



## Z89223/273/323/373

16-BIT DIGITAL SIGNAL PROCESSORS  
WITH A/D CONVERTER

### FEATURES

| Device | Package                   | ROM<br>(Kwords) | OTP<br>(Kwords) | Data RAM<br>(Words) | MIPS |
|--------|---------------------------|-----------------|-----------------|---------------------|------|
| Z89223 | 44-PLCC, 44-PQFP          | 8               |                 | 512                 | 20   |
| Z89273 | 44-PLCC                   |                 | 8               | 512                 | 20   |
| Z89323 | 64-TQFP, 68-PLCC, 80-PQFP | 8               |                 | 512                 | 20   |
| Z89373 | 64-TQFP, 68-PLCC, 80-PQFP |                 | 8               | 512                 | 20   |

### Operating Range

- 5V  $\pm 10\%$
- 0°C to 70°C Standard Temperature  
–40°C to +85°C Extended Temperature

### DSP Core

- 16-Bit Fixed Point DSP, 24-Bit ALU and Accumulator
- Single-Cycle Multiply and ALU Operations
- Six-Level Hardware Stack
- Six Data RAM Pointers and Sixteen Program Memory Pointers
- RISC Processor with 30 Instruction Types

### On-Chip Peripherals

- 4-Channel, 8-Bit Half-Flash A/D Converter
- Serial Peripheral Interface (SPI)
- Three General-Purpose Counter/Timers
  - Two Pulse Width Modulators (PWM)
  - Two Watch-Dog Timers (WDT)
- Up to 40 Bits of I/O
- PLL System Clock
- Three Vectored Interrupts Servicing Eight Sources
- Low Power Clock Modes with Wake-up Options

### GENERAL DESCRIPTION

The Z893x3 products are high-performance Digital Signal Processors (DSP) with a modified Harvard architecture featuring separate program and dual data memory banks. The design is optimized for processing power with a minimum of silicon area.

The Z893x3 16/24-Bit architecture accommodates advanced signal processing algorithms. The operating performance and efficient architecture provide deterministic instruction execution. Compression, filtering, frequency detection, audio, voice detection, speech synthesis, and other vital algorithms can all be implemented.

Six data RAM pointers provide circular buffer capabilities and simultaneous dual operand fetching. Three vectored interrupts are complemented by a six-level stack.

By integrating a high-speed 4-channel, 8-bit A/D, SPI, three Counter/Timers with PWM and WDT support, and up to 40 bits of I/O, the Z893x3 family provides a compact low-cost system solution.

To support a wide variety of development requirements, the Z893x3 DSP product family features the cost-effective Z89223/323 with 8 KWords of ROM. The Z89273/373, an

GENERAL DESCRIPTION (Continued)

OTP version of the Z89223/323, is ideal for prototypes and early production builds.

Throughout this specification, references to the Z893x3 device apply equally to the Z89223/273/323/373, unless otherwise specified.

**Notes:** All signals with an overline are active Low. For example, in RD/WR, RD is active High and WR is active Low. For I/O ports, P1.3 denotes Port1 bit 3. Pins called NC are “No Connection”—they do not connect any power, grounds, or signals.

Power connections follow conventional descriptions:

| Connection | Circuit         | Device          |
|------------|-----------------|-----------------|
| Power      | V <sub>CC</sub> | V <sub>DD</sub> |
| Ground     | GND             | V <sub>SS</sub> |

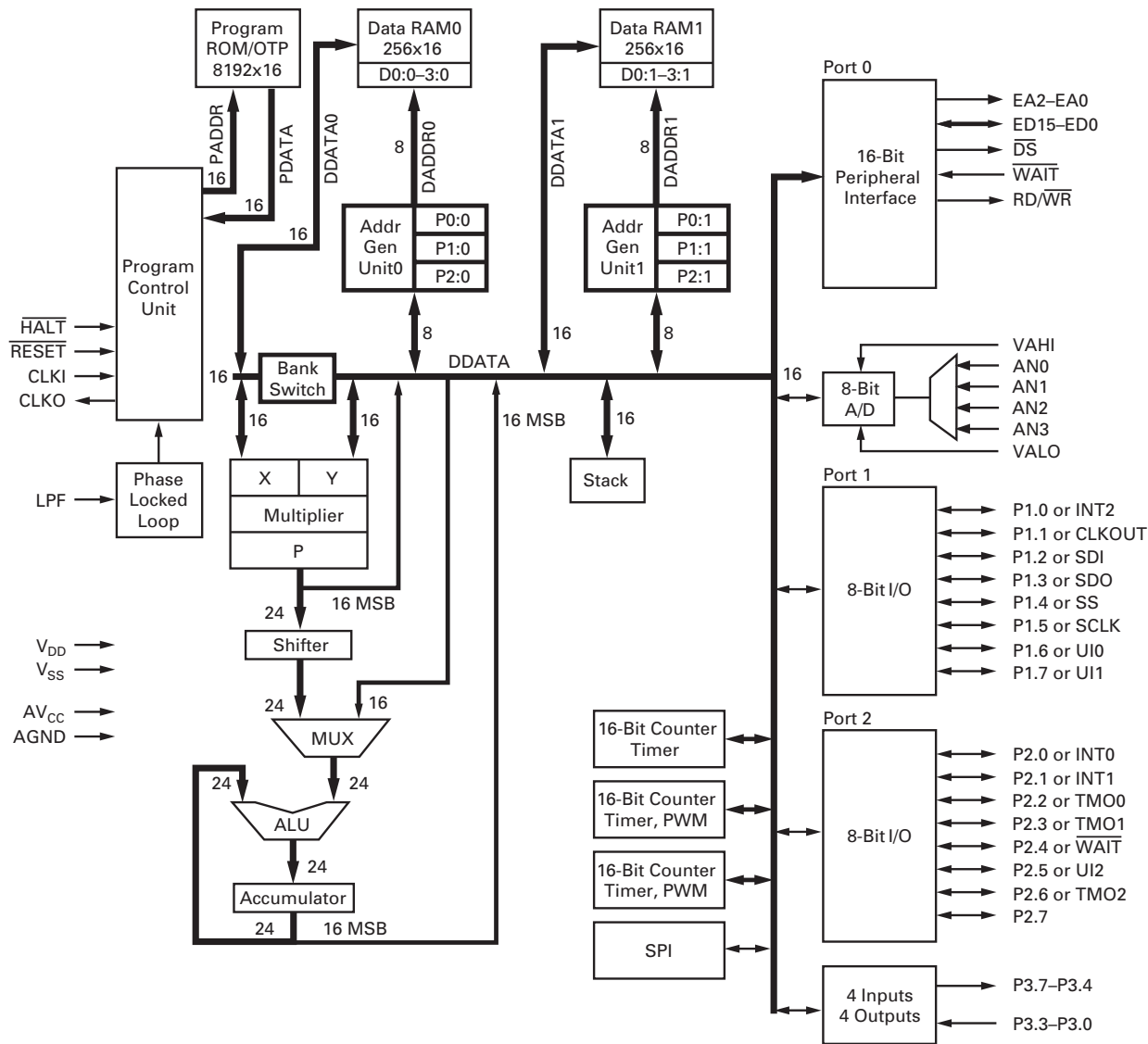
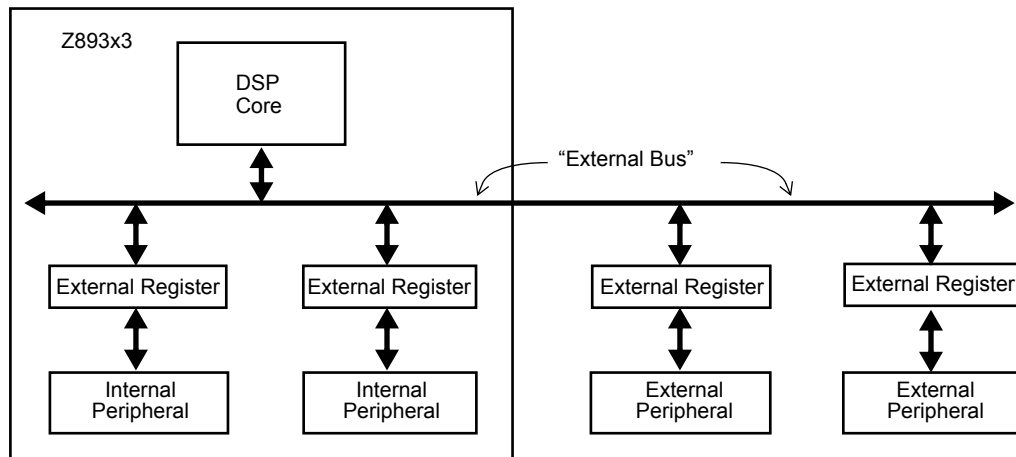


Figure 1. Z892X3/3x3 Functional Block Diagram

**External Bus and External Registers.** The following is made to clarify naming conventions used in this specification. The external bus and external registers are external to

the DSP core, and are used to access internal and external peripherals.



**Figure 2. "External" Bus**

## PIN FUNCTIONS

**EA2–EA0.** External Address Bus (output, latched). These pins provide the External Register Address. This address bus is driven during both internal and external accesses. One of up to seven user-defined external registers is selected by the processor for reads or writes. EXT7 is always reserved for use by the processor.

**ED15–ED0.** External Data Bus (input/output). These pins are the data bus for the user-defined external registers, and are shared by Port0. These pins are normally tristated, except when these registers are specified as destination registers in a write instruction to an external peripheral, or when Port0 is enabled for output. This bus uses the control signals  $\overline{RD}/\overline{WR}$ ,  $\overline{DS}$ , and  $\overline{WAIT}$ , and address pins EA2–EA0.

**$\overline{DS}$ .** Data Strobe (output). This pin provides the data strobe signal for the ED Bus.  $\overline{DS}$  is active for transfers to/from external peripherals only.

**$\overline{RD}/\overline{WR}$ .** Read/Write Select (output). This pin controls the data direction signal for the External Data Bus. Data is available from the processor on ED15–ED0 when this signal and  $\overline{DS}$  are both Low.

**$\overline{WAIT}$ .** Wait State (input). This pin is sampled at the rising edge of the clock with appropriate setup and hold times. A single wait-state can be generated internally by setting the appropriate bits in the wait state register. The user must drive this line if multiple wait states are required. This pin is shared with Port2.

**CLKI.** Clock (input). This pin is the clock circuit input. It can be driven by a signal or connected to a 32 KHz crystal.

**CLKO.** Clock (output). This pin is the clock circuit output. It is used for operation with a 32 KHz crystal and the PLL to generate the system clock.

**$\overline{HALT}$ .** Halt State (input). This pin stops program execution. The processor continuously executes NOPs and the program counter remains constant while this pin is held Low. This pin offers an internal pull-up.

**$\overline{RESET}$ .** Reset (input). This pin resets the processor. It pushes the contents of the Program Counter (PC) onto the stack and then fetches a new PC value from program memory address 0FFCH after the  $\overline{RESET}$  signal is released. The Status register is set to all zeros. At power-up RAM and other registers are undefined, however, they are left unchanged with subsequent resets.  $\overline{RESET}$  can be asserted asynchronously.

**AN0–AN3.** Analog Inputs (input). These are the analog input pins. The analog input signal should be between VALO and VAHI for accurate conversions.

are enabled, and the Counter/Timer is disabled, this pin pro-

**VAHI.** Analog High Reference Voltage (input). This pin provides the reference for the full scale voltage of the analog input signals.

**VALO.** Analog Low Reference Voltage (input). This pin provides the reference for the zero voltage of the analog input signals.

**AV<sub>CC</sub>–AGND.** Filtered Analog Power and Ground must be provided on separate pins to reduce digital noise in the analog circuits.

**Multifunction Pins.** The Z89223/273/323/373 DSP family offers a user-configurable I/O structure, which means that most of the I/O pins offer dual functions. The function, direction (input or output), and for output, the characteristics (push-pull or open drain) are all under user-control, by programming the configuration registers appropriately as described in the I/O Ports section. The following share I/O Port pins:

**INT0–INT2.** External Interrupts (input, edge-triggered). These pins provide three of the eight interrupt sources to the Interrupt Controller. Each is programmable to be rising-edge or falling-edge triggered. The other five interrupt sources are from the on-chip peripherals.

**CLKOUT.** System Clock (output). This pin provides access to the internal processor clock.

**SDI.** Serial Data In (input). This pin is the SPI serial data input.

**SDO.** Serial Data Out (output). This pin is the SPI serial data output.

**SS.** Slave Select (input). This pin is used in SPI Slave Mode only. SS advises the SPI that it is the target of a serial transfer from an external Master.

**SCLK.** SPI Clock (output/input). This pin is an output in Master mode and an input in Slave mode.

**UI0, UI1.** User inputs (input). These general-purpose input pins are directly tested by the conditional branch instructions. They can also be read as bits in the status register. These are asynchronous input signals that require no special clock synchronization. Counter/Timer0 and Counter/Timer1 may use either of these pins as input.

**UI2.** User Input (input). This pin is the input to Counter/Timer 2.

**TMO0/UO0.** Counter/Timer Output or User Output 0 (output). Counter/Timer 0 and Counter/Timer 1 can be programmed to provide output on this pin. When User Outputs provides the complement of Status Register bit 5.

**TMO1/UO1.** Counter/Timer Output or User Output 1 (output). Counter/Timer 0 and Counter/Timer 1 can be programmed to provide output on this pin. When User Outputs are enabled, and the Counter/Timer is disabled, this pin provides the complement of Status Register bit 6.

**TMO2.** Counter/Timer 2 Output (output). This pin is the output of Counter/Timer 2

**P0.15–P0.0.** Port0 (input/output). This is a 16-bit user I/O port. Bits can be configured as input or output or globally as open-drain output. When enabled, Port0 uses the 16 data lines of the ED bus. The function of these pins can be dynamically changed by writing to the Port0 configuration registers. The High byte can also be configured to Port1 as described in the I/O Port section.

**P1.7–P1.0.** Port1 (input/output). These pins are Port1 inputs or outputs when not configured for use as special purpose peripheral interface. The following eight pin functions preempt use of these pins when enabled. INT2, CLKOUT, SDI, SDO, SS, SCLK, UI0, UI1.

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**Note:** These pins are not bonded out on the 44-pin packages.

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**P2.7–P2.0.** Port2 (input/output). These pins are Port2 inputs or outputs when not configured as peripheral interfaces. The following seven pin functions preempt use of P2.6–P2.0 when enabled. INT0, INT1, TMO0/UO0, TMO1/UO1,  $\overline{\text{WAIT}}$ , UI2, TMO2. P2.7 does not include a dual function.

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**Note:** P2.7–P2.5 are not bonded out on the 44-pin packages.

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The following port pins are available only on the 80-pin package:

**P3.7–P3.4.** Port3 (output). These pins are Port3 outputs.

**P3.3–P3.0.** Port3 (input). These pins are Port3 inputs.

PIN CONFIGURATIONS

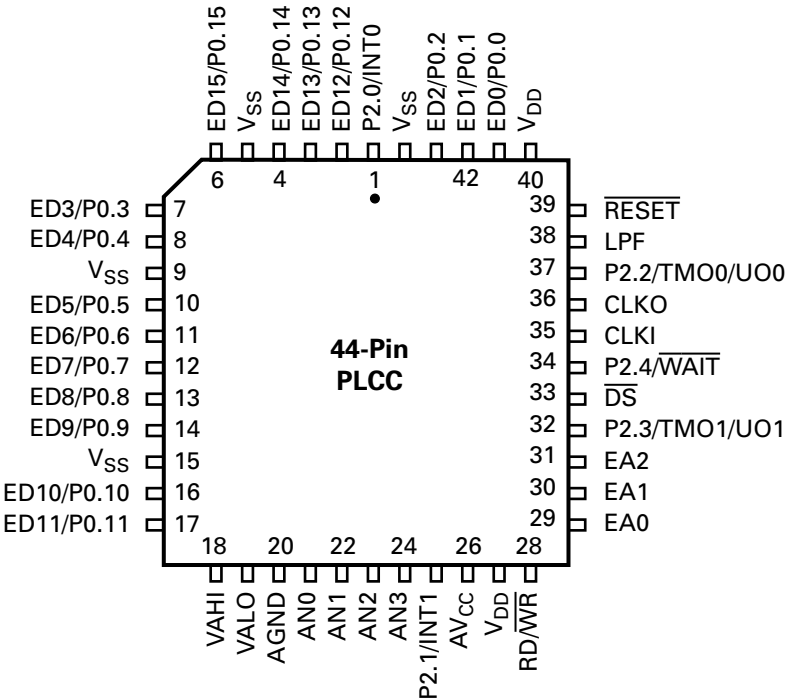


Figure 3. 44-Pin PLCC Z89223/273 Pin Configuration

**Table 1. 44-Pin PLCC Z89223/273 Pin Description**

| No | Symbol          | Function                 | Direction    | No | Symbol                  | Function                | Direction    |
|----|-----------------|--------------------------|--------------|----|-------------------------|-------------------------|--------------|
| 1  | P2.0/INT0       | Port 2.0/Interrupt 0     | Input/Output | 23 | AN2                     | A/D Input 2             | Input        |
| 2  | ED12/P0.12      | External Data Bus/Port0  | Input/Output | 24 | AN3                     | A/D Input 3             | Input        |
| 3  | ED13/P0.13      | External Data Bus/Port0  | Input/Output | 25 | P2.1/INT1               | Port 2.1/Interrupt 1    | Input/Output |
| 4  | ED14/P0.14      | External Data Bus/Port0  | Input/Output | 26 | AV <sub>CC</sub>        | Analog Power            |              |
| 5  | V <sub>SS</sub> | Ground                   |              | 27 | V <sub>DD</sub>         | Power Supply            |              |
| 6  | ED15/P0.15      | External Data Bus/Port0  | Input/Output | 28 | RD/ $\overline{WR}$     | R/W External Bus        | Output       |
| 7  | ED3/P0.3        | External Data Bus/Port0  | Input/Output | 29 | EA0                     | Ext Address 0           | Output       |
| 8  | ED4/P0.4        | External Data Bus/Port0  | Input/Output | 30 | EA1                     | Ext Address 1           | Output       |
| 9  | V <sub>SS</sub> | Ground                   |              | 31 | EA2                     | Ext Address 2           | Output       |
| 10 | ED5/P0.5        | External Data Bus/Port0  | Input/Output | 32 | P2.3/TMO1               | Port 2.3/Timer Output 1 | Input/Output |
| 11 | ED6/P0.6        | External Data Bus/Port0  | Input/Output | 33 | $\overline{DS}$         | Ext Data Strobe         | Output       |
| 12 | ED7/P0.7        | External Data Bus/Port0  | Input/Output | 34 | P2.4/ $\overline{WAIT}$ | Port 2.4/Wait for ED    | Input/Output |
| 13 | ED8/P0.8        | External Data Bus/Port0  | Input/Output | 35 | CLKI                    | Clock/Crystal In        | Input        |
| 14 | ED9/P0.9        | External Data Bus/Port0  | Input/Output | 36 | CLKO                    | Clock/Crystal Out       | Output       |
| 15 | V <sub>SS</sub> | Ground                   |              | 37 | P2.2/TMO0               | Port 2.2/Timer Output 0 | Input/Output |
| 16 | ED10/P0.10      | External Data Bus/Port0  | Input/Output | 38 | LPF                     | PLL Low Pass Filter     | Input        |
| 17 | ED11/P0.11      | External Data Bus/Port0  | Input/Output | 39 | $\overline{RESET}$      | Reset                   | Input        |
| 18 | VAHI            | Analog High Ref. Voltage | Input        | 40 | V <sub>DD</sub>         | Power                   |              |
| 19 | VALO            | Analog Low Ref. Voltage  | Input        | 41 | ED0/P0.0                | External Data Bus/Port0 | Input/Output |
| 20 | AGND            | Analog Ground            |              | 42 | ED1/P0.1                | External Data Bus/Port0 | Input/Output |
| 21 | AN0             | A/D Input 0              | Input        | 43 | ED2/P0.2                | External Data Bus/Port0 | Input/Output |
| 22 | AN1             | A/D Input 1              | Input        | 44 | V <sub>SS</sub>         | Ground                  |              |

PIN CONFIGURATIONS (Continued)

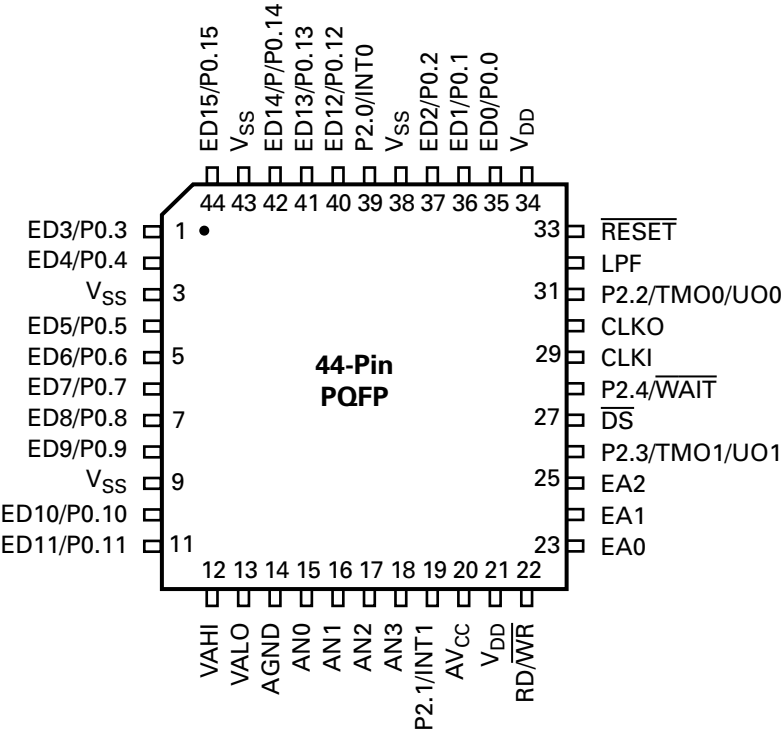


Figure 4. 44-Pin PQFP Z89223/273 Pin Configuration



Table 2. 44-Pin PQFP Z89223/273 Pin Description

| No | Symbol              | Function                 | Direction    | No | Symbol                  | Function                | Direction    |
|----|---------------------|--------------------------|--------------|----|-------------------------|-------------------------|--------------|
| 1  | ED3/P0.3            | External Data Bus/Port0  | Input/Output | 23 | EA0                     | Ext Address 0           | Output       |
| 2  | ED4/P0.4            | External Data Bus/Port0  | Input/Output | 24 | EA1                     | Ext Address 1           | Output       |
| 3  | V <sub>SS</sub>     | Ground                   |              | 25 | EA2                     | Ext Address 2           | Output       |
| 4  | ED5/P0.5            | External Data Bus/Port0  | Input/Output | 26 | P2.3/TMO1               | Port 2.3/Timer Output 1 | Input/Output |
| 5  | ED6/P0.6            | External Data Bus/Port0  | Input/Output | 27 | $\overline{DS}$         | Ext Data Strobe         | Output       |
| 6  | ED7/P0.7            | External Data Bus/Port0  | Input/Output | 28 | P2.4/ $\overline{WAIT}$ | Port 2.4/Wait for ED    | Input/Output |
| 7  | ED8/P0.8            | External Data Bus/Port0  | Input/Output | 29 | CLKI                    | Clock/Crystal In        | Input        |
| 8  | ED9/P0.9            | External Data Bus/Port0  | Input/Output | 30 | CLKO                    | Clock/Crystal Out       | Output       |
| 9  | V <sub>SS</sub>     | Ground                   |              | 31 | P2.2/TMO0               | Port 2.2/Timer Output 0 | Input/Output |
| 10 | ED10/P0.10          | External Data Bus/Port0  | Input/Output | 32 | LPF                     | PLL Low Pass Filter     | Input        |
| 11 | ED11/P0.11          | External Data Bus/Port0  | Input/Output | 33 | $\overline{RESET}$      | Reset                   | Input        |
| 12 | VAHI                | Analog High Ref. Voltage | Input        | 34 | V <sub>DD</sub>         | Power Supply            |              |
| 13 | VALO                | Analog Low Ref. Voltage  | Input        | 35 | ED0/P0.0                | External Data Bus/Port0 | Input/Output |
| 14 | AGND                | Analog Ground            |              | 36 | ED1/P0.1                | External Data Bus/Port0 | Input/Output |
| 15 | AN0                 | A/D Input 0              | Input        | 37 | ED2/P0.2                | External Data Bus/Port0 | Input/Output |
| 16 | AN1                 | A/D Input 1              | Input        | 38 | V <sub>SS</sub>         | Ground                  |              |
| 17 | AN2                 | A/D Input 2              | Input        | 39 | P2.0/INT0               | Port 2.0/Interrupt 0    | Input/Output |
| 18 | AN3                 | A/D Input 3              | Input        | 40 | ED12/P0.12              | External Data Bus/Port0 | Input/Output |
| 19 | P2.1/INT1           | Port 2.1/Interrupt 1     | Input/Output | 41 | ED13/P0.13              | External Data Bus/Port0 | Input/Output |
| 20 | AV <sub>CC</sub>    | Analog Power             |              | 42 | ED14/P0.14              | External Data Bus/Port0 | Input/Output |
| 21 | V <sub>DD</sub>     | Power                    |              | 43 | V <sub>SS</sub>         | Ground                  |              |
| 22 | RD/ $\overline{WR}$ | R/W External Output Bus  |              | 44 | ED15/P0.15              | External Data Bus/Port0 | Input/Output |

