>C Data Register always clears the TRDE bit to 0. When TDRE is asserted, the I<sup>2</sup>C Controller pauses at the beginning of the Acknowledge cycle of the byte currently shifting out until the data register is written with the next value to send or the STOP or START bits are set indicating the current byte is the last one to send.*

The fourth interrupt source is the BRG. If the I<sup>2</sup>C Controller is disabled (IEN bit in the I2CCTL Register = 0) and the BIRQ bit in the I2CCTL Register = 1, an interrupt is generated when the BRG counts down to 1. This allows the I<sup>2</sup>C Baud Rate Generator to be used by software as a general purpose timer when IEN = 0.

## Software Control of I<sup>2</sup>C Transactions

Software controls I<sup>2</sup>C transactions by using the I<sup>2</sup>C Controller interrupt, by polling the I<sup>2</sup>C Status register or by DMA. Note that not all products include a DMA Controller.

To use interrupts, the I<sup>2</sup>C interrupt must be enabled in the Interrupt Controller. The TXI bit in the I<sup>2</sup>C Control Register must be set to enable transmit interrupts.

To control transactions by polling, the interrupt bits (TDRE, RDRF and NCKI) in the I<sup>2</sup>C Status Register should be polled. The TDRE bit asserts regardless of the state of the TXI bit.

Either or both transmit and receive data movement can be controlled by the DMA Controller. The DMA Controller channel(s) must be initialized to select the I<sup>2</sup>C transmit and receive requests. Transmit DMA requests require that the TXI bit in the I<sup>2</sup>C Control Register be set.



**Caution:** *A transmit (write) DMA operation hangs if the slave responds with a Not Acknowledge before the last byte has been sent. After receiving the Not Acknowledge, the I<sup>2</sup>C Controller sets the NCKI bit in the Status Register and pauses until either the STOP or*

*START bits in the Control Register are set.*

*In order for a receive (read) DMA transaction to send a Not Acknowledge on the last byte, the receive DMA must be set up to receive n-1 bytes, then software must set the NAK bit and receive the last (nth) byte directly.*

## Start and Stop Conditions

The Master (I<sup>2</sup>C) drives all Start and Stop signals and initiates all transactions. To start a transaction, the I<sup>2</sup>C Controller generates a START condition by pulling the SDA signal Low while SCL is High. To complete a transaction, the I<sup>2</sup>C Controller generates a Stop condition by creating a low-to-high transition of the SDA signal while the SCL signal is high. The START and STOP bits in the I<sup>2</sup>C Control Register control the sending of the Start and Stop conditions. A Master is also allowed to end one transaction and begin a new one by issuing a Restart. This is accomplished by setting the START bit at the end of a transaction, rather than the STOP bit.

► **Note:** *The Start condition not sent until the START bit is set and data has been written to the I<sup>2</sup>C Data Register.*

## Master Write and Read Transactions

The following sections provide a recommended procedure for performing I<sup>2</sup>C write and read transactions from the I<sup>2</sup>C Controller (Master) to slave I<sup>2</sup>C devices. In general software should rely on the TDRE, RDRF and NCKI bits of the status register (these bits generate interrupts) to initiate software actions. When using interrupts or DMA, the TXI bit is set to start each transaction and cleared at the end of each transaction to eliminate a 'trailing' Transmit Interrupt.

Caution should be used in using the ACK status bit within a transaction because it is difficult for software to tell when it is updated by hardware.

When writing data to a slave, the I<sup>2</sup>C pauses at the beginning of the Acknowledge cycle if the data register has not been written with the next value to be sent (TDRE bit in the I<sup>2</sup>C Status register equal to 1). In this scenario where software is not keeping up with the I<sup>2</sup>C bus (TDRE asserted longer than one byte time), the Acknowledge clock cycle for byte n is delayed until the data register is written with byte n + 1, and appears to be grouped with the data clock cycles for byte n + 1. If either the START or STOP bit is set, the I<sup>2</sup>C does not pause prior to the Acknowledge cycle because no additional data is sent.

When a Not Acknowledge condition is received during a write (either during the address or data phases), the I<sup>2</sup>C Controller generates the Not Acknowledge interrupt (NCKI = 1) and pause until either the STOP or START bit is set. Unless the Not Acknowledge was received on the last byte, the data register will already have been written with the next address or data byte to send. In this case the FLUSH bit of the control register should be set at the same time the STOP or START bit is set to remove the stale transmit data and enable subsequent Transmit Interrupts.

When reading data from the slave, the I<sup>2</sup>C pauses after the data Acknowledge cycle until the receive interrupt is serviced and the RDRF bit of the status register is cleared by reading the I<sup>2</sup>C Data Register. Once the I<sup>2</sup>C Data Register has been read, the I<sup>2</sup>C reads the next data byte.

### Address Only Transaction with a 7-bit Address

In the situation where software determines if a slave with a 7-bit address is responding without sending or receiving data, a transaction can be done which only consists of an address phase. Figure 26 on page 131 displays this “address only” transaction to determine if a slave with a 7-bit address will acknowledge. As an example, this transaction can be used after a “write” has been done to a EEPROM to determine when the EEPROM completes its internal write operation and is once again responding to I<sup>2</sup>C transactions. If the slave does not Acknowledge, the transaction is repeated until the slave does Acknowledge.

|   |               |       |                  |   |
|---|---------------|-------|------------------|---|
| S | Slave Address | W = 0 | A/A <sup>̄</sup> | P |
|---|---------------|-------|------------------|---|

Figure 26. 7-Bit Address Only Transaction Format

Follow the steps below for an address only transaction to a 7-bit addressed slave:

1. Software asserts the IEN bit in the I<sup>2</sup>C Control Register.
2. Software asserts the TXI bit of the I<sup>2</sup>C Control Register to enable Transmit interrupts.
3. The I<sup>2</sup>C interrupt asserts, because the I<sup>2</sup>C Data Register is empty (TDRE = 1)
4. Software responds to the TDRE bit by writing a 7-bit Slave address plus write bit (=0) to the I<sup>2</sup>C Data Register. As an alternative this could be a read operation instead of a write operation.
5. Software sets the START and STOP bits of the I<sup>2</sup>C Control Register and clears the TXI bit.
6. The I<sup>2</sup>C Controller sends the START condition to the I<sup>2</sup>C Slave.
7. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register.
8. Software polls the STOP bit of the I<sup>2</sup>C Control Register. Hardware deasserts the STOP bit when the address only transaction is completed.
9. Software checks the ACK bit of the I<sup>2</sup>C Status Register. If the slave acknowledged, the ACK bit is equal to 1. If the slave does not acknowledge, the ACK bit is equal to 0. The NCKI interrupt does not occur in the not acknowledge case because the STOP bit was set.

## Write Transaction with a 7-Bit Address

Figure 27 displays the data transfer format for a 7-bit addressed slave. Shaded regions indicate data transferred from the I<sup>2</sup>C Controller to slaves and unshaded regions indicate data transferred from the slaves to the I<sup>2</sup>C Controller.

|   |               |       |   |      |   |      |   |      |                  |     |
|---|---------------|-------|---|------|---|------|---|------|------------------|-----|
| S | Slave Address | W = 0 | A | Data | A | Data | A | Data | $\overline{A/A}$ | P/S |
|---|---------------|-------|---|------|---|------|---|------|------------------|-----|

**Figure 27. 7-Bit Addressed Slave Data Transfer Format**

Follow the steps below for a transmit operation to a 7-bit addressed slave:

1. Software asserts the IEN bit in the I<sup>2</sup>C Control Register.
2. Software asserts the TXI bit of the I<sup>2</sup>C Control Register to enable Transmit Interrupts.
3. The I<sup>2</sup>C interrupt asserts, because the I<sup>2</sup>C Data Register is empty.
4. Software responds to the TDRE bit by writing a 7-bit Slave address plus write bit (=0) to the I<sup>2</sup>C Data Register.
5. Software asserts the START bit of the I<sup>2</sup>C Control Register.
6. The I<sup>2</sup>C Controller sends the START condition to the I<sup>2</sup>C Slave.
7. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register.
8. After one bit of address has been shifted out by the SDA signal, the Transmit Interrupt is asserted (TDRE = 1).
9. Software responds by writing the transmit data into the I<sup>2</sup>C Data Register.
10. The I<sup>2</sup>C Controller shifts the rest of the address and write bit out by the SDA signal.
11. If the I<sup>2</sup>C Slave sends an acknowledge (by pulling the SDA signal low) during the next high period of SCL the I<sup>2</sup>C Controller sets the ACK bit in the I<sup>2</sup>C Status register. Continue with [step 12](#).

If the slave does not acknowledge, the Not Acknowledge interrupt occurs (NCKI bit is set in the Status register, ACK bit is cleared). Software responds to the Not Acknowledge interrupt by setting the STOP and FLUSH bits and clearing the TXI bit. The I<sup>2</sup>C Controller sends the STOP condition on the bus and clears the STOP and NCKI bits. The transaction is complete (ignore following steps).

12. The I<sup>2</sup>C Controller loads the contents of the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register.
13. The I<sup>2</sup>C Controller shifts the data out of using the SDA signal. After the first bit is sent, the Transmit Interrupt is asserted.

14. If more bytes remain to be sent, return to [step 9](#).
15. Software responds by setting the STOP bit of the I<sup>2</sup>C Control Register (or START bit to initiate a new transaction). In the STOP case, software clears the TXI bit of the I<sup>2</sup>C Control Register at the same time.
16. The I<sup>2</sup>C Controller completes transmission of the data on the SDA signal.
17. The slave can either Acknowledge or Not Acknowledge the last byte. Because either the STOP or START bit is already set, the NCKI interrupt does not occur.
18. The I<sup>2</sup>C Controller sends the STOP (or RESTART) condition to the I<sup>2</sup>C bus. The STOP or START bit is cleared.

### Address Only Transaction with a 10-bit Address

In the situation where software wants to determine if a slave with a 10-bit address is responding without sending or receiving data, a transaction is done which only consists of an address phase. [Figure 28](#) displays this “address only” transaction to determine if a slave with 10-bit address will acknowledge. As an example, this transaction is used after a “write” has been done to a EEPROM to determine when the EEPROM completes its internal write operation and is once again responding to I<sup>2</sup>C transactions. If the slave does not Acknowledge the transaction is repeated until the slave is able to Acknowledge.

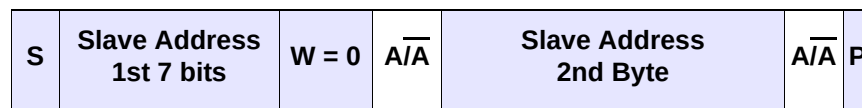


**Figure 28. 10-Bit Address Only Transaction Format**

Follow the steps below for an address only transaction to a 10-bit addressed slave:

1. Software asserts the IEN bit in the I<sup>2</sup>C Control Register.
2. Software asserts the TXI bit of the I<sup>2</sup>C Control Register to enable Transmit interrupts.
3. The I<sup>2</sup>C interrupt asserts, because the I<sup>2</sup>C Data Register is empty (TDRE = 1)
4. Software responds to the TDRE interrupt by writing the first slave address byte. The least-significant bit must be 0 for the write operation.
5. Software asserts the START bit of the I<sup>2</sup>C Control Register.
6. The I<sup>2</sup>C Controller sends the START condition to the I<sup>2</sup>C Slave.
7. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register.
8. After one bit of address is shifted out by the SDA signal, the Transmit Interrupt is asserted.

9. Software responds by writing the second byte of address into the contents of the I<sup>2</sup>C Data Register.
10. The I<sup>2</sup>C Controller shifts the rest of the first byte of address and write bit out the SDA signal.
11. If the I<sup>2</sup>C Slave sends an acknowledge by pulling the SDA signal low during the next high period of SCL the I<sup>2</sup>C Controller sets the ACK bit in the I<sup>2</sup>C Status register. Continue with [step 12](#).

If the slave does not acknowledge the first address byte, the I<sup>2</sup>C Controller sets the NCKI bit and clears the ACK bit in the I<sup>2</sup>C Status register. Software response to the Not Acknowledge interrupt by setting the STOP and FLUSH bits and clearing the TXI bit. The I<sup>2</sup>C Controller sends the STOP condition on the bus and clears the STOP and NCKI bits. The transaction is complete (ignore following steps).

12. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register (2nd byte of address).
13. The I<sup>2</sup>C Controller shifts the second address byte out the SDA signal. After the first bit has been sent, the Transmit Interrupt is asserted.
14. Software responds by setting the STOP bit in the I<sup>2</sup>C Control Register. The TXI bit can be cleared at the same time.
15. Software polls the STOP bit of the I<sup>2</sup>C Control Register. Hardware deasserts the STOP bit when the transaction is completed (STOP condition has been sent).
16. Software checks the ACK bit of the I<sup>2</sup>C Status register. If the slave acknowledged, the ACK bit is equal to 1. If the slave does not acknowledge, the ACK bit is equal to 0. The NCKI interrupt do not occur because the STOP bit was set.

### Write Transaction with a 10-Bit Address

[Figure 29](#) displays the data transfer format for a 10-bit addressed slave. Shaded regions indicate data transferred from the I<sup>2</sup>C Controller to slaves and unshaded regions indicate data transferred from the slaves to the I<sup>2</sup>C Controller.

|   |                             |       |   |                           |   |      |   |      |     |     |
|---|-----------------------------|-------|---|---------------------------|---|------|---|------|-----|-----|
| S | Slave Address<br>1st 7 bits | W = 0 | A | Slave Address<br>2nd Byte | A | Data | A | Data | A/A | P/S |
|---|-----------------------------|-------|---|---------------------------|---|------|---|------|-----|-----|

**Figure 29. 10-Bit Addressed Slave Data Transfer Format**

The first seven bits transmitted in the first byte are 11110XX. The two bits XX are the two most-significant bits of the 10-bit address. The lowest bit of the first byte transferred is the read/write control bit (=0). The transmit operation is carried out in the same manner as 7-bit addressing.

Follow the steps below for a transmit operation on a 10-bit addressed slave:

1. Software asserts the IEN bit in the I<sup>2</sup>C Control Register.
2. Software asserts the TXI bit of the I<sup>2</sup>C Control Register to enable Transmit interrupts.
3. The I<sup>2</sup>C interrupt asserts because the I<sup>2</sup>C Data Register is empty.
4. Software responds to the TDRE interrupt by writing the first slave address byte to the I<sup>2</sup>C Data Register. The least-significant bit must be 0 for the write operation.
5. Software asserts the START bit of the I<sup>2</sup>C Control Register.
6. The I<sup>2</sup>C Controller sends the START condition to the I<sup>2</sup>C Slave.
7. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register.
8. After one bit of address is shifted out by the SDA signal, the Transmit Interrupt is asserted.
9. Software responds by writing the second byte of address into the contents of the I<sup>2</sup>C Data Register.
10. The I<sup>2</sup>C Controller shifts the rest of the first byte of address and write bit out the SDA signal.
11. If the I<sup>2</sup>C Slave acknowledges the first address byte by pulling the SDA signal low during the next high period of SCL, the I<sup>2</sup>C Controller sets the ACK bit in the I<sup>2</sup>C Status register. Continue with [step 12](#).

If the slave does not acknowledge the first address byte, the I<sup>2</sup>C Controller sets the NCKI bit and clears the ACK bit in the I<sup>2</sup>C Status register. Software responds to the Not Acknowledge interrupt by setting the STOP and FLUSH bits and clearing the TXI bit. The I<sup>2</sup>C Controller sends the STOP condition on the bus and clears the STOP and NCKI bits. The transaction is complete (ignore the following steps).

12. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register.
13. The I<sup>2</sup>C Controller shifts the second address byte out the SDA signal. After the first bit has been sent, the Transmit Interrupt is asserted.
14. Software responds by writing a data byte to the I<sup>2</sup>C Data Register.
15. The I<sup>2</sup>C Controller completes shifting the contents of the shift register on the SDA signal.
16. If the I<sup>2</sup>C Slave sends an acknowledge by pulling the SDA signal low during the next high period of SCL, the I<sup>2</sup>C Controller sets the ACK bit in the I<sup>2</sup>C Status register. Continue with [step 17](#).

If the slave does not acknowledge the second address byte or one of the data bytes, the

I<sup>2</sup>C Controller sets the NCKI bit and clears the ACK bit in the I<sup>2</sup>C Status register. Software responds to the Not Acknowledge interrupt by setting the STOP and FLUSH bits and clearing the TXI bit. The I<sup>2</sup>C Controller sends the STOP condition on the bus and clears the STOP and NCKI bits. The transaction is complete (ignore the following steps).

17. The I<sup>2</sup>C Controller shifts the data out by the SDA signal. After the first bit is sent, the Transmit Interrupt is asserted.
18. If more bytes remain to be sent, return to [step 14](#).
19. If the last byte is currently being sent, software sets the STOP bit of the I<sup>2</sup>C Control Register (or START bit to initiate a new transaction). In the STOP case, software also clears the TXI bit of the I<sup>2</sup>C Control Register at the same time.
20. The I<sup>2</sup>C Controller completes transmission of the last data byte on the SDA signal.
21. The slave can either Acknowledge or Not Acknowledge the last byte. Because either the STOP or START bit is already set, the NCKI interrupt does not occur.
22. The I<sup>2</sup>C Controller sends the STOP (or RESTART) condition to the I<sup>2</sup>C bus and clears the STOP (or START) bit.

### Read Transaction with a 7-Bit Address

[Figure 30](#) displays the data transfer format for a read operation to a 7-bit addressed slave. The shaded regions indicate data transferred from the I<sup>2</sup>C Controller to slaves and unshaded regions indicate data transferred from the slaves to the I<sup>2</sup>C Controller.

|   |               |       |   |      |   |      |           |     |
|---|---------------|-------|---|------|---|------|-----------|-----|
| S | Slave Address | R = 1 | A | Data | A | Data | $\bar{A}$ | P/S |
|---|---------------|-------|---|------|---|------|-----------|-----|

**Figure 30. Receive Data Transfer Format for a 7-Bit Addressed Slave**

Follow the steps below for a read operation to a 7-bit addressed slave:

1. Software writes the I<sup>2</sup>C Data Register with a 7-bit Slave address plus the read bit (=1).
2. Software asserts the START bit of the I<sup>2</sup>C Control Register.
3. If this is a single byte transfer, Software asserts the NAK bit of the I<sup>2</sup>C Control Register so that after the first byte of data has been read by the I<sup>2</sup>C Controller, a Not Acknowledge is sent to the I<sup>2</sup>C Slave.
4. The I<sup>2</sup>C Controller sends the START condition.
5. The I<sup>2</sup>C Controller shifts the address and read bit out the SDA signal.
6. If the I<sup>2</sup>C Slave acknowledges the address by pulling the SDA signal Low during the next high period of SCL, the I<sup>2</sup>C Controller sets the ACK bit in the I<sup>2</sup>C Status register. Continue with [step 7](#).

If the slave does not acknowledge, the Not Acknowledge interrupt occurs (NCKI bit is set in the Status register, ACK bit is cleared). Software responds to the Not Acknowledge interrupt by setting the STOP bit and clearing the TXI bit. The I<sup>2</sup>C Controller sends the STOP condition on the bus and clears the STOP and NCKI bits. The transaction is complete (ignore the following steps).

7. The I<sup>2</sup>C Controller shifts in the byte of data from the I<sup>2</sup>C Slave on the SDA signal. The I<sup>2</sup>C Controller sends a Not Acknowledge to the I<sup>2</sup>C Slave if the NAK bit is set (last byte), else it sends an Acknowledge.
8. The I<sup>2</sup>C Controller asserts the Receive interrupt (RDRF bit set in the Status register).
9. Software responds by reading the I<sup>2</sup>C Data Register which clears the RDRF bit. If there is only one more byte to receive, set the NAK bit of the I<sup>2</sup>C Control Register.
10. If there are more bytes to transfer, return to Step 7.
11. After the last byte is shifted in, a Not Acknowledge interrupt is generated by the I<sup>2</sup>C Controller.
12. Software responds by setting the STOP bit of the I<sup>2</sup>C Control Register.
13. A STOP condition is sent to the I<sup>2</sup>C Slave, the STOP and NCKI bits are cleared.

### Read Transaction with a 10-Bit Address

Figure 31 displays the read transaction format for a 10-bit addressed slave. The shaded regions indicate data transferred from the I<sup>2</sup>C Controller to slaves and unshaded regions indicate data transferred from the slaves to the I<sup>2</sup>C Controller.

|   |                             |     |   |                           |   |   |                             |     |   |      |   |      |           |   |
|---|-----------------------------|-----|---|---------------------------|---|---|-----------------------------|-----|---|------|---|------|-----------|---|
| S | Slave Address<br>1st 7 bits | W=0 | A | Slave Address<br>2nd Byte | A | S | Slave Address<br>1st 7 bits | R=1 | A | Data | A | Data | $\bar{A}$ | P |
|---|-----------------------------|-----|---|---------------------------|---|---|-----------------------------|-----|---|------|---|------|-----------|---|

**Figure 31. Receive Data Format for a 10-Bit Addressed Slave**

The first seven bits transmitted in the first byte are 11110XX. The two bits XX are the two most-significant bits of the 10-bit address. The lowest bit of the first byte transferred is the write control bit.

Follow the steps below for the data transfer procedure for a read operation to a 10-bit addressed slave:

1. Software writes 11110B followed by the two address bits and a 0 (write) to the I<sup>2</sup>C Data Register.
2. Software asserts the START and TXI bits of the I<sup>2</sup>C Control Register.
3. The I<sup>2</sup>C Controller sends the Start condition.
4. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register.

5. After the first bit has been shifted out, a Transmit Interrupt is asserted.
6. Software responds by writing the lower eight bits of address to the I<sup>2</sup>C Data Register.
7. The I<sup>2</sup>C Controller completes shifting of the two address bits and a 0 (write).
8. If the I<sup>2</sup>C Slave acknowledges the first address byte by pulling the SDA signal low during the next high period of SCL, the I<sup>2</sup>C Controller sets the ACK bit in the I<sup>2</sup>C Status register. Continue with [step 9](#).

If the slave does not acknowledge the first address byte, the I<sup>2</sup>C Controller sets the NCKI bit and clears the ACK bit in the I<sup>2</sup>C Status register. Software responds to the Not Acknowledge interrupt by setting the STOP and FLUSH bits and clearing the TXI bit. The I<sup>2</sup>C Controller sends the STOP condition on the bus and clears the STOP and NCKI bits. The transaction is complete (ignore following steps).

9. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register (second address byte).
10. The I<sup>2</sup>C Controller shifts out the second address byte. After the first bit is shifted, the I<sup>2</sup>C Controller generates a Transmit Interrupt.
11. Software responds by setting the START bit of the I<sup>2</sup>C Control Register to generate a repeated START and by clearing the TXI bit.
12. Software responds by writing 11110B followed by the 2-bit Slave address and a 1 (read) to the I<sup>2</sup>C Data Register.
13. If only one byte is to be read, software sets the NAK bit of the I<sup>2</sup>C Control Register.
14. After the I<sup>2</sup>C Controller shifts out the 2nd address byte, the I<sup>2</sup>C Slave sends an acknowledge by pulling the SDA signal low during the next high period of SCL, the I<sup>2</sup>C Controller sets the ACK bit in the I<sup>2</sup>C Status register. Continue with step 15.

If the slave does not acknowledge the second address byte, the I<sup>2</sup>C Controller sets the NCKI bit and clears the ACK bit in the I<sup>2</sup>C Status register. Software responds to the Not Acknowledge interrupt by setting the STOP and FLUSH bits and clearing the TXI bit. The I<sup>2</sup>C Controller sends the STOP condition on the bus and clears the STOP and NCKI bits. The transaction is complete (ignore the following steps).

15. The I<sup>2</sup>C Controller sends the repeated START condition.
16. The I<sup>2</sup>C Controller loads the I<sup>2</sup>C Shift register with the contents of the I<sup>2</sup>C Data Register (third address transfer).
17. The I<sup>2</sup>C Controller sends 11110B followed by the two most significant bits of the slave read address and a 1 (read).
18. The I<sup>2</sup>C Slave sends an acknowledge by pulling the SDA signal Low during the next high period of SCL.

If the slave were to Not Acknowledge at this point (this should not happen because the slave did acknowledge the first two address bytes), software would respond by setting the STOP and FLUSH bits and clearing the TXI bit. The I<sup>2</sup>C Controller sends the

STOP condition on the bus and clears the STOP and NCKI bits. The transaction is complete (ignore the following steps).

19. The I<sup>2</sup>C Controller shifts in a byte of data from the I<sup>2</sup>C Slave on the SDA signal. The I<sup>2</sup>C Controller sends a Not Acknowledge to the I<sup>2</sup>C Slave if the NAK bit is set (last byte), else it sends an Acknowledge.
20. The I<sup>2</sup>C Controller asserts the Receive interrupt (RDRF bit set in the Status register).
21. Software responds by reading the I<sup>2</sup>C Data Register which clears the RDRF bit. If there is only one more byte to receive, set the NAK bit of the I<sup>2</sup>C Control Register.
22. If there are one or more bytes to transfer, return to [step 19](#).
23. After the last byte is shifted in, a Not Acknowledge interrupt is generated by the I<sup>2</sup>C Controller.
24. Software responds by setting the STOP bit of the I<sup>2</sup>C Control Register.
25. A STOP condition is sent to the I<sup>2</sup>C Slave and the STOP and NCKI bits are cleared.

## I<sup>2</sup>C Control Register Definitions

### I<sup>2</sup>C Data Register

The I<sup>2</sup>C Data Register ([Table 70](#)) holds the data that is to be loaded into the I<sup>2</sup>C Shift register during a write to a slave. This register also holds data that is loaded from the I<sup>2</sup>C Shift register during a read from a slave. The I<sup>2</sup>C Shift Register is not accessible in the Register File address space, but is used only to buffer incoming and outgoing data.

**Table 70. I<sup>2</sup>C Data Register (I2CDATA)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | DATA |   |   |   |   |   |   |   |
| RESET | 0    |   |   |   |   |   |   |   |
| R/W   | R/W  |   |   |   |   |   |   |   |
| ADDR  | F50H |   |   |   |   |   |   |   |

## I<sup>2</sup>C Status Register

The Read-only I<sup>2</sup>C Status register (Table 71) indicates the status of the I<sup>2</sup>C Controller.

**Table 71. I<sup>2</sup>C Status Register (I2CSTAT)**

| BITS  | 7    | 6    | 5   | 4   | 3  | 2   | 1   | 0    |
|-------|------|------|-----|-----|----|-----|-----|------|
| FIELD | TDRE | RDRF | ACK | 10B | RD | TAS | DSS | NCKI |
| RESET | 1    | 0    |     |     |    |     |     |      |
| R/W   | R    |      |     |     |    |     |     |      |
| ADDR  | F51H |      |     |     |    |     |     |      |

### TDRE—Transmit Data Register Empty

When the I<sup>2</sup>C Controller is enabled, this bit is 1 when the I<sup>2</sup>C Data Register is empty. When this bit is set, an interrupt is generated if the TXI bit is set, except when the I<sup>2</sup>C Controller is shifting in data during the reception of a byte or when shifting an address and the RD bit is set. This bit is cleared by writing to the I2CDATA register.

### RDRF—Receive Data Register Full

This bit is set = 1 when the I<sup>2</sup>C Controller is enabled and the I<sup>2</sup>C Controller has received a byte of data. When asserted, this bit causes the I<sup>2</sup>C Controller to generate an interrupt. This bit is cleared by reading the I<sup>2</sup>C Data Register (unless the read is performed using execution of the OCD's Read Register command).

### ACK—Acknowledge

This bit indicates the status of the Acknowledge for the last byte transmitted or received. When set, this bit indicates that an Acknowledge occurred for the last byte transmitted or received. This bit is cleared when IEN = 0 or when a Not Acknowledge occurred for the last byte transmitted or received. It is not reset at the beginning of each transaction and is not reset when this register is read.



**Caution:** Software must be cautious in making decisions based on this bit within a transaction because software cannot tell when the bit is updated by hardware. In the case of write transactions, the I<sup>2</sup>C pauses at the beginning of the Acknowledge cycle if the next transmit data or address byte has not been written (TDRE = 1) and STOP and START = 0. In this case the ACK bit is not updated until the transmit interrupt is serviced and the Acknowledge cycle for the previous byte completes. For examples on usage of the ACK bit, see [Address Only Transaction with a 7-bit Address](#) on page 131 and [Address Only Transaction with a 10-bit Address](#) on page 133.

### 10B—10-Bit Address

This bit indicates whether a 10-bit or 7-bit address is being transmitted. After the START bit is set, if the five most-significant bits of the address are 11110B, this bit is set. When set, it is reset once the first byte of the address has been sent.

**RD—Read**

This bit indicates the direction of transfer of the data. It is active High during a read. The status of this bit is determined by the least-significant bit of the I<sup>2</sup>C Shift register after the START bit is set.

**TAS—Transmit Address State**

This bit is active High while the address is being shifted out of the I<sup>2</sup>C Shift Register.

**DSS—Data Shift State**

This bit is active High while data is being shifted to or from the I<sup>2</sup>C Shift Register.

**NCKI—NACK Interrupt**

This bit is set high when a Not Acknowledge condition is received or sent and neither the START nor the STOP bit is active. When set, this bit generates an interrupt that can only be cleared by setting the START or STOP bit, allowing you to specify whether you want to perform a STOP or a repeated START.

**I<sup>2</sup>C Control Register**

The I<sup>2</sup>C Control Register (Table 72) enables the I<sup>2</sup>C operation.

**Table 72. I<sup>2</sup>C Control Register (I2CCTL)**

| BITS  | 7    | 6     | 5    | 4    | 3   | 2    | 1     | 0      |
|-------|------|-------|------|------|-----|------|-------|--------|
| FIELD | IEN  | START | STOP | BIRQ | TXI | NAK  | FLUSH | FILTEN |
| RESET | 0    |       |      |      |     |      |       |        |
| R/W   | R/W  | R/W1  | R/W1 | R/W  | R/W | R/W1 | W1    | R/W    |
| ADDR  | F52H |       |      |      |     |      |       |        |

**IEN—I<sup>2</sup>C Enable**

1 = The I<sup>2</sup>C transmitter and receiver are enabled.

0 = The I<sup>2</sup>C transmitter and receiver are disabled.

**START—Send Start Condition**

This bit sends the Start condition. Once asserted, it is cleared by the I<sup>2</sup>C Controller after it sends the START condition or if the IEN bit is deasserted. If this bit is 1, it cannot be cleared to 0 by writing to the register. After this bit is set, the Start condition is sent if there is data in the I<sup>2</sup>C Data or I<sup>2</sup>C Shift register. If there is no data in one of these registers, the I<sup>2</sup>C Controller waits until the data register is written. If this bit is set while the I<sup>2</sup>C Controller is shifting out data, it generates a START condition after the byte shifts and the acknowledge phase completes. If the STOP bit is also set, it also waits until the STOP condition is sent before sending the START condition.

**STOP—Send Stop Condition**

This bit causes the I<sup>2</sup>C Controller to issue a STOP condition after the byte in the I<sup>2</sup>C Shift register has completed transmission or after a byte is received in a receive operation. Once

set, this bit is reset by the I<sup>2</sup>C Controller after a STOP condition is sent or by deasserting the IEN bit. If this bit is 1, it cannot be cleared to 0 by writing to the register.

**BIRQ—Baud Rate Generator Interrupt Request**

This bit allows the I<sup>2</sup>C Controller to be used as an additional timer when the I<sup>2</sup>C Controller is disabled. This bit is ignored when the I<sup>2</sup>C Controller is enabled.

1 = An interrupt occurs every time the BRG counts down to one.

0 = No BRG interrupt occurs.

**TXI—Enable TDRE interrupts**

This bit enables the transmit interrupt when the I<sup>2</sup>C Data Register is empty (TDRE = 1).

1 = Transmit Interrupt (and DMA transmit request) is enabled.

0 = Transmit Interrupt (and DMA transmit request) is disabled.

**NAK—Send NAK**

This bit sends a Not Acknowledge condition after the next byte of data is read from the I<sup>2</sup>C Slave. Once asserted, it is deasserted after a Not Acknowledge is sent or the IEN bit is deasserted. If this bit is 1, it cannot be cleared to 0 by writing to the register.

**FLUSH—Flush Data**

Setting this bit to 1 clears the I<sup>2</sup>C Data Register and sets the TDRE bit to 1. This bit allows flushing of the I<sup>2</sup>C Data Register when a Not Acknowledge interrupt is received after the data has been sent to the I<sup>2</sup>C Data Register. Reading this bit always returns 0.

**FILTEN—I<sup>2</sup>C Signal Filter Enable**

This bit enables low-pass digital filters on the SDA and SCL input signals. These filters reject any input pulse with periods less than a full system clock cycle. The filters introduce a 3-system clock cycle latency on the inputs.

1 = low-pass filters are enabled.

0 = low-pass filters are disabled.

## I<sup>2</sup>C Baud Rate High and Low Byte Registers

The I<sup>2</sup>C Baud Rate High and Low Byte registers (Tables 73 and 73) combine to form a 16-bit reload value, BRG[15:0], for the I<sup>2</sup>C Baud Rate Generator. When configured as a general purpose timer, the interrupt interval is calculated using the following equation:

$$\text{Interrupt Interval (s)} = \text{System Clock Period (s)} \times \text{BRG}[15:0]$$

**Table 73. I<sup>2</sup>C Baud Rate High Byte Register (I2CBRH)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | BRH  |   |   |   |   |   |   |   |
| RESET | FFH  |   |   |   |   |   |   |   |
| R/W   | R/W  |   |   |   |   |   |   |   |
| ADDR  | F53H |   |   |   |   |   |   |   |

### BRH = I<sup>2</sup>C Baud Rate High Byte

Most significant byte, BRG[15:8], of the I<sup>2</sup>C Baud Rate Generator's reload value.

► **Note:** If the DIAG bit in the I<sup>2</sup>C Diagnostic Control Register is set to 1, a read of the I2CBRH register returns the current value of the I<sup>2</sup>C Baud Rate Counter[15:8].

**Table 74. I<sup>2</sup>C Baud Rate Low Byte Register (I2CBRL)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | BRL  |   |   |   |   |   |   |   |
| RESET | FFH  |   |   |   |   |   |   |   |
| R/W   | R/W  |   |   |   |   |   |   |   |
| ADDR  | F54H |   |   |   |   |   |   |   |

### BRL = I<sup>2</sup>C Baud Rate Low Byte

Least significant byte, BRG[7:0], of the I<sup>2</sup>C Baud Rate Generator's reload value.

► **Note:** If the DIAG bit in the I<sup>2</sup>C Diagnostic Control Register is set to 1, a read of the I2CBRL register returns the current value of the I<sup>2</sup>C Baud Rate Counter [7:0].

## I<sup>2</sup>C Diagnostic State Register

The I<sup>2</sup>C Diagnostic State register (Table 75) provides observability of internal state. This is a read only register used for I<sup>2</sup>C diagnostics and manufacturing test.

Table 75. I<sup>2</sup>C Diagnostic State Register (I2CDST)

| BITS  | 7     | 6     | 5      | 4         | 3 | 2 | 1 | 0 |
|-------|-------|-------|--------|-----------|---|---|---|---|
| FIELD | SCLIN | SDAIN | STPCNT | TXRXSTATE |   |   |   |   |
| RESET | X     |       | 0      |           |   |   |   |   |
| R/W   | R     |       |        |           |   |   |   |   |
| ADDR  | F55H  |       |        |           |   |   |   |   |

**SCLIN**—Value of Serial Clock input signal

**SDAIN**—Value of the Serial Data input signal

**STPCNT**—Value of the internal Stop Count control signal

**TXRXSTATE**—Value of the internal I<sup>2</sup>C state machine

| TXRXSTATE | State Description                                                                                                                       |
|-----------|-----------------------------------------------------------------------------------------------------------------------------------------|
| 0_0000    | Idle State                                                                                                                              |
| 0_0001    | START State                                                                                                                             |
| 0_0010    | Send/Receive data bit 7                                                                                                                 |
| 0_0011    | Send/Receive data bit 6                                                                                                                 |
| 0_0100    | Send/Receive data bit 5                                                                                                                 |
| 0_0101    | Send/Receive data bit 4                                                                                                                 |
| 0_0110    | Send/Receive data bit 3                                                                                                                 |
| 0_0111    | Send/Receive data bit 2                                                                                                                 |
| 0_1000    | Send/Receive data bit 1                                                                                                                 |
| 0_1001    | Send/Receive data bit 0                                                                                                                 |
| 0_1010    | Data Acknowledge State                                                                                                                  |
| 0_1011    | Second half of data Acknowledge State used only for not acknowledge                                                                     |
| 0_1100    | First part of STOP state                                                                                                                |
| 0_1101    | Second part of STOP state                                                                                                               |
| 0_1110    | 10-bit addressing: Acknowledge State for 2nd address byte<br>7-bit addressing: Address Acknowledge State                                |
| 0_1111    | 10-bit address: Bit 0 (Least significant bit) of 2nd address byte<br>7-bit address: Bit 0 (Least significant bit) (R/W) of address byte |
| 1_0000    | 10-bit addressing: Bit 7 (Most significant bit) of 1st address byte                                                                     |
| 1_0001    | 10-bit addressing: Bit 6 of 1st address byte                                                                                            |
| 1_0010    | 10-bit addressing: Bit 5 of 1st address byte                                                                                            |
| 1_0011    | 10-bit addressing: Bit 4 of 1st address byte                                                                                            |
| 1_0100    | 10-bit addressing: Bit 3 of 1st address byte                                                                                            |
| 1_0101    | 10-bit addressing: Bit 2 of 1st address byte                                                                                            |
| 1_0110    | 10-bit addressing: Bit 1 of 1st address byte                                                                                            |

| TXRXSTATE | State Description                                                                       |
|-----------|-----------------------------------------------------------------------------------------|
| 1_0111    | 10-bit addressing: Bit 0 (R/W) of 1st address byte                                      |
| 1_1000    | 10-bit addressing: Acknowledge state for 1st address byte                               |
| 1_1001    | 10-bit addressing: Bit 7 of 2nd address byte<br>7-bit addressing: Bit 7 of address byte |
| 1_1010    | 10-bit addressing: Bit 6 of 2nd address byte<br>7-bit addressing: Bit 6 of address byte |
| 1_1011    | 10-bit addressing: Bit 5 of 2nd address byte<br>7-bit addressing: Bit 5 of address byte |
| 1_1100    | 10-bit addressing: Bit 4 of 2nd address byte<br>7-bit addressing: Bit 4 of address byte |
| 1_1101    | 10-bit addressing: Bit 3 of 2nd address byte<br>7-bit addressing: Bit 3 of address byte |
| 1_1110    | 10-bit addressing: Bit 2 of 2nd address byte<br>7-bit addressing: Bit 2 of address byte |
| 1_1111    | 10-bit addressing: Bit 1 of 2nd address byte<br>7-bit addressing: Bit 1 of address byte |

## I<sup>2</sup>C Diagnostic Control Register

The I<sup>2</sup>C Diagnostic register ([Table 76](#)) provides control over diagnostic modes. This register is a read/write register used for I<sup>2</sup>C diagnostics.

**Table 76. I<sup>2</sup>C Diagnostic Control Register (I2CDIAG)**

| BITS  | 7        | 6 | 5 | 4 | 3 | 2 | 1 | 0    |
|-------|----------|---|---|---|---|---|---|------|
| FIELD | Reserved |   |   |   |   |   |   | DIAG |
| RESET | 0        |   |   |   |   |   |   |      |
| R/W   | R        |   |   |   |   |   |   | R/W  |
| ADDR  | F56H     |   |   |   |   |   |   |      |

DIAG = Diagnostic Control Bit—Selects read back value of the Baud Rate Reload registers.

0 = Normal mode. Reading the Baud Rate High and Low Byte registers returns the baud rate reload value.

1 = Diagnostic mode. Reading the Baud Rate High and Low Byte registers returns the baud rate counter value.



# Analog-to-Digital Converter

The Analog-to-Digital Converter (ADC) converts an analog input signal to a 10-bit binary number. The features of the sigma-delta ADC include:

- Five analog input sources are multiplexed with GPIO ports.
- Interrupt upon conversion complete.
- Internal voltage reference generator.

The ADC is available only in the Z8F0822, Z8F0821, Z8F0422, Z8F0421, Z8R0822, Z8R0821, Z8R0422 and Z8R0421 devices.

## Architecture

Figure 32 displays the three major functional blocks (converter, analog multiplexer, and voltage reference generator) of the ADC. The ADC converts an analog input signal to its digital representation. The 5-input analog multiplexer selects one of the 5 analog input sources. The ADC requires an input reference voltage for the conversion. The voltage reference for the conversion can be input through the external VREF pin or generated internally by the voltage reference generator.

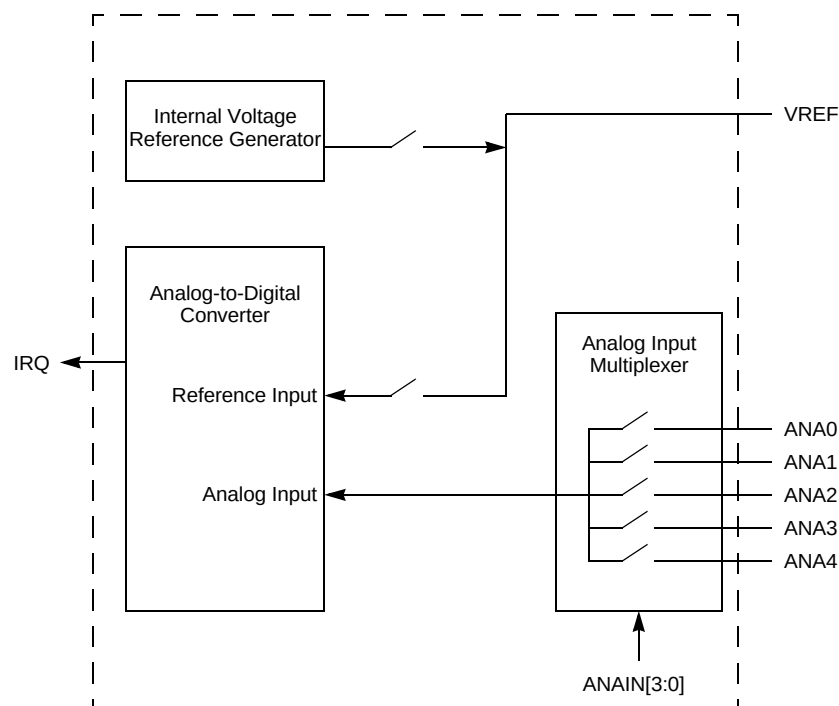


Figure 32. Analog-to-Digital Converter Block Diagram

## Operation

### Automatic Power-Down

If the ADC is idle (no conversions in progress) for 160 consecutive system clock cycles, portions of the ADC are automatically powered-down. From this power-down state, the ADC requires 40 system clock cycles to power-up. The ADC powers up when a conversion is requested using the ADC Control Register.

### Single-Shot Conversion

When configured for single-shot conversion, the ADC performs a single analog-to-digital conversion on the selected analog input channel. After completion of the conversion, the ADC shuts down. Follow the steps below for setting up the ADC and initiating a single-shot conversion:

1. Enable the desired analog inputs by configuring the GPIO pins for alternate function. This configuration disables the digital input and output drivers.
2. Write to the ADC Control Register to configure the ADC and begin the conversion. The bit fields in the ADC Control Register is written simultaneously:
  - Write to the `ANAIN[3 : 0]` field to select one of the 5 analog input sources.
  - Clear `CONT` to 0 to select a single-shot conversion.
  - Write to the `VREF` bit to enable or disable the internal voltage reference generator.
  - Set `CEN` to 1 to start the conversion.
3. `CEN` remains 1 while the conversion is in progress. A single-shot conversion requires 5129 system clock cycles to complete. If a single-shot conversion is requested from an ADC powered-down state, the ADC uses 40 additional clock cycles to power-up before beginning the 5129 cycle conversion.
4. When the conversion is complete, the ADC control logic performs the following operations:
  - 10-bit data result written to `{ADCD_H[7:0], ADCD_L[7:6]}`.
  - `CEN` resets to 0 to indicate the conversion is complete.
  - An interrupt request is sent to the Interrupt Controller.
5. If the ADC remains idle for 160 consecutive system clock cycles, it is automatically powered-down.

### Continuous Conversion

When configured for continuous conversion, the ADC continuously performs an analog-to-digital conversion on the selected analog input. Each new data value over-writes the previous value stored in the ADC Data Registers. An interrupt is generated after each conversion.



**Caution:** *In CONTINUOUS mode, ensure that ADC updates are limited by the input signal bandwidth of the ADC and the latency of the ADC and its digital filter. Step changes at the input are not seen at the next output from the ADC. The response of the ADC (in all modes) is limited by the input signal bandwidth and the latency.*

Follow the steps below for setting up the ADC and initiating continuous conversion:

1. Enable the desired analog input by configuring the GPIO pins for alternate function. This disables the digital input and output driver.
2. Write to the ADC Control Register to configure the ADC for continuous conversion. The bit fields in the ADC Control Register can be written simultaneously:
  - Write to the ANA<sub>IN</sub>[3 : 0] field to select one of the 5 analog input sources.
  - Set CONT to 1 to select continuous conversion.
  - Write to the  $\overline{\text{VREF}}$  bit to enable or disable the internal voltage reference generator.
  - Set CEN to 1 to start the conversions.
3. When the first conversion in continuous operation is complete (after 5129 system clock cycles, plus the 40 cycles for power-up, if necessary), the ADC control logic performs the following operations:
  - CEN resets to 0 to indicate the first conversion is complete. CEN remains 0 for all subsequent conversions in continuous operation.
  - An interrupt request is sent to the Interrupt Controller to indicate the conversion is complete.
4. Thereafter, the ADC writes a new 10-bit data result to {ADCD\_H[7:0], ADCD\_L[7:6]} every 256 system clock cycles. An interrupt request is sent to the Interrupt Controller when each conversion is complete.
5. To disable continuous conversion, clear the CONT bit in the ADC Control Register to 0.

## ADC Control Register Definitions

### ADC Control Register

The ADC Control Register selects the analog input channel and initiates the analog-to-digital conversion.

**Table 77. ADC Control Register (ADCCTL)**

| BITS  | 7    | 6        | 5    | 4    | 3          | 2 | 1 | 0 |
|-------|------|----------|------|------|------------|---|---|---|
| FIELD | CEN  | Reserved | VREF | CONT | ANAIN[3:0] |   |   |   |
| RESET | 0    |          | 1    | 0    |            |   |   |   |
| R/W   | R/W  |          |      |      |            |   |   |   |
| ADDR  | F70H |          |      |      |            |   |   |   |

#### **CEN—Conversion Enable**

0 = Conversion is complete. Writing a 0 produces no effect. The ADC automatically clears this bit to 0 when a conversion has been completed.

1 = Begin conversion. Writing a 1 to this bit starts a conversion. If a conversion is already in progress, the conversion restarts. This bit remains 1 until the conversion is complete.

#### **Reserved—Must be 0**

#### **VREF**

0 = Internal reference generator enabled. The VREF pin must be left unconnected or capacitively coupled to analog ground (AVSS).

1 = Internal voltage reference generator disabled. An external voltage reference must be provided through the VREF pin.

#### **CONT**

0 = SINGLE-SHOT conversion. ADC data is output once at completion of the 5129 system clock cycles.

1 = Continuous conversion. ADC data updated every 256 system clock cycles.

#### **ANAIN—Analog Input Select**

These bits select the analog input for conversion. Not all Port pins in this list are available in all packages for Z8 Encore! XP<sup>®</sup> F0822 Series. See [Signal and Pin Descriptions](#) for information regarding the Port pins available with each package style.

Do not enable unavailable analog inputs.

0000 = ANA0

0001 = ANA1

0010 = ANA2

0011 = ANA3

0100 = ANA4

0101 = Reserved  
011X = Reserved  
1XXX = Reserved

### ADC Data High Byte Register

The ADC Data High Byte register contains the upper eight bits of the 10-bit ADC output. During a SINGLE-SHOT conversion, this value is invalid. Access to the ADC Data High Byte register is read-only. The full 10-bit ADC result is given by {ADCD\_H[7:0], ADCD\_L[7:6]}. Reading the ADC Data High Byte register latches data in the ADC Low Bits register.

**Table 78. ADC Data High Byte Register (ADCD\_H)**

| BITS  | 7      | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|--------|---|---|---|---|---|---|---|
| FIELD | ADCD_H |   |   |   |   |   |   |   |
| RESET | X      |   |   |   |   |   |   |   |
| R/W   | R      |   |   |   |   |   |   |   |
| ADDR  | F72H   |   |   |   |   |   |   |   |

#### ADCD\_H—ADC Data High Byte

This byte contains the upper eight bits of the 10-bit ADC output. These bits are not valid during a single-shot conversion. During a continuous conversion, the last conversion output is held in this register. These bits are undefined after a Reset.

### ADC Data Low Bits Register

The ADC Data Low Bits register contains the lower two bits of the conversion value. The data in the ADC Data Low Bits register is latched each time the ADC Data High Byte register is read. Reading this register always returns the lower two bits of the conversion last read into the ADC High Byte register. Access to the ADC Data Low Bits register is read-only. The full 10-bit ADC result is given by {ADCD\_H[7:0], ADCD\_L[7:6]}.

**Table 79. ADC Data Low Bits Register (ADCD\_L)**

| BITS  | 7      | 6 | 5        | 4 | 3 | 2 | 1 | 0 |
|-------|--------|---|----------|---|---|---|---|---|
| FIELD | ADCD_L |   | Reserved |   |   |   |   |   |
| RESET | X      |   |          |   |   |   |   |   |
| R/W   | R      |   |          |   |   |   |   |   |
| ADDR  | F73H   |   |          |   |   |   |   |   |



**ADCD\_L—ADC Data Low Bits**

These are the least significant two bits of the 10-bit ADC output. These bits are undefined after a Reset.

**Reserved**

These bits are reserved and are always undefined.

# Flash Memory

The products in Z8 Encore! XP<sup>®</sup> F0822 Series feature either 8 KB (8192) or 4 KB (4096) bytes of Flash memory with Read/Write/Erase capability. The Flash memory is programmed and erased in-circuit by either user code or through the OCD.

The Flash memory array is arranged in 512-byte per page. The 512-byte page is the minimum Flash block size that can be erased. The Flash memory is divided into eight sectors which is protected from programming and erase operations on a per sector basis.

[Table 80](#) describes the Flash memory configuration for each device in the Z8F082x family. [Table 81](#) lists the sector address ranges. [Figure 33](#) on page 154 displays the Flash memory arrangement.

**Table 80. Flash Memory Configurations**

| Part Number | Flash Size  | Number of Pages | Flash Memory Addresses | Sector Size  | Number of Sectors | Pages per Sector |
|-------------|-------------|-----------------|------------------------|--------------|-------------------|------------------|
| Z8F08xx     | 8 KB (8192) | 16              | 0000H - 1FFFFH         | 1 KB (1024)  | 8                 | 2                |
| Z8F04xx     | 4 KB (4096) | 8               | 0000H - 0FFFFH         | 0.5 KB (512) | 8                 | 1                |

**Table 81. Flash Memory Sector Addresses**

| Sector Number | Flash Sector Address Ranges |              |
|---------------|-----------------------------|--------------|
|               | Z8F04xx                     | Z8F08xx      |
| 0             | 0000H-01FFFH                | 0000H-03FFFH |
| 1             | 0200H-03FFFH                | 0400H-07FFFH |
| 2             | 0400H-05FFFH                | 0800H-0BFFFH |
| 3             | 0600H-07FFFH                | 0C00H-0FFFFH |
| 4             | 0800H-09FFFH                | 1000H-13FFFH |
| 5             | 0A00H-0BFFFH                | 1400H-17FFFH |
| 6             | 0C00H-0DFFFH                | 1800H-1BFFFH |
| 7             | 0E00H-0FFFFH                | 1C00H-1FFFFH |

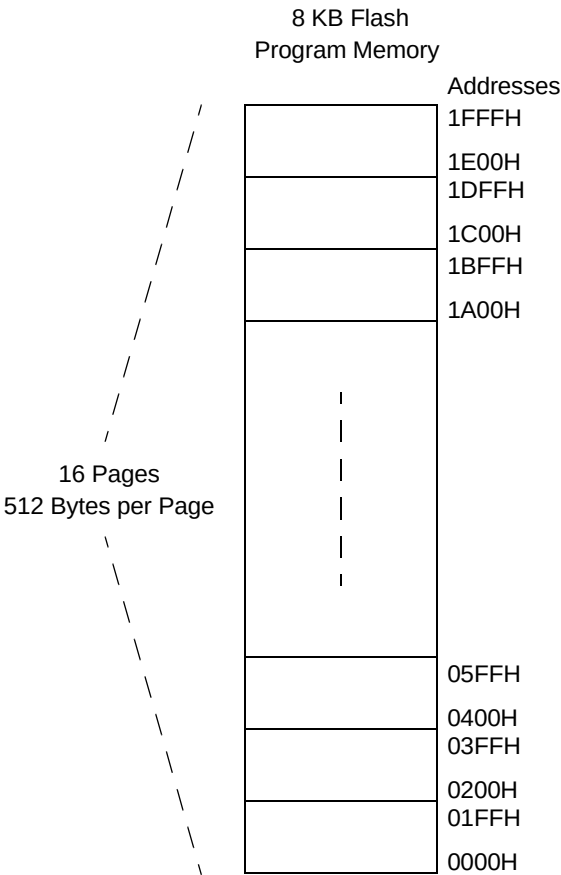


Figure 33. Flash Memory Arrangement

Information Area

Table 82 on page 155 describes the Z8 Encore! XP® F0822 Series Information Area. This 512-byte Information Area is accessed by setting bit 7 of the Page Select Register to 1. When access is enabled, the Information Area is mapped into Flash Memory and overlays the 512 bytes at addresses FE00H to FFFFH. When the Information Area access is enabled, LDC instructions return data from the Information Area. CPU instruction fetches always comes from Flash Memory regardless of the Information Area access bit. Access to the Information Area is read-only.

**Table 82. Z8 Encore! XP<sup>®</sup> F0822 Series Information Area Map**

| Flash Memory Address (Hex) | Function                                                                                           |
|----------------------------|----------------------------------------------------------------------------------------------------|
| FE00H-FE3FH                | Reserved                                                                                           |
| FE40H-FE53H                | <b>Part Number</b><br>20-character ASCII alphanumeric code<br>Left justified and filled with zeros |
| FE54H-FFFFH                | Reserved                                                                                           |

## Operation

The Flash Controller provides the proper signals and timing for Byte Programming, Page Erase, and Mass Erase of the Flash memory. The Flash Controller contains a protection mechanism, using the Flash Control Register (FCTL), to prevent accidental programming or erasure. The following subsections provide details on the various operations (Lock, Unlock, Sector Protect, Byte Programming, Page Erase, and Mass Erase).

### Timing Using the Flash Frequency Registers

Before performing a program or erase operation on the Flash memory, you must first configure the Flash Frequency High and Low Byte registers. The Flash Frequency registers allow programming and erasure of the Flash with system clock frequencies ranging from 20 kHz through 20 MHz (the valid range is limited to the device operating frequencies).

The Flash Frequency High and Low Byte registers combine to form a 16-bit value, FFREQ, to control timing for Flash program and erase operations. The 16-bit Flash Frequency value must contain the system clock frequency in kHz. This value is calculated using the following equation:

$$\text{FFREQ}[15:0] = \frac{\text{System Clock Frequency (Hz)}}{1000}$$

**Caution:**

*Flash programming and erasure are not supported for system clock frequencies below 20 kHz, above 20 MHz, or outside of the device operating frequency range. The Flash Frequency High and Low Byte registers must be loaded with the correct value to insure proper Flash programming and erase operations.*

## Flash Read Protection

The user code contained within the Flash memory can be protected from external access. Programming the Flash Read Protect Option Bit prevents reading of user code by the OCD or by using the Flash Controller Bypass mode. For more information, see [Option Bits](#) on page 163 and [On-Chip Debugger](#) on page 171.

## Flash Write/Erase Protection

Z8 Encore! XP<sup>®</sup> F0822 Series provides several levels of protection against accidental program and erasure of the Flash memory contents. This protection is provided by the Flash Controller unlock mechanism, the Flash Sector Protect Register, and the Flash Write Protect option bit.

### Flash Controller Unlock Mechanism

At Reset, the Flash Controller locks to prevent accidental program or erasure of the Flash memory. To program or erase the Flash memory, the Flash controller must be unlocked. After unlocking the Flash Controller, the Flash can be programmed or erased. Any value written by user code to the Flash Control Register or Page Select Register out of sequence locks the Flash Controller.

Follow the steps below to unlock the Flash Controller from user code:

1. Write 00H to the Flash Control Register to reset the Flash Controller.
2. Write the page to be programmed or erased to the Page Select Register.
3. Write the first unlock command 73H to the Flash Control Register.
4. Write the second unlock command 8CH to the Flash Control Register.
5. Re-write the page written in [step 2](#) to the Page Select Register.

### Flash Sector Protection

The Flash Sector Protect Register is configured to prevent sectors from being programmed or erased. Once a sector is protected, it cannot be unprotected by user code. The Flash Sector Protect Register is cleared after reset and any previously written protection values is lost. User code must write this register in the initialization routine if enable sector protection is desired.

The Flash Sector Protect Register shares its Register File address with the Page Select Register. The Flash Sector Protect Register is accessed by writing the Flash Control Register with 5EH. After the Flash Sector Protect Register is selected, it can be accessed at the Page Select Register address. When the user code writes the Flash Sector Protect Register, bits can only be set to 1. Sectors can be protected, but not unprotected, using register write operations. Writing a value other than 5EH to the Flash Control Register deselects the Flash Sector Protect Register and re-enables access to the Page Select Register.

Follow the steps below to setup the Flash Sector Protect Register from user code:

1. Write 00H to the Flash Control Register to reset the Flash Controller.
2. Write 5EH to the Flash Control Register to select the Flash Sector Protect Register.
3. Read and/or write the Flash Sector Protect Register which is now at Register File address FF9H.
4. Write 00H to the Flash Control Register to return the Flash Controller to its reset state.

### Flash Write Protection Option Bit

The Flash Write Protect option bit can block all program and erase operations from user code. For more information, see [Option Bits](#) on page 163.

## Byte Programming

When the Flash Controller is unlocked, writes to Flash Memory from user code programs a byte into the Flash if the address is located in the unlocked page. An erased Flash byte contains all 1s (FFH). The programming operation is used to change bits from 1 to 0. To change a Flash bit (or multiple bits) from zero to one requires a Page Erase or Mass Erase operation.

Byte Programming is accomplished using the eZ8 CPU's LDC or LDCI instructions. Refer to *eZ8 CPU Core User Manual (UM0128)* for a description of the LDC and LDCI instructions.

While the Flash Controller programs the Flash memory, the eZ8 CPU idles but the system clock and on-chip peripherals continue to operate. Interrupts that occur when a Programming operation is in progress are serviced once the Programming operation is complete. To exit Programming mode and lock the Flash Controller, write 00H to the Flash Control Register.

User code cannot program Flash Memory on a page that is located in a protected sector. When user code writes memory locations, only addresses located in the unlocked page are programmed. Memory writes outside of the unlocked page are ignored.



**Caution:** *Each memory location must not be programmed more than twice before an erase occurs.*

Follow the steps below to program the Flash from user code:

1. Write 00H to the Flash Control Register to reset the Flash Controller.
2. Write the page of memory to be programmed to the Page Select Register.
3. Write the first unlock command 73H to the Flash Control Register.
4. Write the second unlock command 8CH to the Flash Control Register.

5. Re-write the page written in [step 2](#) to the Page Select Register.
6. Write Flash Memory using LDC or LDCI instructions to program the Flash.
7. Repeat [step 6](#) to program additional memory locations on the same page.
8. Write 00H to the Flash Control Register to lock the Flash Controller.

## Page Erase

Flash memory can be erased one page (512 bytes) at a time. Page Erasing the Flash memory sets all bytes in that page to the value FFH. The Page Select Register identifies the page to be erased. While the Flash Controller executes the Page Erase operation, the eZ8 CPU idles but the system clock and on-chip peripherals continue to operate. The eZ8 CPU resumes operation after the Page Erase operation completes. Interrupts that occur when the Page Erase operation is in progress are serviced once the Page Erase operation is complete. When the Page Erase operation is complete, the Flash Controller returns to its locked state. Only pages located in unprotected sectors can be erased.

Follow the steps below to perform a Page Erase operation:

1. Write 00H to the Flash Control Register to reset the Flash Controller.
2. Write the page to be erased to the Page Select Register.
3. Write the first unlock command 73H to the Flash Control Register.
4. Write the second unlock command 8CH to the Flash Control Register.
5. Re-write the page written in [step 2](#) to the Page Select Register.
6. Write the Page Erase command 95H to the Flash Control Register.

## Mass Erase

The Flash memory cannot be Mass Erased by user code.

## Flash Controller Bypass

The Flash Controller can be bypassed and the control signals for the Flash memory brought out to the GPIO pins. Bypassing the Flash Controller allows faster Programming algorithms by controlling the Flash programming signals directly.

Flash Controller Bypass is recommended for gang programming applications and large volume customers who do not require in-circuit programming of the Flash memory.

For more information on bypassing the Flash Controller, refer to *Third-Party Flash Programming Support for Z8 Encore! XP*, available for download at [www.zilog.com](http://www.zilog.com).

## Flash Controller Behavior in Debug Mode

The following changes in behavior of the Flash Controller occur when the Flash Controller is accessed using the OCD:

- The Flash Write Protect option bit is ignored
- The Flash Sector Protect Register is ignored for programming and erase operations
- Programming operations are not limited to the page selected in the Page Select Register
- Bits in the Flash Sector Protect Register can be written to 1 or 0
- The second write of the Page Select Register to unlock the Flash Controller is not necessary
- The Page Select Register is written when the Flash Controller is unlocked
- The Mass Erase command is enabled

## Flash Control Register Definitions

### Flash Control Register

The Flash Control Register ([Table 83](#)) is used to unlock the Flash Controller for programming and erase operations, or to select the Flash Sector Protect Register. The Write-only Flash Control Register shares its Register File address with the Read-only Flash Status Register.

**Table 83. Flash Control Register (FCTL)**

| BITS  | 7    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|------|---|---|---|---|---|---|---|
| FIELD | FCMD |   |   |   |   |   |   |   |
| RESET | 0    |   |   |   |   |   |   |   |
| R/W   | W    |   |   |   |   |   |   |   |
| ADDR  | FF8H |   |   |   |   |   |   |   |

#### FCMD—Flash Command

73H = First unlock command.

8CH = Second unlock command.

95H = Page erase command.

63H = Mass erase command

5EH = Flash Sector Protect Register select.

\* All other commands, or any command out of sequence, lock the Flash Controller.

## Flash Status Register

The Flash Status Register (Table 84) indicates the current state of the Flash Controller. This register can be read at any time. The Read-only Flash Status Register shares its Register File address with the Write-only Flash Control Register.

**Table 84. Flash Status Register (FSTAT)**

| BITS  | 7        | 6 | 5     | 4 | 3 | 2 | 1 | 0 |
|-------|----------|---|-------|---|---|---|---|---|
| FIELD | Reserved |   | FSTAT |   |   |   |   |   |
| RESET | 0        |   |       |   |   |   |   |   |
| R/W   | R        |   |       |   |   |   |   |   |
| ADDR  | FF8H     |   |       |   |   |   |   |   |

### Reserved

These bits are reserved and must be 0.