## PIN CONFIGURATIONS (Continued)

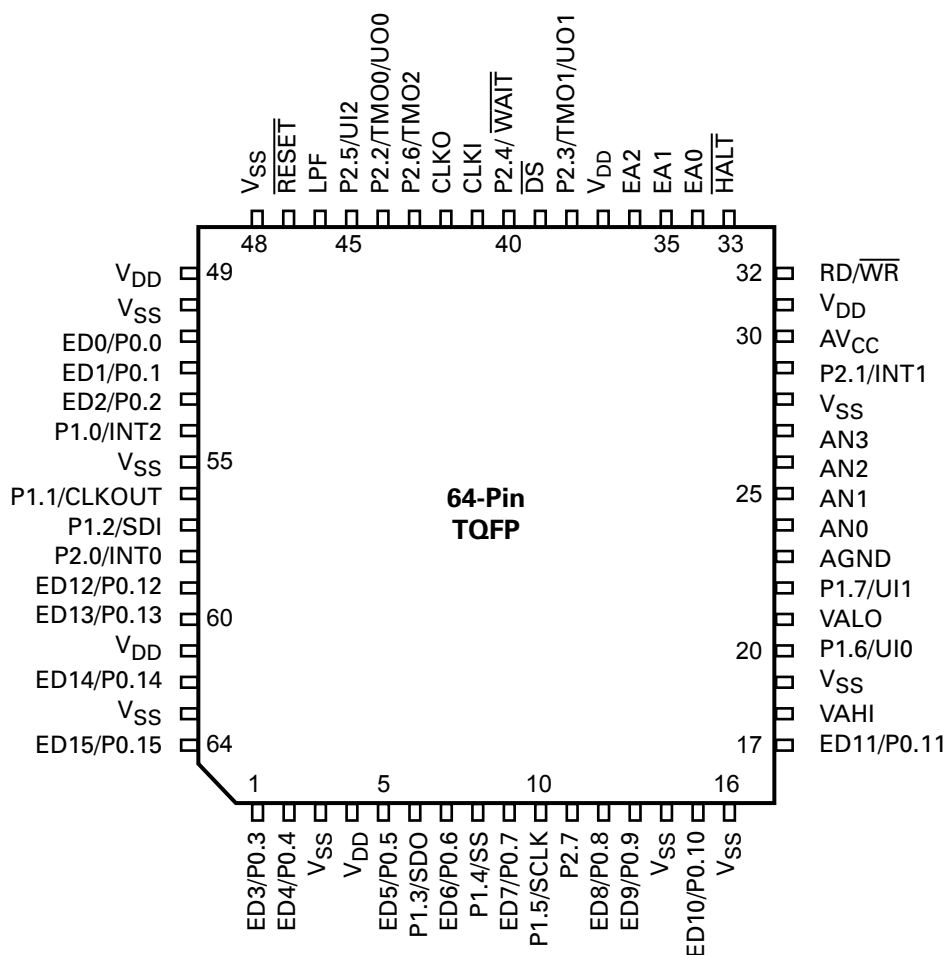


Figure 5. 64-Pin TQFP Z89323/373 Pin Configuration

**Table 3. 64-Pin TQFP Z89223/273 Pin Description**

| No | Symbol                                      | Function                 | Direction    | No | Symbol                         | Function                | Direction    |
|----|---------------------------------------------|--------------------------|--------------|----|--------------------------------|-------------------------|--------------|
| 1  | ED3/P0.3                                    | External Data Bus/Port0  | Input/Output | 33 | $\overline{\text{HALT}}$       | Halt Execution          | Input        |
| 2  | ED4/P0.4                                    | External Data Bus/Port0  | Input/Output | 34 | EA0                            | Ext Address 0           | Output       |
| 3  | V <sub>SS</sub>                             | Ground                   |              | 35 | EA1                            | Ext Address 1           | Output       |
| 4  | V <sub>DD</sub>                             | Power Supply             |              | 36 | EA2                            | Ext Address 2           | Output       |
| 5  | ED5/P0.5                                    | External Data Bus/Port0  | Input/Output | 37 | V <sub>DD</sub>                | Power Supply            |              |
| 6  | P1.3/SDO                                    | Port 1.3/Serial Output   | Input/Output | 38 | P2.3/TMO1                      | Port2.3/Timer Output 1  | Input/Output |
| 7  | ED6/P0.6                                    | External Data Bus/Port0  | Input/Output | 39 | $\overline{\text{DS}}$         | Ext Data Strobe         | Output       |
| 8  | P1.4/SS                                     | Port 1.4/Slave Select    | Input/Output | 40 | P2.4/ $\overline{\text{WAIT}}$ | Port 2.4/Wait for ED    | Input/Output |
| 9  | ED7/P0.7                                    | External Data Bus/Port0  | Input/Output | 41 | CLKI                           | Clock/Crystal In        | Input        |
| 10 | P1.5/SCLK                                   | Port 1.5/Serial Clock    | Input/Output | 42 | CLKO                           | Clock/Crystal Out       | Output       |
| 11 | P2.7                                        | Port 2.7                 | Input/Output | 43 | P2.6/TMO2                      | Port 2.6/Timer Output 2 | Input/Output |
| 12 | ED8/P0.8                                    | External Data Bus/Port0  | Input/Output | 44 | P2.2/TMO0                      | Port 2.2/Timer Output 0 | Input/Output |
| 13 | ED9/P0.9                                    | External Data Bus/Port0  | Input/Output | 45 | P2.5/UI2                       | Port 2.5/User Input 2   | Input/Output |
| 14 | V <sub>SS</sub>                             | Ground                   |              | 46 | LPF                            | PLL Low Pass Filter     | Input        |
| 15 | ED10/P0.10                                  | External Data Bus/Port0  | Input/Output | 47 | $\overline{\text{RESET}}$      | Reset                   | Input        |
| 16 | V <sub>SS</sub>                             | Ground                   |              | 48 | V <sub>SS</sub>                | Ground                  |              |
| 17 | ED11/P0.11                                  | External Data Bus/Port0  | Input/Output | 49 | V <sub>DD</sub>                | Power Supply            |              |
| 18 | VAHI                                        | Analog High Ref. Voltage | Input        | 50 | V <sub>SS</sub>                | Ground                  |              |
| 19 | V <sub>SS</sub>                             | Ground                   |              | 51 | ED0/P0.0                       | External Data Bus/Port0 | Input/Output |
| 20 | P1.6/UI0                                    | Port 1.6/User Input 0    | Input/Output | 52 | ED1/P0.1                       | External Data Bus/Port0 | Input/Output |
| 21 | VALO                                        | Analog Low Ref. Voltage  | Input        | 53 | ED2/P0.2                       | External Data Bus/Port0 | Input/Output |
| 22 | P1.7/UI1                                    | Port 1.7/User Input 1    | Input/Output | 54 | P1.0/INT2                      | Port 1.0/Interrupt 2    | Input/Output |
| 23 | AGND                                        | Analog Ground            |              | 55 | V <sub>SS</sub>                | Ground                  |              |
| 24 | AN0                                         | A/D Input 0              | Input        | 56 | P1.1/CLKOUT                    | Port 1.1/Clock Output   | Input/Output |
| 25 | AN1                                         | A/D Input 1              | Input        | 57 | P1.2/SDI                       | Port 1.2/Serial Input   | Input/Output |
| 26 | AN2                                         | A/D Input 2              | Input        | 58 | P2.0/INT0                      | Port 2.0/Interrupt 0    | Input/Output |
| 27 | AN3                                         | A/D Input 3              | Input        | 59 | ED12/P0.12                     | External Data Bus/Port0 | Input/Output |
| 28 | V <sub>SS</sub>                             | Ground                   |              | 60 | ED13/P0.13                     | External Data Bus/Port0 | Input/Output |
| 29 | P2.1/INT1                                   | Port 2.1/Interrupt 1     | Input/Output | 61 | V <sub>DD</sub>                | Power Supply            |              |
| 30 | AVCC                                        | Analog Power             |              | 62 | ED14/P0.14                     | External Data Bus/Port0 | Input/Output |
| 31 | V <sub>DD</sub>                             | Power Supply             |              | 63 | V <sub>SS</sub>                | Ground                  |              |
| 32 | $\overline{\text{RD}}/\overline{\text{WR}}$ | R/W External Bus         | Output       | 64 | ED15/P0.15                     | External Data Bus/Port0 | Input/Output |

## PIN CONFIGURATIONS (Continued)

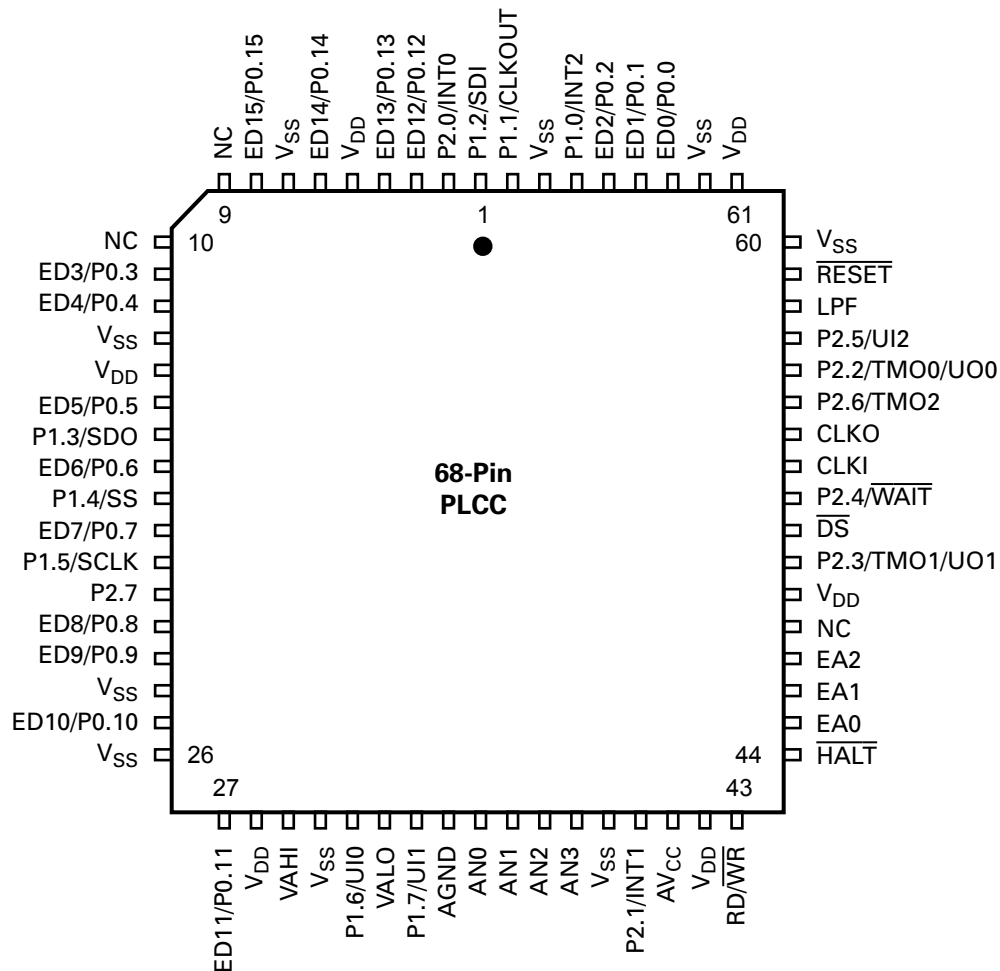


Figure 6. 68-Pin PLCC Z89323/373 Pin Configuration

**Table 4. 68-Pin PLCC Z89323/373 Pin Description**

| No | Symbol          | Function                 | Direction    | No | Symbol                  | Function                | Direction    |
|----|-----------------|--------------------------|--------------|----|-------------------------|-------------------------|--------------|
| 1  | P1.2/SDI        | Port 1.2/Serial Input    | Input/Output | 35 | AN0                     | A/D Input 0             | Input        |
| 2  | P2.0/INT0       | Port 2.0/Interrupt 0     | Input/Output | 36 | AN1                     | A/D Input 1             | Input        |
| 3  | ED12/P0.12      | External Data Bus/Port0  | Input/Output | 37 | AN2                     | A/D Input 2             | Input        |
| 4  | ED13/P0.13      | External Data Bus/Port0  | Input/Output | 38 | AN3                     | A/D Input 3             | Input        |
| 5  | V <sub>DD</sub> | Power Supply             |              | 39 | V <sub>SS</sub>         | Ground                  |              |
| 6  | ED14/P0.14      | External Data Bus/Port0  | Input/Output | 40 | P2.1/INT1               | Port 2.1/Interrupt 1    | Input/Output |
| 7  | V <sub>SS</sub> | Ground                   |              | 41 | AVCC                    | Analog Power            |              |
| 8  | ED15/P0.15      | External Data Bus/Port0  | Input/Output | 42 | V <sub>DD</sub>         | Power Supply            |              |
| 9  | NC              | No Connection            |              | 43 | RD/ $\overline{WR}$     | R/W External Bus        | Output       |
| 10 | NC              | No Connection            |              | 44 | $\overline{HALT}$       | Halt Execution          | Input        |
| 11 | ED3/P0.3        | External Data Bus/Port0  | Input/Output | 45 | EA0                     | Ext Address 0           | Output       |
| 12 | ED4/P0.4        | External Data Bus/Port0  | Input/Output | 46 | EA1                     | Ext Address 1           | Output       |
| 13 | V <sub>SS</sub> | Ground                   |              | 47 | EA2                     | Ext Address 2           | Output       |
| 14 | V <sub>DD</sub> | Power Supply             |              | 48 | NC                      | No Connection           |              |
| 15 | ED5/P0.5        | External Data Bus/Port0  | Input/Output | 49 | V <sub>DD</sub>         | Power Supply            |              |
| 16 | P1.3/SDO        | Port 1.3/Serial Output   | Input/Output | 50 | P2.3/TMO1               | Port2.3/Timer Output 1  | Input/Output |
| 17 | ED6/P0.6        | External Data Bus/Port0  | Input/Output | 51 | $\overline{DS}$         | Ext Data Strobe         | Output       |
| 18 | P1.4/SS         | Port 1.4/Slave Select    | Input/Output | 52 | P2.4/ $\overline{WAIT}$ | Port 2.4/Wait for ED    | Input/Output |
| 19 | ED7/P0.7        | External Data Bus/Port0  | Input/Output | 53 | CLKI                    | Clock/Crystal In        | Input        |
| 20 | P1.5/SCLK       | Port 1.5/Serial Clock    | Input/Output | 54 | CLKO                    | Clock/Crystal Out       | Output       |
| 21 | P2.7            | Port 2.7                 | Input/Output | 55 | P2.6/TMO2               | Port 2.6/Timer Output 2 | Input/Output |
| 22 | ED8/P0.8        | External Data Bus/Port0  | Input/Output | 56 | P2.2/TMO0               | Port 2.2/Timer Output 0 | Input/Output |
| 23 | ED9/P0.9        | External Data Bus/Port0  | Input/Output | 57 | P2.5/UI2                | Port 2.5/User Input 2   | Input/Output |
| 24 | V <sub>SS</sub> | Ground                   |              | 58 | LPF                     | PLL Low Pass Filter     | Input        |
| 25 | ED10/P0.10      | External Data Bus/Port0  | Input/Output | 59 | $\overline{RESET}$      | Reset                   | Input        |
| 26 | V <sub>SS</sub> | Ground                   |              | 60 | V <sub>SS</sub>         | Ground                  |              |
| 27 | ED11/P0.11      | External Data Bus/Port0  | Input/Output | 61 | V <sub>DD</sub>         | Power Supply            |              |
| 28 | V <sub>DD</sub> | Power Supply             |              | 62 | V <sub>SS</sub>         | Ground                  |              |
| 29 | VAHI            | Analog High Ref. Voltage | Input        | 63 | ED0/P0.0                | External Data Bus/Port0 | Input/Output |
| 30 | V <sub>SS</sub> | Ground                   |              | 64 | ED1/P0.1                | External Data Bus/Port0 | Input/Output |
| 31 | P1.6/UI0        | Port 1.6/User Input 0    | Input/Output | 65 | ED2/P0.2                | External Data Bus/Port0 | Input/Output |
| 32 | VALO            | Analog Low Ref. Voltage  | Input        | 66 | P1.0/INT2               | Port 1.0/Interrupt 2    | Input/Output |
| 33 | P1.7/UI1        | Port 1.7/User Input 1    | Input/Output | 67 | V <sub>SS</sub>         | Ground                  |              |
| 34 | AGND            | Analog Ground            |              | 68 | P1.1/CLKOUT             | Port 1.1/Clock Output   | Input/Output |

## PIN CONFIGURATIONS (Continued)

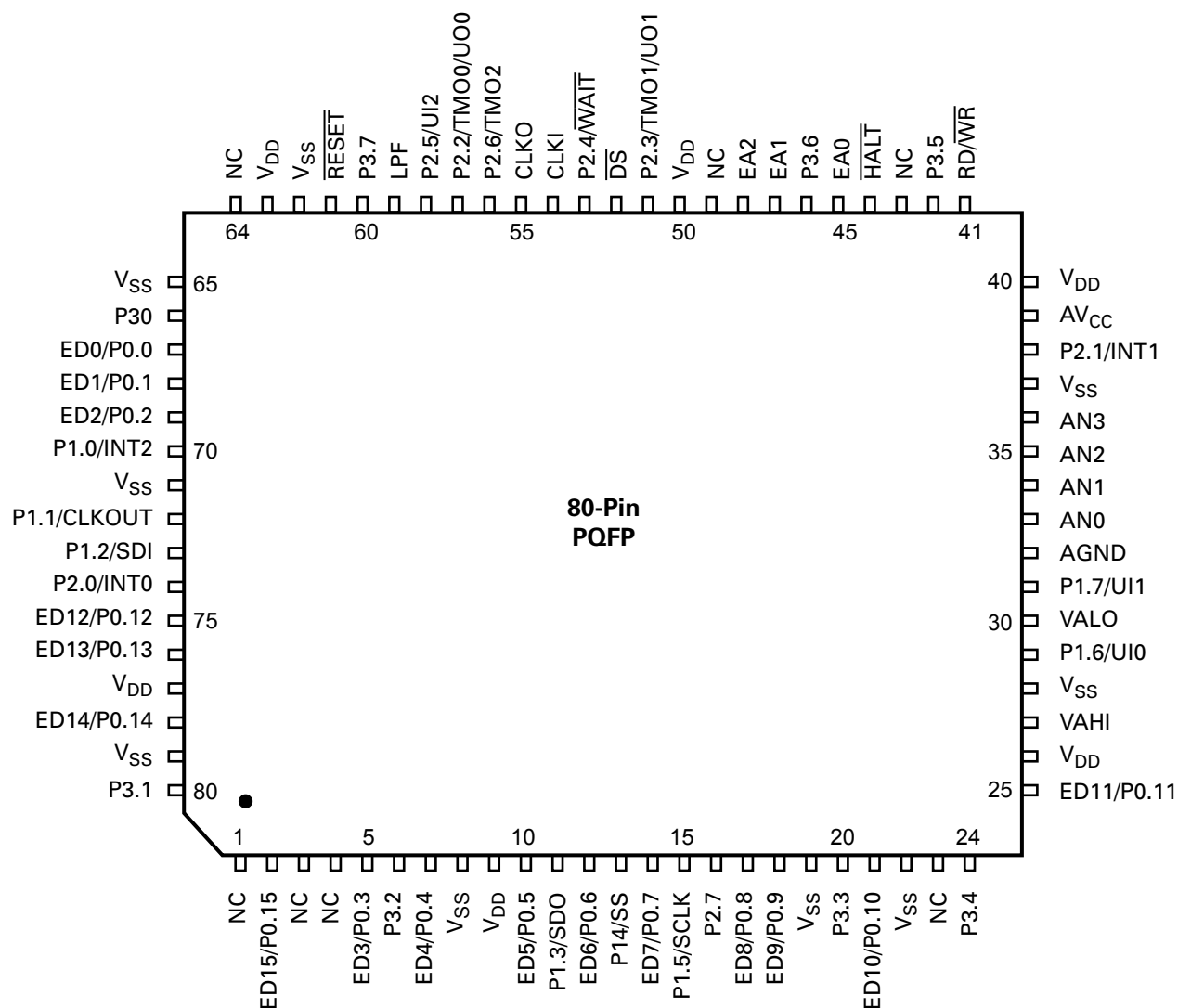


Figure 7. 80-Pin PQFP Z89323/373 Pin Configuration

Table 5. 80-Pin PQFP Z89323/373 Pin Description

| No | Symbol           | Function                 | Direction    | No | Symbol                  | Function                | Direction    |
|----|------------------|--------------------------|--------------|----|-------------------------|-------------------------|--------------|
| 1  | NC               | No Connection            |              | 41 | RD/ $\overline{WR}$     | R/W External Bus        | Output       |
| 2  | ED15/P0.15       | External Data Bus/Port0  | Input/Output | 42 | P3.5                    | Port 3.5                | Output       |
| 3  | NC               | No Connection            |              | 43 | NC                      | No Connection           |              |
| 4  | NC               | No Connection            |              | 44 | $\overline{HALT}$       | Halt Execution          | Input        |
| 5  | ED3/P0.3         | External Data Bus/Port0  | Input/Output | 45 | EA0                     | Ext Address 0           | Output       |
| 6  | P3.2             | Port 3.2                 | Input        | 46 | P3.6                    | Port 3.6                | Output       |
| 7  | ED4/P0.4         | External Data Bus/Port0  | Input/Output | 47 | EA1                     | Ext Address 1           | Output       |
| 8  | V <sub>SS</sub>  | Ground                   |              | 48 | EA2                     | Ext Address 2           | Output       |
| 9  | V <sub>DD</sub>  | Power Supply             |              | 49 | NC                      | No Connection           |              |
| 10 | ED5/P0.5         | External Data Bus/Port0  | Input/Output | 50 | V <sub>DD</sub>         | Power Supply            |              |
| 11 | P1.3/SDO         | Port 1.3/Serial Output   | Input/Output | 51 | P2.3/TMO1               | Port 2.3/Timer Output 1 | Input/Output |
| 12 | ED6/P0.6         | External Data Bus/Port0  | Input/Output | 52 | $\overline{DS}$         | Ext Data Strobe         | Output       |
| 13 | P1.4/SS          | Port 1.4/Slave Select    | Input/Output | 53 | P2.4/ $\overline{WAIT}$ | Port 2.4/Wait for ED    | Input/Output |
| 14 | ED7/P0.7         | External Data Bus/Port0  | Input/Output | 54 | CLKI                    | Clock/Crystal In        | Input        |
| 15 | P1.5/SCLK        | Port 1.5/Serial Clock    | Input/Output | 55 | CLKO                    | Clock/Crystal Out       | Output       |
| 16 | P2.7             | Port 2 7                 | Input/Output | 56 | P2.6/TMO2               | Port 2.6/Timer Output 2 | Input/Output |
| 17 | ED8/P0.8         | External Data Bus/Port0  | Input/Output | 57 | P2.2/TMO0               | Port 2.2/Timer Output 0 | Input/Output |
| 18 | ED9/P0.9         | External Data Bus/Port0  | Input/Output | 58 | P2.5/UI2                | Port 2.5/User Input 2   | Input/Output |
| 19 | V <sub>SS</sub>  | Ground                   |              | 59 | LPF                     | PLL Low Pass Filter     | Input        |
| 20 | P3.3             | Port 3 3                 | Input        | 60 | P3.7                    | Port 3.7                | Output       |
| 21 | ED10/P0.10       | External Data Bus/Port0  | Input/Output | 61 | $\overline{RESET}$      | Reset                   | Input        |
| 22 | V <sub>SS</sub>  | Ground                   |              | 62 | V <sub>SS</sub>         | Ground                  |              |
| 23 | NC               | No Connection            |              | 63 | V <sub>DD</sub>         | Power Supply            |              |
| 24 | P3.4             | Port 3.4                 | Output       | 64 | NC                      | No Connection           |              |
| 25 | ED11/P0.11       | External Data Bus/Port0  | Input/Output | 65 | V <sub>SS</sub>         | Ground                  |              |
| 26 | V <sub>DD</sub>  | Power Supply             |              | 66 | P3.0                    | Port 3.0                | Input        |
| 27 | VAHI             | Analog High Ref. Voltage | Input        | 67 | ED0/P0.0                | External Data Bus/Port0 | Input/Output |
| 28 | V <sub>SS</sub>  | Ground                   |              | 68 | ED1/P0.1                | External Data Bus/Port0 | Input/Output |
| 29 | P1.6/UI0         | Port 1 6/User Input 0    | Input/Output | 69 | ED2/P0.2                | External Data Bus/Port0 | Input/Output |
| 30 | VALO             | Analog Low Ref. Voltage  | Input        | 70 | P1.0/INT2               | Port 1.0/Interrupt 2    | Input/Output |
| 31 | P1.7/UI1         | Port 1 7/User Input 1    | Input/Output | 71 | V <sub>SS</sub>         | Ground                  |              |
| 32 | AGND             | Analog Ground            |              | 72 | P1.1/CLKOUT             | Port 1.1/Clock Output   | Input/Output |
| 33 | AN0              | A/D Input 0              | Input        | 73 | P1.2/SDI                | Port 1.2/Serial Input   | Input/Output |
| 34 | AN1              | A/D Input 1              | Input        | 74 | P2.0/INT0               | Port 2.0/Interrupt 0    | Input/Output |
| 35 | AN2              | A/D Input 2              | Input        | 75 | ED12/P0.12              | External Data Bus/Port0 | Input/Output |
| 36 | AN3              | A/D Input 3              | Input        | 76 | ED13/P0.13              | External Data Bus/Port0 | Input/Output |
| 37 | V <sub>SS</sub>  | Ground                   |              | 77 | V <sub>DD</sub>         | Power Supply            |              |
| 38 | P2.1/INT1        | Port 2.1/Interrupt 1     | Input/Output | 78 | ED14/P0.14              | External Data Bus/Port0 | Input/Output |
| 39 | AV <sub>CC</sub> | Analog Power             |              | 79 | V <sub>SS</sub>         | Ground                  |              |
| 40 | V <sub>DD</sub>  | Power Supply             |              | 80 | P3.1                    | Port 3.1                | Input        |

ABSOLUTE MAXIMUM RATINGS

| Symbol           | Description                   | Min  | Max | Units |
|------------------|-------------------------------|------|-----|-------|
| V <sub>CC</sub>  | Supply Voltage                | −0.3 | 7.0 | V     |
| T <sub>STG</sub> | Storage Temperature           | −65  | 150 | °C    |
| T <sub>A</sub>   | Ambient Operating Temperature |      |     |       |
|                  | “S” device                    | 0    | 70  | °C    |
|                  | “E” device                    | −40  | 85  | °C    |

Stresses greater than those listed under Absolute Maximum Ratings may cause permanent damage to the device. This rating is a stress rating only; operation of the device at any condition above those indicated in the operational sections of these specifications is not implied. Exposure to absolute maximum rating conditions for extended period may affect device reliability.