### FSTAT—Flash Controller Status

00\_0000 = Flash Controller locked.

00\_0001 = First unlock command received.

00\_0010 = Second unlock command received.

00\_0011 = Flash Controller unlocked.

00\_0100 = Flash Sector Protect Register selected.

00\_1xxx = Program operation in progress.

01\_0xxx = Page erase operation in progress.

10\_0xxx = Mass erase operation in progress.

## Page Select Register

The Page Select (FPS) Register (Table 85) selects the Flash memory page to be erased or programmed. Each Flash Page contains 512 bytes of Flash memory. During a Page Erase operation, all Flash memory locations with the 7 most significant bits of the address given by the PAGE field are erased to FFH.

The Page Select Register shares its Register File address with the Flash Sector Protect Register. The Page Select Register cannot be accessed when the Flash Sector Protect Register is enabled.

**Table 85. Page Select Register (FPS)**

| BITS  | 7       | 6    | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|---------|------|---|---|---|---|---|---|
| FIELD | INFO_EN | PAGE |   |   |   |   |   |   |
| RESET | 0       |      |   |   |   |   |   |   |
| R/W   | R/W     |      |   |   |   |   |   |   |
| ADDR  | FF9H    |      |   |   |   |   |   |   |

**INFO\_EN—Information Area Enable**

0 = Information Area is not selected.

1 = Information Area is selected. The Information area is mapped into the Flash Memory address space at addresses FE00H through FFFFH.

**PAGE—Page Select**

This 7-bit field selects the Flash memory page for Programming and Page Erase operations. Flash Memory Address[15:9] = PAGE[6:0].

**Flash Sector Protect Register**

The Flash Sector Protect Register (Table 86) protects Flash memory sectors from being programmed or erased from user code. The Flash Sector Protect Register shares its Register File address with the Page Select Register. The Flash Sector Protect Register can be accessed only after writing the Flash Control Register with 5EH. User code can only write bits in this register to 1 (bits cannot be cleared to 0 by user code).

**Table 86. Flash Sector Protect Register (FPROT)**

| BITS  | 7     | 6     | 5     | 4     | 3     | 2     | 1     | 0     |
|-------|-------|-------|-------|-------|-------|-------|-------|-------|
| FIELD | SECT7 | SECT6 | SECT5 | SECT4 | SECT3 | SECT2 | SECT1 | SECT0 |
| RESET | 0     |       |       |       |       |       |       |       |
| R/W   | R/W1  |       |       |       |       |       |       |       |
| ADDR  | FF9H  |       |       |       |       |       |       |       |

R/W1 = Register is accessible for Read operations. Register can be written to 1 only (using user code).

**SECT<sub>n</sub>—Sector Protect**0 = Sector *n* can be programmed or erased from user code.1 = Sector *n* is protected and cannot be programmed or erased from user code.

User code can only write bits from 0 to 1.

**Flash Frequency High and Low Byte Registers**

The Flash Frequency High and Low Byte Registers (Table 87 and Table 88) combine to form a 16-bit value, FFREQ, to control timing for Flash program and erase operations. The 16-bit Flash Frequency registers must be written with the system clock frequency in kHz for Program and Erase operations. The Flash Frequency value is calculated using the following equation:

$$\text{FFREQ}[15:0] = \{ \text{FFREQH}[7:0], \text{FFREQL}[7:0] \} = \frac{\text{System Clock Frequency}}{1000}$$

**Caution:**

*Flash programming and erasure is not supported for system clock frequencies below 20 kHz, above 20 MHz, or outside of the valid operating*

*frequency range for the device. The Flash Frequency High and Low Byte Registers must be loaded with the correct value to insure proper program and erase times.*

**Table 87. Flash Frequency High Byte Register (FFREQH)**

| BITS  | 7      | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|--------|---|---|---|---|---|---|---|
| FIELD | FFREQH |   |   |   |   |   |   |   |
| RESET | 0      |   |   |   |   |   |   |   |
| R/W   | R/W    |   |   |   |   |   |   |   |
| ADDR  | FFAH   |   |   |   |   |   |   |   |

**Table 88. Flash Frequency Low Byte Register (FFREQL)**

| BITS  | 7      | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|--------|---|---|---|---|---|---|---|
| FIELD | FFREQL |   |   |   |   |   |   |   |
| RESET | 0      |   |   |   |   |   |   |   |
| R/W   | R/W    |   |   |   |   |   |   |   |
| ADDR  | FFBH   |   |   |   |   |   |   |   |

**FFREQH and FFREQL—Flash Frequency High and Low Bytes**

These 2 bytes, {FFREQH[7:0], FFREQL[7:0]}, contain the 16-bit Flash Frequency value.

# Option Bits

Option Bits allow user configuration of certain aspects of Z8 Encore! XP<sup>®</sup> F0822 Series operation. The feature configuration data is stored in Flash Memory and read during Reset. Features available for control through the Option Bits are:

- Watchdog Timer time-out response selection—interrupt or Reset.
- Watchdog Timer enabled at Reset.
- The ability to prevent unwanted read access to user code in Flash Memory.
- The ability to prevent accidental programming and erasure of all or a portion of the user code in Flash Memory.
- Voltage Brownout configuration—always enabled or disabled during STOP mode to reduce STOP mode power consumption.
- Oscillator mode selection—for high, medium, and low power crystal oscillators, or external RC oscillator.

## Operation

### Option Bit Configuration By Reset

During any reset operation (System Reset, Reset, or Stop Mode Recovery), the Option Bits are automatically read from the Flash Memory and written to Option Configuration registers. The Option Configuration registers control operation of the devices within the Z8 Encore! XP F0822 Series. Option Bit control is established before the device exits Reset and the eZ8 CPU begins code execution. The Option Configuration registers are not part of the Register File and are not accessible for read or write access. Each time the Option Bits are programmed or erased, the device must be Reset for the change to take place (Flash version only).

### Option Bit Address Space

The first two bytes of Flash Memory at addresses 0000H ([Table 89](#) on page 164) and 0001H ([Table 90](#) on page 165) are reserved for the user programmable Option Bits. The byte at Program Memory address 0000H configures user options. The byte at Flash Memory address 0001H is reserved for future use and must be left in its unprogrammed state.

## Flash Memory Address 0000H

**Table 89. Option Bits at Flash Memory Address 0000H for 8K Series Flash Devices**

| BITS                                            | 7                    | 6      | 5            | 4 | 3      | 2  | 1        | 0   |
|-------------------------------------------------|----------------------|--------|--------------|---|--------|----|----------|-----|
| FIELD                                           | WDT_RES              | WDT_AO | OSC_SEL[1:0] |   | VBO_AO | RP | Reserved | FWP |
| RESET                                           | U                    |        |              |   |        |    |          |     |
| R/W                                             | R/W                  |        |              |   |        |    |          |     |
| ADDR                                            | Program Memory 0000H |        |              |   |        |    |          |     |
| Note: U = Unchanged by Reset. R/W = Read/Write. |                      |        |              |   |        |    |          |     |

### **WDT\_RES—Watchdog Timer Reset**

- 0 = Watchdog Timer time-out generates an interrupt request. Interrupts must be globally enabled for the eZ8 CPU to acknowledge the interrupt request.
- 1 = Watchdog Timer time-out causes a Reset. This setting is the default for unprogrammed (erased) Flash.

### **WDT\_AO—Watchdog Timer Always On**

- 0 = Watchdog Timer is automatically enabled upon application of system power. Watchdog Timer can not be disabled.
- 1 = Watchdog Timer is enabled upon execution of the WDT instruction. Once enabled, the Watchdog Timer can only be disabled by a Reset or Stop Mode Recovery. This setting is the default for unprogrammed (erased) Flash.

### **OSC\_SEL[1:0]—OSCILLATOR Mode Selection**

- 00 = On-chip oscillator configured for use with external RC networks (<4 MHz).
- 01 = Minimum power for use with very low frequency crystals (32 kHz to 1.0 MHz).
- 10 = Medium power for use with medium frequency crystals or ceramic resonators (0.5 MHz to 10.0 MHz).
- 11 = Maximum power for use with high frequency crystals (8.0 MHz to 20.0 MHz). This setting is the default for unprogrammed (erased) Flash.

### **VBO\_AO—Voltage Brownout Protection Always On**

- 0 = Voltage Brownout Protection is disabled in STOP mode to reduce total power consumption.
- 1 = Voltage Brownout Protection is always enabled including during STOP mode. This setting is the default for unprogrammed (erased) Flash.

### **RP—Read Protect**

- 0 = User program code is inaccessible. Limited control features are available through the OCD.
- 1 = User program code is accessible. All OCD commands are enabled. This setting is the default for unprogrammed (erased) Flash.



### Reserved

These Option Bits are reserved for future use and must always be 1.

The following information applies only to the Flash versions of the F0822 Series devices:

### FWP—Flash Write Protect

These two Option Bits combine to provide three levels of Program Memory protection:

| FWP | Description                                                                                                   |
|-----|---------------------------------------------------------------------------------------------------------------|
| 0   | Programming, Page Erase, and Mass Erase using User Code is disabled. Mass Erase is available through the OCD. |
| 1   | Programming and Page Erase are enabled for all of Flash Program Memory.                                       |

## Flash Memory Address 0001H

Table 90. Options Bits at Flash Memory Address 0001H

| BITS  | 7                    | 6 | 5 | 4 | 3 | 2 | 1 | 0 |
|-------|----------------------|---|---|---|---|---|---|---|
| FIELD | Reserved             |   |   |   |   |   |   |   |
| RESET | U                    |   |   |   |   |   |   |   |
| R/W   | R/W                  |   |   |   |   |   |   |   |
| ADDR  | Program Memory 0001H |   |   |   |   |   |   |   |

Note: U = Unchanged by Reset. R/W = Read/Write.

### Reserved

These Option Bits are reserved for future use and must always be 1. This setting is the default for unprogrammed (erased) Flash.



# On-Chip Oscillator

Z8 Encore! XP<sup>®</sup> F0822 Series products feature an on-chip oscillator for use with external crystals with frequencies from 32 kHz to 20 MHz. In addition, the oscillator can support external RC networks with oscillation frequencies up to 4 MHz or ceramic resonators with oscillation frequencies up to 20 MHz. This oscillator generates the primary system clock for the internal eZ8 CPU and the majority of the on-chip peripherals. Alternatively, the X<sub>IN</sub> input pin can also accept a CMOS-level clock input signal (32 kHz–20 MHz). If an external clock generator is used, the X<sub>OUT</sub> pin must be left unconnected.

When configured for use with crystal oscillators or external clock drivers, the frequency of the signal on the X<sub>IN</sub> input pin determines the frequency of the system clock (that is, no internal clock divider). In RC operation, the system clock is driven by a clock divider (divide by 2) to ensure 50% duty cycle.

## Operating Modes

Z8 Encore! XP F0822 Series products support 4 different oscillator modes:

- On-chip oscillator configured for use with external RC networks (<4 MHz).
- Minimum power for use with very low frequency crystals (32 kHz to 1.0 MHz).
- Medium power for use with medium frequency crystals or ceramic resonators (0.5 MHz to 10.0 MHz).
- Maximum power for use with high frequency crystals or ceramic resonators (8.0 MHz to 20.0 MHz).

The oscillator mode is selected through user-programmable Option Bits. For more information, see [Option Bits](#) on page 163.

## Crystal Oscillator Operation

[Figure 34](#) on page 168 displays a recommended configuration for connection with an external fundamental-mode, parallel-resonant crystal operating at 20 MHz. Recommended 20 MHz crystal specifications are provided in [Table 91](#) on page 168. Resistor R1 is optional and limits total power dissipation by the crystal. The printed circuit board layout must add no more than 4 pF of stray capacitance to either the X<sub>IN</sub> or X<sub>OUT</sub> pins. If oscillation does not occur, reduce the values of capacitors C1 and C2 to decrease loading.

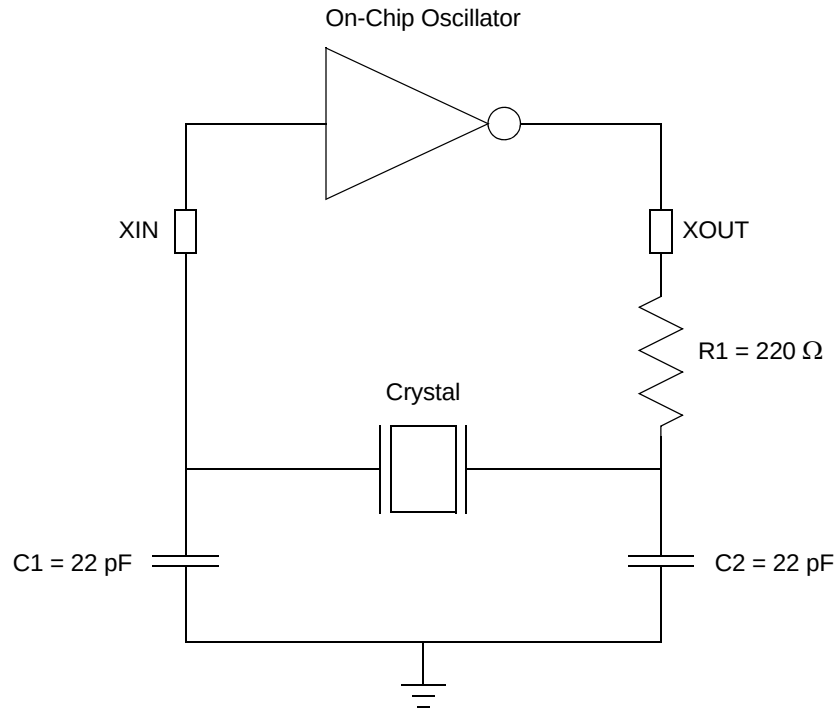


**Figure 34. Recommended 20 MHz Crystal Oscillator Configuration**

**Table 91. Recommended Crystal Oscillator Specifications (20 MHz Operation)**

| Parameter                   | Value       | Units | Comments |
|-----------------------------|-------------|-------|----------|
| Frequency                   | 20          | MHz   |          |
| Resonance                   | Parallel    |       |          |
| Mode                        | Fundamental |       |          |
| Series Resistance ( $R_S$ ) | 25          | W     | Maximum  |
| Load Capacitance ( $C_L$ )  | 20          | pF    | Maximum  |
| Shunt Capacitance ( $C_0$ ) | 7           | pF    | Maximum  |
| Drive Level                 | 1           | mW    | Maximum  |

## Oscillator Operation with an External RC Network

The External RC oscillator mode is applicable to timing insensitive applications. [Figure 35](#) on page 169 displays a recommended configuration for connection with an external resistor-capacitor (RC) network.

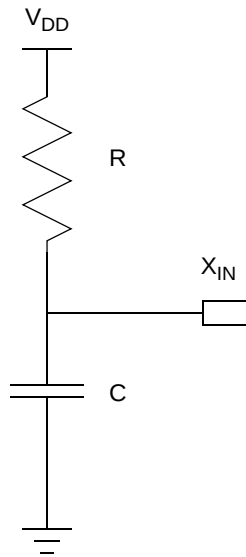


**Figure 35. Connecting the On-Chip Oscillator to an External RC Network**

An external resistance value of 45 k $\Omega$  is recommended for oscillator operation with an external RC network. The minimum resistance value to ensure operation is 40 k $\Omega$ . The typical oscillator frequency can be estimated from the values of the resistor ( $R$  in k $\Omega$ ) and capacitor ( $C$  in pF) elements using the below equation:

$$\text{Oscillator Frequency (kHz)} = \frac{1 \times 10^6}{(0.4 \times R \times C) + (4 \times C)}$$

Figure 36 on page 170 displays the typical (3.3 V and 25  $^{\circ}\text{C}$ ) oscillator frequency as a function of the capacitor ( $C$  in pF) employed in the RC network assuming a 45 k $\Omega$  external resistor. For very small values of  $C$ , the parasitic capacitance of the oscillator  $X_{IN}$  pin and the printed circuit board should be included in the estimation of the oscillator frequency.

It is possible to operate the RC oscillator using only the parasitic capacitance of the package and printed circuit board. To minimize sensitivity to external parasites, external capacitance values in excess of 20 pF are recommended.

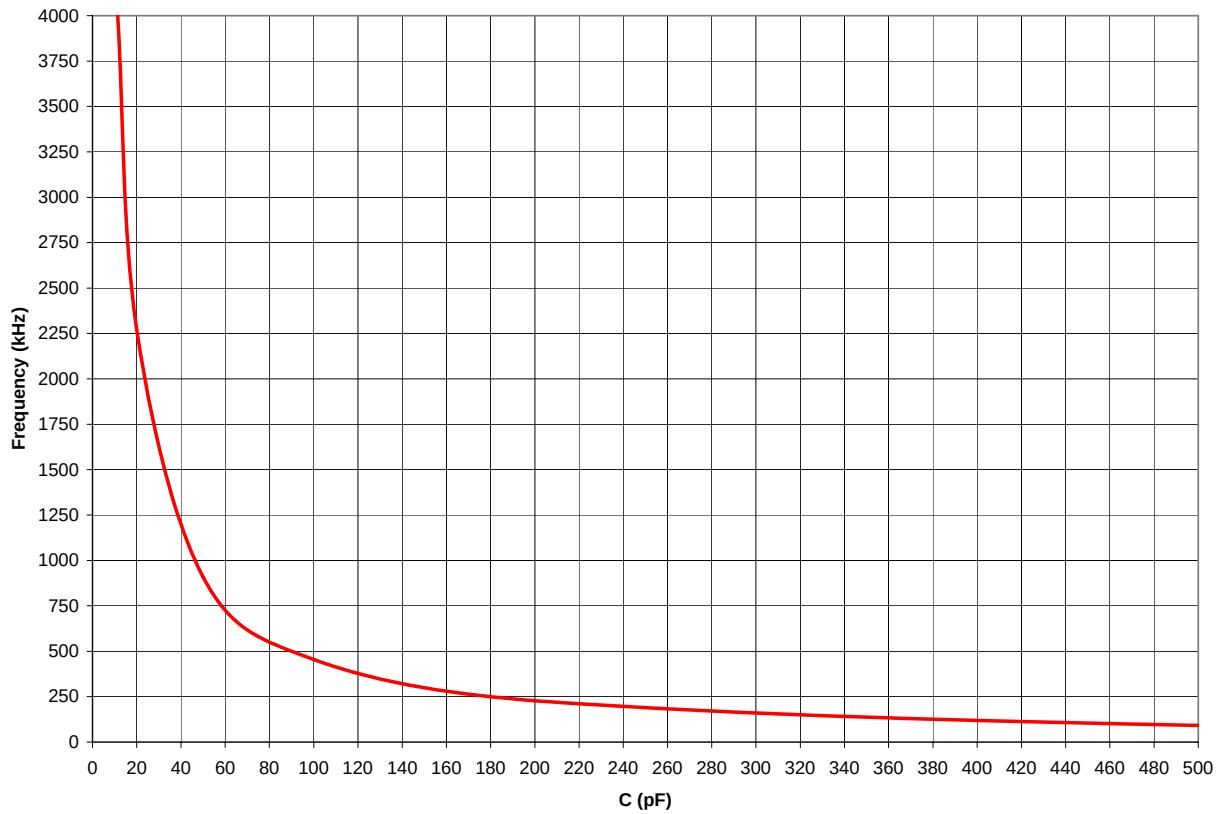


**Figure 36. Typical RC Oscillator Frequency as a Function of the External Capacitance with a 45 kΩ Resistor**



**Caution:**

*When using the external RC oscillator mode, the oscillator can stop oscillating if the power supply drops below 2.7 V, but before the power supply drops to the Voltage Brownout threshold. The oscillator resumes oscillation when the supply voltage exceeds 2.7 V.*

# On-Chip Debugger

Z8 Encore! XP<sup>®</sup> F0822 Series products have an integrated On-Chip Debugger (OCD) that provides advanced debugging features including:

- Reading and writing of the Register File
- Reading and (Flash version only) writing of Program and Data Memory
- Setting of Breakpoints
- Executing eZ8 CPU instructions

## Architecture

The OCD consists of four primary functional blocks: transmitter, receiver, autobaud generator, and debug controller. [Figure 37](#) displays the architecture of the OCD.

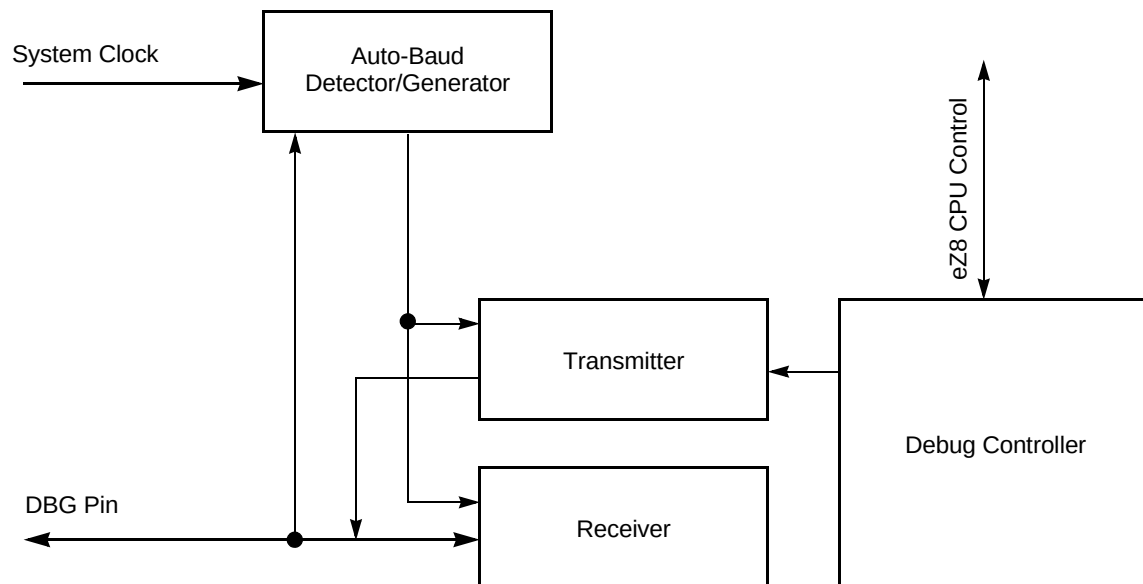


Figure 37. On-Chip Debugger Block Diagram

## Operation

### OCD Interface

The OCD uses the DBG pin for communication with an external host. This one-pin interface is a bi-directional open-drain interface that transmits and receives data. Data

transmission is half-duplex, in that transmit and receive cannot occur simultaneously. The serial data on the DBG pin is sent using the standard asynchronous data format defined in RS-232. This pin can interface the Z8 Encore! XP F0822 Series products to the serial port of a host PC using minimal external hardware. Two different methods for connecting the DBG pin to an RS-232 interface are displayed in Figure 38 and Figure 39.



**Caution:**

*For operation of the OCD, all power pins ( $V_{DD}$  and  $AV_{DD}$ ) must be supplied with power, and all ground pins ( $V_{SS}$  and  $AV_{SS}$ ) must be properly grounded. The DBG pin is open-drain and must always be connected to  $V_{DD}$  through an external pull-up resistor to insure proper operation.*

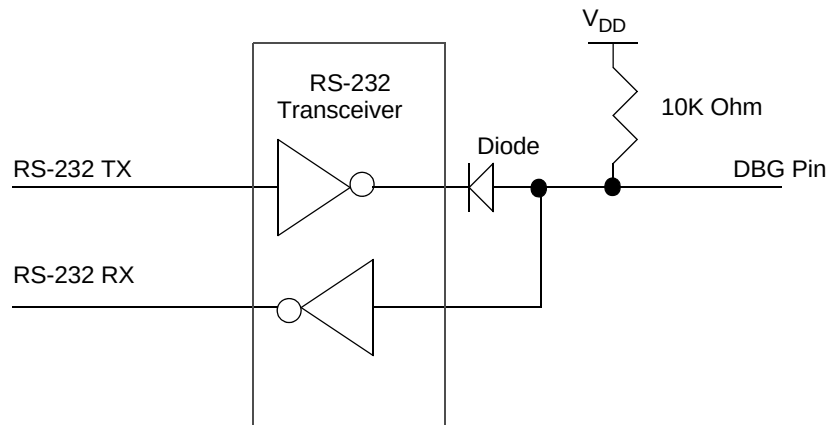


**Figure 38. Interfacing the On-Chip Debugger's DBG Pin with an RS-232 Interface (1)**

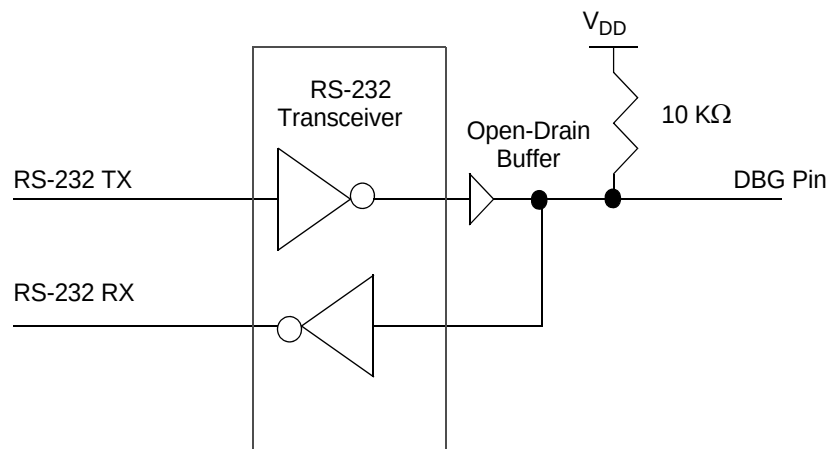


**Figure 39. Interfacing the On-Chip Debugger's DBG Pin with an RS-232 Interface (2)**

## Debug Mode

The operating characteristics of the Z8 Encore! XP<sup>®</sup> F0822 Series devices in DEBUG mode are:

- The eZ8 CPU fetch unit stops, idling the eZ8 CPU, unless directed by the OCD to execute specific instructions.
- The system clock operates unless in STOP mode.
- All enabled on-chip peripherals operate unless in STOP mode.
- Automatically exits HALT mode.
- Constantly refreshes the Watchdog Timer, if enabled.

### Entering Debug Mode

The device enters DEBUG mode following any of the following operations:

- Writing the DBGMODE bit in the OCD Control Register to 1 using the OCD interface.
- eZ8 CPU execution of a BRK (Breakpoint) instruction.
- Match of PC to OCDCNTR register (when enabled)
- OCDCNTR register decrements to 0000H (when enabled)
- If the DBG pin is Low when the device exits Reset, the OCD automatically puts the device into DEBUG mode.

### Exiting Debug Mode

The device exits DEBUG mode following any of the following operations:

- Clearing the DBGMODE bit in the OCD Control Register to 0.
- Power-On Reset
- Voltage Brownout reset
- Asserting the RESET pin Low to initiate a Reset.
- Driving the DBG pin Low while the device is in STOP mode initiates a System Reset.

## OCD Data Format

The OCD interface uses the asynchronous data format defined for RS-232. Each character is transmitted as 1 Start bit, 8 data bits (least-significant bit first), and 1 STOP bit (see [Figure 40](#)).

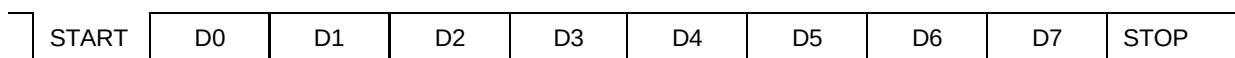


Figure 40. OCD Data Format

## OCD Auto-Baud Detector/Generator

To run over a range of baud rates (bits per second) with various system clock frequencies, the OCD contains an Auto-Baud Detector/Generator. After a reset, the OCD is idle until it receives data. The OCD requires that the first character sent from the host is the character 80H. The character 80H has eight continuous bits Low (one Start bit plus 7 data bits). The Auto-Baud Detector measures this period and sets the OCD Baud Rate Generator accordingly.

The Auto-Baud Detector/Generator is clocked by the system clock. The minimum baud rate is the system clock frequency divided by 512. For optimal operation, the maximum recommended baud rate is the system clock frequency divided by 8. The theoretical maximum baud rate is the system clock frequency divided by 4. This theoretical maximum is possible for low noise designs with clean signals. [Table 92](#) lists minimum and recommended maximum baud rates for sample crystal frequencies.

**Table 92. OCD Baud-Rate Limits**

| System Clock Frequency (MHz) | Recommended Maximum Baud Rate (kbps) | Minimum Baud Rate (Kbps) |
|------------------------------|--------------------------------------|--------------------------|
| 20.0                         | 2500                                 | 39.1                     |
| 1.0                          | 125.0                                | 1.96                     |
| 0.032768 (32 kHz)            | 4.096                                | 0.064                    |

If the OCD receives a Serial Break (nine or more continuous bits Low) the Auto-Baud Detector/Generator resets. The Auto-Baud Detector/Generator can then be reconfigured by sending 80H.

## OCD Serial Errors

The OCD can detect any of the following error conditions on the DBG pin:

- Serial Break (a minimum of nine continuous bits Low)
- Framing Error (received STOP bit is Low)
- Transmit Collision (OCD and host simultaneous transmission detected by the OCD)

When the OCD detects one of these errors, it aborts any command currently in progress, transmits a Serial Break 4096 System Clock cycles long back to the host, and resets the Auto-Baud Detector/Generator. A Framing Error or Transmit Collision can be caused by the host sending a Serial Break to the OCD. Because of the open-drain nature of the interface, returning a Serial Break back to the host only extends the length of the Serial Break if the host releases the Serial Break early.

The host transmits a Serial Break on the DBG pin when first connecting to the Z8 Encore! XP® F0822 Series device or when recovering from an error. A Serial Break from the host resets the Auto-Baud Generator/Detector but does not reset the OCD Control Register. A Serial Break leaves the device in DEBUG mode if that is the current mode. The OCD is held in Reset until the end of the Serial Break when the DBG pin returns High. Because of the open-drain nature of the DBG pin, the host can send a Serial Break to the OCD even if the OCD is transmitting a character.

## Breakpoints

Execution Breakpoints are generated using the BRK instruction (opcode 00H). When the eZ8 CPU decodes a BRK instruction, it signals the OCD. If Breakpoints are enabled, the OCD idles the eZ8 CPU and enters DEBUG mode. If Breakpoints are not enabled, the OCD ignores the BRK signal and the BRK instruction operates as an NOP instruction.

If breakpoints are enabled, the OCD can be configured to automatically enter DEBUG mode, or to loop on the break instruction. If the OCD is configured to loop on the BRK instruction, then the CPU is still enabled to service DMA and interrupt requests.

The loop on BRK instruction can be used to service interrupts in the background. For interrupts to be serviced in the background, there cannot be any breakpoints in the ISR. Otherwise, the CPU stops on the breakpoint in the interrupt routine. For interrupts to be serviced in the background, interrupts must also be enabled. Debugging software should not automatically enable interrupts when using this feature, since interrupts are typically disabled during critical sections of code where interrupts should not occur (such as adjusting the stack pointer or modifying shared data).

Software can poll the IDLE bit of the OCDSTAT register to determine if the OCD is looping on a BRK instruction. When software wants to stop the CPU on the BRK instruction it is looping on, software should not set the DBGMODE bit of the OCDCTL register. The CPU can have vectored to and be in the middle of an ISR when this bit gets set. Instead, software must clear the BRKLP bit. This allows the CPU to finish the ISR it is in and return the BRK instruction. When the CPU returns to the BRK instruction it was previously looping on, it automatically sets the DBGMODE bit and enter DEBUG mode.

Software should also note that the majority of the OCD commands are still disabled when the eZ8 CPU is looping on a BRK instruction. The eZ8 CPU must be stopped and the part must be in DEBUG mode before these commands can be issued.