STANDARD TEST CONDITIONS

The characteristics listed below apply for standard test conditions as noted. All voltages are referenced to Ground. Positive current flows into the referenced pin.

Positive current I<sub>(+)</sub> flows in to the referenced pin.

Negative current I<sub>(−)</sub> flows out of the referenced pin.

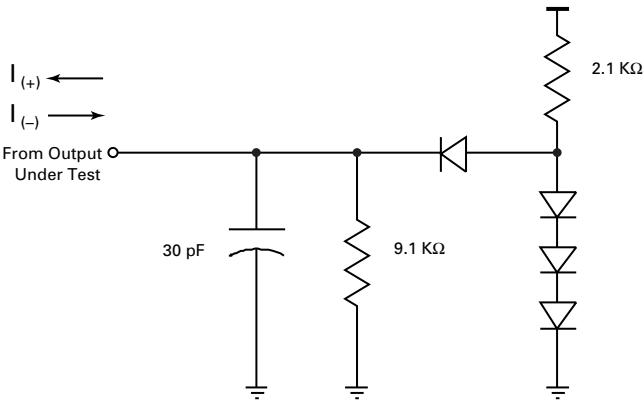


Figure 8. Test Load Diagram



**DC ELECTRICAL CHARACTERISTICS**

**Table 6. ROM Version:  $V_{DD} = 5V \pm 10\%$ ,  $T_A = 0^\circ C$  to  $+70^\circ C$  for “S” temperature range  
 $T_A = -40^\circ C$  to  $+85^\circ C$  for “E” temperature range, unless otherwise noted;  
 IDD measured with peripherals disabled**

| Symbol        | Parameter                                   | Condition                           | Min           | Typical     | Max         |
|---------------|---------------------------------------------|-------------------------------------|---------------|-------------|-------------|
| $I_{DD-PLL}$  | Supply Current using PLL                    | $V_{DD} = 5.0V, 20\text{ MHz}$      |               | 60mA        | 66mA        |
| $I_{DD-ECD}$  | Supply Current using External Clock Direct  | $V_{DD} = 5.0V, 20\text{ MHz}$      |               | 55 mA       | 61mA        |
| $I_{DD-XOD}$  | Supply Current using XTAL Oscillator Direct | $V_{DD} = 5.0V, 32\text{-kHz XTAL}$ |               | 250 $\mu A$ | 275 $\mu A$ |
| $I_{DD-DEEP}$ | Supply Current during Deep Sleep            | $V_{DD} = 5.0V, 32\text{kHz XTAL}$  |               | 175 $\mu A$ | 193 $\mu A$ |
| $V_{IH}$      | Input High Level                            |                                     | 2.7V          |             |             |
| $V_{IL}$      | Input Low Level                             |                                     |               |             | 0.8V        |
| $I_L$         | Input Leakage                               |                                     | -10 $\mu A$   |             | 10 $\mu A$  |
| $V_{OH}$      | Output High Voltage                         | $I_{OH} = -100\text{ }\mu A$        | $V_{DD}-0.2V$ |             |             |
|               |                                             | $I_{OH} = -160\text{ }\mu A$        | 2.4V          |             |             |
| $V_{OL}$      | Output Low Voltage                          | $I_{OL} = 1.6\text{ mA}$            |               |             | 0.4V        |
|               |                                             | $I_{OL} = 2.0\text{ mA}$            |               |             | 0.5V        |
| $I_{FL}$      | Output Floating Leakage Current             |                                     | -10 $\mu A$   |             | 10 $\mu A$  |

**Table 7. OTP Version:  $V_{DD} = 5V \pm 10\%$ ,  $T_A = 0^\circ C$  to  $+70^\circ C$  for “S” temperature range  
 $T_A = -40^\circ C$  to  $+85^\circ C$  for “E” temperature range, unless otherwise noted;  
 IDD measured with peripherals disabled**

| Symbol        | Parameter                                   | Condition                           | Min           | Typical | Max        |
|---------------|---------------------------------------------|-------------------------------------|---------------|---------|------------|
| $I_{DD-PLL}$  | Supply Current using PLL                    | $V_{DD} = 5.0V, 20\text{ MHz}$      |               | 78mA    | 86mA       |
| $I_{DD-ECD}$  | Supply Current using External Clock Direct  | $V_{DD} = 5.0V, 20\text{ MHz}$      |               | 75mA    | 83mA       |
| $I_{DD-XOD}$  | Supply Current using XTAL Oscillator Direct | $V_{DD} = 5.0V, 32\text{-kHz XTAL}$ |               | 17mA    | 19mA       |
| $I_{DD-DEEP}$ | Supply Current during Deep Sleep            | $V_{DD} = 5.0V, 32\text{kHz XTAL}$  |               | 17mA    | 19mA       |
| $V_{IH}$      | Input High Level                            |                                     | 2.7V          |         |            |
| $V_{IL}$      | Input Low Level                             |                                     |               |         | 0.8V       |
| $I_L$         | Input Leakage                               |                                     | -10 $\mu A$   |         | 10 $\mu A$ |
| $V_{OH}$      | Output High Voltage                         | $I_{OH} = -100\text{ }\mu A$        | $V_{DD}-0.2V$ |         |            |
|               |                                             | $I_{OH} = -160\text{ }\mu A$        | 2.4V          |         |            |
| $V_{OL}$      | Output Low Voltage                          | $I_{OL} = 1.6\text{ mA}$            |               |         | 0.4V       |
|               |                                             | $I_{OL} = 2.0\text{ mA}$            |               |         | 0.5V       |
| $I_{FL}$      | Output Floating Leakage Current             |                                     | -10 $\mu A$   |         | 10 $\mu A$ |

DC ELECTRICAL CHARACTERISTICS (Continued)

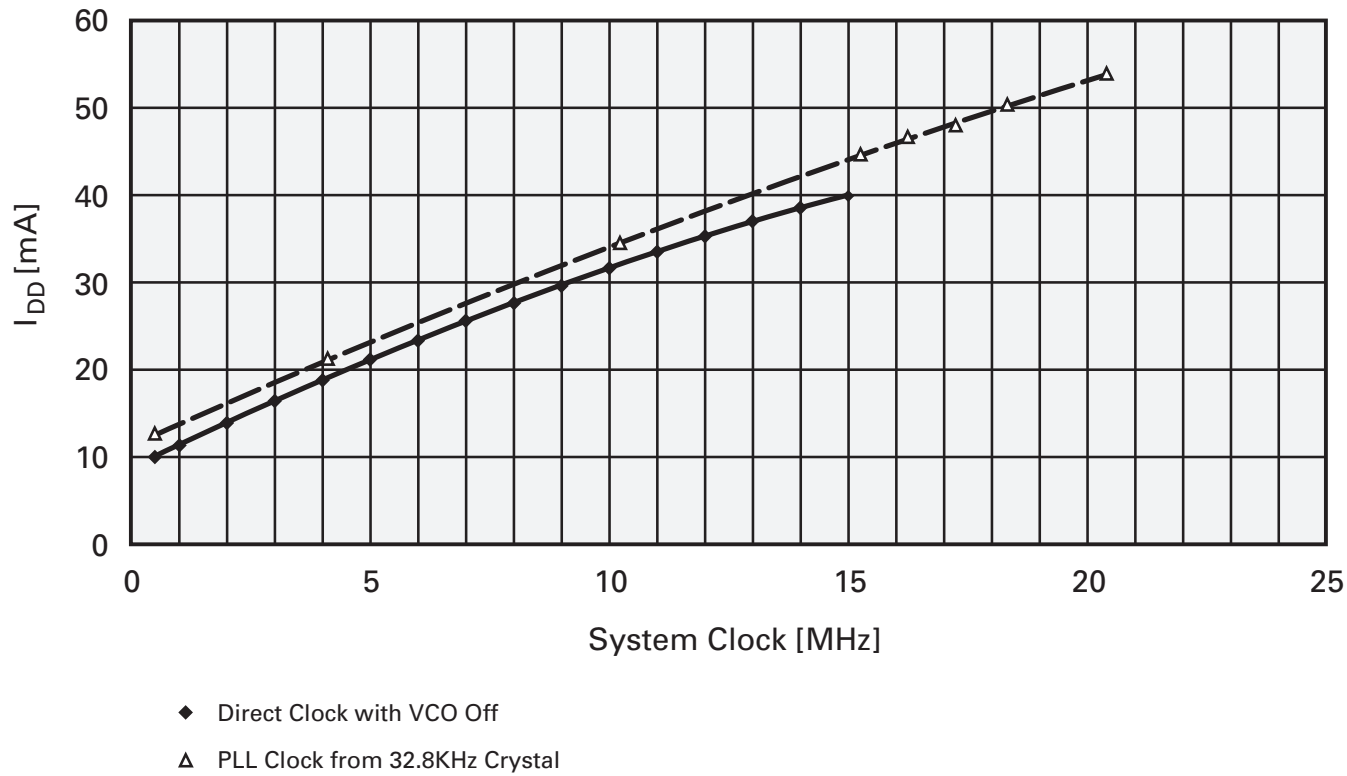


Figure 9. Z89373 Typical OTP Current Consumption

**AC ELECTRICAL CHARACTERISTICS**

**Table 8.  $V_{DD} = 5V \pm 10\%$ ,  $T_A = 0^\circ C$  to  $+70^\circ C$  for “S” Temperature Range  
 $T_A = -40^\circ C$  to  $+85^\circ C$  for “E” temperature range, unless otherwise noted**

| Symbol                         | Parameter                                       | Min [ns]        | Max [ns] |
|--------------------------------|-------------------------------------------------|-----------------|----------|
| <b>Clock</b>                   |                                                 |                 |          |
| TCY                            | CLKI Cycle Time for user-supplied clock         | 50              | 31250    |
| CPWH                           | CLKI Pulse Width High                           | 21              |          |
| CPWL                           | CLKI Pulse Width Low                            | 21              |          |
| Tr                             | CLKI Rise Time for 20-MHz user-supplied clock   |                 | 2        |
| Tf                             | CLKI Fall Time for 20-MHz user-supplied clock   |                 | 2        |
| <b>External Peripheral Bus</b> |                                                 |                 |          |
| EASET                          | EA Setup Time to $\overline{DS}$ Fall           | 10              |          |
| EAHOLD                         | EA Hold Time from $\overline{DS}$ Rise          | 4               |          |
| RWSET                          | Read/Write Setup Time to $\overline{DS}$ Fall   | 10              |          |
| RWHOLD                         | Read/Write Hold Time from $\overline{DS}$ Rise  | 0               |          |
| RDSET                          | Data Read Setup Time to $\overline{DS}$ Rise    | 15              |          |
| RDHOLD                         | Data Read Hold Time from $\overline{DS}$ Rise   | 0               |          |
| WRVALID                        | Data Write Valid Time from $\overline{DS}$ Fall |                 | 5        |
| WRHOLD                         | Data Write Hold Time from $\overline{DS}$ Rise  | 2               |          |
| <b>Reset</b>                   |                                                 |                 |          |
| RRISE                          | Reset Rise Time                                 |                 | 20 TCY   |
| RWIDTH                         | Reset Low Pulse Width                           | 2 TCY           |          |
| <b>Interrupt</b>               |                                                 |                 |          |
| IWIDTH                         | Interrupt Pulse Width                           | 1TCY            |          |
| <b>Halt</b>                    |                                                 |                 |          |
| HWIDTH                         | Halt Low Pulse Width                            | 3 TCY           |          |
| <b>Wait State</b>              |                                                 |                 |          |
| WLAT                           | Wait Latency Time from $\overline{DS}$ Fall     |                 | 7        |
| WDEA                           | Wait Deassert Setup Time to CLKOUT Rise         | TBD             |          |
| <b>SPI</b>                     |                                                 |                 |          |
| SDI-SCLK                       | Serial Data In to Serial Clock Setup Time       | 10              |          |
| SCLK-SDO                       | Serial Clock to Serial Data Out Valid           | 15              |          |
| SS-SCLK                        | Slave Select to Serial Clock Setup Time         | 1/2 SCLK Period |          |
| SS-SDO                         | Slave Select to Serial Data Out Valid           | 15              |          |
| SCLK-SDI                       | Serial Clock to Serial Data In Hold Time        | 10              |          |

## 8-BIT ANALOG/DIGITAL CONVERTER

**Table 9.  $AV_{CC}-AGND = 5V \pm 10\%$   
 $T_A = 0^\circ C$  to  $+70^\circ C$  for "S" temperature range, unless otherwise noted**

| Parameter                                   | Min        | Typ | Max           | Units      |
|---------------------------------------------|------------|-----|---------------|------------|
| Integral Nonlinearity (INL)                 |            | 0.5 | 1             | LSB        |
| Differential Nonlinearity (DNL)             |            | 0.5 | 1             | LSB        |
| Zero Offset Error                           |            | 2   | 3             | LSB        |
| Full Scale Offset Error                     |            | 2   | 3             | LSB        |
| Valid Input Signal Range                    | VALO       |     | VAHI          | V          |
| Input Capacitance                           |            | 33  | 40            | pF         |
| Conversion Time                             | 2          | 3   |               | $\mu s$    |
| Input Impedance                             |            |     |               |            |
| 500kSPS                                     |            | 10  |               | k $\Omega$ |
| 100kSPS                                     |            | 48  |               | k $\Omega$ |
| 44kSPS                                      |            | 110 |               | k $\Omega$ |
| VAHI                                        | VALO + 2.5 |     | $AV_{CC}$     | V          |
| VALO                                        | AGND       |     | $AV_{CC}-2.5$ | V          |
| VAHI-VALO                                   | 2.5        |     | $AV_{CC}$     | V          |
| Reference Ladder Resistance<br>VAHI to VALO |            | 5   |               | k $\Omega$ |
| Power Dissipation                           |            | 50  | 85            | mW         |

**Table 10.  $AV_{CC}-AGND = 5V \pm 10\%$   
 $T_A = -40^\circ C$  to  $+85^\circ C$  for "E" temperature range, unless otherwise noted**

| Parameter                                   | Min        | Typ | Max           | Units      |
|---------------------------------------------|------------|-----|---------------|------------|
| Integral Nonlinearity (INL)                 |            |     | 1             | LSB        |
| Differential Nonlinearity (DNL)             |            |     | 1             | LSB        |
| Zero Offset Error                           |            | 3   | 4             | LSB        |
| Full Scale Offset Error                     |            | 3   | 4             | LSB        |
| Valid Input Signal Range                    | VALO       |     | VAHI          | V          |
| Input Capacitance                           |            | 33  | 40            | pF         |
| Conversion Time                             | 2          | 3   |               | $\mu s$    |
| Input Impedance                             |            |     |               |            |
| 500kSPS                                     |            | 10  |               | k $\Omega$ |
| 100kSPS                                     |            | 48  |               | k $\Omega$ |
| 44kSPS                                      |            | 110 |               | k $\Omega$ |
| VAHI                                        | VALO + 2.5 |     | $AV_{CC}$     | V          |
| VALO                                        | AGND       |     | $AV_{CC}-2.5$ | V          |
| VAHI-VALO                                   | 2.5        |     | $AV_{CC}$     | V          |
| Reference Ladder Resistance<br>VAHI to VALO |            | 5   |               | k $\Omega$ |
| Power Dissipation                           |            |     | 85            | mW         |

## TIMING DIAGRAMS

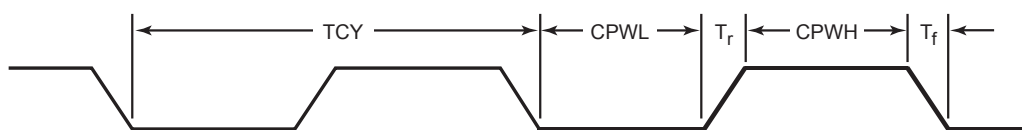


Figure 10. Clock Timing

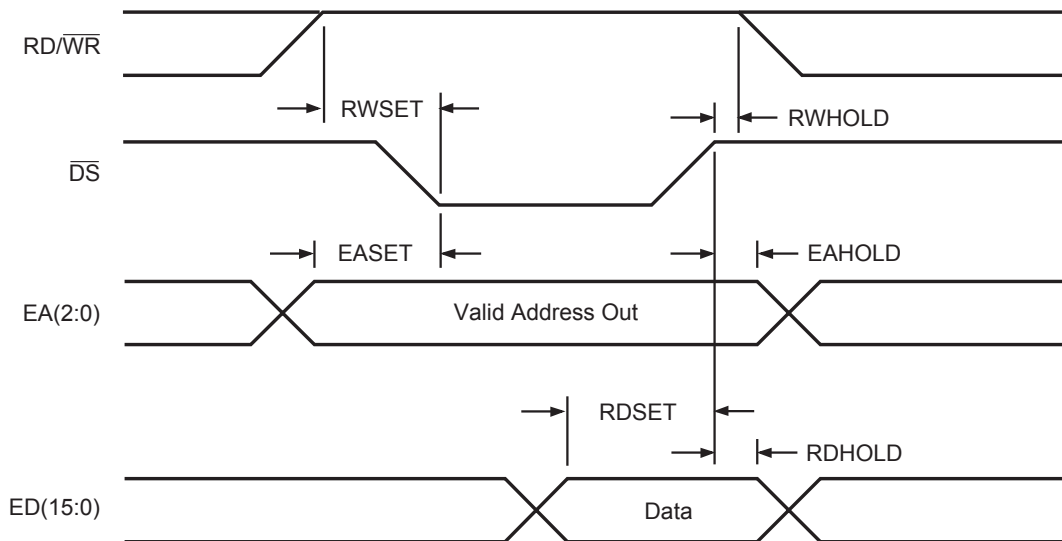
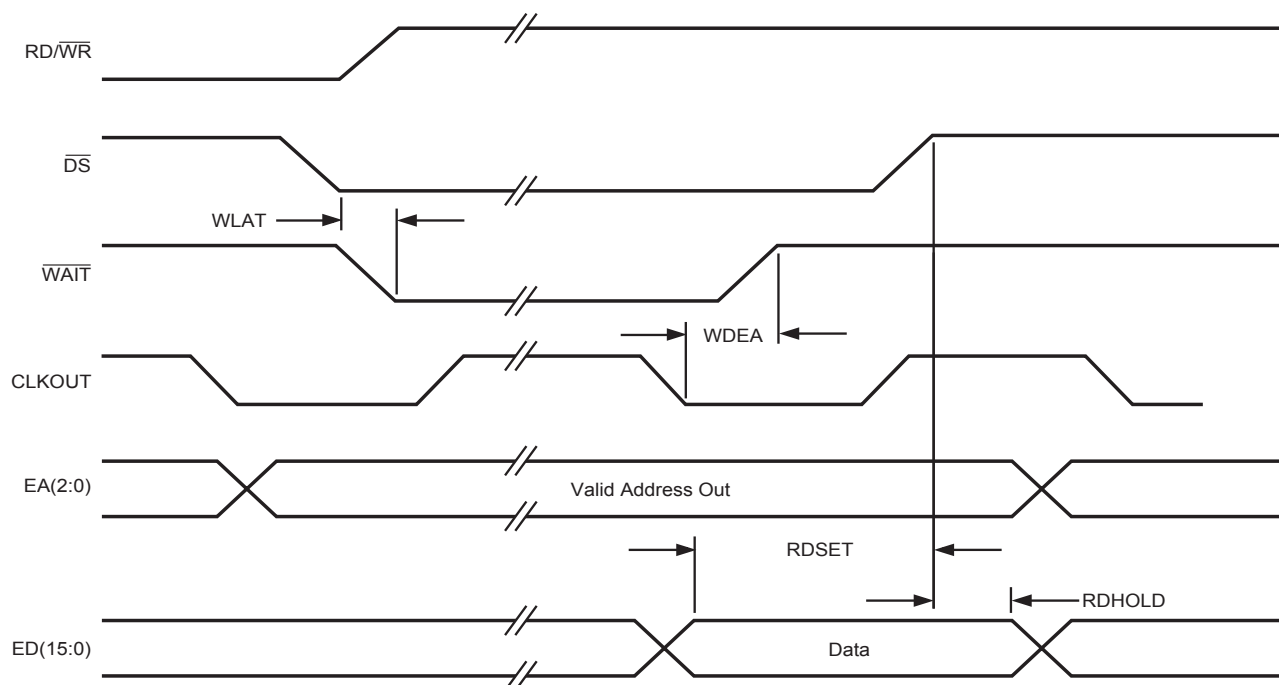


Figure 11. Read Timing

Figure 12. Read Timing Using  $\overline{WAIT}$  Pin

TIMING DIAGRAMS (Continued)