## Breakpoints in Flash Memory

The BRK instruction is opcode 00H, which corresponds to the fully programmed state of a byte in Flash memory. To implement a Breakpoint, write 00H to the desired address, overwriting the current instruction. To remove a Breakpoint, the corresponding page of Flash memory must be erased and reprogrammed with the original data.

## OCDCNTR Register

The OCD contains a multipurpose 16-bit Counter Register. It can be used for the following:

- Count system clock cycles between Breakpoints.
- Generate a BRK when it counts down to zero.
- Generate a BRK when its value matches the Program Counter.

When configured as a counter, the OCDCNTR register starts counting when the OCD leaves DEBUG mode and stops counting when it enters DEBUG mode again or when it reaches the maximum count of FFFFH. The OCDCNTR register automatically resets itself to 0000H when the OCD exits DEBUG mode if it is configured to count clock cycles between breakpoints.

**Caution:**

*The OCDCNTR register is used by many of the OCD commands. It counts the number of bytes for the register and memory read/write commands. It holds the residual value when generating the CRC. Therefore, if the OCD-CNTR is being used to generate a BRK, its value should be written as a last step before leaving DEBUG mode.*

Since this register is overwritten by various OCD commands, it should only be used to generate temporary breakpoints, such as stepping over CALL instructions or running to a specific instruction and stopping.

## On-Chip Debugger Commands

The host communicates to the OCD by sending OCD commands using the DBG interface. During normal operation, only a subset of the OCD commands are available. In DEBUG mode, all OCD commands become available unless the user code and control registers are protected by programming the Read Protect Option Bit (RP). The Read Protect Option Bit prevents the code in memory from being read out of the Z8 Encore! XP F0822 Series products. When this option is enabled, several of the OCD commands are disabled.

[Table 93](#) on page 177 contains a summary of the OCD commands. Each OCD command is described further in the bulleted list. It also lists the commands that operate when the device is not in DEBUG mode (normal operation) and those commands that are disabled by programming the Read Protect Option Bit.

**Table 93. On-Chip Debugger Commands**

| Debug Command              | Command Byte | Enabled when NOT in DEBUG mode? | Disabled by Read Protect Option Bit                                                                                                                                                   |
|----------------------------|--------------|---------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Read OCD Revision          | 00H          | Yes                             | -                                                                                                                                                                                     |
| Write OCD Counter Register | 01H          | -                               | -                                                                                                                                                                                     |
| Read OCD Status Register   | 02H          | Yes                             | -                                                                                                                                                                                     |
| Read OCD Counter Register  | 03H          | -                               | -                                                                                                                                                                                     |
| Write OCD Control Register | 04H          | Yes                             | Cannot clear DBGMODE bit                                                                                                                                                              |
| Read OCD Control Register  | 05H          | Yes                             | -                                                                                                                                                                                     |
| Write Program Counter      | 06H          | -                               | Disabled                                                                                                                                                                              |
| Read Program Counter       | 07H          | -                               | Disabled                                                                                                                                                                              |
| Write Register             | 08H          | -                               | Only writes of the peripheral control registers at address F00H-FFH are allowed.<br>Additionally, only the Mass Erase command is allowed to be written to the Flash Control Register. |
| Read Register              | 09H          | -                               | Only reads of the peripheral control registers at address F00H-FFH are allowed.                                                                                                       |
| Write Program Memory       | 0AH          | -                               | Disabled                                                                                                                                                                              |
| Read Program Memory        | 0BH          | -                               | Disabled                                                                                                                                                                              |
| Write Data Memory          | 0CH          | -                               | Disabled                                                                                                                                                                              |
| Read Data Memory           | 0DH          | -                               | Disabled                                                                                                                                                                              |
| Read Program Memory CRC    | 0EH          | -                               | -                                                                                                                                                                                     |
| Reserved                   | 0FH          | -                               | -                                                                                                                                                                                     |
| Step Instruction           | 10H          | -                               | Disabled                                                                                                                                                                              |
| Stuff Instruction          | 11H          | -                               | Disabled                                                                                                                                                                              |

Table 93. On-Chip Debugger Commands (Continued)

| Debug Command       | Command Byte | Enabled when NOT in DEBUG mode? | Disabled by Read Protect Option Bit |
|---------------------|--------------|---------------------------------|-------------------------------------|
| Execute Instruction | 12H          | -                               | Disabled                            |
| Reserved            | 13H - FFH    | -                               | -                                   |

In the following bulleted list of OCD Commands, data and commands sent from the host to the OCD are identified by 'DBG ← Command/Data'. Data sent from the OCD back to the host is identified by 'DBG → Data'.

- Read OCD Revision (00H)**—The Read OCD Revision command determines the version of the OCD. If OCD commands are added, removed, or changed, this revision number changes.
  - DBG ← 00H
  - DBG → OCDREV[15:8] (Major revision number)
  - DBG → OCDREV[7:0] (Minor revision number)
- Write OCD Counter Register (01H)**—The Write OCD Counter Register command writes the data that follows to the OCDCNTR register. If the device is not in DEBUG mode, the data is discarded.
  - DBG ← 01H
  - DBG ← OCDCNTR[15:8]
  - DBG ← OCDCNTR[7:0]
- Read OCD Status Register (02H)**—The Read OCD Status Register command reads the OCDSTAT register.
  - DBG ← 02H
  - DBG → OCDSTAT[7:0]
- Read OCD Counter Register (03H)**—The OCD Counter Register can be used to count system clock cycles in between Breakpoints, generate a BRK when it counts down to zero, or generate a BRK when its value matches the Program Counter. Since this register is really a down counter, the returned value is inverted when this register is read so the returned result appears to be an up counter. If the device is not in DEBUG mode, this command returns FFFFH.
  - DBG ← 03H
  - DBG → ~OCDCNTR[15:8]
  - DBG → ~OCDCNTR[7:0]
- Write OCD Control Register (04H)**—The Write OCD Control Register command writes the data that follows to the OCDCTL register. When the Read Protect Option Bit is enabled, the DBGMODE bit (OCDCTL[7]) can only be set to 1, it cannot be cleared to 0 and the only method of putting the device back into normal operating mode is to reset the device.
  - DBG ← 04H
  - DBG → OCDCTL[7:0]

DBG ← 04H  
DBG ← OCDCTL[7:0]

- **Read OCD Control Register (05H)**—The Read OCD Control Register command reads the value of the OCDCTL register.

DBG ← 05H  
DBG → OCDCTL[7:0]

- **Write Program Counter (06H)**—The Write Program Counter command writes the data that follows to the eZ8 CPU's Program Counter. If the device is not in DEBUG mode or if the Read Protect Option Bit is enabled, the Program Counter values are discarded.

DBG ← 06H  
DBG ← ProgramCounter[15:8]  
DBG ← ProgramCounter[7:0]

- **Read Program Counter (07H)**—The Read Program Counter command reads the value in the eZ8 CPU's Program Counter. If the device is not in DEBUG mode or if the Read Protect Option Bit is enabled, this command returns FFFFH.

DBG ← 07H  
DBG → ProgramCounter[15:8]  
DBG → ProgramCounter[7:0]

- **Write Register (08H)**—The Write Register command writes data to the Register File. Data can be written 1-256 bytes at a time (256 bytes can be written by setting size to zero). If the device is not in DEBUG mode, the address and data values are discarded. If the Read Protect Option Bit is enabled, then only writes to the Flash Control Registers are allowed and all other register write data values are discarded.

DBG ← 08H  
DBG ← {4'h0, Register Address[11:8]}  
DBG ← Register Address[7:0]  
DBG ← Size[7:0]  
DBG ← 1-256 data bytes

- **Read Register (09H)**—The Read Register command reads data from the Register File. Data can be read 1-256 bytes at a time (256 bytes can be read by setting size to zero). Reading peripheral control registers through the OCD does not effect peripheral operation. For example, register bits that are normally cleared upon a read operation will not be effected (WDTSTAT register is affected by OCD read register operation). If the device is not in DEBUG mode or if the Read Protect Option Bit is enabled, this command returns FFH for all the data values.

DBG ← 09H  
DBG ← {4'h0, Register Address[11:8]}  
DBG ← Register Address[7:0]  
DBG ← Size[7:0]  
DBG → 1-256 data bytes

- **Write Program Memory (0AH)**—The Write Program Memory command writes data to Program Memory. This command is equivalent to the LDC and LDCI instructions. Data can be written 1-65536 bytes at a time (65536 bytes can be written by setting size to zero). The on-chip Flash Controller must be written to and unlocked for the programming operation to occur. If the Flash Controller is not unlocked, the data is discarded. If the device is not in DEBUG mode or if the Read Protect Option Bit is enabled, the data is discarded.

```
DBG ← 0AH
DBG ← Program Memory Address[15:8]
DBG ← Program Memory Address[7:0]
DBG ← Size[15:8]
DBG ← Size[7:0]
DBG ← 1-65536 data bytes
```

- **Read Program Memory (0BH)**—The Read Program Memory command reads data from Program Memory. This command is equivalent to the LDC and LDCI instructions. Data can be read 1-65536 bytes at a time (65536 bytes can be read by setting size to zero). If the device is not in DEBUG mode or if the Read Protect Option Bit is enabled, this command returns FFH for the data.

```
DBG ← 0BH
DBG ← Program Memory Address[15:8]
DBG ← Program Memory Address[7:0]
DBG ← Size[15:8]
DBG ← Size[7:0]
DBG → 1-65536 data bytes
```

- **(Flash version only) Write Data Memory (0CH)**—The Write Data Memory command writes data to Data Memory. This command is equivalent to the LDE and LDEI instructions. Data can be written 1-65536 bytes at a time (65536 bytes can be written by setting size to 0). If the device is not in DEBUG mode or if the Read Protect Option Bit is enabled, the data is discarded.

```
DBG ← 0CH
DBG ← Data Memory Address[15:8]
DBG ← Data Memory Address[7:0]
DBG ← Size[15:8]
DBG ← Size[7:0]
DBG ← 1-65536 data bytes
```

- **Read Data Memory (0DH)**—The Read Data Memory command reads from Data Memory. This command is equivalent to the LDE and LDEI instructions. Data can be read 1-65536 bytes at a time (65536 bytes can be read by setting size to 0). If the device is not in DEBUG mode, this command returns FFH for the data.

```
DBG ← 0DH
DBG ← Data Memory Address[15:8]
DBG ← Data Memory Address[7:0]
DBG ← Size[15:8]
```

DBG ← Size[7:0]  
DBG → 1-65536 data bytes

- **Read Program Memory CRC (0EH)**—The Read Program Memory CRC command computes and returns the CRC (cyclic redundancy check) of Program Memory using the 16-bit CRC-CCITT polynomial. If the device is not in DEBUG mode, this command returns FFFFH for the CRC value. Unlike most other OCD Read commands, there is a delay from issuing of the command until the OCD returns the data. The OCD reads the Program Memory, calculates the CRC value, and returns the result. The delay is a function of the Program Memory size and is approximately equal to the system clock period multiplied by the number of bytes in the Program Memory.

DBG ← 0EH  
DBG → CRC[15:8]  
DBG → CRC[7:0]

- **Step Instruction (10H)**—The Step Instruction command steps one assembly instruction at the current Program Counter location. If the device is not in DEBUG mode or the Read Protect Option Bit is enabled, the OCD ignores this command.

DBG ← 10H

- **Stuff Instruction (11H)**—The Stuff Instruction command steps one assembly instruction and allows specification of the first byte of the instruction. The remaining 0-4 bytes of the instruction are read from Program Memory. This command is useful for stepping over instructions where the first byte of the instruction has been overwritten by a Breakpoint. If the device is not in DEBUG mode or the Read Protect Option Bit is enabled, the OCD ignores this command.

DBG ← 11H  
DBG ← opcode[7:0]

- **Execute Instruction (12H)**—The Execute Instruction command allows sending an entire instruction to be executed to the eZ8 CPU. This command can also step over Breakpoints. The number of bytes to send for the instruction depends on the opcode. If the device is not in DEBUG mode or the Read Protect Option Bit is enabled, the OCD ignores this command

DBG ← 12H  
DBG ← 1-5 byte opcode

## On-Chip Debugger Control Register Definitions

### OCD Control Register

The OCD Control Register controls the state of the OCD. This register enters or exits DEBUG mode and enables the BRK instruction. It can also reset the Z8 Encore! XP<sup>®</sup> F0822 Series device.

A “reset and stop” function can be achieved by writing 81H to this register. A “reset and go” function can be achieved by writing 41H to this register. If the device is in DEBUG mode, a “run” function can be implemented by writing 40H to this register.

**Table 94. OCD Control Register (OCDCTL)**

| BITS  | 7       | 6     | 5      | 4       | 3     | 2      | 1        | 0   |
|-------|---------|-------|--------|---------|-------|--------|----------|-----|
| FIELD | DBGMODE | BRKEN | DBGACK | BRKLOOP | BRKPC | BRKZRO | Reserved | RST |
| RESET | 0       |       |        |         |       |        |          |     |
| R/W   | R/W     |       |        | R       |       |        |          | R/W |

**DBGMODE—Debug Mode**

Setting this bit to 1 causes the device to enter DEBUG mode. When in DEBUG mode, the eZ8 CPU stops fetching new instructions. Clearing this bit causes the eZ8 CPU to start running again. This bit is automatically set when a BRK instruction is decoded and Breakpoints are enabled. If the Read Protect Option Bit is enabled, this bit can only be cleared by resetting the device, it cannot be written to 0.

0 = The Z8 Encore! XP F0822 Series device is operating in NORMAL mode.

1 = The Z8 Encore! XP F0822 Series device is in DEBUG mode.

**BRKEN—Breakpoint Enable**

This bit controls the behavior of the BRK instruction (opcode 00H). By default, Breakpoints are disabled and the BRK instruction behaves like an NOP instruction. If this bit is set to 1 and a BRK instruction is decoded, the OCD takes action dependent upon the BRK-LOOP bit.

0 = BRK instruction is disabled.

1 = BRK instruction is enabled.

**DBGACK—Debug Acknowledge**

This bit enables the debug acknowledge feature. If this bit is set to 1, then the OCD sends an Debug Acknowledge character (FFH) to the host when a Breakpoint occurs.

0 = Debug Acknowledge is disabled.

1 = Debug Acknowledge is enabled.

**BRKLOOP—Breakpoint Loop**

This bit determines what action the OCD takes when a BRK instruction is decoded if breakpoints are enabled (BRKEN is 1). If this bit is 0, then the DBGMODE bit is automatically set to 1 and the OCD enter DEBUG mode. If BRKLOOP is set to 1, then the eZ8 CPU loops on the BRK instruction.

0 = BRK instruction sets DBGMODE to 1.

1 = eZ8 CPU loops on BRK instruction.

**BRKPC—Break when PC == OCDCNTR**

If this bit is set to 1, then the OCDCNTR register is used as a hardware breakpoint. When the program counter matches the value in the OCDCNTR register, DBGMODE is

automatically set to 1. If this bit is set, the OCDCNTR register does not count when the CPU is running.

0 = OCDCNTR is setup as counter

1 = OCDCNTR generates hardware break when PC == OCDCNTR

#### **BRKZRO—Break when OCDCNTR == 0000H**

If this bit is set, then the OCD automatically sets the DBGMODE bit when the OCDCNTR register counts down to 0000H. If this bit is set, the OCDCNTR register is not reset when the part leaves DEBUG Mode.

0 = OCD does not generate BRK when OCDCNTR decrements to 0000H

1 = OCD sets DBGMODE to 1 when OCDCNTR decrements to 0000H

#### **Reserved**

These bits are reserved and must be 0.

#### **RST—Reset**

Setting this bit to 1 resets the Z8 Encore! XP® F0822 Series device. The device goes through a normal POR sequence with the exception that the OCD is not reset. This bit is automatically cleared to 0 when the reset finishes.

0 = No effect.

1 = Reset the Z8 Encore! XP F0822 Series device.

### **OCD Status Register**

The OCD Status register reports status information about the current state of the debugger and the system.

**Table 95. OCD Status Register (OCDSTAT)**

| BITS  | 7    | 6    | 5    | 4        | 3 | 2 | 1 | 0 |
|-------|------|------|------|----------|---|---|---|---|
| FIELD | IDLE | HALT | RPEN | Reserved |   |   |   |   |
| RESET | 0    |      |      |          |   |   |   |   |
| R/W   | R    |      |      |          |   |   |   |   |

#### **IDLE—CPU Idling**

This bit is set if the part is in DEBUG mode (DBGMODE is 1), or if a BRK instruction occurred since the last time OCDCTL was written. This can be used to determine if the CPU is running or if it is idling.

0 = The eZ8 CPU is running.

1 = The eZ8 CPU is either stopped or looping on a BRK instruction.

#### **HALT—HALT Mode**

0 = The device is not in HALT mode.

1 = The device is in HALT mode.



**RPEN—Read Protect Option Bit Enabled**

0 = The Read Protect Option Bit is disabled (1).

1 = The Read Protect Option Bit is enabled (0), disabling many OCD commands.

**Reserved. Must be 0**

# Electrical Characteristics

## Absolute Maximum Ratings



**Caution:** Stresses greater than those listed in [Table 96](#) can cause permanent damage to the device.

These ratings are stress ratings only. Operation of the device at any condition outside those indicated in the operational sections of these specifications is not implied. Exposure to absolute maximum rating conditions for extended periods can affect device reliability. For improved reliability, unused inputs must be tied to one of the supply voltages ( $V_{DD}$  or  $V_{SS}$ ).

**Table 96. Absolute Maximum Ratings**

| Parameter                                                     | Minimum | Maximum | Units | Notes |
|---------------------------------------------------------------|---------|---------|-------|-------|
| Ambient temperature under bias                                | -40     | +105    | °C    | 1     |
| Storage temperature                                           | -65     | +150    | °C    |       |
| Voltage on any pin with respect to $V_{SS}$                   | -0.3    | +5.5    | V     | 2     |
| Voltage on $AV_{SS}$ pin with respect to $V_{SS}$             | -0.3    | +0.3    | V     | 2     |
| Voltage on $V_{DD}$ pin with respect to $V_{SS}$              | -0.3    | +3.6    | V     |       |
| Voltage on $AV_{DD}$ pin with respect to $V_{DD}$             | -0.3    | +0.3    | V     |       |
| Maximum current on input and/or inactive output pin           | -5      | +5      | μA    |       |
| Maximum output current from active output pin                 | -25     | +25     | mA    |       |
| <b>20-pin SSOP Package Maximum Ratings at -40 °C to 70 °C</b> |         |         |       |       |
| Total power dissipation                                       |         | 430     | mW    |       |
| Maximum current into $V_{DD}$ or out of $V_{SS}$              |         | 120     | mA    |       |
| <b>20-pin SSOP Package Maximum Ratings at 70 °C to 105 °C</b> |         |         |       |       |
| Total power dissipation                                       |         | 250     | mW    |       |
| Maximum current into $V_{DD}$ or out of $V_{SS}$              |         | 69      | mA    |       |
| <b>20-pin PDIP Package Maximum Ratings at -40 °C to 70 °C</b> |         |         |       |       |
| Total power dissipation                                       |         | 775     | mW    |       |
| Maximum current into $V_{DD}$ or out of $V_{SS}$              |         | 215     | mA    |       |

**Table 96. Absolute Maximum Ratings (Continued)**

| Parameter                                                                                                                                                                | Minimum | Maximum | Units | Notes |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------|---------|-------|-------|
| <b>20-pin PDIP Package Maximum Ratings at 70 °C to 105 °C</b>                                                                                                            |         |         |       |       |
| Total power dissipation                                                                                                                                                  |         | 285     | mW    |       |
| Maximum current into $V_{DD}$ or out of $V_{SS}$                                                                                                                         |         | 79      | mA    |       |
| <b>28-pin SOIC Package Maximum Ratings at -40 °C to 70 °C</b>                                                                                                            |         |         |       |       |
| Total power dissipation                                                                                                                                                  |         | 450     | mW    |       |
| Maximum current into $V_{DD}$ or out of $V_{SS}$                                                                                                                         |         | 125     | mA    |       |
| <b>28-pin SOIC Package Maximum Ratings at 70 °C to 105 °C</b>                                                                                                            |         |         |       |       |
| Total power dissipation                                                                                                                                                  |         | 260     | mW    |       |
| Maximum current into $V_{DD}$ or out of $V_{SS}$                                                                                                                         |         | 73      | mA    |       |
| <b>28-pin PDIP Package Maximum Ratings at -40 °C to 70 °C</b>                                                                                                            |         |         |       |       |
| Total power dissipation                                                                                                                                                  |         | 1100    | mW    |       |
| Maximum current into $V_{DD}$ or out of $V_{SS}$                                                                                                                         |         | 305     | mA    |       |
| <b>28-pin PDIP Package Maximum Ratings at 70 °C to 105 °C</b>                                                                                                            |         |         |       |       |
| Total power dissipation                                                                                                                                                  |         | 400     | mW    |       |
| Maximum current into $V_{DD}$ or out of $V_{SS}$                                                                                                                         |         | 110     | mA    |       |
| <b>Note:</b> This voltage applies to all pins except the following: $V_{DD}$ , $AV_{DD}$ , $V_{REF}$ , pins supporting analog input (Port B), and where noted otherwise. |         |         |       |       |

## DC Characteristics

Table 97 lists the DC characteristics of the Z8 Encore! XP<sup>®</sup> F0822 Series products. All voltages are referenced to  $V_{SS}$ , the primary system ground.

**Table 97. DC Characteristics**

| Symbol    | Parameter                            | $T_A = -40\text{ }^{\circ}\text{C to }105\text{ }^{\circ}\text{C}$ |         |                    | Units | Conditions                                                                                                                                             |
|-----------|--------------------------------------|--------------------------------------------------------------------|---------|--------------------|-------|--------------------------------------------------------------------------------------------------------------------------------------------------------|
|           |                                      | Minimum                                                            | Typical | Maximum            |       |                                                                                                                                                        |
| $V_{DD}$  | Supply Voltage                       | 2.7                                                                | —       | 3.6                | V     |                                                                                                                                                        |
| $V_{IL1}$ | Low Level Input Voltage              | -0.3                                                               | —       | $0.3 \cdot V_{DD}$ | V     | For all input pins except $\overline{\text{RESET}}$ , DBG, and XIN.                                                                                    |
| $V_{IL2}$ | Low Level Input Voltage              | -0.3                                                               | —       | $0.2 \cdot V_{DD}$ | V     | For $\overline{\text{RESET}}$ , DBG, and XIN.                                                                                                          |
| $V_{IH1}$ | High Level Input Voltage             | $0.7 \cdot V_{DD}$                                                 | —       | 5.5                | V     | Ports A and C pins when their programmable pull-ups are disabled.                                                                                      |
| $V_{IH2}$ | High Level Input Voltage             | $0.7 \cdot V_{DD}$                                                 | —       | $V_{DD} + 0.3$     | V     | Port B pins. Ports A and C pins when their programmable pull-ups are enabled.                                                                          |
| $V_{IH3}$ | High Level Input Voltage             | $0.8 \cdot V_{DD}$                                                 | —       | $V_{DD} + 0.3$     | V     | $\overline{\text{RESET}}$ , DBG, and XIN pins.                                                                                                         |
| $V_{OL1}$ | Low Level Output Voltage             | —                                                                  | —       | 0.4                | V     | $I_{OL} = 2\text{ mA}$ ; $V_{DD} = 3.0\text{ V}$<br>High Output Drive disabled.                                                                        |
| $V_{OH1}$ | High Level Output Voltage            | 2.4                                                                | —       | —                  | V     | $I_{OH} = -2\text{ mA}$ ; $V_{DD} = 3.0\text{ V}$<br>High Output Drive disabled.                                                                       |
| $V_{OL2}$ | Low Level Output Voltage High Drive  | —                                                                  | —       | 0.6                | V     | $I_{OL} = 20\text{ mA}$ ; $V_{DD} = 3.3\text{ V}$<br>High Output Drive enabled<br>$T_A = -40\text{ }^{\circ}\text{C to }+70\text{ }^{\circ}\text{C}$   |
| $V_{OH2}$ | High Level Output Voltage High Drive | 2.4                                                                | —       | —                  | V     | $I_{OH} = -20\text{ mA}$ ; $V_{DD} = 3.3\text{ V}$<br>High Output Drive enabled;<br>$T_A = -40\text{ }^{\circ}\text{C to }+70\text{ }^{\circ}\text{C}$ |
| $V_{OL3}$ | Low Level Output Voltage High Drive  | —                                                                  | —       | 0.6                | V     | $I_{OL} = 15\text{ mA}$ ; $V_{DD} = 3.3\text{ V}$<br>High Output Drive enabled;<br>$T_A = +70\text{ }^{\circ}\text{C to }+105\text{ }^{\circ}\text{C}$ |
| $V_{OH3}$ | High Level Output Voltage High Drive | 2.4                                                                | —       | —                  | V     | $I_{OH} = 15\text{ mA}$ ; $V_{DD} = 3.3\text{ V}$<br>High Output Drive enabled;<br>$T_A = +70\text{ }^{\circ}\text{C to }+105\text{ }^{\circ}\text{C}$ |

**Table 97. DC Characteristics (Continued)**

| Symbol            | Parameter                 | T <sub>A</sub> = -40 °C to 105 °C |                  |         | Units | Conditions                                                            |
|-------------------|---------------------------|-----------------------------------|------------------|---------|-------|-----------------------------------------------------------------------|
|                   |                           | Minimum                           | Typical          | Maximum |       |                                                                       |
| V <sub>RAM</sub>  | RAM Data Retention        | 0.7                               | –                | –       | V     |                                                                       |
| I <sub>IL</sub>   | Input Leakage Current     | -5                                | –                | +5      | μA    | V <sub>DD</sub> = 3.6 V;<br>V <sub>IN</sub> = VDD or VSS <sup>1</sup> |
| I <sub>TL</sub>   | Tri-State Leakage Current | -5                                | –                | +5      | μA    | V <sub>DD</sub> = 3.6 V                                               |
| C <sub>PAD</sub>  | GPIO Port Pad Capacitance | –                                 | 8.0 <sup>2</sup> | –       | pF    |                                                                       |
| C <sub>XIN</sub>  | XIN Pad Capacitance       | –                                 | 8.0 <sup>2</sup> | –       | pF    |                                                                       |
| C <sub>XOUT</sub> | XOUT Pad Capacitance      | –                                 | 9.5 <sup>2</sup> | –       | pF    |                                                                       |
| I <sub>PU1</sub>  | Weak Pull-up Current      | 9                                 | 20               | 50      | μA    | VDD = 2.7–3.6 V.<br>T <sub>A</sub> = 0 °C to +70 °C                   |
| I <sub>PU2</sub>  | Weak Pull-up Current      | 7                                 | 20               | 75      | μA    | VDD = 2.7–3.6 V.<br>T <sub>A</sub> = -40 °C to +105 °C                |

<sup>1</sup> This condition excludes all pins that have on-chip pull-ups, when driven Low.

<sup>2</sup> These values are provided for design guidance only and are not tested in production.

Figure 41 on page 189 displays the typical active mode current consumption while operating at 25 °C, 3.3 V, versus the system clock frequency. All GPIO pins are configured as outputs and driven High.

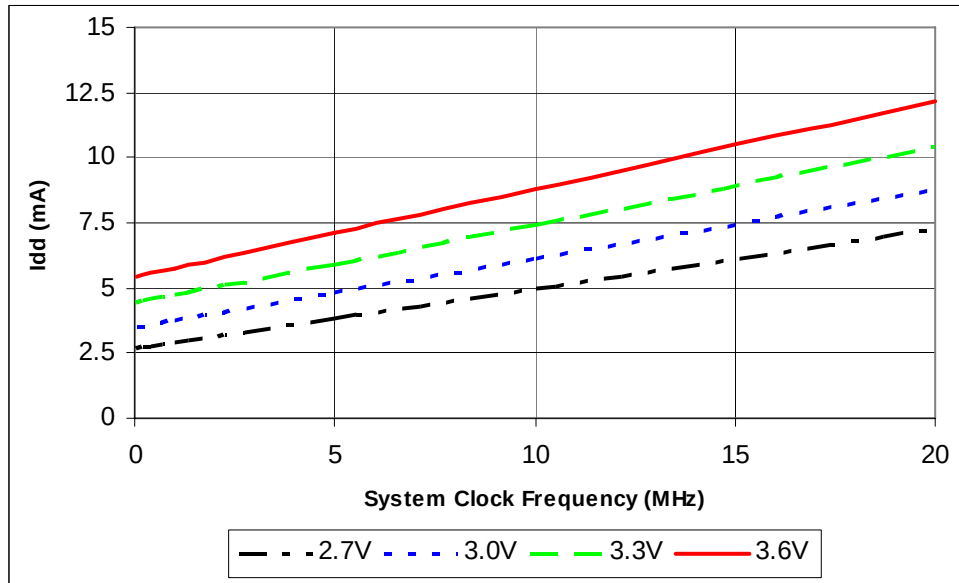


**Figure 41. Typical Active Mode  $I_{DD}$  Versus System Clock Frequency**

Figure 42 displays the maximum active mode current consumption across the full operating temperature range of the device and versus the system clock frequency. All GPIO pins are configured as outputs and driven High.

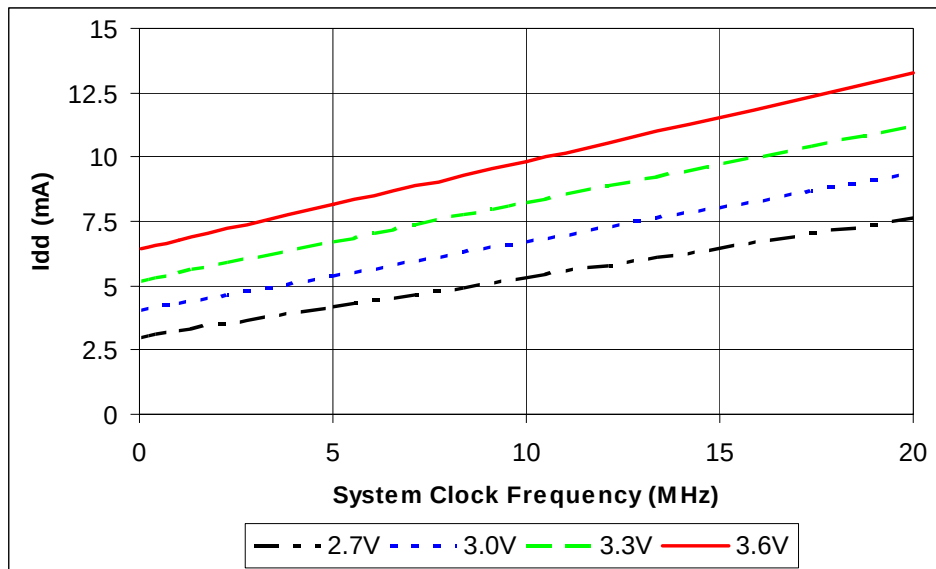


**Figure 42. Maximum Active Mode  $I_{DD}$  Versus System Clock Frequency**

Figure 43 displays the typical current consumption in HALT mode while operating at 25 °C versus the system clock frequency. All GPIO pins are configured as outputs and driven High.