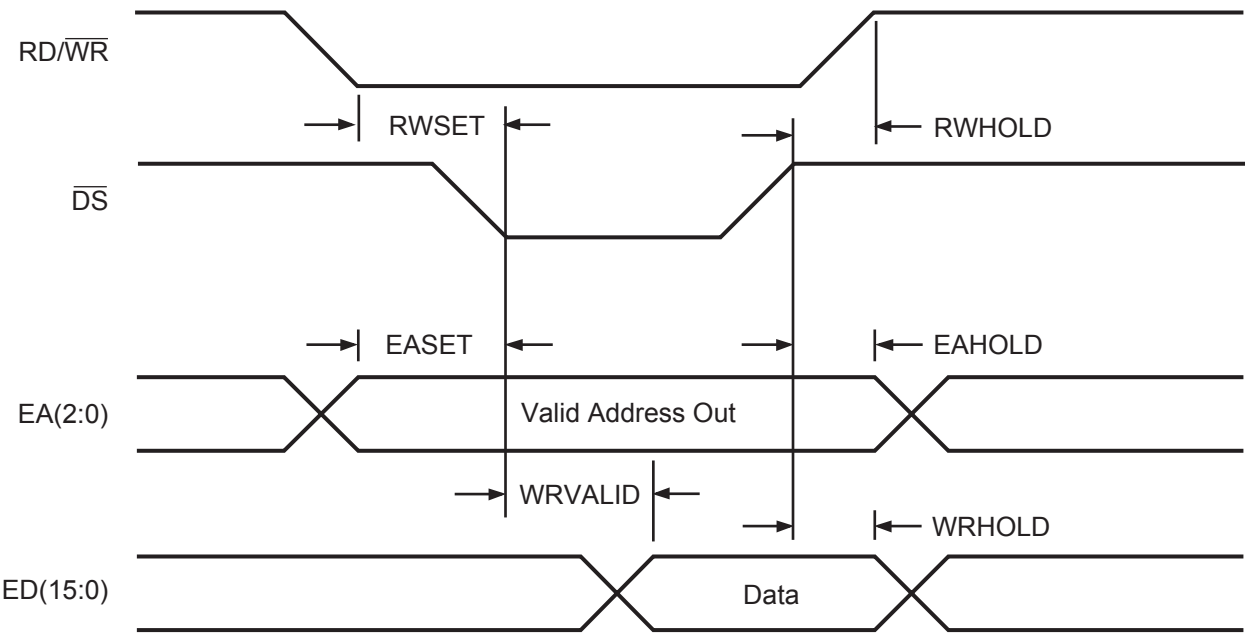


Figure 13. Write Timing

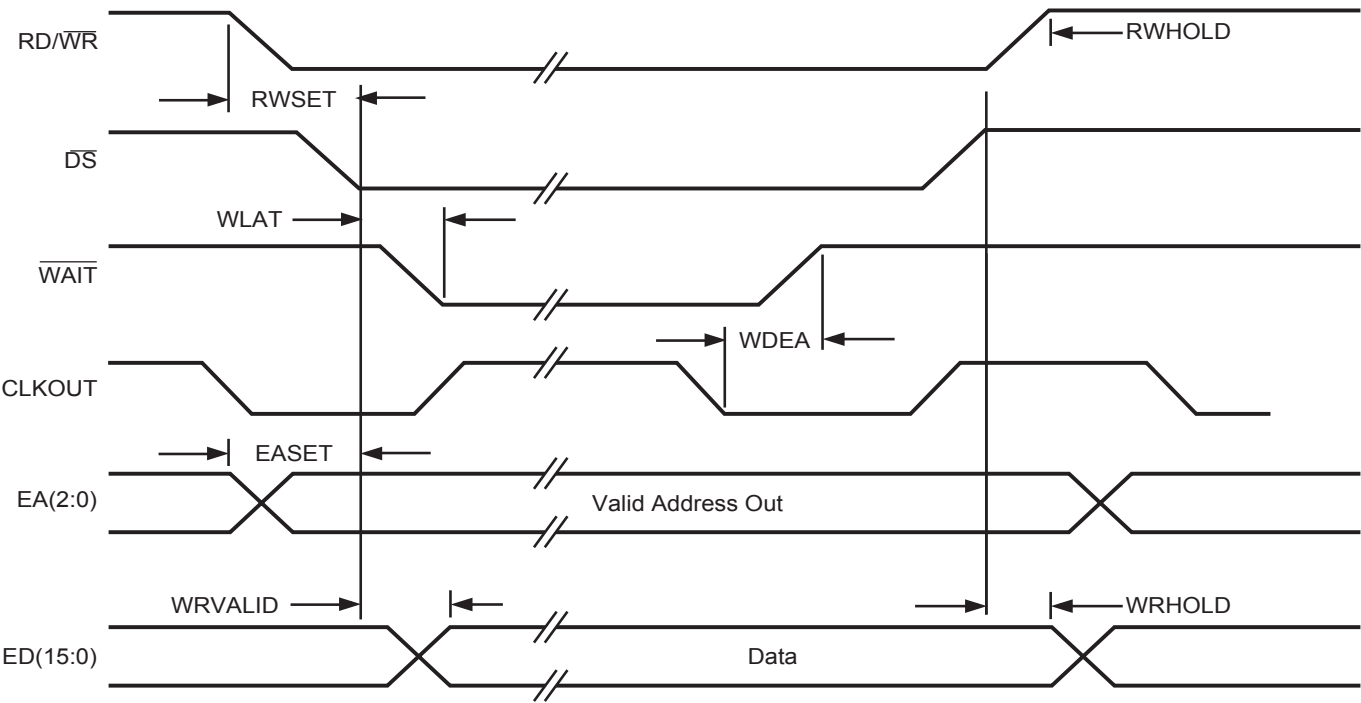
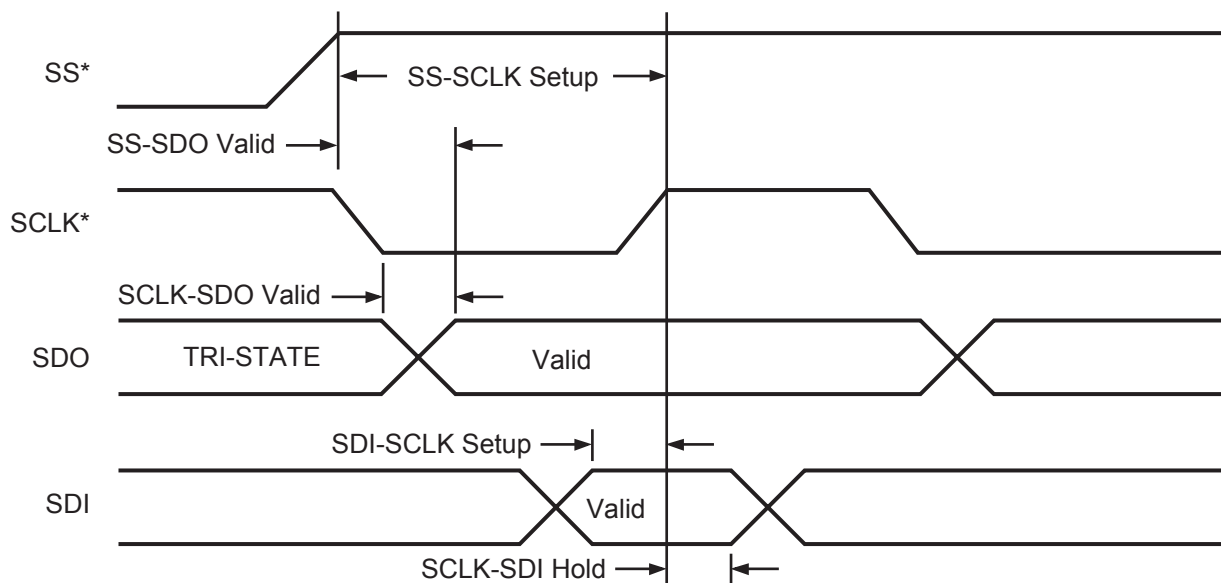


Figure 14. Write Timing Using WAIT Pin



\*Notes: The polarity of SCLK and SS are programmable by the user. SS is used in Slave Mode only. This figure illustrates data transmission on the falling edge of SCLK, data reception on the rising edge of SCLK, with SS active Low (default).

**Figure 15. SPI Timing (Master and Slave Modes)**

## FUNCTIONAL DESCRIPTION

**Instruction Timing.** Most instructions are executed in one machine cycle. A multiplication or multiply/accumulate instruction requires a single cycle. Long immediate instructions, and Jump or Call instructions, are executed in two machine cycles. Specific instruction cycle times are described in the Instruction Description section.

**Multiply/Accumulate.** The multiplier can perform a 16-bit x 16-bit multiply, or multiply/accumulate, in one machine cycle using the Accumulator and/or both the X and Y inputs. The multiplier produces a 32-bit result, however, only the 24 most significant bits are saved for the next instruction or accumulation. For operations on very small numbers where the least significant bits are important, the data should first be scaled to avoid truncation errors.

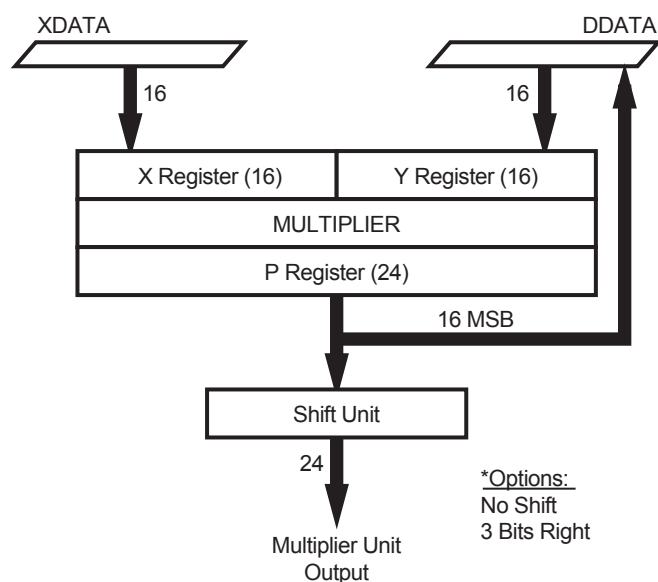


Figure 16. Multiplier Block Diagram

All inputs to the multiplier should be fractional two's-complement, 16-bit binary numbers, which places them in the range  $[-1$  to  $0.9999695]$ . The result is in 24 bits, so the range is  $[-1$  to  $0.9999999]$ .

If 8000H is loaded into both the X and Y registers, the multiplication produces an incorrect result. Positive one cannot be represented in fractional notation, and the multiplier actually yields the result  $8000H \times 8000H = 8000H$  ( $-1 \times -1 = -1$ ). The user should avoid this case to prevent erroneous results.

A shifter between the P Register and the Multiplier Unit Output can shift the data by three bits right or no shift.

**Data Bus Bank Switch.** There is a switch that connects the X Bus to the DDATA Bus that allows both the X and Y registers to be loaded with the same operand for a one cycle squaring operation. The switch is also used to read the X register.

**ALU.** The ALU features two input ports. One is connected to the output of the 24-bit Accumulator. The other input selects either the Multiplier Unit Output or the 16-bit DDATA bus (left-justified with zeros in the eight LSBs). The ALU performs arithmetic, logic, and shift operations.

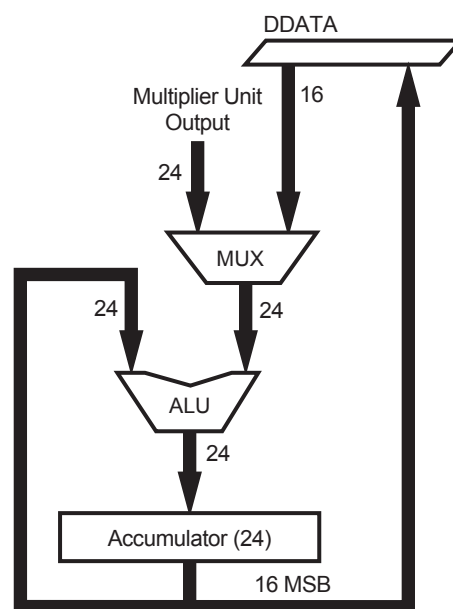


Figure 17. ALU Block Diagram

**Hardware Stack.** A six-level hardware stack is connected to the DDATA bus to hold subroutine return addresses or data. The CALL instruction pushes PC+2 onto the stack, and the RET instruction pops the contents of the stack to the PC.

**User Inputs and Outputs.** The Z893x3 features three User Inputs, UI0, UI1, and UI2. Pins UI0 and UI1 are connected directly to status register bits S10 and S11, and can be read, or used as a condition code in any conditional instruction. Pins UI0, UI1 and UI2 may also be used to clock the Counter/Timers. There are two user output bits, UO0 and UO1, which share pins with the timer outputs TMO0 and TMO1 on Port2. When the User Outputs are enabled, they are the complements of bits S5 and S6 of the Status Register.



**Interrupts.** The Z893x3 features three user interrupt inputs which can be programmed to be positive or negative edge-triggered. There are five interrupts generated by internal peripherals: the A/D converter, the Serial Peripheral Interface, and the three Counter/Timers. Internally there are three priority levels. The internal signals for Interrupt service Requests are denoted ISR0, ISR1, and ISR2, with ISR0 having the highest priority, and ISR2 the lowest. The user can program which interrupt sources are enabled, and which sources are serviced by the highest, middle, and lowest priority service routines. An interrupt is serviced at the end of an instruction execution. Two machine cycles are required to enter an interrupt instruction sequence. The PC is pushed onto the stack. The Interrupt Controller fetches the address of the interrupt service routine from the following locations in program memory:

| Device             | ISR0  | ISR1  | ISR2  |
|--------------------|-------|-------|-------|
| Z89223/273/323/373 | 1FFFH | 1FFEh | 1FFDH |

At the end of the interrupt service routine, a RET instruction is used to pop the stack into the PC.

The Set-Interrupt-Enable-Flag (SIEF) instruction enables the interrupts. Interrupts are automatically disabled when entering an interrupt service routine. Before exiting an interrupt service routine the SIEF instruction can be used to reenable interrupts.

**Registers.** In addition to the internal registers for processing, control, and configuration, the Z893x3 offers up to seven user-defined 16-bit external registers, EXT0–EXT6, depending on the Register Bank Select value. The external register address space is shared by the Z893x3 internal peripherals. Selecting banks 0–4 of the EXT Register Assignment allows access to/from three to seven of these addresses for general-purpose use.

**I/O Ports.** The Z893X3 DSP family features a user-configurable I/O structure. Most of the I/O pins include dual functions. The Counter/Timer, Serial Peripheral Interface, and External Interrupt Enables determine whether a pin is dedicated to peripheral or I/O port use.

**Port0.** A 16-bit user I/O port. Bits can be configured as input or output or globally as open-drain output. When enabled, Port0 consumes the 16 data lines used by the ED bus. Port0 function and ED bus use can be dynamically alternated by enabling and disabling Port0.

**Port1.** A multifunctional 8-bit port. Bits can be configured as input or output or globally as open-drain output. Port1 also supports INT2, CLKOUT, the Serial Peripheral Interface, and User Inputs 0 and 1.

**Port2.** A multifunctional 8-bit port. Bits can be configured as input or output or globally as open-drain output. Port2 also supports INT0 and INT1, all three Counter/Timer outputs, ED Bus,  $\overline{\text{WAIT}}$ , and UI2.

**Port3.** Port3 is an 8-bit user I/O port with 4 bits of input and 4 bits of output. It is available only on the 80-pin package.

**External Register Usage.** The external registers EXT0–EXT6 are accessed using the External Address Bus EA2–EA0, the External Data Bus (ED Bus) ED15–ED0, and control signals  $\overline{\text{DS}}$ ,  $\overline{\text{WAIT}}$ , and RD/ $\overline{\text{WR}}$ . These provide a convenient data transfer capability with external peripherals. Data transfers can be performed in a single-cycle. An internal wait state generator is provided to accommodate slower external peripherals. A single wait state can be implemented through control register Bank15/EXT3. For additional wait states, the  $\overline{\text{WAIT}}$  pin can be used. The  $\overline{\text{WAIT}}$  pin is monitored only during execution of a read or write instruction to external peripherals on the ED bus.

**Wait-State Generator.** An internal Wait-State generator is provided to accommodate slow external peripherals. A single Wait-State can be implemented through a control register. For additional states, a dedicated pin ( $\overline{\text{WAIT}}$ ) can be held Low. The  $\overline{\text{WAIT}}$  pin is monitored only during execution of a read or write instruction to external peripherals (ED bus).

**Analog to Digital Converter.** The A/D Converter is a 4-channel, 8-bit half-flash converter. Two external reference voltages provide a scalable input range. The A/D sample rate is determined by a prescaler connected to the system clock. An interrupt is optionally generated at the end of a conversion. The four input channels can be programmed to operate on demand, continuously, or upon an event (timer or interrupt).

**Counter/Timers (C/T0 and C/T1).** These C/Ts are 16-bit with 8-bit prescalers. They also offer the option of being used as PWM generators and include both hardware and software Watch-Dog capabilities. Both C/Ts are identical and can be externally or internally clocked. Either C/T can drive TMO0 or TMO1. Either C/T can drive any of the three interrupt service requests (ISR0, ISR1, or ISR2).

**Counter/Timer (C/T2).** This C/T is 16-bits, externally or internally clocked, and can drive TMO2 and/or any of the three interrupt service requests (ISR0, ISR1, or ISR2).

**Serial Peripheral Interface (SPI).** The Serial Peripheral Interface provides a convenient means of inter-processor and processor-peripheral communication. It offers the capability to transmit and receive simultaneously. The SPI is designed to operate in either master or slave mode.

MEMORY MAP

**Program Memory.** Programs of up to 8K words can be masked into internal ROM (Z89323) or programmed into OTP (Z89373). Four locations are dedicated to the vector addresses for the three interrupt service routines (1FFDH–1FFFH) and for the starting address following a RESET (1FFCH). Internal ROM is mapped from 0000H to 1FFFH, and the highest location for program instructions is 1FFBH.

**Internal Data RAM.** All Z893x3 family members feature internal 512 x 16-bit data RAM organized as two banks of 256 x 16-bit words each (RAM0 and RAM1). The three addressing modes available to access the data RAM are direct addressing, short form direct, and register indirect.

The contents of both data RAM banks can be read simultaneously and loaded into the X and Y inputs of the multiplier during a multiply instruction.

The addresses for each data RAM bank are:

- 0–255 (0000H–00FFH) for RAM0
- 256–511 (0100H–01FFH) for RAM1

**Data RAM Pointers.** In register indirect, each data RAM bank is addressed by one of three data RAM address pointers:

**Example:** Pn:b, where  
n = pointer number = 0, 1, or 2  
b = bank = 0 or 1,

thus,

- P0:0, P1:0, P2:0 for RAM0
- P0:1, P1:1, P2:1 for RAM1

In auto-increment, loop-increment, and loop-decrement indirect addressing, the pointer is automatically modified.

The data RAM pointers, which may be read or written directly, are 8-bit registers connected to the lower byte of the internal 16-bit DDATA Bus.

**Program Memory Pointers.** The first 16 locations of each data RAM bank can be used as pointers to locations in Program Memory. These pointers provide an efficient way to address coefficients. The programmer selects a pointer location using two bits in the status register and two bits in the operand. At any one time, there are eight usable pointers, four per bank, and the four pointers are in consecutive locations.

**Example:** Dn:b, where  
n = pointer number = 0, 1, 2, or 3  
b = bank = 0 or 1,

thus,

- D0:0, D1:0, D2:0, D3:0 for RAM0
- D0:1, D1:1, D2:1, D3:1 for RAM1

If S3/S4 = 01 in the status register, then D0:0/D1:0/D2:0/D3:0 refer to register locations 4/5/6/7 in data RAM Bank 0.

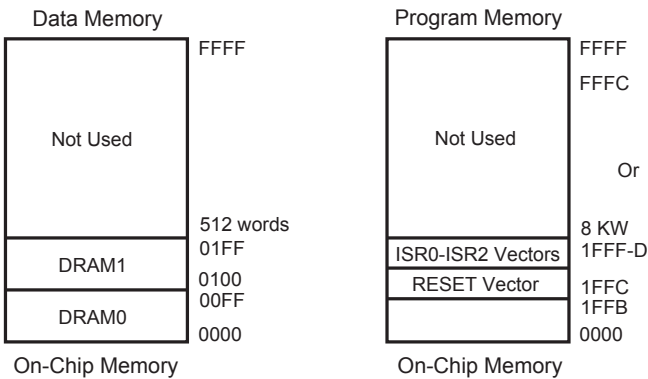


Figure 18. Memory Map

## REGISTERS

Both external and internal registers are accessed in one machine cycle. The external registers are used to access the on-chip peripherals when they are enabled.

The internal registers of the Z893X3 are defined below:

| Register | Register Definition                   |
|----------|---------------------------------------|
| X        | Multiplier X Input, 16-bits           |
| Y        | Multiplier Y Input, 16-bits           |
| P        | Multiplier Output, 24-bits            |
| A        | Accumulator, 24-bits                  |
| Pn:b     | Six Data RAM Pointers, 8-bits each    |
| PC       | Program Counter, 16-bits              |
| SR       | Status Register, 16-bits              |
| EXT0     | depends on Bank Select #, 16-bits     |
| EXT1     | depends on Bank Select #, 16-bits     |
| EXT2     | depends on Bank Select #, 16-bits     |
| EXT3     | depends on Bank Select #, 16-bits     |
| EXT4     | depends on Bank Select #, 16-bits     |
| EXT5     | depends on Bank Select #, 16-bits     |
| EXT6     | depends on Bank Select #, 16-bits     |
| EXT7     | Interrupt Status/Bank Select, 16-bits |

**X** and **Y** are two 16-bit input registers for the multiplier. These registers can be utilized as temporary registers when the multiplier is not being used.

**P** holds the result of multiplications and is read-only.

**A** is a 24-bit Accumulator. The output of the ALU is sent to this register. When 16-bit data is transferred into this register, it is placed into the 16 MSBs and the least significant eight bits are set to zero. Only the upper 16 bits are transferred to the destination register when the Accumulator is selected as a source register in transfer instructions.

**Pn:b** are the pointer registers for accessing data RAM where  $n = 0, 1, \text{ or } 2$ , and  $b = 0 \text{ or } 1$ . They can be directly read or written. They point to locations in data RAM.

**PC** is the Program Counter. Any instruction which may modify this register requires two clock cycles.

**SR** is the status register. It contains the ALU status and processor control bits. The status register can always be read in its entirety. S15–S10 are set/reset by hardware and can

only be read by software. S9–S0 control hardware operations and can be written by software.

**Table 11. Status Register Bit Functions**

| SR Bit                         | Function                                                    | Read/Write |
|--------------------------------|-------------------------------------------------------------|------------|
| S15 (N)                        | ALU Negative                                                | RO         |
| S14 (OV)                       | ALU Overflow                                                | RO         |
| S13 (Z)                        | ALU Zero                                                    | RO         |
| S12 (C)                        | Carry                                                       | RO         |
| S11 (UI1)                      | User Input 1                                                | RO         |
| S10 (UI0)                      | User Input 0                                                | RO         |
| S9 (SH3)                       | MPY Output<br>Arithmetically Shifted<br>Right by Three Bits | R/W        |
| S8 (OP)                        | Overflow Protection                                         | R/W        |
| S7 (IE)                        | Interrupt Enable                                            | R/W        |
| S6 ( $\overline{\text{UO1}}$ ) | User Output 1                                               | R/W        |
| S5 ( $\overline{\text{UO0}}$ ) | User Output 0                                               | R/W        |
| S4–S3                          | “Short Form Direct” bits                                    | R/W        |
| S2–S0 (RPL)                    | RAM Pointer Loop Size                                       | R/W        |

**Note:** RO = read only, RW = read/write. The status register can always be read in its entirety.

**S15–S12** are set/reset by the ALU after an operation.

**S11–S10** are set/reset by the user input pins.

If **S9** is set and a multiply/shift option is used, the shifter shifts the result three bits right. This feature allows the data to be scaled and prevents overflows.

If **S8** is set, the hardware clamps at maximum positive or negative values instead of overflowing.

**S7** enables interrupts.

**S6–S5** are User Outputs. The complement of the value in the Status Register appears on bits 2 and 3 of Port2 if the User Outputs are enabled by writing a 1 to Bit 15 of Bank 15–EXT3, and Counter/Timer 0 and 1 are disabled.

**S4–S3** are the two MSBs in the “short form direct” mode of addressing.

**S2–S0** define the RAM pointer loop size as indicated in Table 12.

REGISTERS (Continued)

Table 12. RPL Description

| S2 | S1 | S0 | Loop Size |
|----|----|----|-----------|
| 0  | 0  | 0  | 256       |
| 0  | 0  | 1  | 2         |
| 0  | 1  | 0  | 4         |
| 0  | 1  | 1  | 8         |
| 1  | 0  | 0  | 16        |
| 1  | 0  | 1  | 32        |
| 1  | 1  | 0  | 64        |
| 1  | 1  | 1  | 128       |

The following are not actually registers, but are read or written in the same way as hardware registers on the chip:

| Register | Register Definition       |
|----------|---------------------------|
| BUS      | D-Bus                     |
| Dn:b     | Eight Data Pointers       |
| EXTn     | External Register, 16-bit |

**BUS** is a read-only register which, when accessed, returns the contents of the D-Bus. BUS is used for emulation only.

**Dn:b** refers to locations in RAM that can be used as a pointer to locations in program memory which is efficient for co-efficient addressing. The programmer decides which location to choose from two bits in the status register and two bits in the operand. Thus, only the lower 16 possible locations in RAM can be specified. At any one time, there are eight usable pointers, four per bank, and the four pointers are in consecutive locations in RAM. For example, if S3/S4=01 in the status register, then D0:0/D1:0/D2:0/D3:0 refer to register locations 4/5/6/7 in RAM Bank 0. Note that when the data pointers are being written to, a number is actually being loaded to Data RAM, so they can be used as a limited method for writing to RAM.

**EXTn** are external registers (n = 0 to 6). These are seven 16-bit register addresses provided for mapping internal and external peripherals into the address space of the processor. Note that for external peripherals the actual register RAM does not exist on the chip, but would exist as part of the external device, such as an A/D result latch. The External Address Bus, EA2–EA0, the External Data Bus, ED15–ED0,  $\overline{DS}$ ,  $\overline{WAIT}$ , and  $RD/\overline{WR}$  are used to access external peripherals.

**EXT7** is used for Register Bank Select, and to program wait states for EXT0–EXT6, and is not available for accessing an external peripheral.

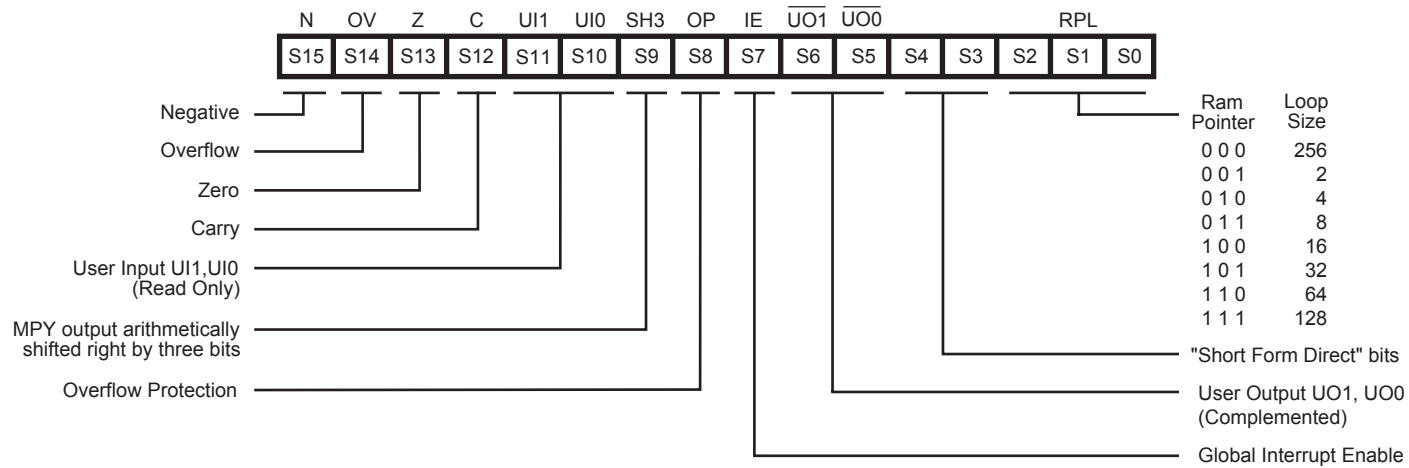


Figure 19. Status Register

## BANK/EXT REGISTER ASSIGNMENTS

There are 16 different Banks of EXT registers. Control of the bank switching is done via the EXT7 register. The same EXT7 register exists in all Banks.