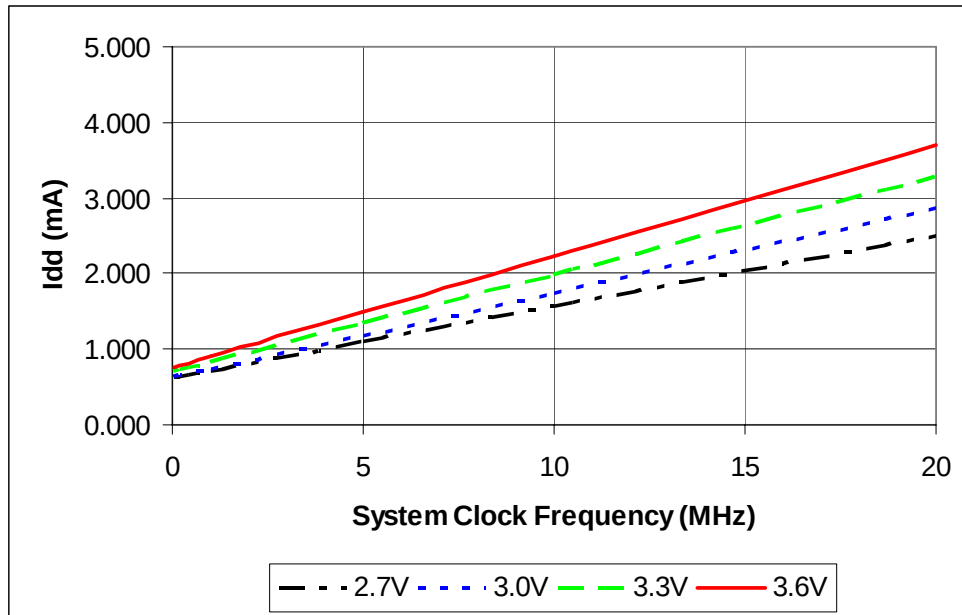


Figure 43. Typical HALT Mode  $I_{DD}$  Versus System Clock Frequency

Figure 44 displays the maximum HALT mode current consumption across the full operating temperature range of the device and versus the system clock frequency. All GPIO pins are configured as outputs and driven High.

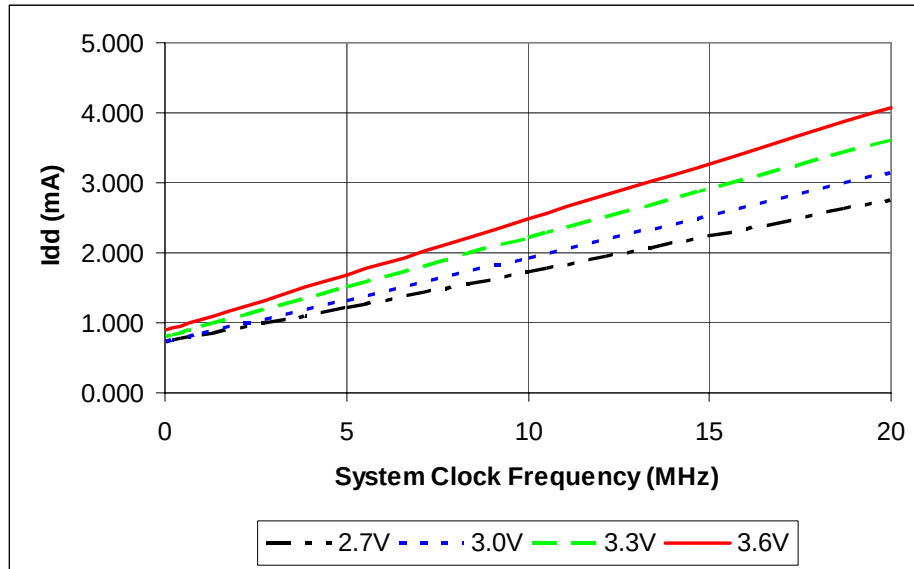


Figure 44. Maximum HALT Mode  $I_{CC}$  Versus System Clock Frequency

Figure 45 displays the maximum current consumption in STOP mode with the VBO and Watchdog Timer enabled versus the power supply voltage. All GPIO pins are configured as outputs and driven High.

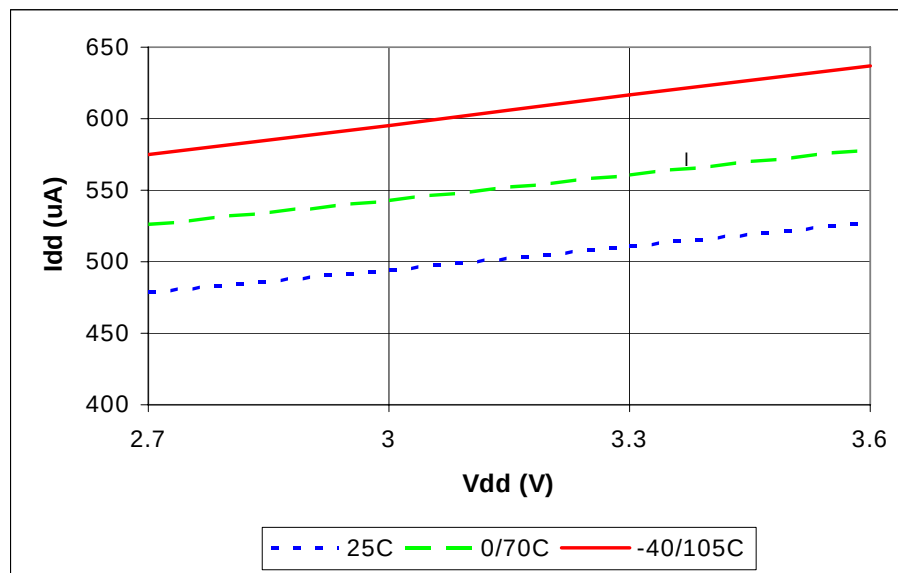


**Figure 45. Maximum STOP Mode  $I_{DD}$  with VBO Enabled versus Power Supply Voltage**

Figure 46 on page 193 displays the maximum current consumption in STOP mode with the VBO disabled and Watchdog Timer enabled versus the power supply voltage. All GPIO pins are configured as outputs and driven High. Disabling the Watchdog Timer and its internal RC oscillator in STOP mode will provide some additional reduction in STOP mode current consumption. This small current reduction is indistinguishable on the scale of Figure 46 on page 193.

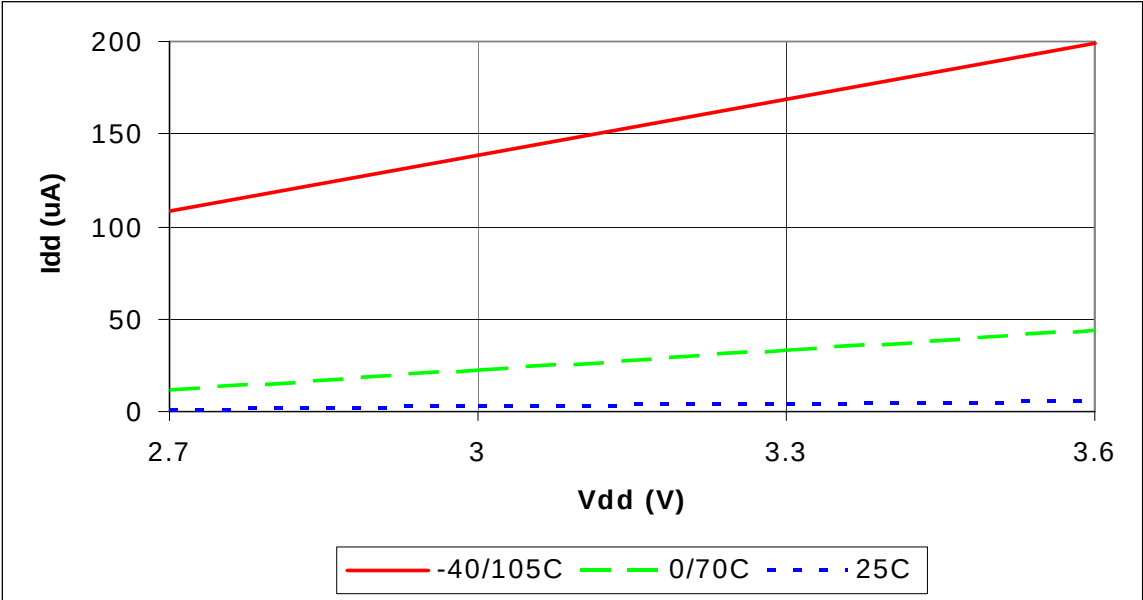


Figure 46. Maximum STOP Mode  $I_{DD}$  with VBO Disabled versus Power Supply Voltage

## AC Characteristics

Table 98 provides information on the AC characteristics and timing. All AC timing information assumes a standard load of 50 pF on all outputs.

**Table 98. AC Characteristics**

| Symbol              | Parameter                      | V <sub>DD</sub> = 2.7 - 3.6 V<br>T <sub>A</sub> = -40 °C to 105 °C |         | Units | Conditions                                                                                      |
|---------------------|--------------------------------|--------------------------------------------------------------------|---------|-------|-------------------------------------------------------------------------------------------------|
|                     |                                | Minimum                                                            | Maximum |       |                                                                                                 |
| F <sub>SYSCLK</sub> | System Clock Frequency (ROM)   | –                                                                  | 20.0    | MHz   |                                                                                                 |
| F <sub>SYSCLK</sub> | System Clock Frequency (Flash) | –                                                                  | 20.0    | MHz   | Read-only from Flash memory.                                                                    |
|                     |                                | 0.032768                                                           | 20.0    | MHz   | Program or erasure of the Flash memory.                                                         |
| F <sub>XTAL</sub>   | Crystal Oscillator Frequency   | 0.032768                                                           | 20.0    | MHz   | System clock frequencies below the crystal oscillator minimum require an external clock driver. |
| T <sub>XIN</sub>    | System Clock Period            | 50                                                                 | –       | ns    | T <sub>CLK</sub> = 1/F <sub>sysclk</sub>                                                        |
| T <sub>XINH</sub>   | System Clock High Time         | 20                                                                 | 30      | ns    | T <sub>CLK</sub> = 50 ns                                                                        |
| T <sub>XINL</sub>   | System Clock Low Time          | 20                                                                 | 30      | ns    | T <sub>CLK</sub> = 50 ns                                                                        |

## On-Chip Peripheral AC and DC Electrical Characteristics

Table 99 provides information on the Power-On Reset and Voltage Brownout electrical characteristics.

**Table 99. Power-On Reset and Voltage Brownout Electrical Characteristics and Timing**

| Symbol            | Parameter                                                                                 | T <sub>A</sub> = -40 °C to 105 °C |                      |         | Units | Conditions                                                                                         |
|-------------------|-------------------------------------------------------------------------------------------|-----------------------------------|----------------------|---------|-------|----------------------------------------------------------------------------------------------------|
|                   |                                                                                           | Minimum                           | Typical <sup>1</sup> | Maximum |       |                                                                                                    |
| V <sub>POR</sub>  | Power-On Reset Voltage Threshold                                                          | 2.15                              | 2.40                 | 2.60    | V     | V <sub>DD</sub> = V <sub>POR</sub>                                                                 |
| V <sub>VBO</sub>  | Voltage Brownout Reset Voltage Threshold                                                  | 2.05                              | 2.30                 | 2.55    | V     | V <sub>DD</sub> = V <sub>VBO</sub>                                                                 |
|                   | V <sub>POR</sub> to V <sub>VBO</sub> hysteresis                                           | 50                                | 100                  | –       | mV    |                                                                                                    |
|                   | Starting V <sub>DD</sub> voltage to ensure valid POR                                      | –                                 | V <sub>SS</sub>      | –       | V     |                                                                                                    |
| T <sub>ANA</sub>  | POR Analog Delay                                                                          | –                                 | 50                   | –       | μs    | V <sub>DD</sub> > V <sub>POR</sub> ; T <sub>POR</sub> Digital Reset delay follows T <sub>ANA</sub> |
| T <sub>POR</sub>  | POR Digital Delay                                                                         | –                                 | 5.0                  | –       | ms    | 50 WDT Oscillator cycles (10 kHz) + 16 System Clock cycles (20 MHz)                                |
| T <sub>VBO</sub>  | Voltage Brownout Pulse Rejection Period                                                   | –                                 | 10                   | –       | μs    | V <sub>DD</sub> < V <sub>VBO</sub> to generate a Reset.                                            |
| T <sub>RAMP</sub> | Time for VDD to transition from V <sub>SS</sub> to V <sub>POR</sub> to ensure valid Reset | 0.10                              | –                    | 100     | ms    |                                                                                                    |

<sup>1</sup> Data in the typical column is from characterization at 3.3 V and 25 °C. These values are provided for design guidance only and are not tested in production.

Table 100 provides information on the external RC oscillator electrical characteristics and timing, and Table 101 provides information on the Flash memory electrical characteristics and timing.

**Table 100. External RC Oscillator Electrical Characteristics and Timing**

| Symbol                                                                                                                                                                                                                                                                                        | Parameter                            | T <sub>A</sub> = -40 °C to 105 °C |                      |         | Units | Conditions |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------|-----------------------------------|----------------------|---------|-------|------------|
|                                                                                                                                                                                                                                                                                               |                                      | Minimum                           | Typical <sup>1</sup> | Maximum |       |            |
| V <sub>DD</sub>                                                                                                                                                                                                                                                                               | Operating Voltage Range              | 2.70 <sup>1</sup>                 | –                    | –       | V     |            |
| R <sub>EXT</sub>                                                                                                                                                                                                                                                                              | External Resistance from XIN to VDD  | 40                                | 45                   | 200     | kΩ    |            |
| C <sub>EXT</sub>                                                                                                                                                                                                                                                                              | External Capacitance from XIN to VSS | 0                                 | 20                   | 1000    | pF    |            |
| F <sub>OSC</sub>                                                                                                                                                                                                                                                                              | External RC Oscillation Frequency    | –                                 | –                    | 4       | MHz   |            |
| <sup>1</sup> When using the external RC oscillator mode, the oscillator can stop oscillating if the power supply drops below 2.7 V, but before the power supply drops to the voltage brown-out threshold. The oscillator will resume oscillation as soon as the supply voltage exceeds 2.7 V. |                                      |                                   |                      |         |       |            |

**Table 101. Flash Memory Electrical Characteristics and Timing**

| Parameter                                  | V <sub>DD</sub> = 2.7 - 3.6V<br>T <sub>A</sub> = -40 °C to 105 °C |         |         | Units | Notes                                                                                                                                              |
|--------------------------------------------|-------------------------------------------------------------------|---------|---------|-------|----------------------------------------------------------------------------------------------------------------------------------------------------|
|                                            | Minimum                                                           | Typical | Maximum |       |                                                                                                                                                    |
| Flash Byte Read Time                       | 50                                                                | –       | –       | μs    |                                                                                                                                                    |
| Flash Byte Program Time                    | 20                                                                | –       | 40      | μs    |                                                                                                                                                    |
| Flash Page Erase Time                      | 10                                                                | –       | –       | ms    |                                                                                                                                                    |
| Flash Mass Erase Time                      | 200                                                               | –       | –       | ms    |                                                                                                                                                    |
| Writes to Single Address Before Next Erase | –                                                                 | –       | 2       |       |                                                                                                                                                    |
| Flash Row Program Time                     | –                                                                 | –       | 8       | ms    | Cumulative program time for single row cannot exceed limit before next erase. This parameter is only an issue when bypassing the Flash Controller. |

**Table 101. Flash Memory Electrical Characteristics and Timing (Continued)**

| Parameter      | V <sub>DD</sub> = 2.7 - 3.6V<br>T <sub>A</sub> = -40 °C to 105 °C |         |         | Units  | Notes                  |
|----------------|-------------------------------------------------------------------|---------|---------|--------|------------------------|
|                | Minimum                                                           | Typical | Maximum |        |                        |
| Data Retention | 100                                                               | –       | –       | years  | 25 °C                  |
| Endurance      | 10,000                                                            | –       | –       | cycles | Program / erase cycles |

Table 102 provides information on the Reset and Stop Mode Recovery pin timing and Table 103 provides information on the Watchdog Timer Electrical Characteristics and Timing.

**Table 102. Reset and Stop Mode Recovery Pin Timing**

| Symbol             | Parameter                                      | T <sub>A</sub> = -40 °C to 105 °C |         |         | Units            | Conditions                                                   |
|--------------------|------------------------------------------------|-----------------------------------|---------|---------|------------------|--------------------------------------------------------------|
|                    |                                                | Minimum                           | Typical | Maximum |                  |                                                              |
| T <sub>RESET</sub> | Reset pin assertion to initiate a System Reset | 4                                 | –       | –       | T <sub>CLK</sub> | Not in STOP mode.<br>T <sub>CLK</sub> = System Clock period. |
| T <sub>SMR</sub>   | Stop Mode Recovery pin Pulse Rejection Period  | 10                                | 20      | 40      | ns               | RESET, DBG and GPIO pins configured as SMR sources.          |

<sup>1</sup> When using the external RC oscillator mode, the oscillator can stop oscillating if the power supply drops below 2.7 V, but before the power supply drops to the voltage brown-out threshold. The oscillator will resume oscillation as soon as the supply voltage exceeds 2.7 V.

**Table 103. Watchdog Timer Electrical Characteristics and Timing**

| Symbol           | Parameter                                               | V <sub>DD</sub> = 2.7–3.6 V<br>T <sub>A</sub> = -40 °C to 105 °C |         |         | Units | Conditions |
|------------------|---------------------------------------------------------|------------------------------------------------------------------|---------|---------|-------|------------|
|                  |                                                         | Minimum                                                          | Typical | Maximum |       |            |
| F <sub>WDT</sub> | WDT Oscillator Frequency                                | 5                                                                | 10      | 20      | kHz   |            |
| I <sub>WDT</sub> | WDT Oscillator Current including internal RC oscillator | –                                                                | < 1     | 5       | μA    |            |

Figure 47 displays the input frequency response of the ADC.

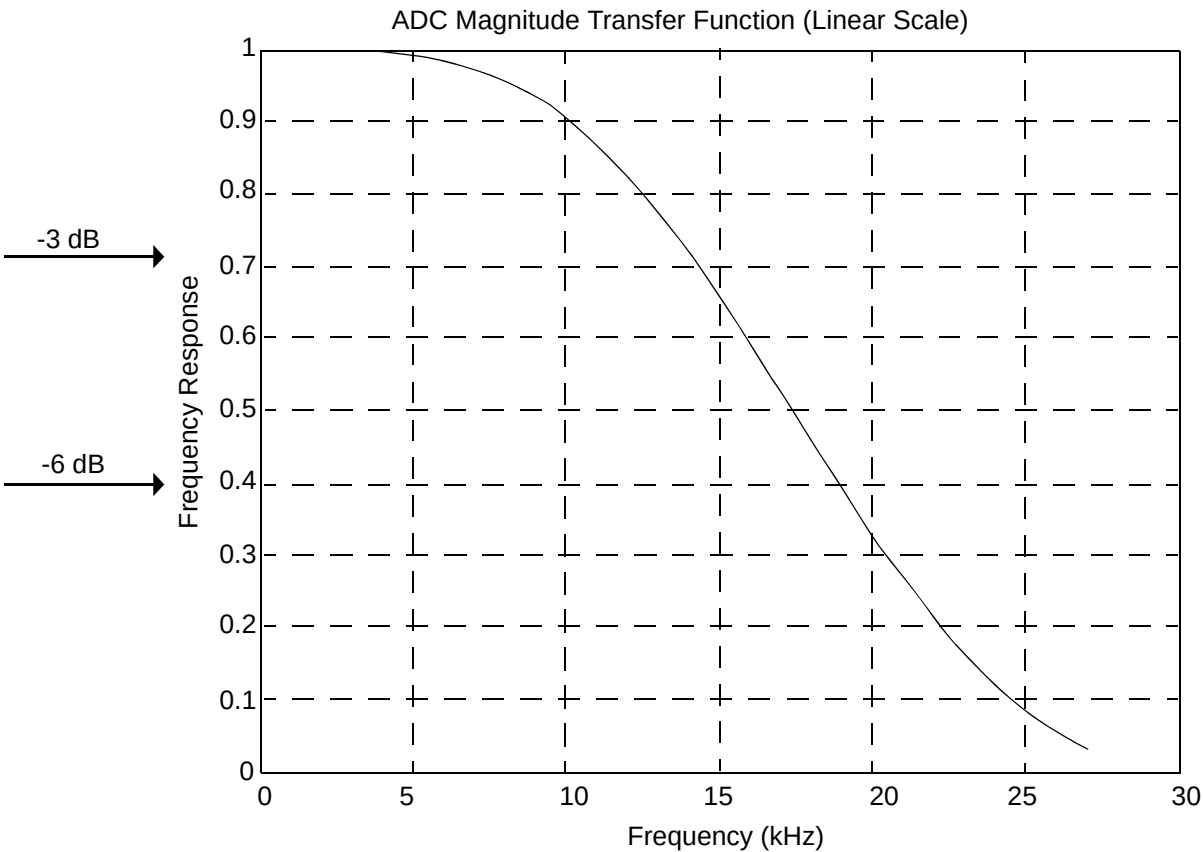


Figure 47. Analog-to-Digital Converter Frequency Response

**Table 104. Analog-to-Digital Converter Electrical Characteristics and Timing**

| Symbol            | Parameter                                                     | V <sub>DD</sub> = 3.0–3.6 V<br>T <sub>A</sub> = -40 °C to 105 °C |         |         | Units  | Conditions                                                                                                       |
|-------------------|---------------------------------------------------------------|------------------------------------------------------------------|---------|---------|--------|------------------------------------------------------------------------------------------------------------------|
|                   |                                                               | Minimum                                                          | Typical | Maximum |        |                                                                                                                  |
|                   | Resolution                                                    | 10                                                               | –       | –       | bits   | External V <sub>REF</sub> = 3.0 V;                                                                               |
|                   | Differential Nonlinearity (DNL)                               | -0.25                                                            | –       | 0.25    | lsb    | Guaranteed by design                                                                                             |
|                   | Integral Nonlinearity (INL)                                   | -2.0                                                             | –       | 2.0     | lsb    | External V <sub>REF</sub> = 3.0 V                                                                                |
|                   | DC Offset Error                                               | -35                                                              | –       | 25      | mV     |                                                                                                                  |
| V <sub>REF</sub>  | Internal Reference Voltage                                    | 1.9                                                              | 2.0     | 2.4     | V      | V <sub>DD</sub> = 3.0 - 3.6 V<br>T <sub>A</sub> = -40 °C to 105 °C                                               |
| VC <sub>REF</sub> | Voltage Coefficient of Internal Reference Voltage             | –                                                                | 78      | –       | mV/V   | V <sub>REF</sub> variation as a function of AVDD.                                                                |
| TC <sub>REF</sub> | Temperature Coefficient of Internal Reference Voltage         | –                                                                | 1       | –       | mV/°C  |                                                                                                                  |
|                   | Single-Shot Conversion Period                                 | 5129                                                             |         |         | cycles | System clock cycles                                                                                              |
|                   | Continuous Conversion Period                                  | 256                                                              |         |         | cycles | System clock cycles                                                                                              |
| R <sub>S</sub>    | Analog Source Impedance                                       | –                                                                | –       | 150     | W      | Recommended                                                                                                      |
| Z <sub>in</sub>   | Input Impedance                                               |                                                                  | 150     |         | KΩ     |                                                                                                                  |
| V <sub>REF</sub>  | External Reference Voltage                                    |                                                                  |         | AVDD    | V      | AVDD ≤ VDD. When using an external reference voltage, decoupling capacitance should be placed from VREF to AVSS. |
| I <sub>REF</sub>  | Current draw into VREF pin when driving with external source. |                                                                  | 25.0    | 40.0    | μA     |                                                                                                                  |

## General Purpose I/O Port Input Data Sample Timing

Figure 48 displays timing of the GPIO Port input sampling. Table 105 lists the GPIO port input timing.

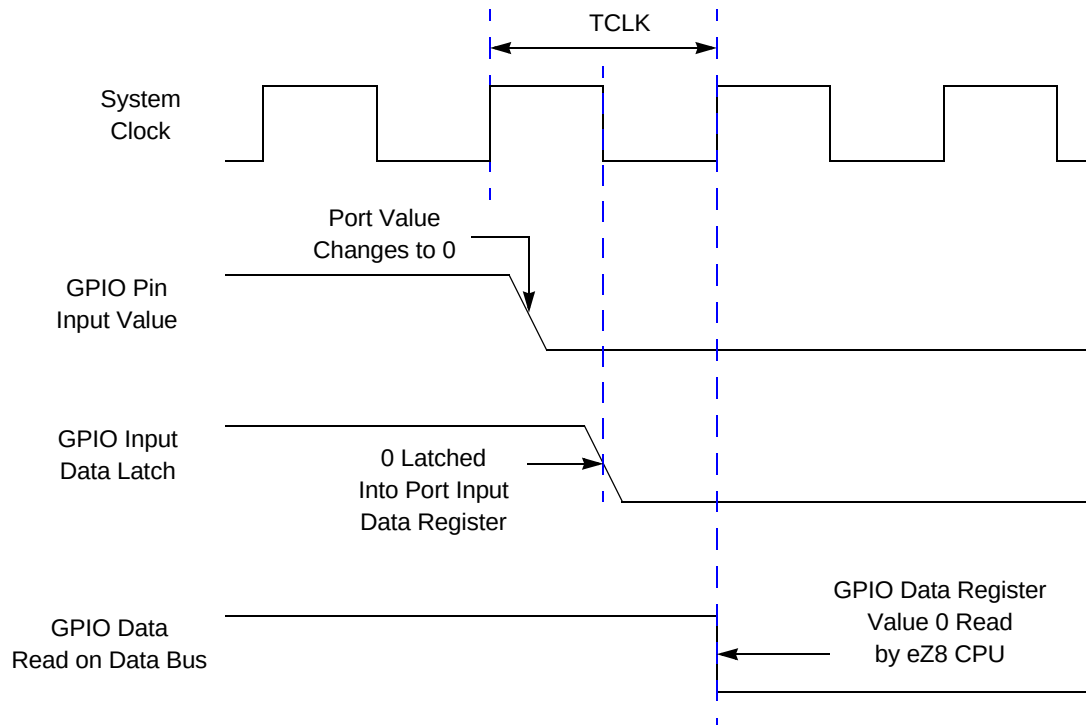


Figure 48. Port Input Sample Timing

Table 105. GPIO Port Input Timing

| Parameter           | Abbreviation                                                                                          | Delay (ns) |         |
|---------------------|-------------------------------------------------------------------------------------------------------|------------|---------|
|                     |                                                                                                       | Minimum    | Maximum |
| T <sub>S_PORT</sub> | Port Input Transition to XIN Fall Setup Time<br>(Not pictured)                                        | 5          | –       |
| T <sub>H_PORT</sub> | XIN Fall to Port Input Transition Hold Time<br>(Not pictured)                                         | 5          | –       |
| T <sub>SMR</sub>    | GPIO Port Pin Pulse Width to Insure Stop Mode Recovery<br>(for GPIO Port Pins enabled as SMR sources) | 1μs        |         |

General Purpose I/O Port Output Timing

Figure 49 and Table 106 provide timing information for GPIO Port pins.

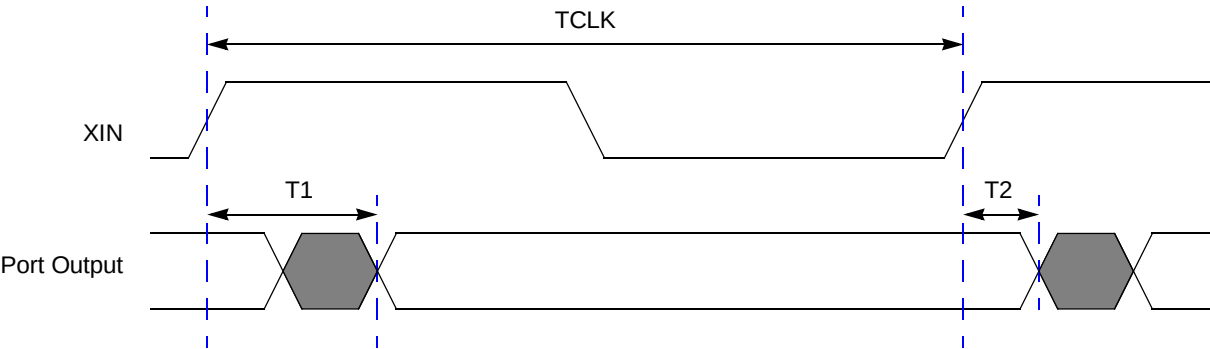


Figure 49. GPIO Port Output Timing

Table 106. GPIO Port Output Timing

| Parameter Abbreviation |                                     | Delay (ns) |         |
|------------------------|-------------------------------------|------------|---------|
|                        |                                     | Minimum    | Maximum |
| GPIO Port pins         |                                     |            |         |
| T <sub>1</sub>         | XIN Rise to Port Output Valid Delay | –          | 15      |
| T <sub>2</sub>         | XIN Rise to Port Output Hold Time   | 2          | –       |

## On-Chip Debugger Timing

Figure 50 and Table 107 provide timing information for the DBG pin. The DBG pin timing specifications assume a 4  $\mu$ s maximum rise and fall time.

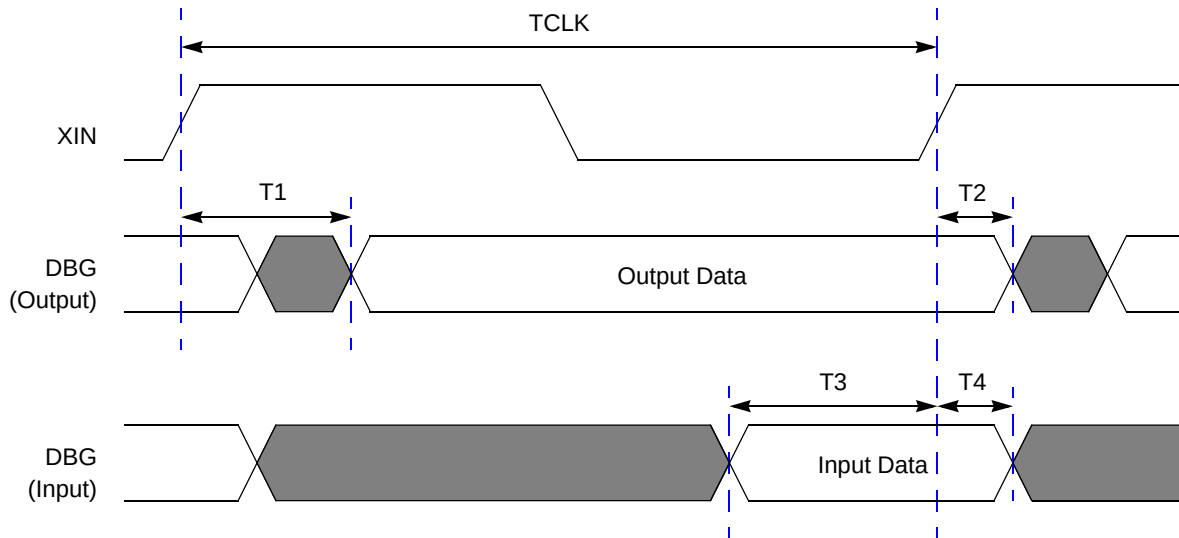


Figure 50. On-Chip Debugger Timing

Table 107. On-Chip Debugger Timing

| Parameter Abbreviation |                                  | Delay (ns) |                |
|------------------------|----------------------------------|------------|----------------|
|                        |                                  | Minimum    | Maximum        |
| <b>DBG</b>             |                                  |            |                |
| T <sub>1</sub>         | XIN Rise to DBG Valid Delay      | –          | 15             |
| T <sub>2</sub>         | XIN Rise to DBG Output Hold Time | 2          | –              |
| T <sub>3</sub>         | DBG to XIN Rise Input Setup Time | 10         | –              |
| T <sub>4</sub>         | DBG to XIN Rise Input Hold Time  | 5          | –              |
| DBG frequency          |                                  |            | System Clock/4 |

SPI MASTER Mode Timing

Figure 51 and Table 108 provide timing information for SPI MASTER mode pins. Timing is shown with SCK rising edge used to source MOSI output data, SCK falling edge used to sample MISO input data. Timing on the SS output pin(s) is controlled by software.

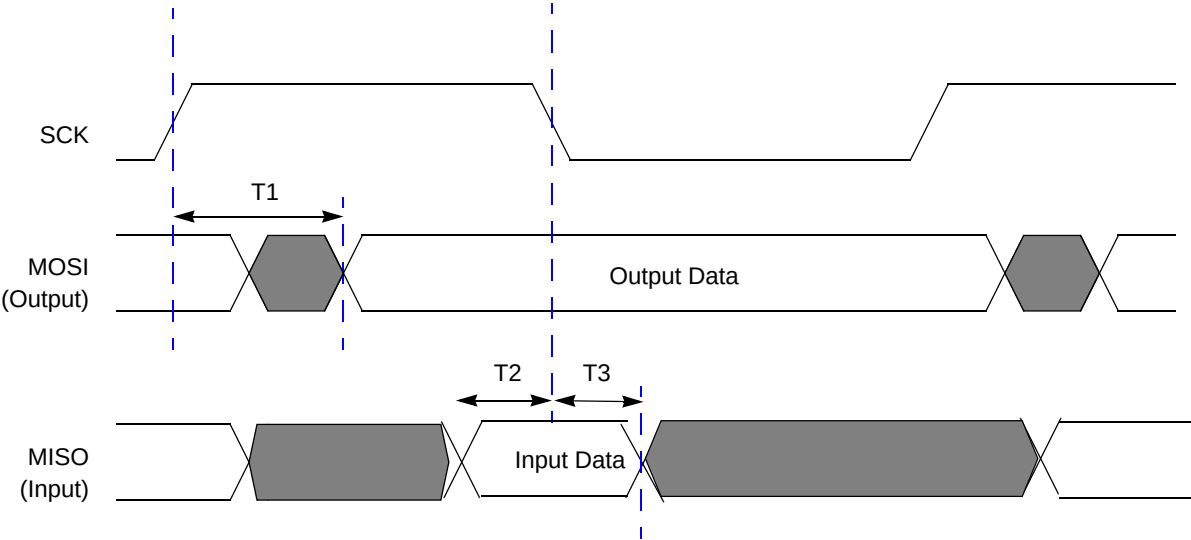


Figure 51. SPI MASTER Mode Timing

Table 108. SPI MASTER Mode Timing

| Parameter      | Abbreviation                                | Delay (ns) |         |
|----------------|---------------------------------------------|------------|---------|
|                |                                             | Minimum    | Maximum |
| SPI MASTER     |                                             |            |         |
| T <sub>1</sub> | SCK Rise to MOSI output Valid Delay         | -5         | +5      |
| T <sub>2</sub> | MISO input to SCK (receive edge) Setup Time | 20         |         |
| T <sub>3</sub> | MISO input to SCK (receive edge) Hold Time  | 0          |         |

## SPI SLAVE Mode Timing

Figure 52 and Table 109 provide timing information for the SPI SLAVE mode pins. Timing is shown with SCK rising edge used to source MISO output data, SCK falling edge used to sample MOSI input data.

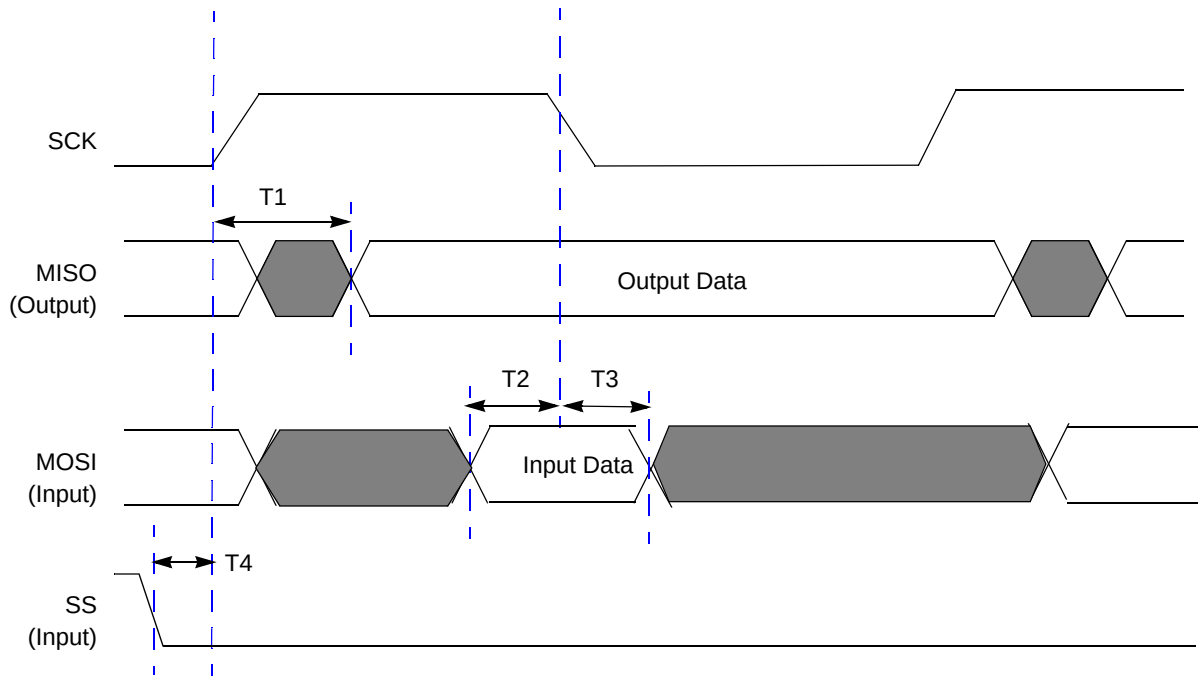


Figure 52. SPI SLAVE Mode Timing

Table 109. SPI SLAVE Mode Timing

| Parameter      | Abbreviation                                   | Delay (ns)     |                          |
|----------------|------------------------------------------------|----------------|--------------------------|
|                |                                                | Minimum        | Maximum                  |
| SPI SLAVE      |                                                |                |                          |
| T <sub>1</sub> | SCK (transmit edge) to MISO output Valid Delay | 2 * Xin period | 3 * Xin period + 20 nsec |
| T <sub>2</sub> | MOSI input to SCK (receive edge) Setup Time    | 0              |                          |
| T <sub>3</sub> | MOSI input to SCK (receive edge) Hold Time     | 3 * Xin period |                          |
| T <sub>4</sub> | SS input assertion to SCK setup                | 1 * Xin period |                          |

I<sup>2</sup>C Timing

Figure 53 and Table 110 provide timing information for I<sup>2</sup>C pins.

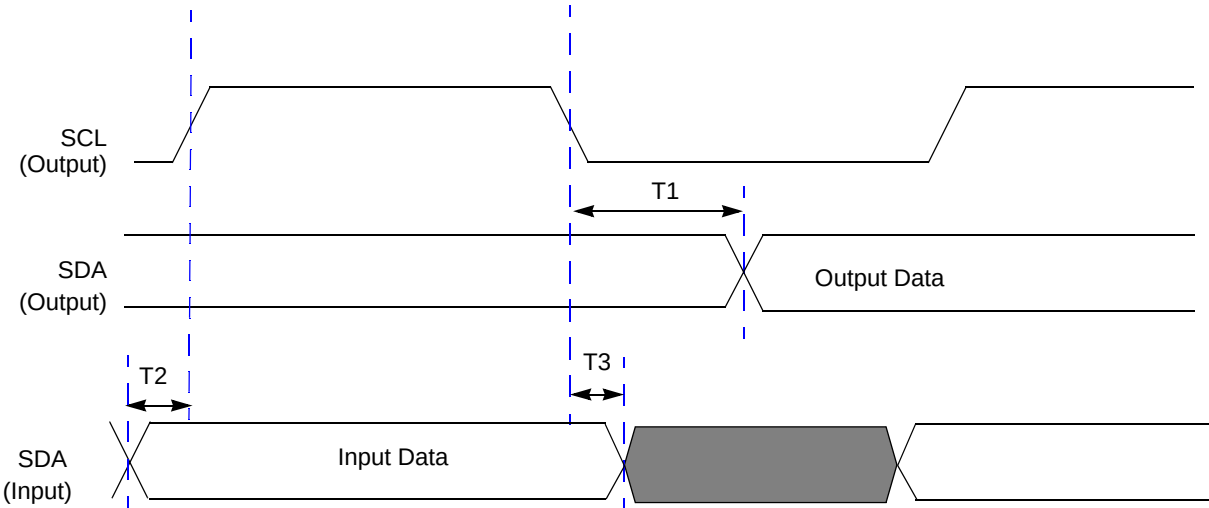


Figure 53. I<sup>2</sup>C Timing

Table 110. I<sup>2</sup>C Timing

| Parameter        | Abbreviation                            | Delay (ns)   |         |
|------------------|-----------------------------------------|--------------|---------|
|                  |                                         | Minimum      | Maximum |
| I <sup>2</sup> C |                                         |              |         |
| T <sub>1</sub>   | SCL Fall to SDA output delay            | SCL period/4 |         |
| T <sub>2</sub>   | SDA Input to SCL rising edge Setup Time | 0            |         |
| T <sub>3</sub>   | SDA Input to SCL falling edge Hold Time | 0            |         |

## UART Timing

Figure 54 and Table 111 provide timing information for UART pins for the case where the Clear To Send input pin ( $\overline{\text{CTS}}$ ) is used for flow control. In this example, it is assumed that the Driver Enable polarity has been configured to be Active Low and is represented here by  $\overline{\text{DE}}$ . The  $\overline{\text{CTS}}$  to  $\overline{\text{DE}}$  assertion delay ( $T_1$ ) assumes the UART Transmit Data Register has been loaded with data prior to  $\overline{\text{CTS}}$  assertion.

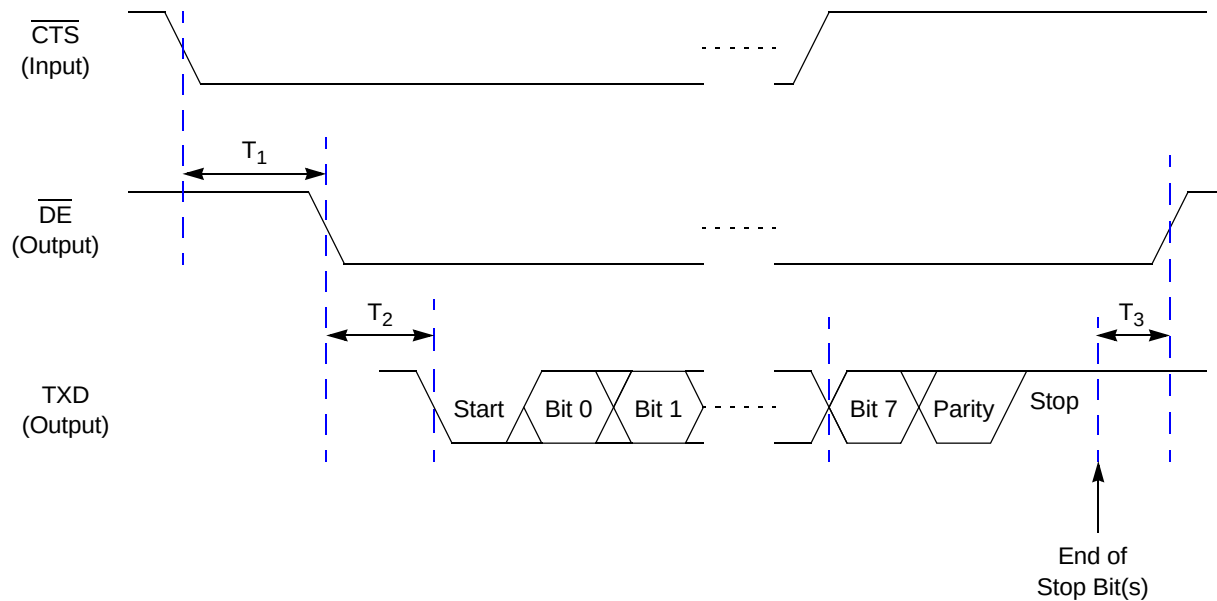


Figure 54. UART Timing with  $\overline{\text{CTS}}$

Table 111. UART Timing with  $\overline{\text{CTS}}$

| Parameter | Abbreviation                                                           | Delay (ns)     |                               |
|-----------|------------------------------------------------------------------------|----------------|-------------------------------|
|           |                                                                        | Minimum        | Maximum                       |
| $T_1$     | $\overline{\text{CTS}}$ Fall to $\overline{\text{DE}}$ Assertion Delay | 2 * XIN period | 2 * XIN period + 1 Bit period |
| $T_2$     | $\overline{\text{DE}}$ Assertion to TXD Falling Edge (Start) Delay     | 1 Bit period   | 1 Bit period + 1 * XIN period |
| $T_3$     | End of Stop Bit(s) to $\overline{\text{DE}}$ Deassertion Delay         | 1 * XIN period | 2 * XIN period                |

Figure 55 and Table 112 provide timing information for UART pins for the case where the Clear To Send input signal ( $\overline{\text{CTS}}$ ) is not used for flow control. In this example, it is assumed that the Driver Enable polarity has been configured to be Active Low and is represented here by  $\overline{\text{DE}}$ .  $\overline{\text{DE}}$  asserts after the UART Transmit Data Register has been written.  $\overline{\text{DE}}$  remains asserted for multiple characters as long as the Transmit Data Register is written with the next character before the current character has completed.

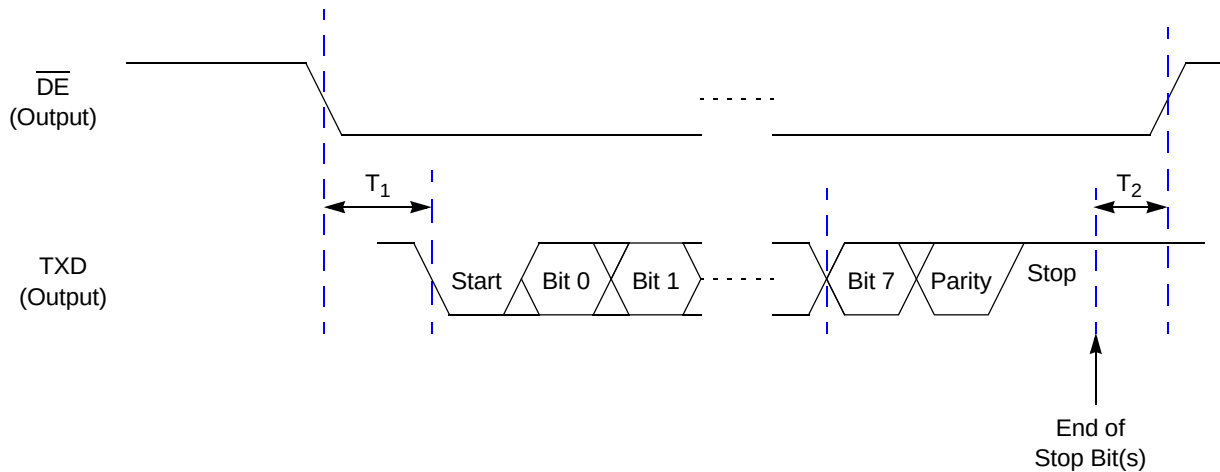


Figure 55. UART Timing without  $\overline{\text{CTS}}$

Table 112. UART Timing without  $\overline{\text{CTS}}$

| Parameter | Abbreviation                                                       | Delay (ns)     |                               |
|-----------|--------------------------------------------------------------------|----------------|-------------------------------|
|           |                                                                    | Minimum        | Maximum                       |
| $T_1$     | $\overline{\text{DE}}$ Assertion to TXD Falling Edge (Start) Delay | 1 Bit period   | 1 Bit period + 1 * XIN period |
| $T_2$     | End of Stop Bit(s) to $\overline{\text{DE}}$ Deassertion Delay     | 1 * XIN period | 2 * XIN period                |



# eZ8 CPU Instruction Set

## Assembly Language Programming Introduction

The eZ8 CPU assembly language provides a means for writing an application program without having to be concerned with actual memory addresses or machine instruction formats. A program written in assembly language is called a source program. Assembly language allows the use of symbolic addresses to identify memory locations. It also allows mnemonic codes (opcodes and operands) to represent the instructions themselves. The opcodes identify the instruction while the operands represent memory locations, registers, or immediate data values.

Each assembly language program consists of a series of symbolic commands called statements. Each statement can contain labels, operations, operands and comments.

Labels can be assigned to a particular instruction step in a source program. The label identifies that step in the program as an entry point for use by other instructions.

The assembly language also includes assembler directives that supplement the machine instruction. The assembler directives, or pseudo-ops, are not translated into a machine instruction. Rather, the pseudo-ops are interpreted as directives that control or assist the assembly process.

The source program is processed (assembled) by the assembler to obtain a machine language program called the object code. The object code is executed by the eZ8 CPU. An example segment of an assembly language program is detailed in the following example.

### Assembly Language Source Program Example

```
JP  START      ; Everything after the semicolon is a comment.

START:         ; A label called "START". The first instruction (JP  START) in this
               ; example causes program execution to jump to the point within the
               ; program where the START label occurs.

LD  R4, R7     ; A Load (LD) instruction with two operands. The first operand,
               ; Working Register R4, is the destination. The second operand,
               ; Working Register R7, is the source. The contents of R7 is
               ; written into R4.

LD  234H, 01H  ; Another Load (LD) instruction with two operands.
               ; The first operand, Extended Mode Register Address 234H,
               ; is the destination. The second operand, Immediate Data
               ; value 01H, is the source. The value 01H is written into the
               ; Register at address 234H.
```



## Assembly Language Syntax

For proper instruction execution, eZ8 CPU assembly language syntax requires that the operands be written as ‘destination, source’. After assembly, the object code usually has the operands in the order ‘source, destination’, but ordering is opcode-dependent. The following instruction examples illustrate the format of some basic assembly instructions and the resulting object code produced by the assembler. This binary format must be followed by users that prefer manual program coding or intend to implement their own assembler.

**Example 1:** If the contents of Registers 43H and 08H are added and the result is stored in 43H, the assembly syntax and resulting object code is:

**Table 113. Assembly Language Syntax Example 1**

|                               |     |     |     |                |
|-------------------------------|-----|-----|-----|----------------|
| <b>Assembly Language Code</b> | ADD | 43H | 08H | (ADD dst, src) |
| <b>Object Code</b>            | 04  | 08  | 43  | (OPC src, dst) |

**Example 2:** In general, when an instruction format requires an 8-bit register address, that address can specify any register location in the range 0–255 or, using Escaped Mode Addressing, a Working Register R0–R15. If the contents of Register 43H and Working Register R8 are added and the result is stored in 43H, the assembly syntax and resulting object code is:

**Table 114. Assembly Language Syntax Example 2**

|                               |     |      |    |                |
|-------------------------------|-----|------|----|----------------|
| <b>Assembly Language Code</b> | ADD | 43H, | R8 | (ADD dst, src) |
| <b>Object Code</b>            | 04  | E8   | 43 | (OPC src, dst) |

See the device-specific Product Specification to determine the exact register file range available. The register file size varies, depending on the device type.

## eZ8 CPU Instruction Notation

In the eZ8 CPU Instruction Summary and Description sections, the operands, condition codes, status flags, and address modes are represented by a notational shorthand that is described in [Table 115](#) on page 211.

Table 115. Notational Shorthand

| Notation | Description                    | Operand | Range                                                                                                                 |
|----------|--------------------------------|---------|-----------------------------------------------------------------------------------------------------------------------|
| b        | Bit                            | b       | b represents a value from 0 to 7 (000B to 111B).                                                                      |
| cc       | Condition Code                 | —       | See Condition Codes overview in the eZ8 CPU User Manual.                                                              |
| DA       | Direct Address                 | Addr    | Addr. represents a number in the range of 0000H to FFFFH                                                              |
| ER       | Extended Addressing Register   | Reg     | Reg. represents a number in the range of 000H to FFFH                                                                 |
| IM       | Immediate Data                 | #Data   | Data is a number between 00H to FFH                                                                                   |
| Ir       | Indirect Working Register      | @Rn     | n = 0 –15                                                                                                             |
| IR       | Indirect Register              | @Reg    | Reg. represents a number in the range of 00H to FFH                                                                   |
| Irr      | Indirect Working Register Pair | @RRp    | p = 0, 2, 4, 6, 8, 10, 12, or 14                                                                                      |
| IRR      | Indirect Register Pair         | @Reg    | Reg. represents an even number in the range 00H to FEH                                                                |
| p        | Polarity                       | p       | Polarity is a single bit binary value of either 0B or 1B.                                                             |
| r        | Working Register               | Rn      | n = 0 – 15                                                                                                            |
| R        | Register                       | Reg     | Reg. represents a number in the range of 00H to FFH                                                                   |
| RA       | Relative Address               | X       | X represents an index in the range of +127 to –128 which is an offset relative to the address of the next instruction |
| rr       | Working Register Pair          | RRp     | p = 0, 2, 4, 6, 8, 10, 12, or 14                                                                                      |
| RR       | Register Pair                  | Reg     | Reg. represents an even number in the range of 00H to FEH                                                             |
| Vector   | Vector Address                 | Vector  | Vector represents a number in the range of 00H to FFH                                                                 |
| X        | Indexed                        | #Index  | The register or register pair to be indexed is offset by the signed Index value (#Index) in a +127 to -128 range.     |

Table 116 contains additional symbols that are used throughout the Instruction Summary and Instruction Set Description sections.

**Table 116. Additional Symbols**

| Symbol | Definition                |
|--------|---------------------------|
| dst    | Destination Operand       |
| src    | Source Operand            |
| @      | Indirect Address Prefix   |
| SP     | Stack Pointer             |
| PC     | Program Counter           |
| FLAGS  | Flags Register            |
| RP     | Register Pointer          |
| #      | Immediate Operand Prefix  |
| B      | Binary Number Suffix      |
| %      | Hexadecimal Number Prefix |
| H      | Hexadecimal Number Suffix |

Assignment of a value is indicated by an arrow. For example,

$$\text{dst} \leftarrow \text{dst} + \text{src}$$

indicates the source data is added to the destination data and the result is stored in the destination location.

## Condition Codes

The C, Z, S, and V flags control the operation of the conditional jump (JP cc and JR cc) instructions. Sixteen frequently useful functions of the flag settings are encoded in a 4-bit field called the condition code (cc), which forms Bits 7:4 of the conditional jump instructions. The condition codes are summarized in [Table 117](#). Some binary condition codes can be created using more than one assembly code mnemonic. The result of the flag test operation decides if the conditional jump is executed.

**Table 117. Condition Codes**

| Binary | Hex | Assembly Mnemonic | Definition                     | Flag Test Operation                      |
|--------|-----|-------------------|--------------------------------|------------------------------------------|
| 0000   | 0   | F                 | Always False                   | –                                        |
| 0001   | 1   | LT                | Less Than                      | $(S \text{ XOR } V) = 1$                 |
| 0010   | 2   | LE                | Less Than or Equal             | $(Z \text{ OR } (S \text{ XOR } V)) = 1$ |
| 0011   | 3   | ULE               | Unsigned Less Than or Equal    | $(C \text{ OR } Z) = 1$                  |
| 0100   | 4   | OV                | Overflow                       | $V = 1$                                  |
| 0101   | 5   | MI                | Minus                          | $S = 1$                                  |
| 0110   | 6   | Z                 | Zero                           | $Z = 1$                                  |
| 0110   | 6   | EQ                | Equal                          | $Z = 1$                                  |
| 0111   | 7   | C                 | Carry                          | $C = 1$                                  |
| 0111   | 7   | ULT               | Unsigned Less Than             | $C = 1$                                  |
| 1000   | 8   | T (or blank)      | Always True                    | –                                        |
| 1001   | 9   | GE                | Greater Than or Equal          | $(S \text{ XOR } V) = 0$                 |
| 1010   | A   | GT                | Greater Than                   | $(Z \text{ OR } (S \text{ XOR } V)) = 0$ |
| 1011   | B   | UGT               | Unsigned Greater Than          | $(C = 0 \text{ AND } Z = 0) = 1$         |
| 1100   | C   | NOV               | No Overflow                    | $V = 0$                                  |
| 1101   | D   | PL                | Plus                           | $S = 0$                                  |
| 1110   | E   | NZ                | Non-Zero                       | $Z = 0$                                  |
| 1110   | E   | NE                | Not Equal                      | $Z = 0$                                  |
| 1111   | F   | NC                | No Carry                       | $C = 0$                                  |
| 1111   | F   | UGE               | Unsigned Greater Than or Equal | $C = 0$                                  |

## eZ8 CPU Instruction Classes

eZ8 CPU instructions are divided functionally into the following groups:

- Arithmetic
- Bit Manipulation
- Block Transfer
- CPU Control
- Load
- Logical
- Program Control
- Rotate and Shift

Tables 118 through Table 125 on page 218 contain the instructions belonging to each group and the number of operands required for each instruction. Some instructions appear in more than one table as these instruction can be considered as a subset of more than one category. Within these tables, the source operand is identified as 'src', the destination operand is 'dst' and a condition code is 'cc'.

**Table 118. Arithmetic Instructions**

| Mnemonic | Operands | Instruction                                  |
|----------|----------|----------------------------------------------|
| ADC      | dst, src | Add with Carry                               |
| ADCX     | dst, src | Add with Carry using Extended Addressing     |
| ADD      | dst, src | Add                                          |
| ADDX     | dst, src | Add using Extended Addressing                |
| CP       | dst, src | Compare                                      |
| CPC      | dst, src | Compare with Carry                           |
| CPCX     | dst, src | Compare with Carry using Extended Addressing |
| CPX      | dst, src | Compare using Extended Addressing            |
| DA       | dst      | Decimal Adjust                               |
| DEC      | dst      | Decrement                                    |
| DECW     | dst      | Decrement Word                               |
| INC      | dst      | Increment                                    |
| INCW     | dst      | Increment Word                               |
| MULT     | dst      | Multiply                                     |

**Table 118. Arithmetic Instructions (Continued)**

| Mnemonic | Operands | Instruction                                   |
|----------|----------|-----------------------------------------------|
| SBC      | dst, src | Subtract with Carry                           |
| SBCX     | dst, src | Subtract with Carry using Extended Addressing |
| SUB      | dst, src | Subtract                                      |
| SUBX     | dst, src | Subtract using Extended Addressing            |

**Table 119. Bit Manipulation Instructions**

| Mnemonic | Operands    | Instruction                                          |
|----------|-------------|------------------------------------------------------|
| BCLR     | bit, dst    | Bit Clear                                            |
| BIT      | p, bit, dst | Bit Set or Clear                                     |
| BSET     | bit, dst    | Bit Set                                              |
| BSWAP    | dst         | Bit Swap                                             |
| CCF      | —           | Complement Carry Flag                                |
| RCF      | —           | Reset Carry Flag                                     |
| SCF      | —           | Set Carry Flag                                       |
| TCM      | dst, src    | Test Complement Under Mask                           |
| TCMX     | dst, src    | Test Complement Under Mask using Extended Addressing |
| TM       | dst, src    | Test Under Mask                                      |
| TMX      | dst, src    | Test Under Mask using Extended Addressing            |

**Table 120. Block Transfer Instructions**

| Mnemonic | Operands | Instruction                                                         |
|----------|----------|---------------------------------------------------------------------|
| LDCI     | dst, src | Load Constant to/from Program Memory and Auto-Increment Addresses   |
| LDEI     | dst, src | Load External Data to/from Data Memory and Auto-Increment Addresses |

**Table 121. CPU Control Instructions**

| Mnemonic | Operands | Instruction            |
|----------|----------|------------------------|
| CCF      | —        | Complement Carry Flag  |
| DI       | —        | Disable Interrupts     |
| EI       | —        | Enable Interrupts      |
| HALT     | —        | HALT Mode              |
| NOP      | —        | No Operation           |
| RCF      | —        | Reset Carry Flag       |
| SCF      | —        | Set Carry Flag         |
| SRP      | src      | Set Register Pointer   |
| STOP     | —        | STOP Mode              |
| WDT      | —        | Watchdog Timer Refresh |

**Table 122. Load Instructions**

| Mnemonic | Operands    | Instruction                                                         |
|----------|-------------|---------------------------------------------------------------------|
| CLR      | dst         | Clear                                                               |
| LD       | dst, src    | Load                                                                |
| LDC      | dst, src    | Load Constant to/from Program Memory                                |
| LDCI     | dst, src    | Load Constant to/from Program Memory and Auto-Increment Addresses   |
| LDE      | dst, src    | Load External Data to/from Data Memory                              |
| LDEI     | dst, src    | Load External Data to/from Data Memory and Auto-Increment Addresses |
| LDX      | dst, src    | Load using Extended Addressing                                      |
| LEA      | dst, X(src) | Load Effective Address                                              |
| POP      | dst         | Pop                                                                 |
| POPX     | dst         | Pop using Extended Addressing                                       |
| PUSH     | src         | Push                                                                |
| PUSHX    | src         | Push using Extended Addressing                                      |

**Table 123. Logical Instructions**

| <b>Mnemonic</b> | <b>Operands</b> | <b>Instruction</b>                             |
|-----------------|-----------------|------------------------------------------------|
| AND             | dst, src        | Logical AND                                    |
| ANDX            | dst, src        | Logical AND using Extended Addressing          |
| COM             | dst             | Complement                                     |
| OR              | dst, src        | Logical OR                                     |
| ORX             | dst, src        | Logical OR using Extended Addressing           |
| XOR             | dst, src        | Logical Exclusive OR                           |
| XORX            | dst, src        | Logical Exclusive OR using Extended Addressing |

**Table 124. Program Control Instructions**

| <b>Mnemonic</b> | <b>Operands</b> | <b>Instruction</b>            |
|-----------------|-----------------|-------------------------------|
| BRK             | —               | On-Chip Debugger Break        |
| BTJ             | p, bit, src, DA | Bit Test and Jump             |
| BTJNZ           | bit, src, DA    | Bit Test and Jump if Non-Zero |
| BTJZ            | bit, src, DA    | Bit Test and Jump if Zero     |
| CALL            | dst             | Call Procedure                |
| DJNZ            | dst, src, RA    | Decrement and Jump Non-Zero   |
| IRET            | —               | Interrupt Return              |
| JP              | dst             | Jump                          |
| JP cc           | dst             | Jump Conditional              |
| JR              | DA              | Jump Relative                 |
| JR cc           | DA              | Jump Relative Conditional     |
| RET             | —               | Return                        |
| TRAP            | vector          | Software Trap                 |

Table 125. Rotate and Shift Instructions

| Mnemonic | Operands | Instruction                |
|----------|----------|----------------------------|
| BSWAP    | dst      | Bit Swap                   |
| RL       | dst      | Rotate Left                |
| RLC      | dst      | Rotate Left through Carry  |
| RR       | dst      | Rotate Right               |
| RRC      | dst      | Rotate Right through Carry |
| SRA      | dst      | Shift Right Arithmetic     |
| SRL      | dst      | Shift Right Logical        |
| SWAP     | dst      | Swap Nibbles               |

## eZ8 CPU Instruction Summary

Table 126 summarizes the eZ8 CPU instructions. The table identifies the addressing modes employed by the instruction, the effect upon the Flags register, the number of CPU clock cycles required for the instruction fetch, and the number of CPU clock cycles required for the instruction execution.