Banks 0–5 support different combinations of external registers for external peripherals, and external registers for internal (on-chip) peripherals. Use the bank that offers the optimum combination of internal and external registers to

support the application. Use it as a preferred working bank to minimize bank switching.

Banks 6–12 only decode EXT6 and EXT7. Do not use EXT0–5 for Banks 6–12.

Banks 13–15 are control register banks. These banks are used in the initialization routines and whenever a configuration change is required. Refer to the sections on I/O Ports and Peripherals for details.

**Table 13. EXT Register Assignments Banks 0–4**

|      | <b>Bank0</b>                     | <b>Bank1</b>                     | <b>Bank2</b>                     | <b>Bank3</b>                     | <b>Bank4</b>                     |
|------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| EXT0 | User                             | User                             | User                             | User                             | User                             |
| EXT1 | User                             | User                             | User                             | User                             | User                             |
| EXT2 | User                             | User                             | User                             | User                             | User                             |
| EXT3 | SPI Data                         | User                             | User                             | SPI Data                         | User                             |
| EXT4 | Port0 Data                       | Port0 Data                       | User                             | User                             | User                             |
| EXT5 | Port2–Port1 Data                 | Port2–Port1 Data                 | Port3 Data                       | User                             | User                             |
| EXT6 | A/D_Ch0 Data                     | A/D_Ch1 Data                     | A/D_Ch2 Data                     | A/D_Ch3 Data                     | User                             |
| EXT7 | Interrupt status/<br>Bank Select | Interrupt status/<br>Bank Select | Interrupt status/<br>Bank Select | Interrupt status/<br>Bank Select | Interrupt status/<br>Bank Select |

**Table 14. EXT Register Assignments Banks 5–15**

|      | <b>Bank5</b>                     | <b>Bank6–12</b>                  | <b>Bank13</b>                    | <b>Bank14</b>                    | <b>Bank15</b>                    |
|------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|----------------------------------|
| EXT0 | A/D_Ch1 Data                     | not defined                      | A/D Control                      | C/T2 Load/Read                   | Port0 Control                    |
| EXT1 | A/D_Ch2 Data                     | not defined                      | C/T0 Control                     | C/T1 Control                     | Port1 Ctrl/Port0 Alloc           |
| EXT2 | A/D_Ch3 Data                     | not defined                      | C/T0 Load                        | C/T1 Load                        | Ports 2, 3, & C/T2 Control       |
| EXT3 | SPI Data                         | not defined                      | C/T0 Counter                     | C/T1 Counter                     | Wait State Control               |
| EXT4 | Port0 Data                       | not defined                      | C/T0 Prescaler Ld                | C/T1 Prescaler Ld                | SPI Control                      |
| EXT5 | Port2–Port1 Data                 | not defined                      | C/T0 Prescaler                   | C/T1 Prescaler                   | System Clock Control             |
| EXT6 | A/D_Ch0 Data                     | A/D_Ch0 Data                     | A/D_Ch0 Data                     | Interrupt Polarity               | Interrupt Allocation             |
| EXT7 | Interrupt status/<br>Bank Select | Interrupt status/<br>Bank Select | Interrupt status/<br>Bank Select | Interrupt status/<br>Bank Select | Interrupt status/<br>Bank Select |

BANK/EXT REGISTER ASSIGNMENTS (Continued)

Interrupt Status/Bank Select Register—EXT7

Following is a description of EXT7. It contains both a Bank Select Field and Interrupt Status Bits.

**Bank Select Field.** The four LSBs of EXT7 denote which bank is selected as the current working bank.

**Interrupt Status Bits.** These bits can be read to identify which interrupts are pending. A “1” denotes interrupt pending, and a “0” denotes no interrupt. This ability to identify interrupts is particularly useful in polled interrupt operation or when servicing ISR2, which may come from several sources.

**Note:** Write “1” to a particular status bit to clear that bit. Before exiting an interrupt service routine, the relevant interrupt bit(s) should be cleared. To clear a bit efficiently:

- Load the value of EXT7 into a register or memory location
- Then load that value back into EXT7

Performing these steps clear all of the interrupts that were pending, but leave the Register Bank Select unchanged.

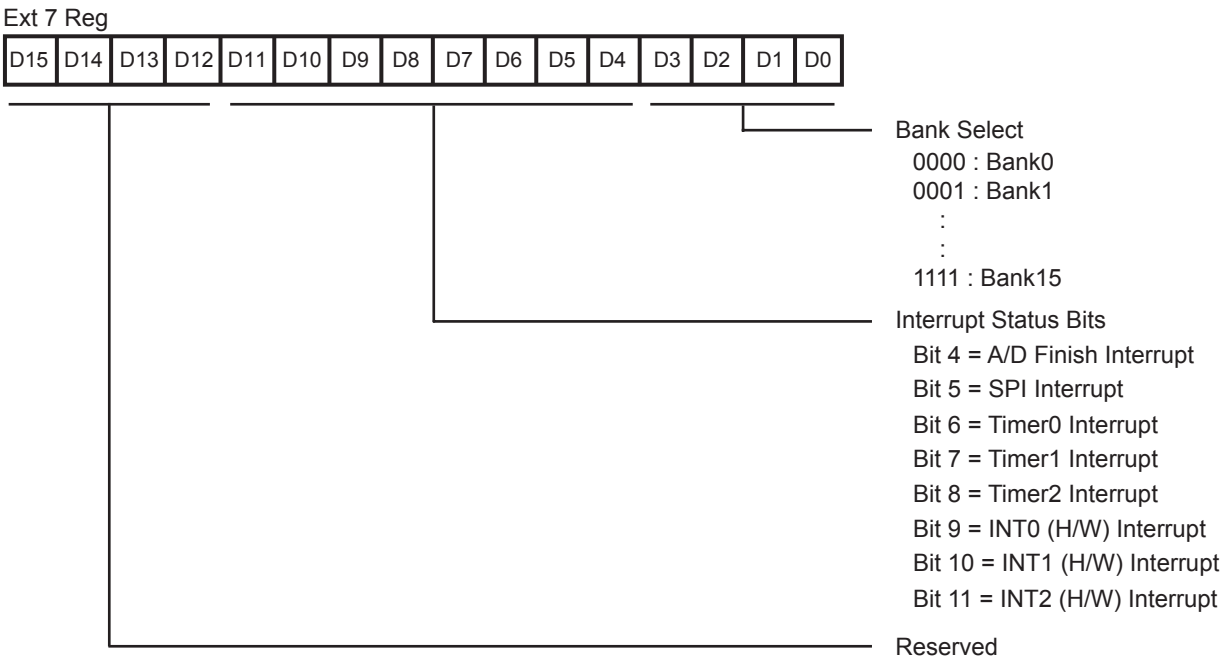


Figure 20. EXT7 Register

Interrupt Allocation Register—Bank15/EXT6

Bits 3–0 of the Interrupt Allocation Register define which unique interrupt source the highest priority, and is allocated to ISR0 (Interrupt Service Request 0).

Bits 7–4 of the Interrupt Allocation Register define which unique interrupt source has the second highest priority, and is allocated to ISR1 (Interrupt Service Request 1).

Bits 15–8 of the Interrupt Allocation Register are enable bits for common interrupt sources which have the lowest priority, and are all allocated to ISR2 (Interrupt Service Request 2). All the enabled interrupts which are not allocated to ISR0 or ISR1, are allocated to ISR2. When an ISR2 interrupt occurs, the interrupt service routine must read the Interrupt Status Register in EXT7 to determine the source. The Interrupt Status Register can be used for polling interrupts. An Interrupt that is not selected as a source to ISR0, ISR1, or ISR2, is disabled.

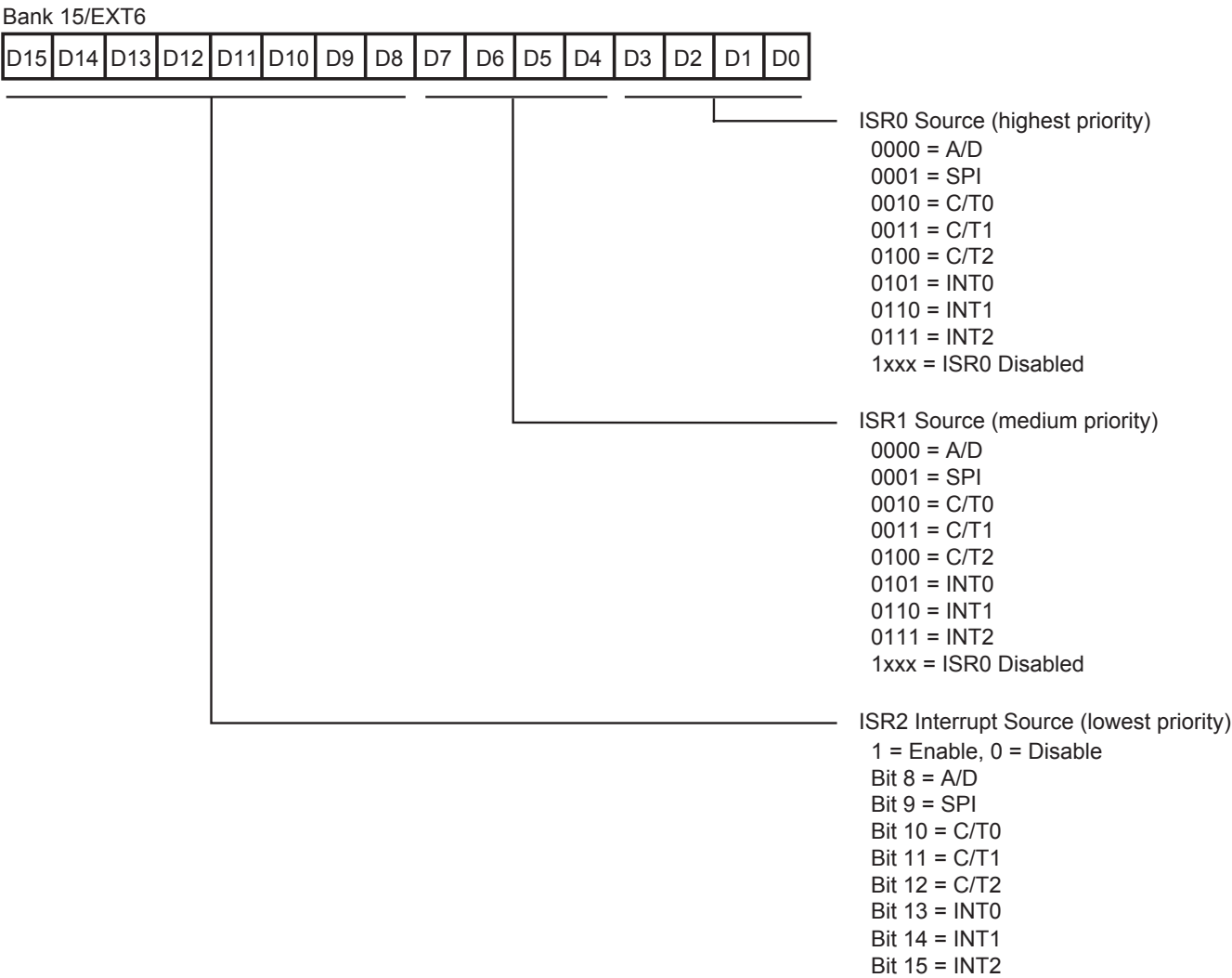


Figure 21. Interrupt Allocation Register



BANK/EXT REGISTER ASSIGNMENTS (Continued)

Interrupt Polarity Register—Bank14/EXT6

The trigger polarities, rising-edge or falling-edge, of all the external interrupts are programmable.

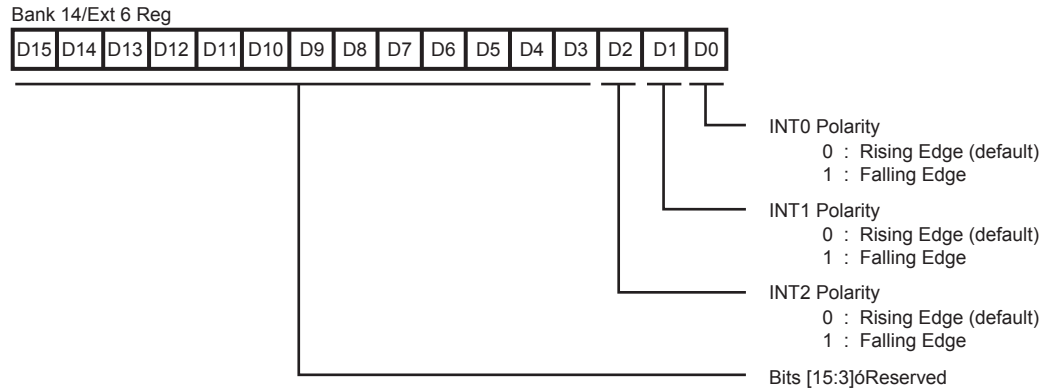


Figure 22. Interrupt Polarity Register

Wait-State Control Register—Bank15/EXT3

The Wait-State Control Register enables the insertion of wait states when the DSP accesses slow peripherals. This register enables the insertion of one wait state on the ED bus, providing 100 ns of access time instead of 50 ns when operating at 20 MHz. When more than one wait state is nec-

essary, input pin P2.4/  $\overline{\text{WAIT}}$  can be used to provide additional wait states. The Wait-State Register enables the user to specify which EXT registers, EXT0–EXT6, and which operation, read and/or write, require a wait state. EXT7 is an internal register, and requires no wait state.

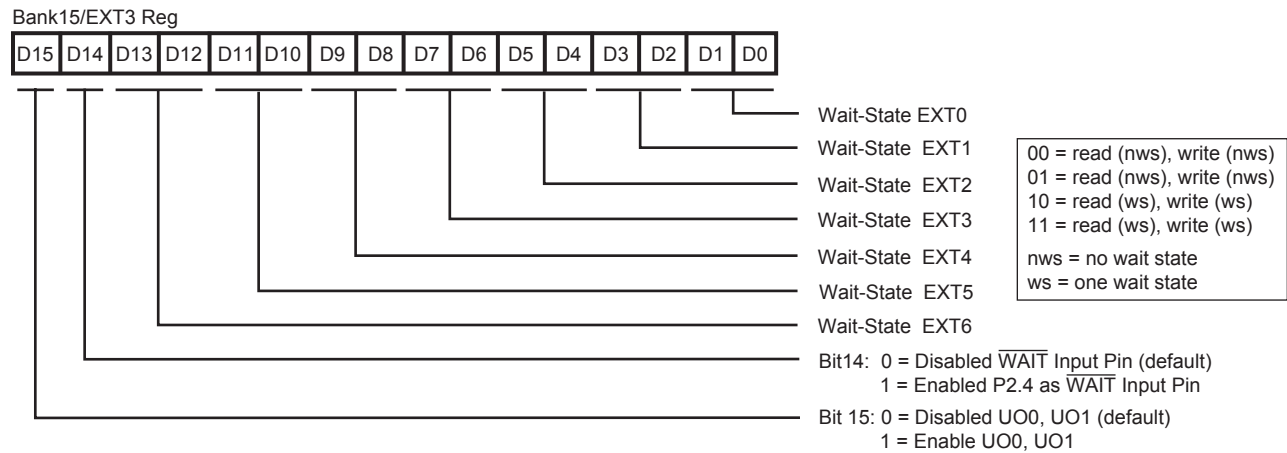


Figure 23. Wait-State Control Register



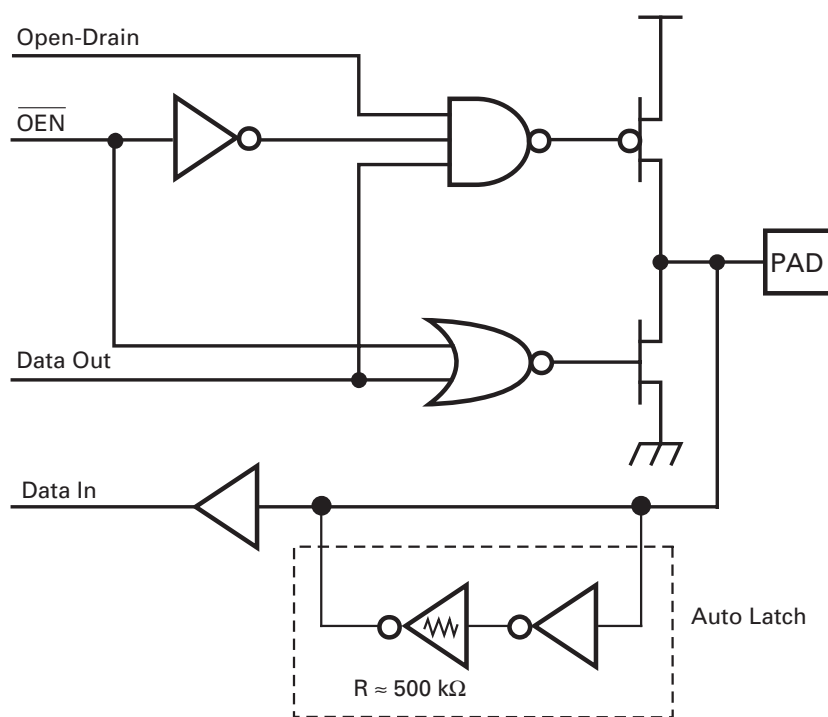
## I/O PORTS

I/O pin allocation of ports for the different package types is designed to provide configuration flexibility. Each port line of Ports 0, 1, and 2 can be independently selected as

an input or an output. Each port's output lines can be globally selected as push-pull or as open-drain outputs

**Table 15. I/O Port Bit Allocations**

| Device Pins | 44-Pin PLCC,<br>44-Pin PQFP                 | 64-Pin TQFP,<br>68-Pin PLCC | 80-Pin PQFP                |
|-------------|---------------------------------------------|-----------------------------|----------------------------|
| P0 MSB      | ED15–ED8, or<br>P0.15–P0.8, or<br>P1.7–P1.0 | ED15–ED8, or<br>P0.15–P0.8  | ED15–ED8, or<br>P0.15–P0.8 |
| P0 LSB      | ED7–ED0, or<br>P0.7–P0.0                    | ED7–ED0, or<br>P0.7–P0.0    | ED7–ED0, or<br>P0.7–P0.0   |
| P1          |                                             | P1.7–P1.0                   | P1.7–P1.0                  |
| P2          | P2.4–P2.0                                   | P2.7–P2.0                   | P2.7–P2.0                  |
| P3          |                                             |                             | P3.7–P3.0                  |



**Figure 24. Port 0, 1 and 2 Configuration**

I/O PORTS (Continued)

Port0—16-Bit Programmable I/O

Bank15/EXT0 is the Port0 direction control register.  
Bank15/EXT1 includes specific bits to enable and config-  
ure Port0. The Port0 data register is Ext4 in Banks 0, 1, or 5.

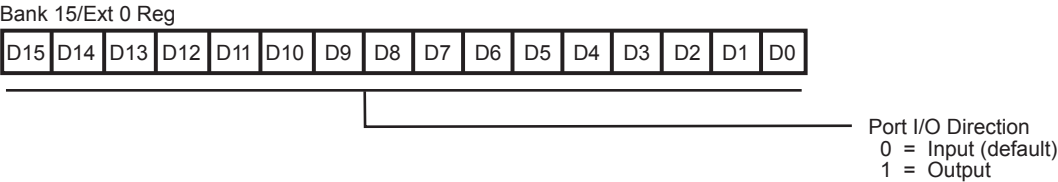


Figure 25. Port 0 Control Register

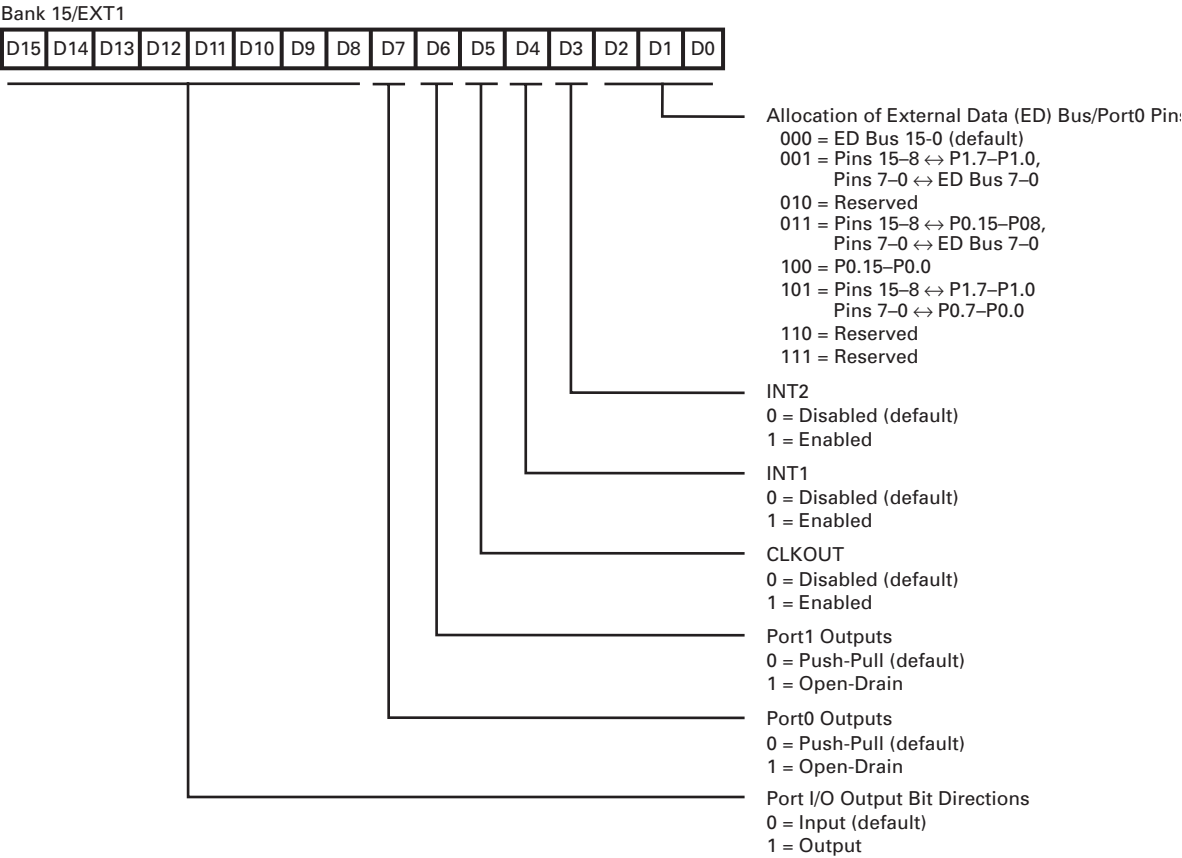


Figure 26. Bank15/EXT1 Register

**Port1—8-Bit Programmable I/O**

Bank15/EXT1 is the Port1 control register. The MSB is the Port1 direction control. Port1 data is accessed as the LSB of EXT5 in Banks 0, 1, or 5. The Port1 pins can also be mapped to internal functions. When INT2, CLKOUT, UI0

and UI1, or the SPI are enabled, they use Port1 pins. The 44-pin packages do not feature Port1 pins, however, Port1 and its internal functions can be mapped to the MSB of the ED Bus/Port0 pins. See bits 2–0 of Bank15/EXT1.