Table 126. eZ8 CPU Instruction Summary

| Assembly Mnemonic | Symbolic Operation                                         | Address Mode |     | Opcode(s)<br>(Hex) | Flags |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|-------------------|------------------------------------------------------------|--------------|-----|--------------------|-------|---|---|---|---|---|--------------|---------------|
|                   |                                                            | dst          | src |                    | C     | Z | S | V | D | H |              |               |
| ADC dst, src      | $\text{dst} \leftarrow \text{dst} + \text{src} + \text{C}$ | r            | r   | 12                 | *     | * | * | * | 0 | * | 2            | 3             |
|                   |                                                            | r            | lr  | 13                 |       |   |   |   |   |   | 2            | 4             |
|                   |                                                            | R            | R   | 14                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                            | R            | IR  | 15                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                            | R            | IM  | 16                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                            | IR           | IM  | 17                 |       |   |   |   |   |   | 3            | 4             |
| ADCX dst, src     | $\text{dst} \leftarrow \text{dst} + \text{src} + \text{C}$ | ER           | ER  | 18                 | *     | * | * | * | 0 | * | 4            | 3             |
|                   |                                                            | ER           | IM  | 19                 |       |   |   |   |   |   | 4            | 3             |



Table 126. eZ8 CPU Instruction Summary (Continued)

| Assembly Mnemonic    | Symbolic Operation                                                                    | Address Mode |     | Opcode(s)<br>(Hex) | Flags |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|----------------------|---------------------------------------------------------------------------------------|--------------|-----|--------------------|-------|---|---|---|---|---|--------------|---------------|
|                      |                                                                                       | dst          | src |                    | C     | Z | S | V | D | H |              |               |
| ADD dst, src         | $\text{dst} \leftarrow \text{dst} + \text{src}$                                       | r            | r   | 02                 | *     | * | * | * | 0 | * | 2            | 3             |
|                      |                                                                                       | r            | lr  | 03                 |       |   |   |   |   |   | 2            | 4             |
|                      |                                                                                       | R            | R   | 04                 |       |   |   |   |   |   | 3            | 3             |
|                      |                                                                                       | R            | IR  | 05                 |       |   |   |   |   |   | 3            | 4             |
|                      |                                                                                       | R            | IM  | 06                 |       |   |   |   |   |   | 3            | 3             |
|                      |                                                                                       | IR           | IM  | 07                 |       |   |   |   |   |   | 3            | 4             |
| ADDX dst, src        | $\text{dst} \leftarrow \text{dst} + \text{src}$                                       | ER           | ER  | 08                 | *     | * | * | * | 0 | * | 4            | 3             |
|                      |                                                                                       | ER           | IM  | 09                 |       |   |   |   |   |   | 4            | 3             |
| AND dst, src         | $\text{dst} \leftarrow \text{dst} \text{ AND } \text{src}$                            | r            | r   | 52                 | -     | * | * | 0 | - | - | 2            | 3             |
|                      |                                                                                       | r            | lr  | 53                 |       |   |   |   |   |   | 2            | 4             |
|                      |                                                                                       | R            | R   | 54                 |       |   |   |   |   |   | 3            | 3             |
|                      |                                                                                       | R            | IR  | 55                 |       |   |   |   |   |   | 3            | 4             |
|                      |                                                                                       | R            | IM  | 56                 |       |   |   |   |   |   | 3            | 3             |
|                      |                                                                                       | IR           | IM  | 57                 |       |   |   |   |   |   | 3            | 4             |
| ANDX dst, src        | $\text{dst} \leftarrow \text{dst} \text{ AND } \text{src}$                            | ER           | ER  | 58                 | -     | * | * | 0 | - | - | 4            | 3             |
|                      |                                                                                       | ER           | IM  | 59                 |       |   |   |   |   |   | 4            | 3             |
| BCLR bit, dst        | $\text{dst}[\text{bit}] \leftarrow 0$                                                 | r            |     | E2                 | -     | - | - | - | - | - | 2            | 2             |
| BIT p, bit, dst      | $\text{dst}[\text{bit}] \leftarrow \text{p}$                                          | r            |     | E2                 | -     | - | - | - | - | - | 2            | 2             |
| BRK                  | Debugger Break                                                                        |              |     | 00                 | -     | - | - | - | - | - | 1            | 1             |
| BSET bit, dst        | $\text{dst}[\text{bit}] \leftarrow 1$                                                 | r            |     | E2                 | -     | - | - | - | - | - | 2            | 2             |
| BSWAP dst            | $\text{dst}[7:0] \leftarrow \text{dst}[0:7]$                                          | R            |     | D5                 | X     | * | * | 0 | - | - | 2            | 2             |
| BTJ p, bit, src, dst | if $\text{src}[\text{bit}] = \text{p}$<br>$\text{PC} \leftarrow \text{PC} + \text{X}$ |              | r   | F6                 | -     | - | - | - | - | - | 3            | 3             |
|                      |                                                                                       |              | lr  | F7                 |       |   |   |   |   |   | 3            | 4             |
| BTJNZ bit, src, dst  | if $\text{src}[\text{bit}] = 1$<br>$\text{PC} \leftarrow \text{PC} + \text{X}$        |              | r   | F6                 | -     | - | - | - | - | - | 3            | 3             |
|                      |                                                                                       |              | lr  | F7                 |       |   |   |   |   |   | 3            | 4             |
| BTJZ bit, src, dst   | if $\text{src}[\text{bit}] = 0$<br>$\text{PC} \leftarrow \text{PC} + \text{X}$        |              | r   | F6                 | -     | - | - | - | - | - | 3            | 3             |
|                      |                                                                                       |              | lr  | F7                 |       |   |   |   |   |   | 3            | 4             |

Table 126. eZ8 CPU Instruction Summary (Continued)

| Assembly Mnemonic | Symbolic Operation                 | Address Mode |     | Opcode(s)<br>(Hex) | Flags |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|-------------------|------------------------------------|--------------|-----|--------------------|-------|---|---|---|---|---|--------------|---------------|
|                   |                                    | dst          | src |                    | C     | Z | S | V | D | H |              |               |
| CALL dst          | SP ← SP -2<br>@SP ← PC<br>PC ← dst | IRR          |     | D4                 | -     | - | - | - | - | - | 2            | 6             |
|                   |                                    | DA           |     | D6                 |       |   |   |   |   |   | 3            | 3             |
| CCF               | C ← ~C                             |              |     | EF                 | *     | - | - | - | - | - | 1            | 2             |
| CLR dst           | dst ← 00H                          | R            |     | B0                 | -     | - | - | - | - | - | 2            | 2             |
|                   |                                    | IR           |     | B1                 |       |   |   |   |   |   | 2            | 3             |
| COM dst           | dst ← ~dst                         | R            |     | 60                 | -     | * | * | 0 | - | - | 2            | 2             |
|                   |                                    | IR           |     | 61                 |       |   |   |   |   |   | 2            | 3             |
| CP dst, src       | dst - src                          | r            | r   | A2                 | *     | * | * | * | - | - | 2            | 3             |
|                   |                                    | r            | lr  | A3                 |       |   |   |   |   |   | 2            | 4             |
|                   |                                    | R            | R   | A4                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                    | R            | IR  | A5                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                    | R            | IM  | A6                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                    | IR           | IM  | A7                 |       |   |   |   |   |   | 3            | 4             |
| CPC dst, src      | dst - src - C                      | r            | r   | 1F A2              | *     | * | * | * | - | - | 3            | 3             |
|                   |                                    | r            | lr  | 1F A3              |       |   |   |   |   |   | 3            | 4             |
|                   |                                    | R            | R   | 1F A4              |       |   |   |   |   |   | 4            | 3             |
|                   |                                    | R            | IR  | 1F A5              |       |   |   |   |   |   | 4            | 4             |
|                   |                                    | R            | IM  | 1F A6              |       |   |   |   |   |   | 4            | 3             |
|                   |                                    | IR           | IM  | 1F A7              |       |   |   |   |   |   | 4            | 4             |
| CPCX dst, src     | dst - src - C                      | ER           | ER  | 1F A8              | *     | * | * | * | - | - | 5            | 3             |
|                   |                                    | ER           | IM  | 1F A9              |       |   |   |   |   |   | 5            | 3             |
| CPX dst, src      | dst - src                          | ER           | ER  | A8                 | *     | * | * | * | - | - | 4            | 3             |
|                   |                                    | ER           | IM  | A9                 |       |   |   |   |   |   | 4            | 3             |
| DA dst            | dst ← DA(dst)                      | R            |     | 40                 | *     | * | * | X | - | - | 2            | 2             |
|                   |                                    | IR           |     | 41                 |       |   |   |   |   |   | 2            | 3             |
| DEC dst           | dst ← dst - 1                      | R            |     | 30                 | -     | * | * | * | - | - | 2            | 2             |
|                   |                                    | IR           |     | 31                 |       |   |   |   |   |   | 2            | 3             |



Table 126. eZ8 CPU Instruction Summary (Continued)

| Assembly Mnemonic | Symbolic Operation                                                                                                                                                                           | Address Mode |     | Opcode(s)<br>(Hex) | Flags |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|-------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------|-----|--------------------|-------|---|---|---|---|---|--------------|---------------|
|                   |                                                                                                                                                                                              | dst          | src |                    | C     | Z | S | V | D | H |              |               |
| DECW dst          | $\text{dst} \leftarrow \text{dst} - 1$                                                                                                                                                       | RR           |     | 80                 | -     | * | * | * | - | - | 2            | 5             |
|                   |                                                                                                                                                                                              | IRR          |     | 81                 |       |   |   |   |   |   | 2            | 6             |
| DI                | $\text{IRQCTL}[7] \leftarrow 0$                                                                                                                                                              |              |     | 8F                 | -     | - | - | - | - | - | 1            | 2             |
| DJNZ dst, RA      | $\text{dst} \leftarrow \text{dst} - 1$<br>if $\text{dst} \neq 0$<br>$\text{PC} \leftarrow \text{PC} + \text{X}$                                                                              | r            |     | 0A-FA              | -     | - | - | - | - | - | 2            | 3             |
| EI                | $\text{IRQCTL}[7] \leftarrow 1$                                                                                                                                                              |              |     | 9F                 | -     | - | - | - | - | - | 1            | 2             |
| HALT              | HALT Mode                                                                                                                                                                                    |              |     | 7F                 | -     | - | - | - | - | - | 1            | 2             |
| INC dst           | $\text{dst} \leftarrow \text{dst} + 1$                                                                                                                                                       | R            |     | 20                 | -     | * | * | * | - | - | 2            | 2             |
|                   |                                                                                                                                                                                              | IR           |     | 21                 |       |   |   |   |   |   | 2            | 3             |
|                   |                                                                                                                                                                                              | r            |     | 0E-FE              |       |   |   |   |   |   | 1            | 2             |
| INCW dst          | $\text{dst} \leftarrow \text{dst} + 1$                                                                                                                                                       | RR           |     | A0                 | -     | * | * | * | - | - | 2            | 5             |
|                   |                                                                                                                                                                                              | IRR          |     | A1                 |       |   |   |   |   |   | 2            | 6             |
| IRET              | $\text{FLAGS} \leftarrow @\text{SP}$<br>$\text{SP} \leftarrow \text{SP} + 1$<br>$\text{PC} \leftarrow @\text{SP}$<br>$\text{SP} \leftarrow \text{SP} + 2$<br>$\text{IRQCTL}[7] \leftarrow 1$ |              |     | BF                 | *     | * | * | * | * | * | 1            | 5             |
| JP dst            | $\text{PC} \leftarrow \text{dst}$                                                                                                                                                            | DA           |     | 8D                 | -     | - | - | - | - | - | 3            | 2             |
|                   |                                                                                                                                                                                              | IRR          |     | C4                 |       |   |   |   |   |   | 2            | 3             |
| JP cc, dst        | if cc is true<br>$\text{PC} \leftarrow \text{dst}$                                                                                                                                           | DA           |     | 0D-FD              | -     | - | - | - | - | - | 3            | 2             |
| JR dst            | $\text{PC} \leftarrow \text{PC} + \text{X}$                                                                                                                                                  | DA           |     | 8B                 | -     | - | - | - | - | - | 2            | 2             |
| JR cc, dst        | if cc is true<br>$\text{PC} \leftarrow \text{PC} + \text{X}$                                                                                                                                 | DA           |     | 0B-FB              | -     | - | - | - | - | - | 2            | 2             |

Table 126. eZ8 CPU Instruction Summary (Continued)

| Assembly Mnemonic | Symbolic Operation                                                                                               | Address Mode |      | Opcode(s)<br>(Hex) | Flags |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|-------------------|------------------------------------------------------------------------------------------------------------------|--------------|------|--------------------|-------|---|---|---|---|---|--------------|---------------|
|                   |                                                                                                                  | dst          | src  |                    | C     | Z | S | V | D | H |              |               |
| LD dst, rc        | $\text{dst} \leftarrow \text{src}$                                                                               | r            | IM   | 0C-FC              | -     | - | - | - | - | - | 2            | 2             |
|                   |                                                                                                                  | r            | X(r) | C7                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                                                                  | X(r)         | r    | D7                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                                                                  | r            | lr   | E3                 |       |   |   |   |   |   | 2            | 3             |
|                   |                                                                                                                  | R            | R    | E4                 |       |   |   |   |   |   | 3            | 2             |
|                   |                                                                                                                  | R            | IR   | E5                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                                                                  | R            | IM   | E6                 |       |   |   |   |   |   | 3            | 2             |
|                   |                                                                                                                  | IR           | IM   | E7                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                                                                  | lr           | r    | F3                 |       |   |   |   |   |   | 2            | 3             |
|                   |                                                                                                                  | IR           | R    | F5                 |       |   |   |   |   |   | 3            | 3             |
| LDC dst, src      | $\text{dst} \leftarrow \text{src}$                                                                               | r            | lrr  | C2                 | -     | - | - | - | - | - | 2            | 5             |
|                   |                                                                                                                  | lr           | lrr  | C5                 |       |   |   |   |   |   | 2            | 9             |
|                   |                                                                                                                  | lrr          | r    | D2                 |       |   |   |   |   |   | 2            | 5             |
| LDCI dst, src     | $\text{dst} \leftarrow \text{src}$<br>$\text{r} \leftarrow \text{r} + 1$<br>$\text{rr} \leftarrow \text{rr} + 1$ | lr           | lrr  | C3                 | -     | - | - | - | - | - | 2            | 9             |
|                   |                                                                                                                  | lrr          | lr   | D3                 |       |   |   |   |   |   | 2            | 9             |
| LDE dst, src      | $\text{dst} \leftarrow \text{src}$                                                                               | r            | lrr  | 82                 | -     | - | - | - | - | - | 2            | 5             |
|                   |                                                                                                                  | lrr          | r    | 92                 |       |   |   |   |   |   | 2            | 5             |
| LDEI dst, src     | $\text{dst} \leftarrow \text{src}$<br>$\text{r} \leftarrow \text{r} + 1$<br>$\text{rr} \leftarrow \text{rr} + 1$ | lr           | lrr  | 83                 | -     | - | - | - | - | - | 2            | 9             |
|                   |                                                                                                                  | lrr          | lr   | 93                 |       |   |   |   |   |   | 2            | 9             |

Table 126. eZ8 CPU Instruction Summary (Continued)

| Assembly Mnemonic | Symbolic Operation                                                         | Address Mode |       | Opcode(s)<br>(Hex) | Flags |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|-------------------|----------------------------------------------------------------------------|--------------|-------|--------------------|-------|---|---|---|---|---|--------------|---------------|
|                   |                                                                            | dst          | src   |                    | C     | Z | S | V | D | H |              |               |
| LDX dst, src      | $\text{dst} \leftarrow \text{src}$                                         | r            | ER    | 84                 | -     | - | - | - | - | - | 3            | 2             |
|                   |                                                                            | lr           | ER    | 85                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                            | R            | IRR   | 86                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                            | IR           | IRR   | 87                 |       |   |   |   |   |   | 3            | 5             |
|                   |                                                                            | r            | X(rr) | 88                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                            | X(rr)        | r     | 89                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                            | ER           | r     | 94                 |       |   |   |   |   |   | 3            | 2             |
|                   |                                                                            | ER           | lr    | 95                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                            | IRR          | R     | 96                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                            | IRR          | IR    | 97                 |       |   |   |   |   |   | 3            | 5             |
|                   |                                                                            | ER           | ER    | E8                 |       |   |   |   |   |   | 4            | 2             |
|                   |                                                                            | ER           | IM    | E9                 |       |   |   |   |   |   | 4            | 2             |
| LEA dst, X(src)   | $\text{dst} \leftarrow \text{src} + \text{X}$                              | r            | X(r)  | 98                 | -     | - | - | - | - | - | 3            | 3             |
|                   |                                                                            | rr           | X(rr) | 99                 |       |   |   |   |   |   | 3            | 5             |
| MULT dst          | $\text{dst}[15:0] \leftarrow \text{dst}[15:8] * \text{dst}[7:0]$           | RR           |       | F4                 | -     | - | - | - | - | - | 2            | 8             |
| NOP               | No operation                                                               |              |       | 0F                 | -     | - | - | - | - | - | 1            | 2             |
| OR dst, src       | $\text{dst} \leftarrow \text{dst OR src}$                                  | r            | r     | 42                 | -     | * | * | 0 | - | - | 2            | 3             |
|                   |                                                                            | r            | lr    | 43                 |       |   |   |   |   |   | 2            | 4             |
|                   |                                                                            | R            | R     | 44                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                            | R            | IR    | 45                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                            | R            | IM    | 46                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                            | IR           | IM    | 47                 |       |   |   |   |   |   | 3            | 4             |
| ORX dst, src      | $\text{dst} \leftarrow \text{dst OR src}$                                  | ER           | ER    | 48                 | -     | * | * | 0 | - | - | 4            | 3             |
|                   |                                                                            | ER           | IM    | 49                 |       |   |   |   |   |   | 4            | 3             |
| POP dst           | $\text{dst} \leftarrow @\text{SP}$<br>$\text{SP} \leftarrow \text{SP} + 1$ | R            |       | 50                 | -     | - | - | - | - | - | 2            | 2             |
|                   |                                                                            | IR           |       | 51                 |       |   |   |   |   |   | 2            | 3             |

Table 126. eZ8 CPU Instruction Summary (Continued)

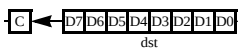
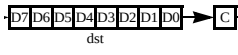
| Assembly Mnemonic | Symbolic Operation                                                                  | Address Mode |     | Opcode(s)<br>(Hex) | Flags |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|-------------------|-------------------------------------------------------------------------------------|--------------|-----|--------------------|-------|---|---|---|---|---|--------------|---------------|
|                   |                                                                                     | dst          | src |                    | C     | Z | S | V | D | H |              |               |
| POPX dst          | dst ← @SP<br>SP ← SP + 1                                                            | ER           |     | D8                 | -     | - | - | - | - | - | 3            | 2             |
| PUSH src          | SP ← SP - 1<br>@SP ← src                                                            | R            |     | 70                 | -     | - | - | - | - | - | 2            | 2             |
|                   |                                                                                     | IR           |     | 71                 |       |   |   |   |   |   | 2            | 3             |
| PUSHX src         | SP ← SP - 1<br>@SP ← src                                                            | ER           |     | C8                 | -     | - | - | - | - | - | 3            | 2             |
| RCF               | C ← 0                                                                               |              |     | CF                 | 0     | - | - | - | - | - | 1            | 2             |
| RET               | PC ← @SP<br>SP ← SP + 2                                                             |              |     | AF                 | -     | - | - | - | - | - | 1            | 4             |
| RL dst            |   | R            |     | 90                 | *     | * | * | * | - | - | 2            | 2             |
|                   |                                                                                     | IR           |     | 91                 |       |   |   |   |   |   | 2            | 3             |
| RLC dst           |  | R            |     | 10                 | *     | * | * | * | - | - | 2            | 2             |
|                   |                                                                                     | IR           |     | 11                 |       |   |   |   |   |   | 2            | 3             |
| RR dst            |  | R            |     | E0                 | *     | * | * | * | - | - | 2            | 2             |
|                   |                                                                                     | IR           |     | E1                 |       |   |   |   |   |   | 2            | 3             |
| RRC dst           |  | R            |     | C0                 | *     | * | * | * | - | - | 2            | 2             |
|                   |                                                                                     | IR           |     | C1                 |       |   |   |   |   |   | 2            | 3             |
| SBC dst, src      | dst ← dst - src - C                                                                 | r            | r   | 32                 | *     | * | * | * | 1 | * | 2            | 3             |
|                   |                                                                                     | r            | lr  | 33                 |       |   |   |   |   |   | 2            | 4             |
|                   |                                                                                     | R            | R   | 34                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                                     | R            | IR  | 35                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                                     | R            | IM  | 36                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                                     | IR           | IM  | 37                 |       |   |   |   |   |   | 3            | 4             |
| SBCX dst, src     | dst ← dst - src - C                                                                 | ER           | ER  | 38                 | *     | * | * | * | 1 | * | 4            | 3             |
|                   |                                                                                     | ER           | IM  | 39                 |       |   |   |   |   |   | 4            | 3             |

Table 126. eZ8 CPU Instruction Summary (Continued)

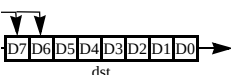
| Assembly Mnemonic | Symbolic Operation                                                                | Address Mode |     | Opcode(s)<br>(Hex) | Flags |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|-------------------|-----------------------------------------------------------------------------------|--------------|-----|--------------------|-------|---|---|---|---|---|--------------|---------------|
|                   |                                                                                   | dst          | src |                    | C     | Z | S | V | D | H |              |               |
| SCF               | $C \leftarrow 1$                                                                  |              |     | DF                 | 1     | - | - | - | - | - | 1            | 2             |
| SRA dst           |  | R            |     | D0                 | *     | * | * | 0 | - | - | 2            | 2             |
|                   |                                                                                   | IR           |     | D1                 |       |   |   |   |   |   | 2            | 3             |
| SRL dst           |  | R            |     | 1F C0              | *     | * | 0 | * | - | - | 3            | 2             |
|                   |                                                                                   | IR           |     | 1F C1              |       |   |   |   |   |   | 3            | 3             |
| SRP src           | $RP \leftarrow src$                                                               |              | IM  | 01                 | -     | - | - | - | - | - | 2            | 2             |
| STOP              | STOP Mode                                                                         |              |     | 6F                 | -     | - | - | - | - | - | 1            | 2             |
| SUB dst, src      | $dst \leftarrow dst - src$                                                        | r            | r   | 22                 | *     | * | * | * | 1 | * | 2            | 3             |
|                   |                                                                                   | r            | lr  | 23                 |       |   |   |   |   |   | 2            | 4             |
|                   |                                                                                   | R            | R   | 24                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                                   | R            | IR  | 25                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                                   | R            | IM  | 26                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                                   | IR           | IM  | 27                 |       |   |   |   |   |   | 3            | 4             |
| SUBX dst, src     | $dst \leftarrow dst - src$                                                        | ER           | ER  | 28                 | *     | * | * | * | 1 | * | 4            | 3             |
|                   |                                                                                   | ER           | IM  | 29                 |       |   |   |   |   |   | 4            | 3             |
| SWAP dst          | $dst[7:4] \leftrightarrow dst[3:0]$                                               | R            |     | F0                 | X     | * | * | X | - | - | 2            | 2             |
|                   |                                                                                   | IR           |     | F1                 |       |   |   |   |   |   | 2            | 3             |
| TCM dst, src      | (NOT dst) AND src                                                                 | r            | r   | 62                 | -     | * | * | 0 | - | - | 2            | 3             |
|                   |                                                                                   | r            | lr  | 63                 |       |   |   |   |   |   | 2            | 4             |
|                   |                                                                                   | R            | R   | 64                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                                   | R            | IR  | 65                 |       |   |   |   |   |   | 3            | 4             |
|                   |                                                                                   | R            | IM  | 66                 |       |   |   |   |   |   | 3            | 3             |
|                   |                                                                                   | IR           | IM  | 67                 |       |   |   |   |   |   | 3            | 4             |
| TCMX dst, src     | (NOT dst) AND src                                                                 | ER           | ER  | 68                 | -     | * | * | 0 | - | - | 4            | 3             |
|                   |                                                                                   | ER           | IM  | 69                 |       |   |   |   |   |   | 4            | 3             |

Table 126. eZ8 CPU Instruction Summary (Continued)

| Assembly Mnemonic                                                                                          | Symbolic Operation                                                    | Address Mode |        | Opcode(s)<br>(Hex) | Flags                          |   |   |   |   |   | Fetch Cycles | Instr. Cycles |
|------------------------------------------------------------------------------------------------------------|-----------------------------------------------------------------------|--------------|--------|--------------------|--------------------------------|---|---|---|---|---|--------------|---------------|
|                                                                                                            |                                                                       | dst          | src    |                    | C                              | Z | S | V | D | H |              |               |
| TM dst, src                                                                                                | dst AND src                                                           | r            | r      | 72                 | -                              | * | * | 0 | - | - | 2            | 3             |
|                                                                                                            |                                                                       | r            | lr     | 73                 |                                |   |   |   |   |   | 2            | 4             |
|                                                                                                            |                                                                       | R            | R      | 74                 |                                |   |   |   |   |   | 3            | 3             |
|                                                                                                            |                                                                       | R            | IR     | 75                 |                                |   |   |   |   |   | 3            | 4             |
|                                                                                                            |                                                                       | R            | IM     | 76                 |                                |   |   |   |   |   | 3            | 3             |
|                                                                                                            |                                                                       | IR           | IM     | 77                 |                                |   |   |   |   |   | 3            | 4             |
| TMX dst, src                                                                                               | dst AND src                                                           | ER           | ER     | 78                 | -                              | * | * | 0 | - | - | 4            | 3             |
|                                                                                                            |                                                                       | ER           | IM     | 79                 |                                |   |   |   |   |   | 4            | 3             |
| TRAP Vector                                                                                                | SP ← SP – 2<br>@SP ← PC<br>SP ← SP – 1<br>@SP ← FLAGS<br>PC ← @Vector |              | Vector | F2                 | -                              | - | - | - | - | - | 2            | 6             |
| WDT                                                                                                        |                                                                       |              |        | 5F                 | -                              | - | - | - | - | - | 1            | 2             |
| XOR dst, src                                                                                               | dst ← dst XOR src                                                     | r            | r      | B2                 | -                              | * | * | 0 | - | - | 2            | 3             |
|                                                                                                            |                                                                       | r            | lr     | B3                 |                                |   |   |   |   |   | 2            | 4             |
|                                                                                                            |                                                                       | R            | R      | B4                 |                                |   |   |   |   |   | 3            | 3             |
|                                                                                                            |                                                                       | R            | IR     | B5                 |                                |   |   |   |   |   | 3            | 4             |
|                                                                                                            |                                                                       | R            | IM     | B6                 |                                |   |   |   |   |   | 3            | 3             |
|                                                                                                            |                                                                       | IR           | IM     | B7                 |                                |   |   |   |   |   | 3            | 4             |
| XORX dst, src                                                                                              | dst ← dst XOR src                                                     | ER           | ER     | B8                 | -                              | * | * | 0 | - | - | 4            | 3             |
|                                                                                                            |                                                                       | ER           | IM     | B9                 |                                |   |   |   |   |   | 4            | 3             |
| Flags Notation: * = Value is a function of the result of the operation.<br>- = Unaffected<br>X = Undefined |                                                                       |              |        |                    | 0 = Reset to 0<br>1 = Set to 1 |   |   |   |   |   |              |               |

## Flags Register

The Flags Register contains the status information regarding the most recent arithmetic, logical, bit manipulation or rotate and shift operation. The Flags Register contains six bits of status information that are set or cleared by CPU operations. Four of the bits (C, V, Z and S) can be tested with conditional jump instructions. Two flags (H and D) cannot be tested and are used for Binary-Coded Decimal (BCD) arithmetic.

The two remaining bits, User Flags (F1 and F2), are available as general-purpose status bits. User Flags are unaffected by arithmetic operations and must be set or cleared by instructions. The User Flags cannot be used with conditional Jumps. They are undefined at initial power-up and are unaffected by Reset. [Figure 56](#) illustrates the flags and their bit positions in the Flags Register.

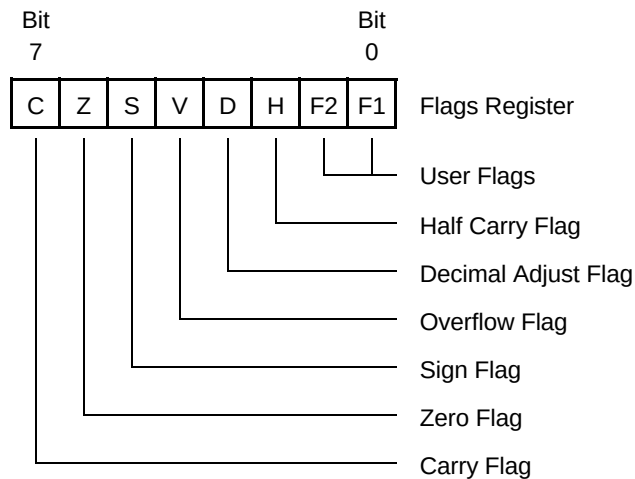


**Figure 56. Flags Register**

Interrupts, the Software Trap (TRAP) instruction, and Illegal Instruction Traps all write the value of the Flags Register to the stack. Executing an Interrupt Return (IRET) instruction restores the value saved on the stack into the Flags Register.



# Opcode Maps

A description of the opcode map data and the abbreviations are provided in [Figure 57](#) and [Table 127](#) on page 230. [Figure 58](#) on page 231 and [Figure 59](#) on page 232 provide information on each of the eZ8 CPU instructions.

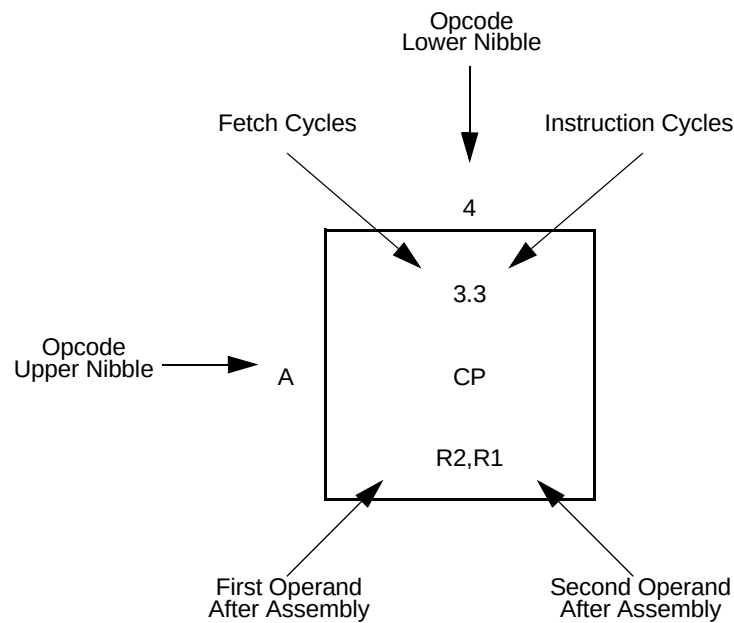


**Figure 57. Opcode Map Cell Description**

**Table 127. Opcode Map Abbreviations**

| Abbreviation | Description                        | Abbreviation                                | Description            |
|--------------|------------------------------------|---------------------------------------------|------------------------|
| b            | Bit position                       | IRR                                         | Indirect Register Pair |
| cc           | Condition code                     | p                                           | Polarity (0 or 1)      |
| X            | 8-bit signed index or displacement | r                                           | 4-bit Working Register |
| DA           | Destination address                | R                                           | 8-bit register         |
| ER           | Extended Addressing register       | r1, R1, Ir1, Irr1, IR1, rr1, RR1, IRR1, ER1 | Destination address    |
| IM           | Immediate data value               | r2, R2, Ir2, Irr2, IR2, rr2, RR2, IRR2, ER2 | Source address         |
| Ir           | Indirect Working Register          | RA                                          | Relative               |
| IR           | Indirect register                  | rr                                          | Working Register Pair  |
| Irr          | Indirect Working Register Pair     | RR                                          | Register Pair          |

|                    |   | Lower Nibble (Hex) |                     |                       |                        |                      |                       |                        |                         |                        |                        |                     |                   |                    |                    |                  |                          |
|--------------------|---|--------------------|---------------------|-----------------------|------------------------|----------------------|-----------------------|------------------------|-------------------------|------------------------|------------------------|---------------------|-------------------|--------------------|--------------------|------------------|--------------------------|
|                    |   | 0                  | 1                   | 2                     | 3                      | 4                    | 5                     | 6                      | 7                       | 8                      | 9                      | A                   | B                 | C                  | D                  | E                | F                        |
| Upper Nibble (Hex) | 0 | 1.2<br>BRK         | 2.2<br>SRP<br>IM    | 2.3<br>ADD<br>r1,r2   | 2.4<br>ADD<br>r1,lr2   | 3.3<br>ADD<br>R2,R1  | 3.4<br>ADD<br>IR2,R1  | 3.3<br>ADD<br>R1,IM    | 3.4<br>ADD<br>IR1,IM    | 4.3<br>ADDX<br>ER2,ER1 | 4.3<br>ADDX<br>IM,ER1  | 2.3<br>DJNZ<br>r1,X | 2.2<br>JR<br>cc,X | 2.2<br>LD<br>r1,IM | 3.2<br>JP<br>cc,DA | 1.2<br>INC<br>r1 | 1.2<br>NOP               |
|                    | 1 | 2.2<br>RLC<br>R1   | 2.3<br>RLC<br>IR1   | 2.3<br>ADC<br>r1,r2   | 2.4<br>ADC<br>r1,lr2   | 3.3<br>ADC<br>R2,R1  | 3.4<br>ADC<br>IR2,R1  | 3.3<br>ADC<br>R1,IM    | 3.4<br>ADC<br>IR1,IM    | 4.3<br>ADCX<br>ER2,ER1 | 4.3<br>ADCX<br>IM,ER1  |                     |                   |                    |                    |                  | See 2nd<br>Opcode<br>Map |
|                    | 2 | 2.2<br>INC<br>R1   | 2.3<br>INC<br>IR1   | 2.3<br>SUB<br>r1,r2   | 2.4<br>SUB<br>r1,lr2   | 3.3<br>SUB<br>R2,R1  | 3.4<br>SUB<br>IR2,R1  | 3.3<br>SUB<br>R1,IM    | 3.4<br>SUB<br>IR1,IM    | 4.3<br>SUBX<br>ER2,ER1 | 4.3<br>SUBX<br>IM,ER1  |                     |                   |                    |                    |                  |                          |
|                    | 3 | 2.2<br>DEC<br>R1   | 2.3<br>DEC<br>IR1   | 2.3<br>SBC<br>r1,r2   | 2.4<br>SBC<br>r1,lr2   | 3.3<br>SBC<br>R2,R1  | 3.4<br>SBC<br>IR2,R1  | 3.3<br>SBC<br>R1,IM    | 3.4<br>SBC<br>IR1,IM    | 4.3<br>SBCX<br>ER2,ER1 | 4.3<br>SBCX<br>IM,ER1  |                     |                   |                    |                    |                  |                          |
|                    | 4 | 2.2<br>DA<br>R1    | 2.3<br>DA<br>IR1    | 2.3<br>OR<br>r1,r2    | 2.4<br>OR<br>r1,lr2    | 3.3<br>OR<br>R2,R1   | 3.4<br>OR<br>IR2,R1   | 3.3<br>OR<br>R1,IM     | 3.4<br>OR<br>IR1,IM     | 4.3<br>ORX<br>ER2,ER1  | 4.3<br>ORX<br>IM,ER1   |                     |                   |                    |                    |                  |                          |
|                    | 5 | 2.2<br>POP<br>R1   | 2.3<br>POP<br>IR1   | 2.3<br>AND<br>r1,r2   | 2.4<br>AND<br>r1,lr2   | 3.3<br>AND<br>R2,R1  | 3.4<br>AND<br>IR2,R1  | 3.3<br>AND<br>R1,IM    | 3.4<br>AND<br>IR1,IM    | 4.3<br>ANDX<br>ER2,ER1 | 4.3<br>ANDX<br>IM,ER1  |                     |                   |                    |                    |                  | 1.2<br>WDT               |
|                    | 6 | 2.2<br>COM<br>R1   | 2.3<br>COM<br>IR1   | 2.3<br>TCM<br>r1,r2   | 2.4<br>TCM<br>r1,lr2   | 3.3<br>TCM<br>R2,R1  | 3.4<br>TCM<br>IR2,R1  | 3.3<br>TCM<br>R1,IM    | 3.4<br>TCM<br>IR1,IM    | 4.3<br>TCMX<br>ER2,ER1 | 4.3<br>TCMX<br>IM,ER1  |                     |                   |                    |                    |                  | 1.2<br>STOP              |
|                    | 7 | 2.2<br>PUSH<br>R2  | 2.3<br>PUSH<br>IR2  | 2.3<br>TM<br>r1,r2    | 2.4<br>TM<br>r1,lr2    | 3.3<br>TM<br>R2,R1   | 3.4<br>TM<br>IR2,R1   | 3.3<br>TM<br>R1,IM     | 3.4<br>TM<br>IR1,IM     | 4.3<br>TMX<br>ER2,ER1  | 4.3<br>TMX<br>IM,ER1   |                     |                   |                    |                    |                  | 1.2<br>HALT              |
|                    | 8 | 2.5<br>DECW<br>RR1 | 2.6<br>DECW<br>IRR1 | 2.5<br>LDE<br>r1,lr2  | 2.9<br>LDEI<br>lr1,lr2 | 3.2<br>LDX<br>r1,ER2 | 3.3<br>LDX<br>lr1,ER2 | 3.4<br>LDX<br>IRR2,R1  | 3.5<br>LDX<br>IRR2,IR1  | 3.4<br>LDX<br>r1,rr2,X | 3.4<br>LDX<br>rr1,r2,X |                     |                   |                    |                    |                  | 1.2<br>DI                |
|                    | 9 | 2.2<br>RL<br>R1    | 2.3<br>RL<br>IR1    | 2.5<br>LDE<br>r2,lr1  | 2.9<br>LDEI<br>lr2,lr1 | 3.2<br>LDX<br>r2,ER1 | 3.3<br>LDX<br>lr2,ER1 | 3.4<br>LDX<br>R2,IRR1  | 3.5<br>LDX<br>IR2,IRR1  | 3.3<br>LEA<br>r1,r2,X  | 3.5<br>LEA<br>rr1,r2,X |                     |                   |                    |                    |                  | 1.2<br>EI                |
|                    | A | 2.5<br>INCW<br>RR1 | 2.6<br>INCW<br>IRR1 | 2.3<br>CP<br>r1,r2    | 2.4<br>CP<br>r1,lr2    | 3.3<br>CP<br>R2,R1   | 3.4<br>CP<br>IR2,R1   | 3.3<br>CP<br>R1,IM     | 3.4<br>CP<br>IR1,IM     | 4.3<br>CPX<br>ER2,ER1  | 4.3<br>CPX<br>IM,ER1   |                     |                   |                    |                    |                  | 1.4<br>RET               |
|                    | B | 2.2<br>CLR<br>R1   | 2.3<br>CLR<br>IR1   | 2.3<br>XOR<br>r1,r2   | 2.4<br>XOR<br>r1,lr2   | 3.3<br>XOR<br>R2,R1  | 3.4<br>XOR<br>IR2,R1  | 3.3<br>XOR<br>R1,IM    | 3.4<br>XOR<br>IR1,IM    | 4.3<br>XORX<br>ER2,ER1 | 4.3<br>XORX<br>IM,ER1  |                     |                   |                    |                    |                  | 1.5<br>IRET              |
|                    | C | 2.2<br>RRC<br>R1   | 2.3<br>RRC<br>IR1   | 2.5<br>LDC<br>r1,lr2  | 2.9<br>LDCI<br>lr1,lr2 | 2.3<br>JP<br>IRR1    | 2.9<br>LDC<br>lr1,lr2 |                        | 3.4<br>LD<br>r1,r2,X    | 3.2<br>PUSHX<br>ER2    |                        |                     |                   |                    |                    |                  | 1.2<br>RCF               |
|                    | D | 2.2<br>SRA<br>R1   | 2.3<br>SRA<br>IR1   | 2.5<br>LDC<br>r2,lr1  | 2.9<br>LDCI<br>lr2,lr1 | 2.6<br>CALL<br>IRR1  | 2.2<br>BSWAP<br>R1    | 3.3<br>CALL<br>DA      | 3.4<br>LD<br>r2,r1,X    | 3.2<br>POPX<br>ER1     |                        |                     |                   |                    |                    |                  | 1.2<br>SCF               |
|                    | E | 2.2<br>RR<br>R1    | 2.3<br>RR<br>IR1    | 2.2<br>BIT<br>p,b,r1  | 2.3<br>LD<br>r1,lr2    | 3.2<br>LD<br>R2,R1   | 3.3<br>LD<br>IR2,R1   | 3.2<br>LD<br>R1,IM     | 3.3<br>LD<br>IR1,IM     | 4.2<br>LDX<br>ER2,ER1  | 4.2<br>LDX<br>IM,ER1   |                     |                   |                    |                    |                  | 1.2<br>CCF               |
|                    | F | 2.2<br>SWAP<br>R1  | 2.3<br>SWAP<br>IR1  | 2.6<br>TRAP<br>Vector | 2.3<br>LD<br>lr1,r2    | 2.8<br>MULT<br>RR1   | 3.3<br>LD<br>R2,IR1   | 3.3<br>BTJ<br>p,b,r1,X | 3.4<br>BTJ<br>p,b,lr1,X |                        |                        |                     |                   |                    |                    |                  |                          |

Figure 58. First Opcode Map



|                    |   | Lower Nibble (Hex) |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|--------------------|---|--------------------|-------------------|---------------------|----------------------|---------------------|----------------------|---------------------|----------------------|------------------------|-----------------------|---|---|---|---|---|---|
|                    |   | 0                  | 1                 | 2                   | 3                    | 4                   | 5                    | 6                   | 7                    | 8                      | 9                     | A | B | C | D | E | F |
| Upper Nibble (Hex) | 0 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 1 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 2 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 3 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 4 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 5 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 6 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 7 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 8 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | 9 |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | A |                    |                   | 3.3<br>CPC<br>r1,r2 | 3.4<br>CPC<br>r1,lr2 | 4.3<br>CPC<br>R2,R1 | 4.4<br>CPC<br>IR2,R1 | 4.3<br>CPC<br>R1,IM | 4.4<br>CPC<br>IR1,IM | 5.3<br>CPCX<br>ER2,ER1 | 5.3<br>CPCX<br>IM,ER1 |   |   |   |   |   |   |
|                    | B |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | C | 3.2<br>SRL<br>R1   | 3.3<br>SRL<br>IR1 |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | D |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | E |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |
|                    | F |                    |                   |                     |                      |                     |                      |                     |                      |                        |                       |   |   |   |   |   |   |

Figure 59. Second Opcode Map after 1FH

Packaging

Figure 60 displays the 20-pin SSOP package available for Z8 Encore! XP<sup>®</sup> F0822 Series devices.

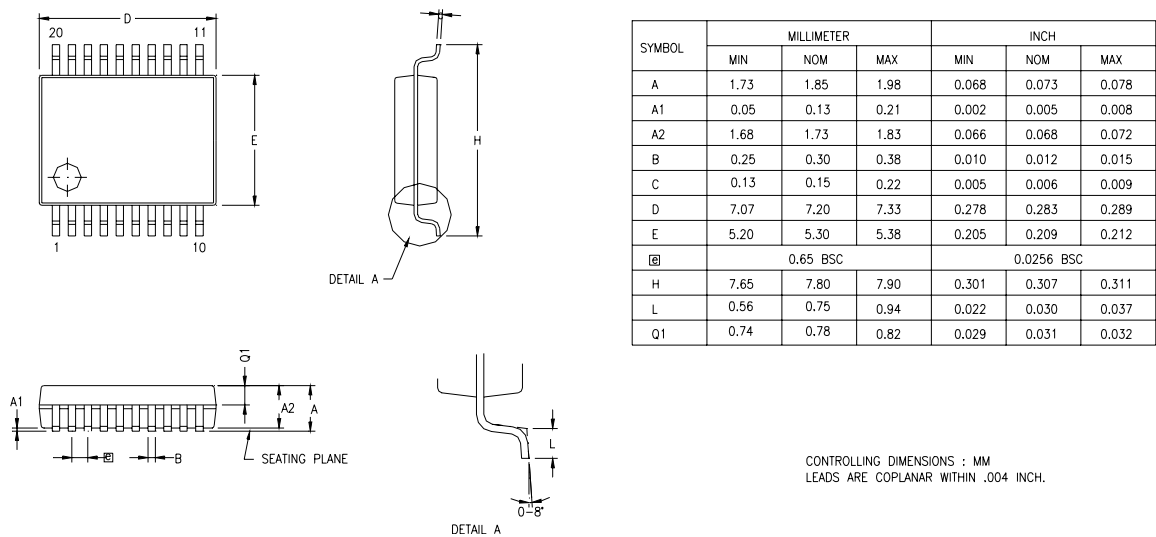


Figure 60. 20-Pin Small Shrink Outline Package (SSOP)

Figure 61 displays the 20-pin PDIP package available for Z8 Encore! XP F0822 Series devices.

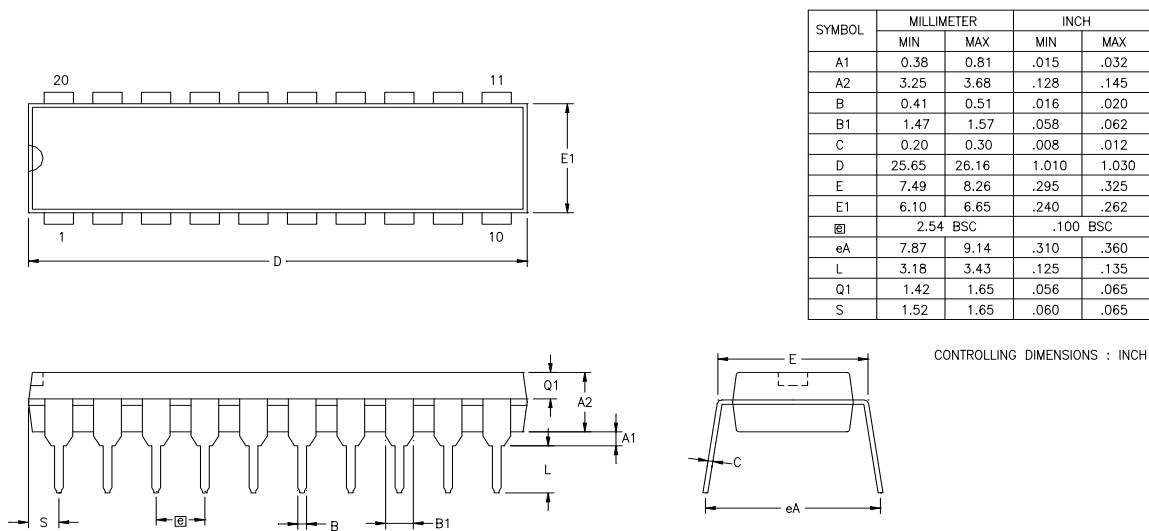


Figure 61. 20-Pin Plastic Dual-Inline Package (PDIP)



Figure 62 displays the 28-pin SOIC package available for Z8 Encore! XP F0822 Series devices.

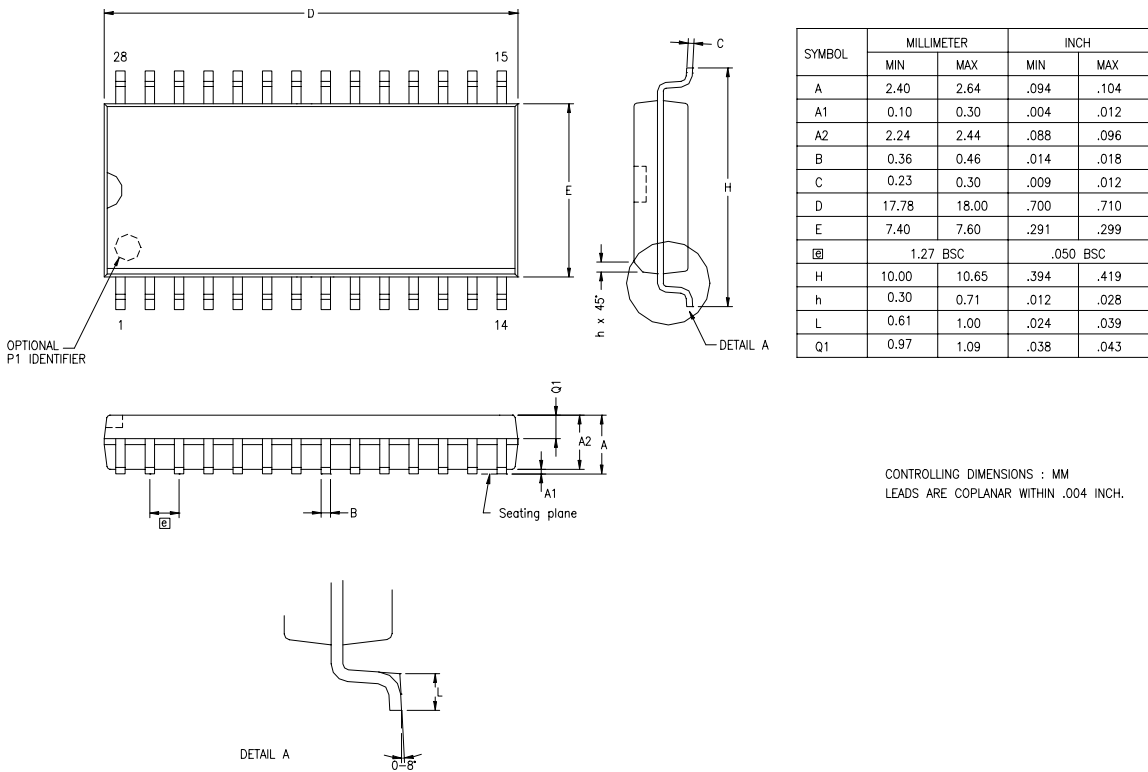
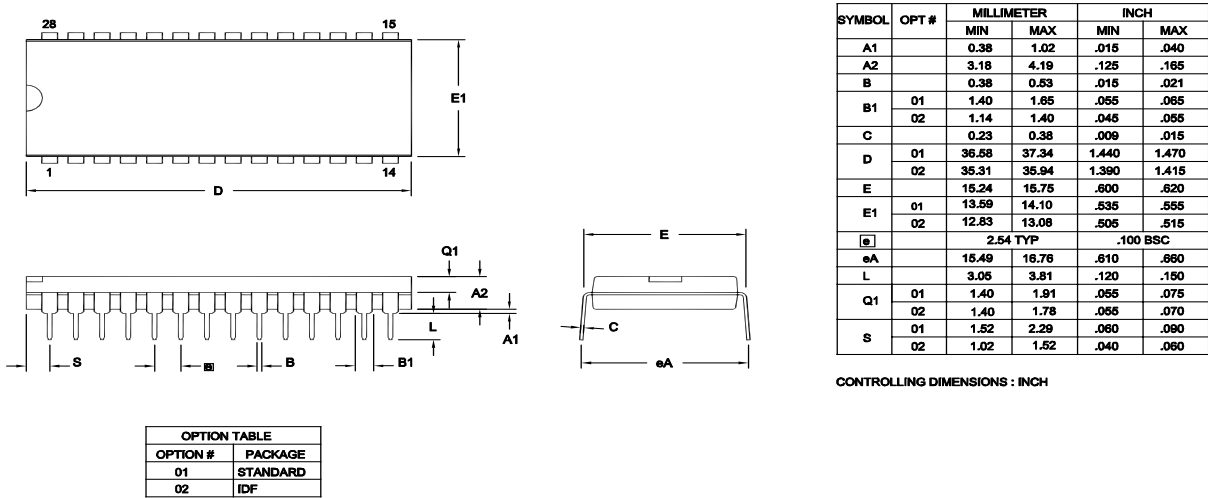


Figure 62. 28-Pin Small Outline Integrated Circuit Package (SOIC)



Figure 63 displays the 28-pin PDIP package available for Z8 Encore! XP F0822 Series devices.



Note: ZILOG supplies both options for production. Component layout PCB design should cover bigger option 01.

Figure 63. 28-Pin Plastic Dual-Inline Package (PDIP)

## Ordering Information

Order Z8 Encore! XP F0822 Series from Zilog®, using the following part numbers. For more information regarding ordering, consult your local Zilog sales office. Zilog website at [www.zilog.com](http://www.zilog.com) lists all regional offices and provides additional Z8 Encore! XP product information.

| Part Number                                                        | Flash | RAM  | I/O Lines | Interrupts | 16-Bit Timers w/PWM | 10-Bit A/D Channels | I <sup>2</sup> C | SPI | UARTs with IrDA | Description         |
|--------------------------------------------------------------------|-------|------|-----------|------------|---------------------|---------------------|------------------|-----|-----------------|---------------------|
| <b>Z8F08xx with 8 KB Flash, 10-Bit Analog-to-Digital Converter</b> |       |      |           |            |                     |                     |                  |     |                 |                     |
| Standard Temperature: 0 °C to 70 °C                                |       |      |           |            |                     |                     |                  |     |                 |                     |
| Z8F0821HH020SC                                                     | 8 KB  | 1 KB | 11        | 16         | 2                   | 2                   | 1                | 0   | 1               | SSOP 20-pin package |
| Z8F0821PH020SC                                                     | 8 KB  | 1 KB | 11        | 16         | 2                   | 2                   | 1                | 0   | 1               | PDIP 20-pin package |
| Z8F0822SJ020SC                                                     | 8 KB  | 1 KB | 19        | 19         | 2                   | 5                   | 1                | 1   | 1               | SOIC 28-pin package |
| Z8F0822PJ020SC                                                     | 8 KB  | 1 KB | 19        | 19         | 2                   | 5                   | 1                | 1   | 1               | PDIP 28-pin package |
| Extended Temperature: -40° to +105°C                               |       |      |           |            |                     |                     |                  |     |                 |                     |
| Z8F0821HH020EC                                                     | 8 KB  | 1 KB | 11        | 16         | 2                   | 2                   | 1                | 0   | 1               | SSOP 20-pin package |
| Z8F0821PH020EC                                                     | 8 KB  | 1 KB | 11        | 16         | 2                   | 2                   | 1                | 0   | 1               | PDIP 20-pin package |
| Z8F0822SJ020EC                                                     | 8 KB  | 1 KB | 19        | 19         | 2                   | 5                   | 1                | 1   | 1               | SOIC 28-pin package |
| Z8F0822PJ020EC                                                     | 8 KB  | 1 KB | 19        | 19         | 2                   | 5                   | 1                | 1   | 1               | PDIP 28-pin package |

| Part Number                             | Flash | RAM  | I/O Lines | Interrupts | 16-Bit Timers w/PWM | 10-Bit A/D Channels | I <sup>2</sup> C | SPI | UARTs with IrDA | Description         |
|-----------------------------------------|-------|------|-----------|------------|---------------------|---------------------|------------------|-----|-----------------|---------------------|
| <b>Z8F08xx with 8 KB Flash</b>          |       |      |           |            |                     |                     |                  |     |                 |                     |
| Standard Temperature: 0 °C to 70 °C     |       |      |           |            |                     |                     |                  |     |                 |                     |
| Z8F0811HH020SC                          | 8 KB  | 1 KB | 11        | 16         | 2                   | 0                   | 1                | 0   | 1               | SSOP 20-pin package |
| Z8F0811PH020SC                          | 8 KB  | 1 KB | 11        | 16         | 2                   | 0                   | 1                | 0   | 1               | PDIP 20-pin package |
| Z8F0812SJ020SC                          | 8 KB  | 1 KB | 19        | 19         | 2                   | 0                   | 1                | 1   | 1               | SOIC 28-pin package |
| Z8F0812PJ020SC                          | 8 KB  | 1 KB | 19        | 19         | 2                   | 0                   | 1                | 1   | 1               | PDIP 28-pin package |
| Extended Temperature: -40 °C to +105 °C |       |      |           |            |                     |                     |                  |     |                 |                     |
| Z8F0811HH020EC                          | 8 KB  | 1 KB | 11        | 16         | 2                   | 0                   | 1                | 0   | 1               | SSOP 20-pin package |
| Z8F0811PH020EC                          | 8 KB  | 1 KB | 11        | 16         | 2                   | 0                   | 1                | 0   | 1               | PDIP 20-pin package |
| Z8F0812SJ020EC                          | 8 KB  | 1 KB | 19        | 19         | 2                   | 0                   | 1                | 1   | 1               | SOIC 28-pin package |
| Z8F0812PJ020EC                          | 8 KB  | 1 KB | 19        | 19         | 2                   | 0                   | 1                | 1   | 1               | PDIP 28-pin package |



| Part Number                                                        | Flash | RAM  | I/O Lines | Interrupts | 16-Bit Timers w/PWM | 10-Bit A/D Channels | I <sup>2</sup> C | SPI | UARTs with IrDA | Description         |
|--------------------------------------------------------------------|-------|------|-----------|------------|---------------------|---------------------|------------------|-----|-----------------|---------------------|
| <b>Z8F04xx with 4 KB Flash, 10-Bit Analog-to-Digital Converter</b> |       |      |           |            |                     |                     |                  |     |                 |                     |
| Standard Temperature: 0 °C to 70 °C                                |       |      |           |            |                     |                     |                  |     |                 |                     |
| Z8F0421HH020SC                                                     | 4 KB  | 1 KB | 11        | 16         | 2                   | 2                   | 1                | 0   | 1               | SSOP 20-pin package |
| Z8F0421PH020SC                                                     | 4 KB  | 1 KB | 11        | 16         | 2                   | 2                   | 1                | 0   | 1               | PDIP 20-pin package |
| Z8F0422SJ020SC                                                     | 4 KB  | 1 KB | 19        | 19         | 2                   | 5                   | 1                | 1   | 1               | SOIC 28-pin package |
| Z8F0422PJ020SC                                                     | 4 KB  | 1 KB | 19        | 19         | 2                   | 5                   | 1                | 1   | 1               | PDIP 28-pin package |
| Extended Temperature: -40 °C to 105 °C                             |       |      |           |            |                     |                     |                  |     |                 |                     |
| Z8F0421HH020EC                                                     | 4 KB  | 1 KB | 11        | 16         | 2                   | 2                   | 1                | 0   | 1               | SSOP 20-pin package |
| Z8F0421PH020EC                                                     | 4 KB  | 1 KB | 11        | 16         | 2                   | 2                   | 1                | 0   | 1               | PDIP 20-pin package |
| Z8F0422SJ020EC                                                     | 4 KB  | 1 KB | 19        | 19         | 2                   | 5                   | 1                | 1   | 1               | SOIC 28-pin package |
| Z8F0422PJ020EC                                                     | 4 KB  | 1 KB | 19        | 19         | 2                   | 5                   | 1                | 1   | 1               | PDIP 28-pin package |

| Part Number                                            | Flash | RAM  | I/O Lines | Interrupts | 16-Bit Timers w/PWM | 10-Bit A/D Channels | I <sup>2</sup> C | SPI | UARTs with IrDA | Description                                 |
|--------------------------------------------------------|-------|------|-----------|------------|---------------------|---------------------|------------------|-----|-----------------|---------------------------------------------|
| <b>Z8F04xx with 4 KB Flash</b>                         |       |      |           |            |                     |                     |                  |     |                 |                                             |
| Standard Temperature: 0 °C to 70 °C                    |       |      |           |            |                     |                     |                  |     |                 |                                             |
| Z8F0411HH020SC                                         | 4 KB  | 1 KB | 11        | 16         | 2                   | 0                   | 1                | 0   | 1               | SSOP 20-pin package                         |
| Z8F0411PH020SC                                         | 4 KB  | 1 KB | 11        | 16         | 2                   | 0                   | 1                | 0   | 1               | PDIP 20-pin package                         |
| Z8F0412SJ020SC                                         | 4 KB  | 1 KB | 19        | 19         | 2                   | 0                   | 1                | 1   | 1               | SOIC 28-pin package                         |
| Z8F0412PJ020SC                                         | 4 KB  | 1 KB | 19        | 19         | 2                   | 0                   | 1                | 1   | 1               | PDIP 28-pin package                         |
| Extended Temperature: -40 °C to 105 °C                 |       |      |           |            |                     |                     |                  |     |                 |                                             |
| Z8F0411HH020EC                                         | 4 KB  | 1 KB | 11        | 16         | 2                   | 0                   | 1                | 0   | 1               | SSOP 20-pin package                         |
| Z8F0411PH020EC                                         | 4 KB  | 1 KB | 11        | 16         | 2                   | 0                   | 1                | 0   | 1               | PDIP 20-pin package                         |
| Z8F0412SJ020EC                                         | 4 KB  | 1 KB | 19        | 19         | 2                   | 0                   | 1                | 1   | 1               | SOIC 28-pin package                         |
| Z8F0412PJ020EC                                         | 4 KB  | 1 KB | 19        | 19         | 2                   | 0                   | 1                | 1   | 1               | PDIP 28-pin package                         |
| Z8F08200100KITG                                        |       |      |           |            |                     |                     |                  |     |                 | Development Kit (20- and 28-pin)            |
| ZUSBSC00100ZACG                                        |       |      |           |            |                     |                     |                  |     |                 | USB Smart Cable Accessory Kit               |
| ZUSBOPTSC01ZACG                                        |       |      |           |            |                     |                     |                  |     |                 | Opto-Isolated USB Smart Cable Accessory Kit |
| <b>Note:</b> Replace C with G for lead-free packaging. |       |      |           |            |                     |                     |                  |     |                 |                                             |

## Part Number Suffix Designations

| Z8 | F | 08 | 21 | H | H | 020 | S | C |                                             |
|----|---|----|----|---|---|-----|---|---|---------------------------------------------|
|    |   |    |    |   |   |     |   |   | <b>Environmental Flow</b>                   |
|    |   |    |    |   |   |     |   |   | C = Plastic Standard                        |
|    |   |    |    |   |   |     |   |   | G = Lead-Free Package                       |
|    |   |    |    |   |   |     |   |   | <b>Temperature Range (°C)</b>               |
|    |   |    |    |   |   |     |   |   | S = Standard, 0 to 70                       |
|    |   |    |    |   |   |     |   |   | E = Extended, -40 to +105                   |
|    |   |    |    |   |   |     |   |   | <b>Speed</b>                                |
|    |   |    |    |   |   |     |   |   | 020 = 20 MHz                                |
|    |   |    |    |   |   |     |   |   | <b>Pin Count</b>                            |
|    |   |    |    |   |   |     |   |   | H = 20                                      |
|    |   |    |    |   |   |     |   |   | J = 28                                      |
|    |   |    |    |   |   |     |   |   | <b>Package</b>                              |
|    |   |    |    |   |   |     |   |   | H = SSOP                                    |
|    |   |    |    |   |   |     |   |   | P = PDIP                                    |
|    |   |    |    |   |   |     |   |   | S = SOIC                                    |
|    |   |    |    |   |   |     |   |   | <b>Device Type</b>                          |
|    |   |    |    |   |   |     |   |   | 22 = 19 I/O lines, 5 ADC channels, one SPI  |
|    |   |    |    |   |   |     |   |   | 21 = 11 I/O lines, 2 ADC channels, no SPI   |
|    |   |    |    |   |   |     |   |   | 12 = 19 I/O lines, no ADC channels, one SPI |
|    |   |    |    |   |   |     |   |   | 11 = 11 I/O lines, no ADC channels, no SPI  |
|    |   |    |    |   |   |     |   |   | <b>Memory Size</b>                          |
|    |   |    |    |   |   |     |   |   | 08 = 8 KB Flash, 1 KB RAM                   |
|    |   |    |    |   |   |     |   |   | 04 = 4 KB Flash, 1 KB RAM                   |
|    |   |    |    |   |   |     |   |   | <b>Memory Type</b>                          |
|    |   |    |    |   |   |     |   |   | F = Flash                                   |
|    |   |    |    |   |   |     |   |   | <b>Device Family</b>                        |
|    |   |    |    |   |   |     |   |   | Z8 = Zilog's 8-Bit Microcontroller          |

For example, part number Z8F0821HH020SC is a Z8 Encore! XP Flash 8 KB microcontroller in a 20-pin SSOP package, operating with a maximum 20 MHz external clock frequency over a 0 °C to +70 °C temperature range and built using the Plastic-Standard environmental flow.

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