**Table 16. Port1 Bit Function Allocation**

| Port Pin    | IF                                                             | Condition     | Then   | Else |
|-------------|----------------------------------------------------------------|---------------|--------|------|
| P1.0/INT2   | Bank15/EXT1 Bit 3 = 1                                          | Enable INT2   | INT2   | P1.0 |
| P1.1/CLKOUT | Bank15/EXT1 Bit 5 = 1                                          | Enable CLKOUT | CLKOUT | P1.1 |
| P1.2/SDI    | Bank15/EXT4 Bit 0 = 1                                          | Enable SPI    | SDI    | P1.2 |
| P1.3/SDO    | Bank15/EXT4 Bit 0 = 1                                          | Enable SPI    | SDO    | P1.3 |
| P1.4/SS     | Bank15/EXT4 Bit 0 = 1                                          | Enable SPI    | SS     | P1.4 |
| P1.5/SCLK   | Bank15/EXT4 Bit 0 = 1                                          | Enable SPI    | SCLK   | P1.5 |
| P1.6/UI0    | Bank13/EXT1 Bits [2,1] = 10, or<br>Bank14/EXT1 Bits [2,1] = 10 | Enable UI0    | UI0    | P1.6 |
| P1.7/UI1    | Bank13/EXT1 Bits [2,1] = 11, or<br>Bank14/EXT1 Bits [2,1] = 11 | Enable UI1    | UI1    | P1.7 |

## I/O PORTS (Continued)

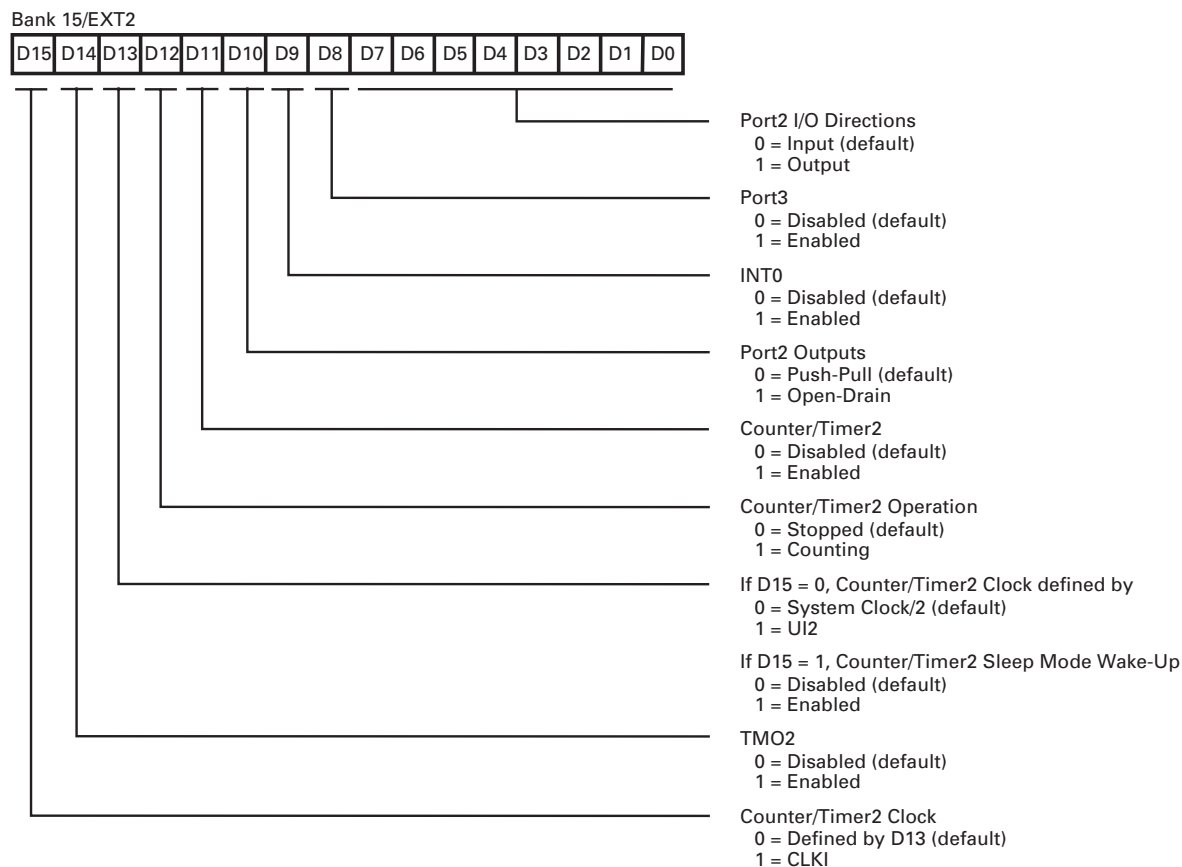
### Port2—8-Bit Programmable I/O

Bank15/EXT2 is the Port2 control register. The LSB is the Port2 direction control. Port2 data is accessed as the MSB of EXT5 in Banks 0,1,or 5. The Port2 pins can also be

mapped to internal functions. When INT0, INT1, TMO0, TMO1,  $\overline{\text{WAIT}}$ , UI2, or TMO2 are enabled, they use Port2 pins. The 44-pin packages do not feature Port2 pins P2.7–P2.5.

**Table 17. Port2 Bit Function Allocation**

| Port Pin                       | IF                                                           | Condition                       | Then                     | Else |
|--------------------------------|--------------------------------------------------------------|---------------------------------|--------------------------|------|
| P2.0/INT0                      | Bank15/EXT2 Bit 9 = 1                                        | Enable INT0                     | INT0                     | P2.0 |
| P2.1/INT1                      | Bank15/EXT1 Bit 4 = 1                                        | Enable INT1                     | INT1                     | P2.1 |
| P2.2/TMO0                      | Bank13/EXT1 Bit [6,5] = 10, or<br>Bank14/EXT1 Bit [6,5] = 10 | Enable TMO0                     | TMO0                     | P2.2 |
| P2.3/TMO1                      | Bank13/EXT1 Bit [6,5] = 11, or<br>Bank14/EXT1 Bit [6,5] = 11 | Enable TMO1                     | TMO1                     | P2.3 |
| P2.4/ $\overline{\text{WAIT}}$ | Bank15/EXT3 Bit 14 = 1                                       | Enable $\overline{\text{WAIT}}$ | $\overline{\text{WAIT}}$ | P2.4 |
| P2.5/UI2                       | Bank15/EXT2 Bit 13 = 1                                       | C/T2 clock is UI2               | UI2                      | P2.5 |
| P2.6/TMO2                      | Bank15/EXT2 Bits 14 = 1                                      | Enable TMO2                     | TMO2                     | P2.6 |
| P2.7                           |                                                              |                                 | P2.7                     | P2.7 |



**Figure 27. Bank15/EXT2 Register**

**Port3—8-Bit Programmable I/O**

Port3 is an additional I/O port available only in the 80-pin package. P3.3–P3.0 are inputs and P3.7–P3.4 are outputs. Bit 8 of Bank15/EXT2 enables and disables Port3. The LSB of Bank2/EXT5 is the Port3 Data Register.

## PERIPHERALS

### Analog to Digital Converter (A/D)

The A/D is a 4-channel 8-bit half-flash converter. It uses two reference resistor ladders, one for the upper 5 bits, and another for the lower 3 bits. Two external reference voltage input pins, VAHI and VALO, set the input voltage measurement conversion range. The converter is auto-zeroed prior to each sampling period. Bank13/EXT0 is the A/D control register.

The conversion time depends on the system clock frequency and the selection of the A/D prescaler value, bits DIV2–DIV0. The clock prescaler can be programmed to derive a 2  $\mu$ s conversion time. For example, when deriving the A/D clock from a 20-MHz system clock, the A/D prescaler value should be set to divide by 40.

Bits ADST1–ADST0 determine one of the following start conversion options:

- Writing to the ADCTL control register
- ISR1
- C/T2 time-out
- C/T0 time-out

The start conversion operation may begin at any time. If a conversion is in progress, and a new start conversion signal is received, the conversion in progress will abort, and a new conversion will initiate.

Bits QUAD and SCAN determine one of the following Modes of operation:

- One channel is converted four times, with the results sequentially written to result registers 0, 1, 2 and 3.
- One channel is converted one time, with the respective result register updated.
- Four channels are converted one time each, with the respective four result registers updated.
- Four channels are converted repeatedly, with the respective four result registers constantly updated.

When one of the two four-channel modes is selected, the channel specified by CSEL1–CSEL0 will convert first. The other three channels will convert in sequence. In the sequence, AN0 follows AN3.

Bit ADIE enables the A/D to generate interrupts at the end of a conversion. Bit ADIT determines whether an interrupt occurs after the first or fourth conversion.

To reduce power consumption the A/D can be disabled by clearing the ADE bit.

Though the A/D will function with smaller input signals and reference voltages, the noise and offsets remain constant. The relative error of the converter will increase and the conversion time will also take longer.

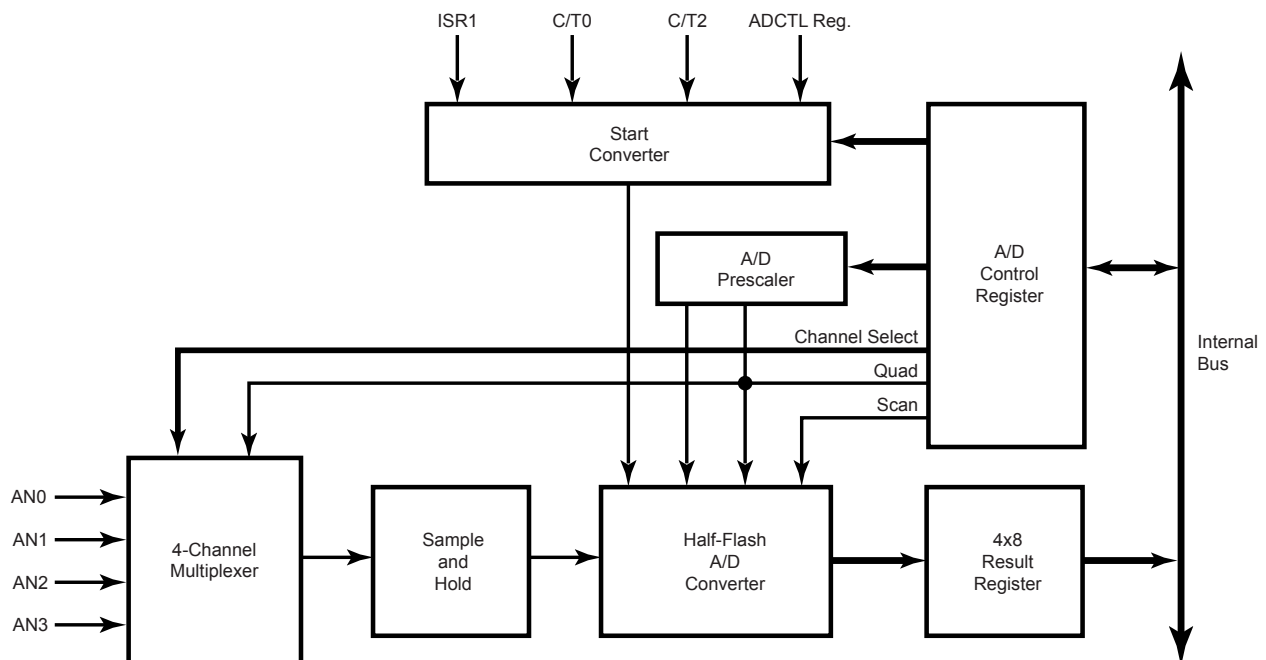


Figure 28. ADC Architecture

Bank13/EXT0 (LSB)

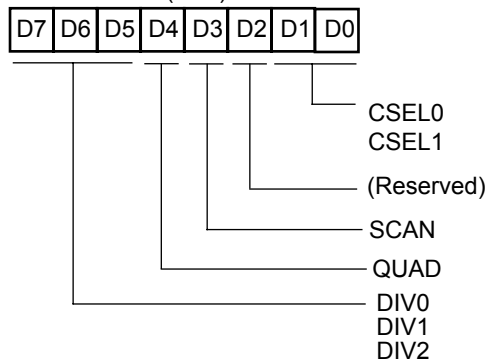


Figure 29. ADCTL Register (LSB)

Bank13/EXT0 (MSB)

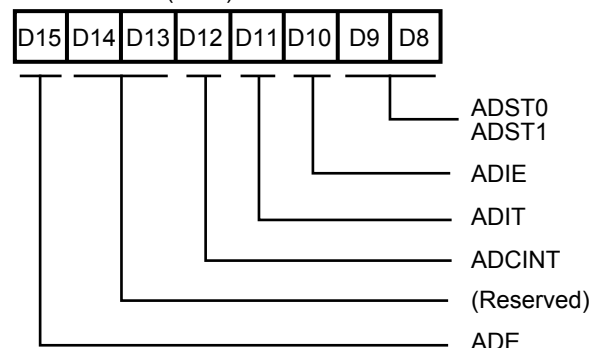


Figure 30. ADCTL Register (MSB)

Table 18. A/D Prescaler Values (Bits 7, 6, 5)

| DIV2 | DIV1 | DIV0 | A/D Prescaler<br>(Crystal divided by) |
|------|------|------|---------------------------------------|
| 0    | 0    | 0    | 8                                     |
| 0    | 0    | 1    | 16                                    |
| 0    | 1    | 0    | 24                                    |
| 0    | 1    | 1    | 32                                    |
| 1    | 0    | 0    | 40                                    |
| 1    | 0    | 1    | 48                                    |
| 1    | 1    | 0    | 56                                    |
| 1    | 1    | 1    | 64                                    |

Table 19. Operating Modes (Bits 4, 3)

| QUAD | SCAN | Option                                      |
|------|------|---------------------------------------------|
| 0    | 0    | Convert selected channel 4 times, then stop |
| 0    | 1    | Convert selected channel, then stop.        |
| 1    | 0    | Convert 4 channels, then stop.              |
| 1    | 1    | Convert 4 channels continuously.            |

Table 20. Channel Select (Bits 1, 0)

| CSEL1 | CSEL0 | Channel |
|-------|-------|---------|
| 0     | 0     | AN0     |
| 0     | 1     | AN1     |
| 1     | 0     | AN2     |
| 1     | 1     | AN3     |

**ADE (Bit 15).** A “0” disables any A/D conversions or accessing any A/D registers, except writing to the ADE bit. A “1” enables all A/D accesses.

**Reserved (Bits 14, 13).** Reserved for future use.

**ADCINT (Bit 12).** The A/D interrupt bit is read-only. The ADCINT will reset every time this register is written.

**ADIT (Bit 11).** Selects when to set the A/D interrupt if interrupts are enabled (ADIE=1). A value of “0” sets the interrupt after the first A/D conversion is complete. A value of “1” sets the interrupt after the fourth A/D conversion is complete.

**ADIE (Bit 10).** A/D Interrupt Enable. A value of “0” disables the A/D Interrupt. A value of “1” enables the A/D Interrupt.

Table 21. START (Bits 9, 8)

| ADST1 | ADST0 | Option                                                      |
|-------|-------|-------------------------------------------------------------|
| 0     | 0     | Conversion starts when this register is written.            |
| 0     | 1     | Conversion starts on INT1 per Interrupt Allocation Register |
| 1     | 0     | Conversion starts on C/T2 time-out.                         |
| 1     | 1     | Conversion starts on C/T0 time-out.                         |

There are four A/D result registers. See the EXT Register Assignments for their location in the different banks.

## PERIPHERALS (Continued)

### Counter/Timers (C/T0 and C/T1)

The Z893x3 features two 16-bit Counter/Timers (C/T) that can be independently configured to operate in various modes. Each is implemented as a 16-bit Load Register and a 16-bit down counter. Either C/T input can be selected from UI0 or UI1. Either C/T output can be directed to TMO0 or TMO1. The C/T clock is a scaled version of the system clock. Each C/T features an 8-bit prescaler. The clock rates of the two C/T are independent of each other. The C/Ts can be programmed to recognize clock events on the rising edge, the falling edge, or both rising and falling edges of the input signal. Outputs on TMO0 or TMO1 can be programmed to occur with either polarity.

If either C/T is enabled and an output pin TMO0 or TMO1 is selected, and at the same time User Outputs are enabled, the C/T takes precedence, and Status Register bits 5 or 6 do not affect the state of the selected pin.

#### C/T Modes of Operation:

**MODE 0—Square Wave Output.** The C/T is configured to generate a continuous square wave of 50% duty cycle. Writing a new value to the TMLR Register takes effect at the end of the current cycle, unless TMR is written.

**MODE 1—Retriggerable One-Shot.** The C/T is configured to generate a single pulse of programmable duration. The pulse may be either logic High or logic Low. Retriggering the one-shot before the end of the pulse causes it to retrigger for a new duration.

**MODE 2—8-Bit PWM.** The C/T is configured to generate a pulse-width modulated waveform. The duty cycle ranges from 0–100% (0/256 to 255/256; 8-bits) of a cycle in steps of 1/256 of a cycle. The asserted state of the waveform may be either logic High or logic Low. Writing a new pulse-width value to the TMLR Register takes effect at the end of current cycle, unless TMR is written.

**MODE 3—16-Bit PWM.** The C/T is configured to generate a pulse-width modulated waveform. The duty cycle ranges

from 0–100% (0/65,536 to 65,535/65,536; 16-bits) of a cycle in steps of 1/65,536 of a cycle. The asserted state of the waveform may be either logic High or logic Low. Writing a new pulse-width value to the TMLR Register takes effect at the end of current cycle, unless TMR is written.

**MODE 4—Finite Pulse String Generator.** The C/T is configured to generate 1 to 65,535 pulses. The output pulses are actually from the Timer Clock Prescaler divided by 2 (TMCLK). They are gated to the output until the Timer Down-Counter underflows.

**MODE 5—Externally Clocked One-Shot.** The C/T is configured to generate an output pulse. The pulse may be either logic High or logic Low. It is deasserted when a programmable number of input events (up to 65,535) occur on the input pin, UI0 or UI1.

**MODE 6—Software Watch-Dog Timer.** The C/T is configured to generate a Hardware Reset on time-out, unless retriggered by software.

**MODE 7—Hardware Watch-Dog Timer.** The C/T is configured to generate a Hardware Reset on time-out unless retriggered by an event on the input pin, UI0 or UI1.

**MODE 8—Pulse Stopwatch.** The C/T is configured to measure the time during which its input is asserted.

**MODE 9—Edge-to-Edge Stopwatch.** The C/T is configured to measure the period from one rising (falling) edge to the next rising (falling) edge on the input.

**MODE 10—Edge Counter.** The C/T is configured to count a number of input edges (up to 65,535). Input edges may be selected as rising or falling or both.

**MODE 11—Gated Edge Counter.** The C/T is configured to count the number of input edges (up to 65,535) in a time window set by the second timer. Edges are counted until the second timer underflows. Input edges may be selected as rising, falling, or both.

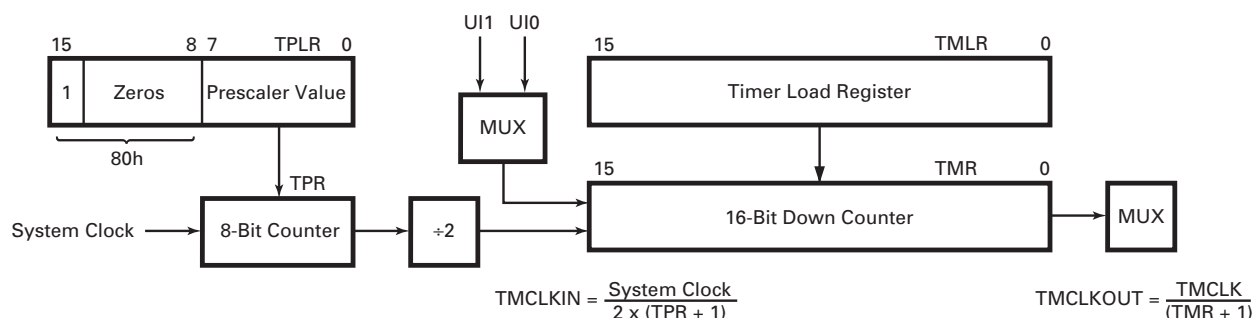


Figure 31. Counter/Timer 0 and 1 Block Diagram



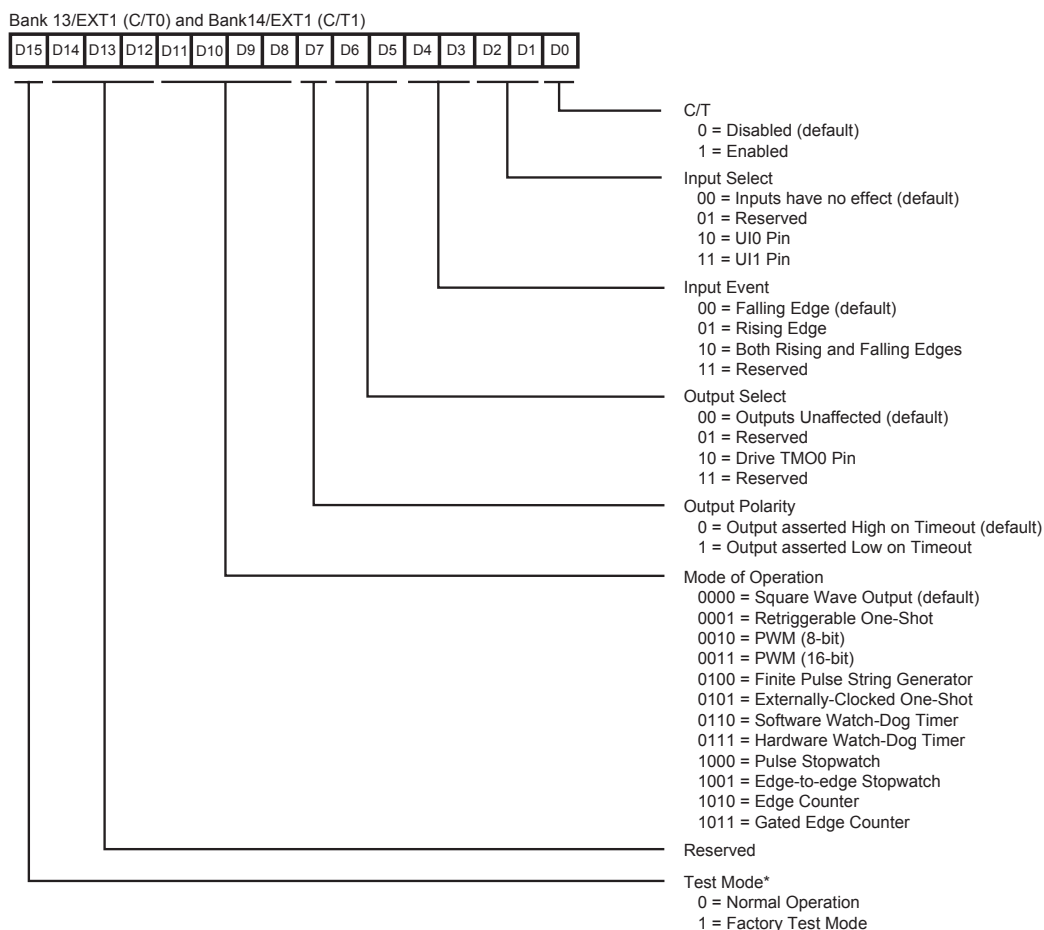


Figure 32. C/T0 and C/T1 Control Register

## C/T Registers

Each C/T contains a set of five 16-bit Registers. Bank13 is used to access the registers for C/T0 and Bank14 is for the C/T1 registers. All accesses to C/T Registers occur with zero wait states.

**Counter/Timer Control Register (Bank13,14/EXT1).** The C/T Control register enables/disables the C/T, selects input and output options, and the mode of operation.

**TMLR—Load Register (Bank13,14/EXT2).** The 16-bit TMLR register holds the value that is loaded into TMR when TMR underflows.

**TMR—Counter Register (Bank13,14/EXT3).** TMR is a 16-bit down counter that holds the current C/T value. It can be read like any other ordinary register. However, writing

to TMR is different than writing to an ordinary register. A write to TMR causes the contents of TMLR to be written into TMR, causing the C/T to be retriggered.

**TPLR—Prescaler Load Register (Bank13,14/EXT4).** The 16-bit TPLR register holds the prescaler load value in its lower 8 bits. Bit 15 must be written with a "1", and bits 14–8 must be written with "0's".

**Note:** If the C/T interrupt is being used, this register must be re-written at the end of the interrupt service routine in order to enable the next interrupt. The number of clock cycles from the beginning of the interrupt service routine to the write must exceed the prescaler load value.

PERIPHERALS (Continued)

**TPR—Prescaler Register (Bank13,14/EXT5).** TPR is an 8-bit down counter that holds the current Prescaler Count Value. It can be read like any other ordinary register. However, writing to TPR is different than writing to an ordinary register. A write to TPR causes the lower 8-bit contents of TPLR to be written into TPR, causing the Prescaler to be retriggered.

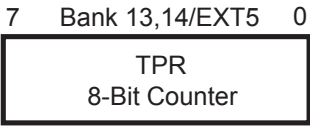


Figure 36. TPR—Prescaler Register

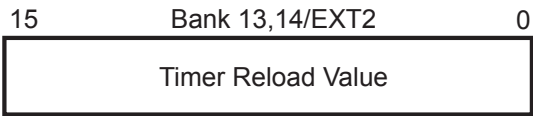


Figure 33. TMLR—Load Register

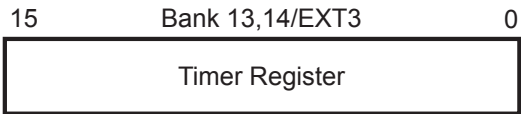


Figure 34. TMR—Counter Register

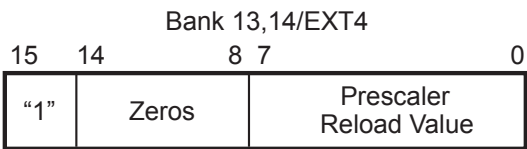


Figure 35. TPLR—Prescaler Load Register

Prescaler Operation

The Prescaler section comprises TPLR and TPR, followed by a divide-by-two flip-flop. This operation generates a 50 percent duty cycle output, TMCLKIN. TPR’s input clock is the system clock. The maximum prescaler output frequency is 1/2 the system clock frequency.

After TPR is loaded, it decrements at the system clock frequency and generates an output to the divide-by-two flip-flop. When the count reaches 0, the TPR counter is reloaded from the lower 8 bits of TPLR Register.

Two other events cause a reloading of the TPR counter:

- 1. Writing to TPR
- 2. Reloading TMR, which happens when TMR underflows, or when TMR is written.

**Note:** For C/T Modes 8–11, the external input signal on UI0 or UI1 is synchronized with TMCLKIN before being applied to TMR. The external input signal frequency must be no higher than 1/2 of the TMCLKIN frequency.

GENERAL-PURPOSE COUNTER/TIMER (C/T2)

This versatile 16-bit C/T offers multiple uses, including Sleep Mode Wake-up. It can be clocked with the slow 32 kHz crystal clock (CLKI), while the DSP and other peripheral functions operate at a higher frequency generated by the PLL. Also included is an independent long duration timer.

GPT is a 16-bit down counter that holds the current C/T value. It can be read like any other ordinary register. GPTL and GPT share the same address, Bank14/EXT0. A write to GPTL reloads GPT, causing the C/T to be retriggered. When C/T2 underflows, it is reloaded with the most recent value written to GPTL. If the C/T2 interrupt is enabled, at underflow an interrupt is generated. The counting operation of the counter can be disabled. The C/T clock source can be selected to be CLKI, UI2, or the system clock divided

by 2. When the C/T2 output is enabled, it drives the TMO2 pin.

Bank 15/EXT2 is the control register for C/T2, and for I/O Ports 2 and 3. Refer to the I/O Ports section, page 33, for a description of the I/O port bit allocation.

Table 22. C/T2 Bits D15 and D13

| D15 | D13 | C/T2 Clock           | Sleep/Wake-Up Mode |
|-----|-----|----------------------|--------------------|
| 0   | 0   | SYSCLK ÷ 2 (default) | n/a                |
| 0   | 1   | UI2                  | n/a                |
| 1   | 0   | CLKI                 | Disabled           |
| 1   | 1   | CLKI                 | Enabled            |

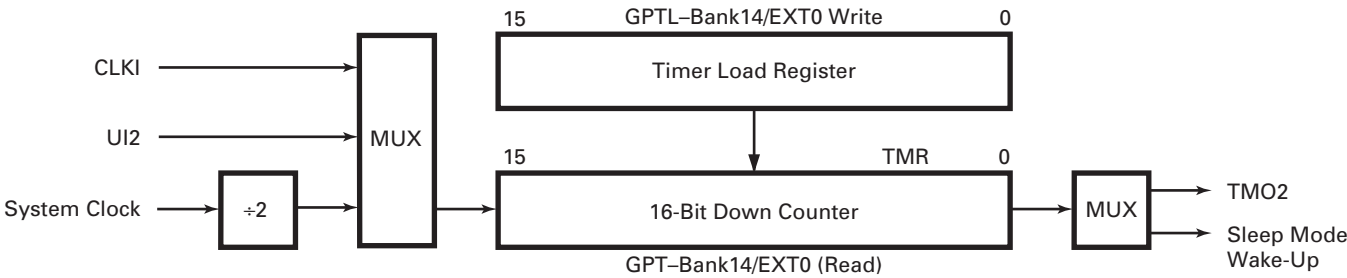


Figure 37. Counter/Timer2 Block Diagram

GENERAL-PURPOSE COUNTER/TIMER (C/T2) (Continued)

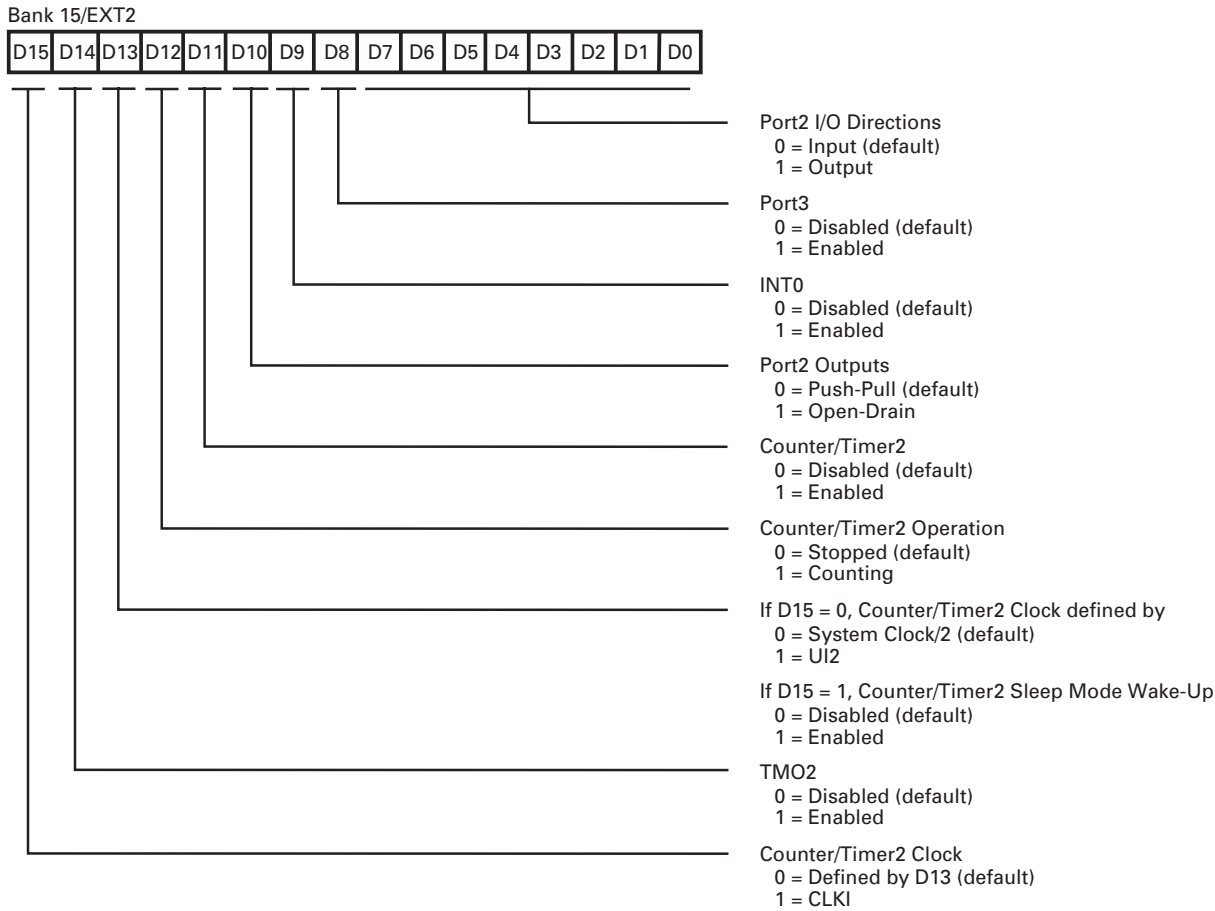


Figure 38. Counter/Timer2 Control Register

SERIAL PERIPHERAL INTERFACE

The Z893x3 incorporates a Serial Peripheral Interface (SPI) for communication with other microcontrollers and peripherals. The SPI can be operated either as the system Master, or as a system Slave. The SPI consists of three registers: the SPI Control Register (Bank15/EXT4), the SPI Receive/Buffer Register (RxBUF), and the SPI Shift Register.

SPI Data Access

Receive operations are double buffered. Bank0/EXT3 accesses both RxBUF for read (receive) operations, and the SPI shift register for write (transmit) operations.

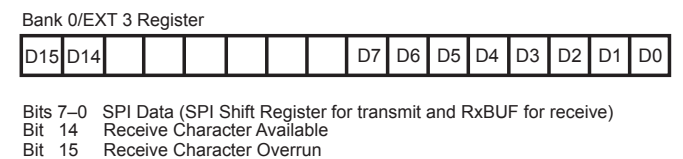


Figure 39. SPI Data Access

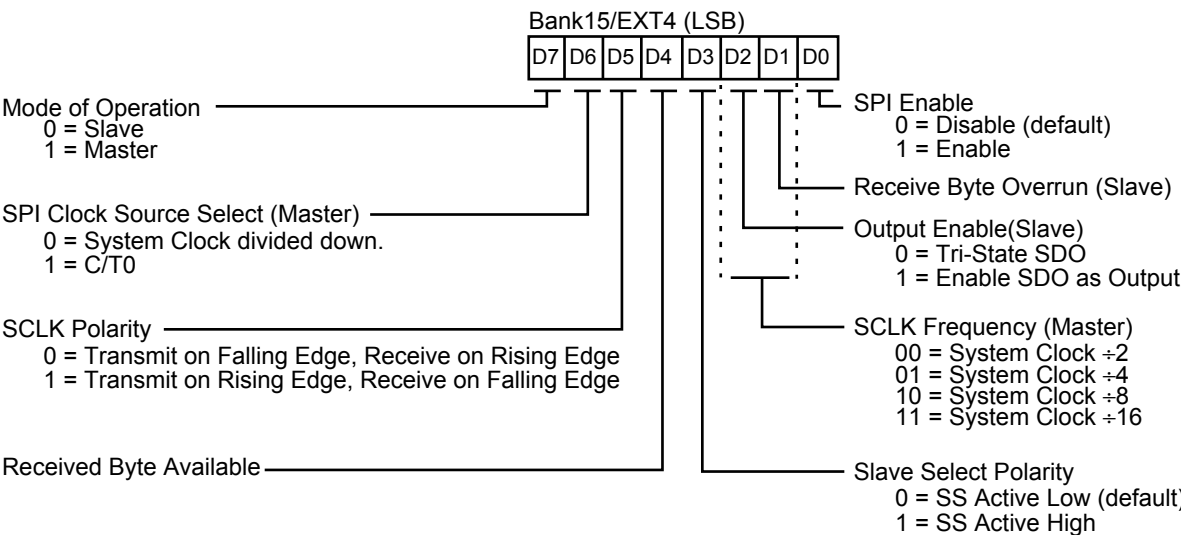


Figure 40. SPI Control Register

Master Mode Operation

The DSP must first activate the target slave’s select pin through an I/O port. Loading data into the SPI Shift Register initiates the transfer. Data is transferred out the SDO pin to the slave one data bit per SCLK cycle. The MSB is shifted out first. At the conclusion of the transfer, the Receive Byte

SPI Control Register

This register is the Low byte of Bank15/EXT4. It is a read/write register that controls Master/Slave selection, SS polarity, clock source and phase selection, and indicates byte available and data overrun conditions. The control register is multifunction depending on Master/Slave mode selection.

In Master mode, Bit 6 defines the SPI clock source. A “1” selects SCLK = C/T0 output, and a “0” selects SCLK = System Clock divided down by 2, 4, 8, or 16, as determined by bits 1 and 2.

In Slave Mode, bit 1 is the Receive Byte Overrun flag. This flag can be cleared by writing a “0” to this bit. Bit 2 is the SDO output enable. A “0” tristates SDO, a “1” enables data output on SDO. Bit 4 signals that a receive byte is available in the RxBUF Register. If the associated interrupt enable bit is enabled, an interrupt is generated.

## SERIAL PERIPHERAL INTERFACE (Continued)

### Slave Mode Operation

SS must be asserted to enable a data transfer. Incoming data on the SDI pin is shifted into the SPI Shift Register one data bit per SCLK cycle. When a byte of data is received, the SPI Shift Register contents are automatically copied into RxBUF. The Receive Byte Available flag is set, and if enabled, an SPI interrupt is generated. The next byte of data may be received at this time. The current byte in RxBUF must be read before the next byte's reception is complete, or the Receive Byte Overrun flag will set, and the data in

RxBUF will be overwritten. The Receive Byte Available flag is reset when RxBUF is read.

Unless the SPI output, SDO, is disabled, for every bit that is transferred into the slave through the SDI pin, a bit is transferred out through the SDO pin on the opposite clock edge. During slave operation, SCLK is an input.

**Note:** Slave Mode is not available on the 44-pin package.

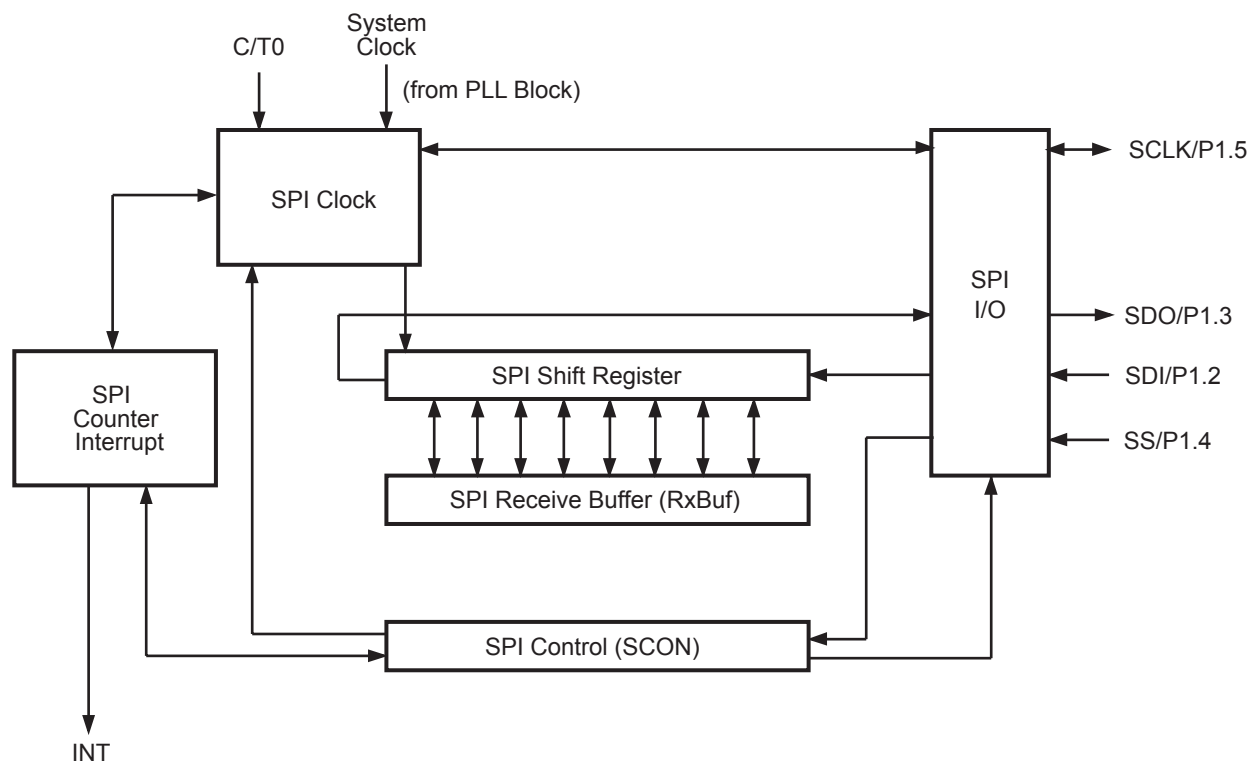


Figure 41. SPI Block Diagram

## SYSTEM CLOCK GENERATOR

The System Clock can be generated from an external clock signal, or from the internal crystal oscillator. For the latter case, a 32-kHz crystal is used in conjunction with the internal crystal oscillator. The system clock generator includes a Phase-Locked Loop (PLL) circuit to derive a high-frequency System Clock from the low-frequency crystal oscillator. The benefits of using a low-frequency crystal are

lower system cost, lower power consumption and lower EMI.

The Z893x3 supports several low-power clock modes to optimize power consumption. Total power consumption depends on System Clock frequency, and which oscillators and peripherals are enabled.

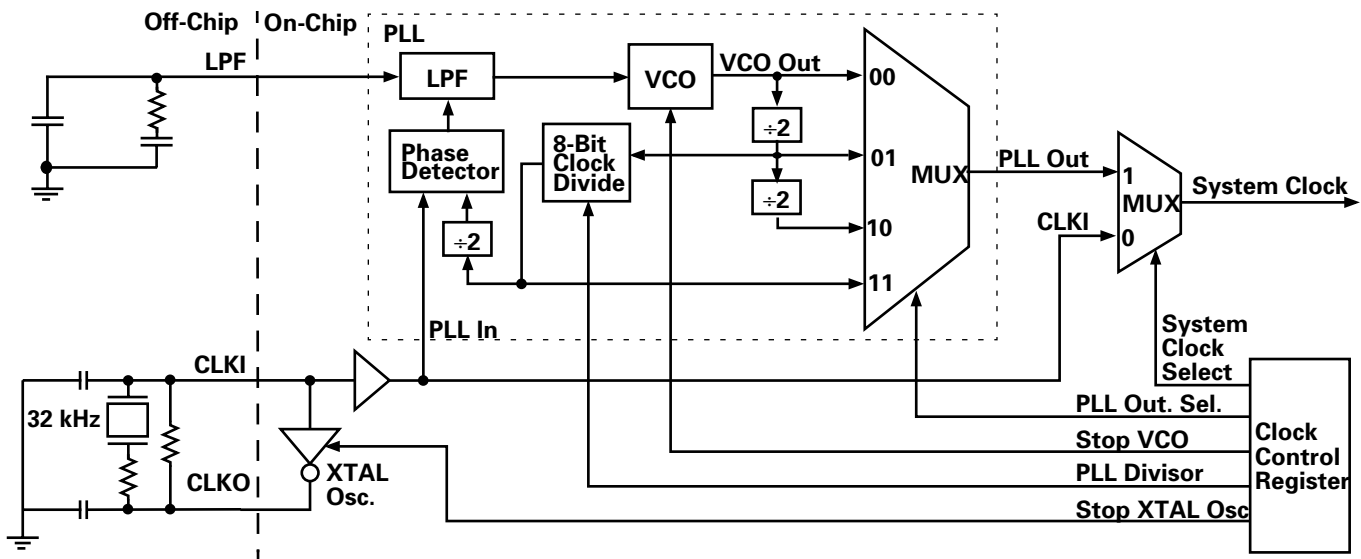


Figure 42. System Clock Generator

### Modes of Operation

The various modes of clock operation are selected by writing to the appropriate bits and fields of the Clock Control Register, Bank15/EXT5. The mode of operation can be switched dynamically during program execution.

#### Power-up and Reset (Default)

At power-up, and following a reset or Sleep Mode Recovery, System Clock Select = 0, therefore system clock = CLKI. The XTAL Oscillator is running, so CLKI may be provided by a crystal, as depicted, or by an external clock (not shown). The VCO is running to minimize the time required to switch the system clock to PLL Out.

#### External Clock Direct

In this mode, an external clock on CLKI provides the System Clock. CLKO is not connected. System Clock Select = 0. The PLL is not used. The XTAL oscillator and VCO are both stopped to reduce power consumption.

#### Crystal Oscillator Direct

In this mode of operation, the XTAL Oscillator is running, and an external crystal provides a 32-kHz (typical) clock at CLKI. System Clock Select = 0, so the System Clock is the frequency at CLKI (32 kHz). This mode requires less power than running at a high-frequency clock rate. The VCO may be stopped to conserve even more power, or left running for rapid switching (wake up) to a high-frequency PLL generated clock. Whenever the PLL circuit is enabled, Stop VCO = 0, and a software delay of 10 ms must be observed before switching System Clock from CLKI to PLL Out. As a result, the PLL has time to stabilize.

#### PLL Clock

An external 32-kHz crystal, together with the on-chip XTAL oscillator, provides the PLL input. The VCO generates the System Clock. A low-pass filter must be connected to LPF as depicted. The XTAL oscillator and VCO are both running, and System Clock = PLL Out (System Clock Select = 1). The frequency generated by the PLL is deter-

SYSTEM CLOCK GENERATOR (Continued)

mined by the PLL Divisor value in the MSB of the Clock Control Register, Bank15/EXT5:

$$\text{VCO Frequency} = 4 \times \text{PLL Divisor} \times \text{PLL In Frequency.}$$

The PLL Divisor value should be between 1 and156 to obtain a VCO Frequency between 128 kHz and 20 MHz from a 32-kHz input.

There are four options for PLL Out: VCO Out, VCO Out divided by 2, VCO Out divided by four, or twice the crystal frequency. This selection is determined by the PLL Out Select bits in the Clock Control Register.

**Note:** The PLL is designed and tested to operate with an input frequency of approximately 32 kHz. It is possible to drive the input with a crystal or user-generated clock at some other frequency, but the results are not guaranteed.

Sleep Modes

The Z893x3 supports various Clock Modes to minimize device power consumption. The lowest power mode is Deep Sleep in which the System Clock is stopped, and the VCO and XTAL Oscillator are both turned off.

Table 23. Standard Clock Mode Summary

| Mode                      | CLKI Src   | Stop XTAL Osc. | Stop VCO | Sys Clk Sel |
|---------------------------|------------|----------------|----------|-------------|
| Power-up/Reset (default)  | XTAL, User | 0              | 0        | 0           |
| PLL Clock                 | XTAL       | 0              | 0        | 1           |
| Crystal Oscillator Direct | XTAL       | 0              | 1        | 0           |
| External Clock Direct     | User       | 1              | 1        | 0           |
| Deep Sleep (lowest power) | XTAL, User | 1              | 1        | 1           |

Wake-Up From Sleep Modes

The Wake-up Trigger Source is specified by bits 5 and 6 of the Clock Control Register. The polarity of the Wake-up signal is defined by bit 7. Wake-up occurs when the wake-up signal is toggled to the specified wake-up polarity. Wake-up resumes operation starting from the reset vector address in the same way the chip responds to an external RESET.

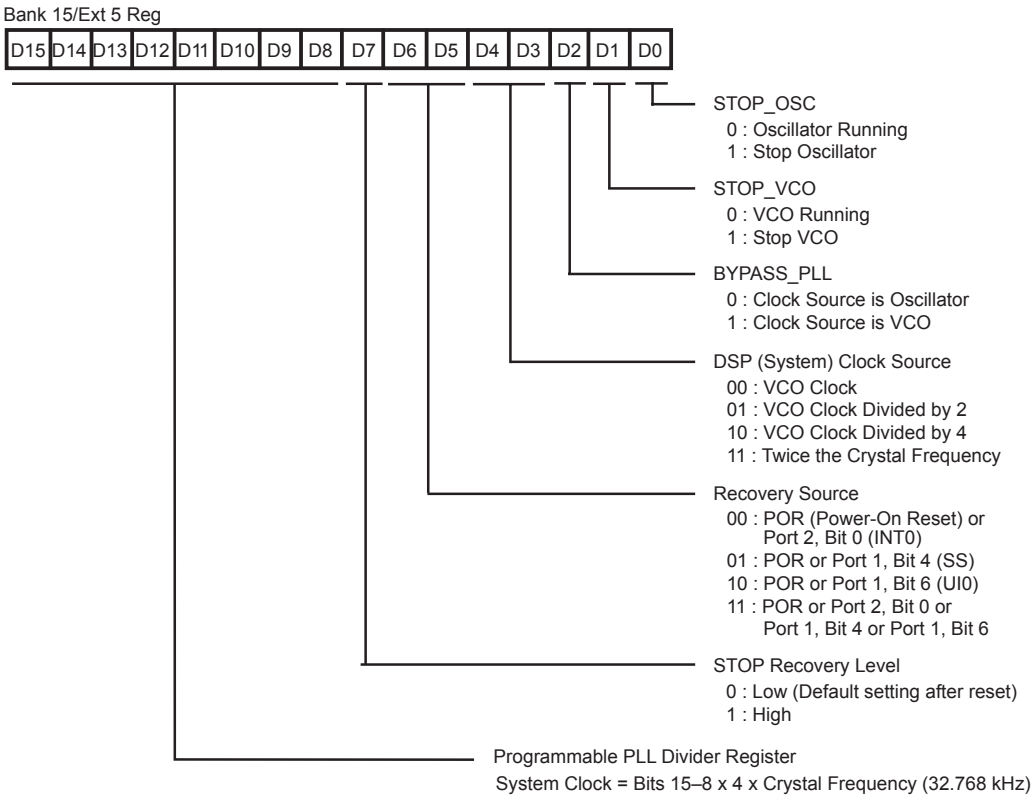


Figure 43. System Clock Control Register



## INSTRUCTION SET

The addressing modes are:

**<pregs>, <hwregs>.** These modes are used for loads to and from registers within the chip, such as loading to the accumulator, or loading from a pointer register. The names of the registers are specified in the operand field (destination first, then source).

**<dregs>.** This mode is used for access to the lower 16 addresses in each bank of RAM. The 4-bit address comes from 2 bits of the status register and 2 bits of the operand field of the data pointer. Data registers can be used to access data in RAM, but typically are used as pointers to access data from the program memory.

**<accind>.** Similar to the previous mode, the address for the program memory read is stored in the Accumulator. Hence, @A in the second operand field loads the number in memory specified by the address in A.

**<direct>.** The direct mode allows read or write to data RAM from the Accumulator by specifying the absolute address of the RAM in the operand of the instruction. A number between 0 and 255 indicates a location in RAM bank 0, and a number between 256 and 511 indicates a location in RAM bank 1.

**<limm>.** This address mode indicates a long immediate operand. A 16-bit word can be loaded directly from the operand into the specified register or memory location.

**<simm>.** This address mode indicates a short immediate operand. It is used to load 8-bit data into the specified RAM pointer.

**<regind>.** This mode is used for indirect access to the data RAM. The address of the RAM location is stored in the pointer. The “@” symbol indicates “indirect” and precedes the pointer. For example, @P1:1 refers to the location in RAM bank 1 specified by the value in the pointer.

**<memind>.** This mode is used for indirect access to the program memory. The address of the memory is located in a RAM location, which is specified by the value in a pointer. Therefore, @@P1:1 instructs the processor to read from a location in memory, which is specified by a value in RAM, and the location of the RAM is in turn specified by the value in the pointer.

**Note:** the data pointer can also be used for a memory access in this manner, but only one “@” precedes the pointer. In both cases, each time the addressing mode is used, the memory address stored in RAM is incremented by one to allow easy transfer of sequential data from program memory.

**Table 24. Instruction Set Addressing Modes**

| Symbolic Name                       | Syntax                       | Description                                          |
|-------------------------------------|------------------------------|------------------------------------------------------|
| <pregs>                             | Pn:b                         | Pointer Registers                                    |
| <dregs> (points to RAM)             | Dn:b                         | Data Registers                                       |
| <hwregs>                            | X, Y, PC, SR, P, EDn, A, BUS | Hardware Registers                                   |
| <accind> (points to Program Memory) | @A                           | Accumulator Memory Indirect                          |
| <direct>                            | <expression>                 | Direct Address Expression                            |
| <limm>                              | #<const exp>                 | Long (16-bit) Immediate Value                        |
| <simm>                              | #<const exp>                 | Short (8-bit) Immediate Value                        |
| <regind> (points to RAM)            | @Pn:b                        | Pointer Register Indirect                            |
|                                     | @Pn:b+                       | Pointer Register Indirect with Increment             |
|                                     | @Pn:b-LOOP                   | Pointer Register Indirect with Loop Decrement        |
|                                     | @Pn:b+LOOP                   | Pointer register Indirect with Loop Increment        |
| <memind> (points to Program Memory) | @@Pn:b                       | Pointer Register Memory Indirect                     |
|                                     | @Dn:b                        | Data Register Memory Indirect                        |
|                                     | @@Pn:b-LOOP                  | Pointer Register Memory Indirect with Loop Decrement |
|                                     | @@Pn:b+LOOP                  | Pointer Register Memory Indirect with Loop Increment |
|                                     | @@Pn:b+                      | Pointer Register Memory Indirect with Increment      |

## CONDITION CODES

The following Instruction Description defines the condition codes supported by the DSP assembler. If the instruction description refers to the <cc> (condition code) symbol in one of its addressing modes, the instruction only executes if the condition is true.

| Code | Description                                 |
|------|---------------------------------------------|
| C    | Carry                                       |
| EQ   | Equal (same as Z)                           |
| F    | False                                       |
| IE   | Interrupts Enabled                          |
| MI   | Minus                                       |
| NC   | No Carry                                    |
| NE   | Not Equal (same as NZ)                      |
| NIE  | Not Interrupts Enabled                      |
| NOV  | Not Overflow                                |
| NU0  | Not User Zero                               |
| NU1  | Not User One                                |
| NZ   | Not zero                                    |
| OV   | Overflow                                    |
| PL   | Plus (Positive)                             |
| U0   | User Zero                                   |
| U1   | User One                                    |
| UGE  | Unsigned Greater Than or Equal (Same as NC) |
| ULT  | Unsigned Less Than (Same as C)              |
| Z    | Zero                                        |

## INSTRUCTION DESCRIPTIONS

| Inst. | Description     | Synopsis                | Operands                                                                                               | Words                                | Cycles                               | Examples                                                                                                              |
|-------|-----------------|-------------------------|--------------------------------------------------------------------------------------------------------|--------------------------------------|--------------------------------------|-----------------------------------------------------------------------------------------------------------------------|
| ABS   | Absolute Value  | ABS[<cc>,<src>          | <cc>,A<br>A                                                                                            | 1<br>1                               | 1<br>1                               | ABS NC, A<br>ABS A                                                                                                    |
| ADD   | Addition        | ADD<dest>,<src>         | A,<pregs><br>A,<dregs><br>A,<limm><br>A,<memind><br>A,<direct><br>A,<regind><br>A,<hwregs><br>A,<simm> | 1<br>1<br>2<br>1<br>1<br>1<br>1<br>1 | 1<br>1<br>2<br>3<br>1<br>1<br>1<br>1 | ADD A,P0:0<br>ADD A,D0:0<br>ADD A,#%1234<br>ADD A,@P0:0<br>ADD A,%F2<br>ADD A,@P1:1<br>ADD A,X<br>ADD A, #%12         |
| AND   | Bitwise AND     | AND<dest>,<src>         | A,<pregs><br>A,<dregs><br>A,<limm><br>A,<memind><br>A,<direct><br>A,<regind><br>A,<hwregs><br>A,<simm> | 1<br>1<br>2<br>1<br>1<br>1<br>1<br>1 | 1<br>1<br>2<br>3<br>1<br>1<br>1<br>1 | AND A,P2:0<br>AND A,D0:1<br>AND A,#%1234<br>AND A,@P1:0<br>AND A,%2C<br>AND A,@P1:2+LOOP<br>AND A,EXT3<br>AND A, #%12 |
| CALL  | Subroutine call | CALL<br>[<cc>,<address> | <cc>,<direct><br><direct>                                                                              | 2<br>2                               | 2<br>2                               | CALL Z,sub2<br>CALL sub1                                                                                              |
| CCF   | Clear C flag    | CCF                     | None                                                                                                   | 1                                    | 1                                    | CCF                                                                                                                   |
| CIEF  | Clear IE Flag   | CIEF                    | None                                                                                                   | 1                                    | 1                                    | CIEF                                                                                                                  |
| COPF  | Clear OP flag   | COPF                    | None                                                                                                   | 1                                    | 1                                    | COPF                                                                                                                  |
| CP    | Comparison      | CP<src1>,<src2>         | A,<pregs><br>A,<dregs><br>A,<memind><br>A,<direct><br>A,<regind><br>A,<hwregs><br>A,<limm><br>A,<simm> | 1<br>1<br>1<br>1<br>1<br>1<br>2<br>1 | 1<br>1<br>3<br>1<br>1<br>1<br>2<br>1 | CP A,P0:0<br>CP A,D3:1<br>CP A,@P0:1<br>CP A,%FF<br>CP A,@P2:1+<br>CP A,STACK<br>CP A,#%FFCF<br>CP A, #%12            |
| DEC   | Decrement       | DEC [<cc>,<dest>        | <cc>,A,<br>A                                                                                           | 1<br>1                               | 1<br>1                               | DEC NZ,A<br>DEC A                                                                                                     |
| INC   | Increment       | INC [<cc>,<dest>        | <cc>,A<br>A                                                                                            | 1<br>1                               | 1<br>1                               | INC PL,A<br>INC A                                                                                                     |
| JP    | Jump            | JP [<cc>,<address>      | <cc>,<direct><br><direct>                                                                              | 2<br>2                               | 2<br>2                               | JP C,Label<br>JP Label                                                                                                |

## INSTRUCTION DESCRIPTIONS (Continued)

| Inst. | Description                  | Synopsis       | Operands          | Words | Cycles | Examples        |
|-------|------------------------------|----------------|-------------------|-------|--------|-----------------|
| LD    | Load destination with source | LD<dest>,<src> | A,<hwregs>        | 1     | 1      | LD A,X          |
|       |                              |                | A,<dregs>         | 1     | 1      | LD A,D0:0       |
|       |                              |                | A,<pregs>         | 1     | 1      | LD A,P0:1       |
|       |                              |                | A,<regind>        | 1     | 1      | LD A,@P1:1      |
|       |                              |                | A,<memind>        | 1     | 3      | LD A,@D0:0      |
|       |                              |                | A,<direct>        | 1     | 1      | LD A,124        |
|       |                              |                | <direct>,A        | 1     | 1      | LD 124,A        |
|       |                              |                | <dregs>,<hwregs>  | 1     | 1      | LD D0:0,EXT7    |
|       |                              |                | <pregs>,<sim>     | 1     | 1      | LD P1:1,#%FA    |
|       |                              |                | <pregs>,<hwregs>  | 1     | 1      | LD P1:1,EXT1    |
|       |                              |                | <regind>,<limm>   | 1     | 1      | LD@P1:1,#1234   |
|       |                              |                | <regind>,<hwregs> | 1     | 1      | LD @P1:1+,X     |
|       |                              |                | <hwregs>,<pregs>  | 1     | 1      | LD Y,P0:0       |
|       |                              |                | <hwregs>,<dregs>  | 1     | 1      | LD SR,D0:0      |
|       |                              |                | <hwregs>,<limm>   | 2     | 2      | LD PC,#%1234    |
|       |                              |                | <hwregs>,<accind> | 1     | 3      | LD X,@A         |
|       |                              |                | <hwregs>,<memind> | 1     | 3      | LD Y,@D0:0      |
|       |                              |                | <hwregs>,<regind> | 1     | 1      | LD A,@P0:0-LOOP |
|       |                              |                | <hwregs>,<hwregs> | 1     | 1      | LD X,EXT6       |

### Notes:

When <dest> is <hwregs>, <dest> cannot be P.

When <dest> is <hwregs> and <src> is <hwregs>, <dest> cannot be EXTn if <src> is EXTn, <dest> cannot be X if <src> is X, <dest> cannot be SR if <src> is SR.

When <src> is <accind> <dest> cannot be A.

|     |          |                                       |                                 |   |   |                    |
|-----|----------|---------------------------------------|---------------------------------|---|---|--------------------|
| MLD | Multiply | MLD <src1>,<src2><br>[,<bank switch>] | <hwregs>,<regind>               | 1 | 1 | MLD A,@P0:0+LOOP   |
|     |          |                                       | <hwregs>,<regind>,<bank switch> | 1 | 1 | MLD A,@P1:0,OFF    |
|     |          |                                       | <regind>,<regind>               | 1 | 1 | MLD @P1:1,@P2:0    |
|     |          |                                       | <regind>,<regind>,<bank switch> | 1 | 1 | MLD @P0:1,@P1:0,ON |
|     |          |                                       |                                 |   |   |                    |

### Notes:

If src1 is <regind> it must be a bank 1 register. Src2's <regind> must be a bank 0 register.

<hwregs> for src1 cannot be X.

For the operands <hwregs>, <regind> the <bank switch> defaults to OFF. For the operands <regind>, the <bank switch> defaults to ON.

|      |                  |                                        |                                 |   |   |                    |
|------|------------------|----------------------------------------|---------------------------------|---|---|--------------------|
| MPYA | Multiply and add | MPYA <src1>,<src2><br>[,<bank switch>] | <hwregs>,<regind>               | 1 | 1 | MPYA A,@P0:0       |
|      |                  |                                        | <hwregs>,<regind>,<bank switch> | 1 | 1 | MPYA A,@P1:0,OFF   |
|      |                  |                                        | <regind>,<regind>               | 1 | 1 | MPYA @P1:1,@P2:0   |
|      |                  |                                        | <regind>,<regind>,<bank switch> | 1 | 1 | MPYA@P0:1,@P1:0,ON |
|      |                  |                                        |                                 |   |   |                    |

### Notes:

If src1 is <regind> it must be a bank 1 register. Src2's <regind> must be a bank 0 register.

<hwregs> for src1 cannot be X.

For the operands <hwregs>, <regind> the <bank switch> defaults to OFF. For the operands <regind>, the <bank switch> defaults to ON.

|      |                       |                                        |                                 |   |   |                     |
|------|-----------------------|----------------------------------------|---------------------------------|---|---|---------------------|
| MPYS | Multiply and subtract | MPYS <src1>,<src2><br>[,<bank switch>] | <hwregs>,<regind>               | 1 | 1 | MPYS A,@P0:0        |
|      |                       |                                        | <hwregs>,<regind>,<bank switch> | 1 | 1 | MPYS A,@P1:0,OFF    |
|      |                       |                                        | <regind>,<regind>               | 1 | 1 | MPYS @P1:1,@P2:0    |
|      |                       |                                        | <regind>,<regind>,<bank switch> | 1 | 1 | MPYS @P0:1,@P1:0,ON |
|      |                       |                                        |                                 |   |   |                     |

| Inst.                                                                                                                                        | Description            | Synopsis        | Operands     | Words  | Cycles | Examples          |
|----------------------------------------------------------------------------------------------------------------------------------------------|------------------------|-----------------|--------------|--------|--------|-------------------|
| <b>Notes:</b>                                                                                                                                |                        |                 |              |        |        |                   |
| If src1 is <regind> it must be a bank 1 register. Src2's <regind> must be a bank 0 register.                                                 |                        |                 |              |        |        |                   |
| <hwregs> for src1 cannot be X.                                                                                                               |                        |                 |              |        |        |                   |
| For the operands <hwregs>, <regind> the <bank switch> defaults to OFF. For the operands <regind>, <regind> the <bank switch> defaults to ON. |                        |                 |              |        |        |                   |
| NEG                                                                                                                                          | Negate                 | NEG <cc>,A      | <cc>, A<br>A | 1<br>1 | 1<br>1 | NEG MI,A<br>NEG A |
| NOP                                                                                                                                          | No operation           | NOP             | None         | 1      | 1      | NOP               |
| OR                                                                                                                                           | Bitwise OR             | OR <dest>,<src> | A,<pregs>    | 1      | 1      | OR A,P0:1         |
|                                                                                                                                              |                        |                 | A,<dregs>    | 1      | 1      | OR A, D0:1        |
|                                                                                                                                              |                        |                 | A,<limm>     | 2      | 2      | OR A,#%2C21       |
|                                                                                                                                              |                        |                 | A,<memind>   | 1      | 3      | OR A,@P2:1+       |
|                                                                                                                                              |                        |                 | A,<direct>   | 1      | 1      | OR A,%2C          |
|                                                                                                                                              |                        |                 | A,<regind>   | 1      | 1      | OR A,@P1:0–LOOP   |
|                                                                                                                                              |                        |                 | A,<hwregs>   | 1      | 1      | OR A,EXT6         |
|                                                                                                                                              |                        |                 | A,<simm>     | 1      | 1      | OR A,#%12         |
| POP                                                                                                                                          | Pop value from stack   | POP <dest>      | <pregs>      | 1      | 1      | POP P0:0          |
|                                                                                                                                              |                        |                 | <dregs>      | 1      | 1      | POP D0:1          |
|                                                                                                                                              |                        |                 | <regind>     | 1      | 1      | POP @P0:0         |
|                                                                                                                                              |                        |                 | <hwregs>     | 1      | 1      | POP A             |
| PUSH                                                                                                                                         | Push value onto stack  | PUSH <src>      | <pregs>      | 1      | 1      | PUSH P0:0         |
|                                                                                                                                              |                        |                 | <dregs>      | 1      | 1      | PUSH D0:1         |
|                                                                                                                                              |                        |                 | <regind>     | 1      | 1      | PUSH @P0:0        |
|                                                                                                                                              |                        |                 | <hwregs>     | 1      | 1      | PUSH BUS          |
|                                                                                                                                              |                        |                 | <limm>       | 2      | 2      | PUSH #12345       |
|                                                                                                                                              |                        |                 | <accind>     | 1      | 3      | PUSH @A           |
|                                                                                                                                              |                        |                 | <memind>     | 1      | 3      | PUSH @@P0:0       |
| RET                                                                                                                                          | Return from subroutine | RET             | None         | 1      | 2      | RET               |
| RL                                                                                                                                           | Rotate Left            | RL <cc>,A       | <cc>,A       | 1      | 1      | RL NZ,A           |
|                                                                                                                                              |                        |                 | A            | 1      | 1      | RL A              |
| RR                                                                                                                                           | Rotate Right           | RR <cc>,A       | <cc>,A       | 1      | 1      | RR C,A            |
|                                                                                                                                              |                        |                 | A            | 1      | 1      | RR A              |
| SCF                                                                                                                                          | Set C flag             | SCF             | None         | 1      | 1      | SCF               |
| SIEF                                                                                                                                         | Set IE flag            | SIEF            | None         | 1      | 1      | SIEF              |
| SLL                                                                                                                                          | Shift left logical     | SLL             | [<cc>],A     | 1      | 1      | SLL NZ,A          |
|                                                                                                                                              |                        |                 | A            | 1      | 1      | SLL A             |
| SOPF                                                                                                                                         | Set OP flag            | SOPF            | None         | 1      | 1      | SOPF              |
| SRA                                                                                                                                          | Shift right arithmetic | SRA<cc>,A       | <cc>,A       | 1      | 1      | SRA NZ,A          |
|                                                                                                                                              |                        |                 | A            | 1      | 1      | SRA A             |
| SUB                                                                                                                                          | Subtract               | SUB<dest>,<src> | A,<pregs>    | 1      | 1      | SUB A,P1:1        |
|                                                                                                                                              |                        |                 | A,<dregs>    | 1      | 1      | SUB A,D0:1        |
|                                                                                                                                              |                        |                 | A,<limm>     | 2      | 2      | SUB A,#%2C2C      |
|                                                                                                                                              |                        |                 | A,<memind>   | 1      | 3      | SUB A,@D0:1       |
|                                                                                                                                              |                        |                 | A,<direct>   | 1      | 1      | SUB A,%15         |
|                                                                                                                                              |                        |                 | A,<regind>   | 1      | 1      | SUB A,@P2:0–LOOP  |
|                                                                                                                                              |                        |                 | A,<hwregs>   | 1      | 1      | SUB A,STACK       |
|                                                                                                                                              |                        |                 | A,<simm>     | 1      | 1      | SUB A, #%12       |

INSTRUCTION DESCRIPTIONS (Continued)

| Inst. | Description             | Synopsis         | Operands   | Words | Cycles | Examples      |
|-------|-------------------------|------------------|------------|-------|--------|---------------|
| XOR   | Bitwise<br>exclusive OR | XOR <dest>,<src> | A,<pregs>  | 1     | 1      | XOR A,P2:0    |
|       |                         |                  | A,<dregs>  | 1     | 1      | XOR A,D0:1    |
|       |                         |                  | A,<limm>   | 2     | 2      | XOR A,#13933  |
|       |                         |                  | A,<memind> | 1     | 3      | XOR A,@@P2:1+ |
|       |                         |                  | A,<direct> | 1     | 1      | XOR A,%2F     |
|       |                         |                  | A,<regind> | 1     | 1      | XOR A,@P2:0   |
|       |                         |                  | A,<hwregs> | 1     | 1      | XOR A,BUS     |
|       |                         |                  | A,<simm>   | 1     | 1      | XOR A, #%12   |

**Bank Switch Operand.** The third (optional) operand of the MLD, MPYA and MPYS instructions represents whether the bank switch is set to ON or OFF. To illustrate, the keywords ON and OFF are used to state the direction of the

switch. These keywords are referenced in the instruction descriptions through the <bank switch> symbol. The most notable capability is that a source operand can be multiplied by itself (squared).

PACKAGE INFORMATION

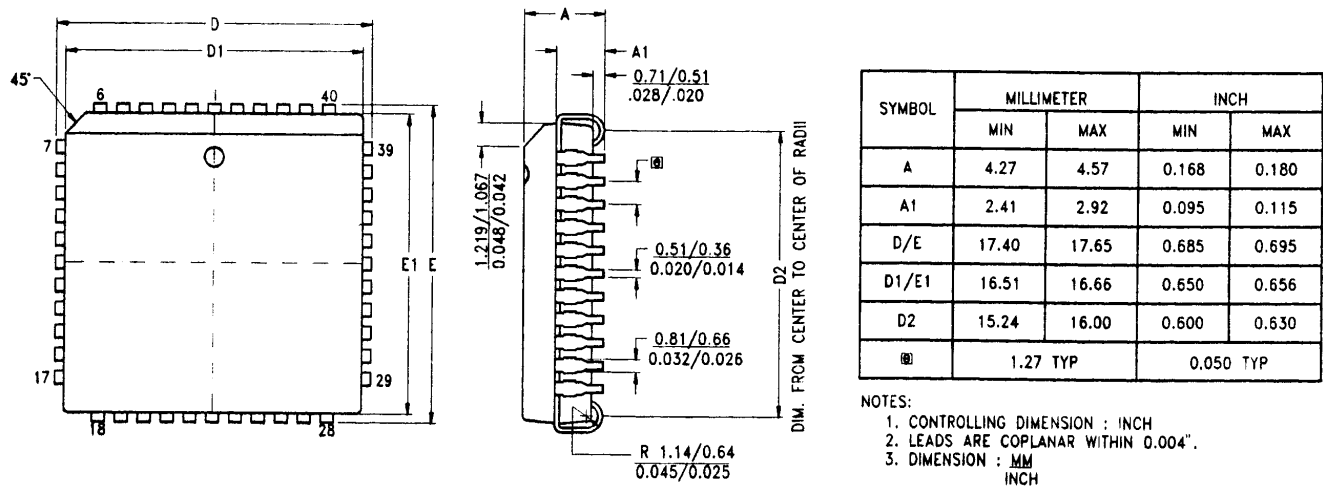


Figure 44. 44-Pin PLCC Package Diagram

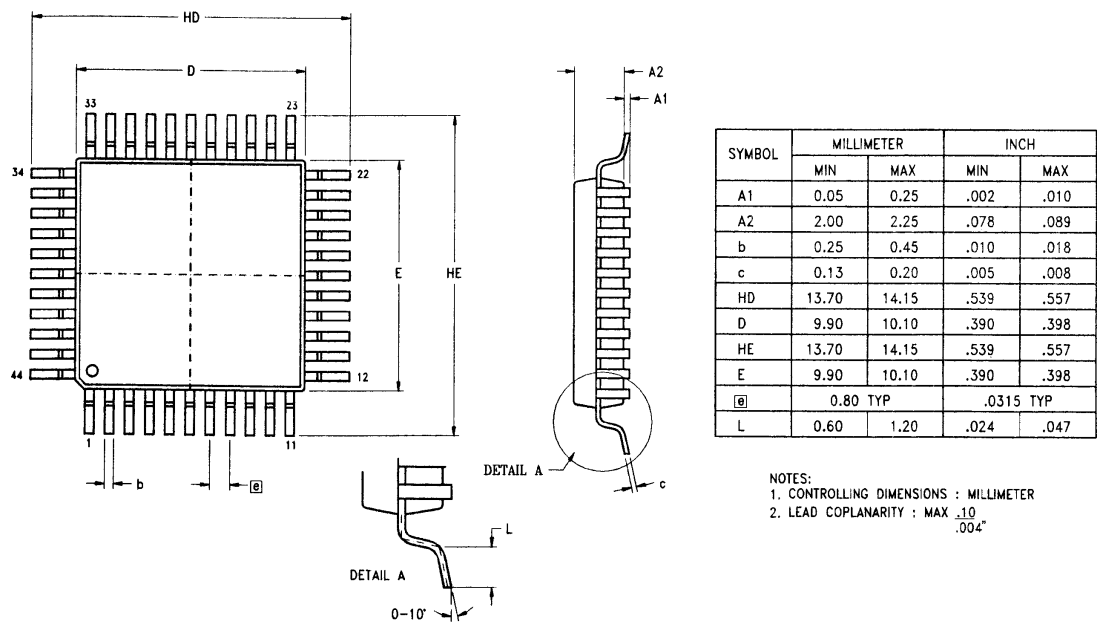


Figure 45. 44-Pin PQFP Package Diagram

PACKAGE INFORMATION (Continued)

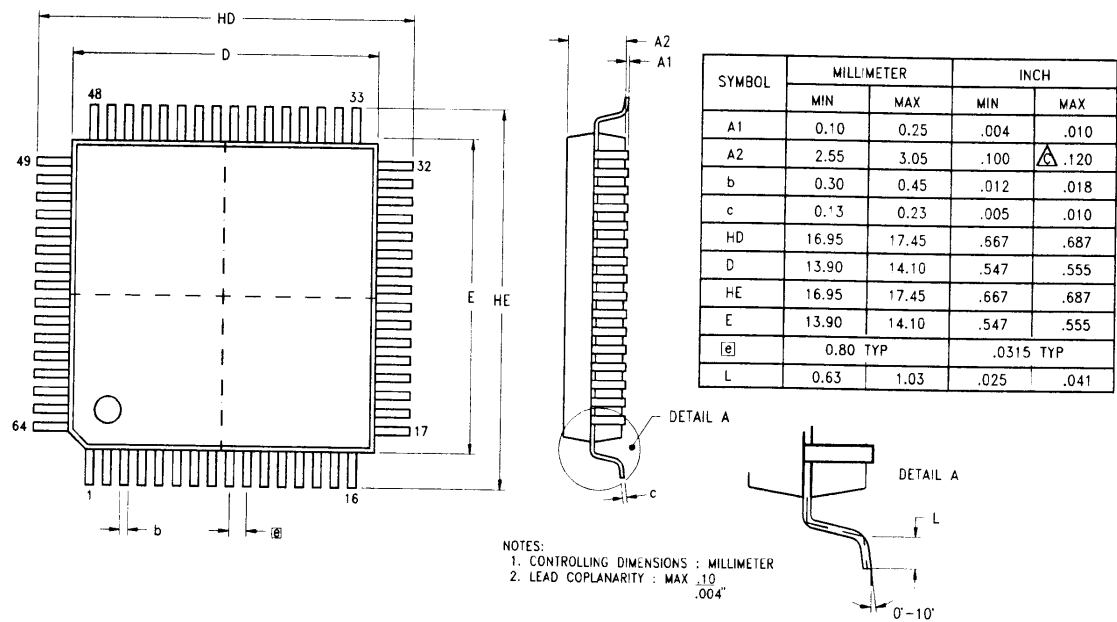


Figure 46. 64-Pin TQFP Package Diagram



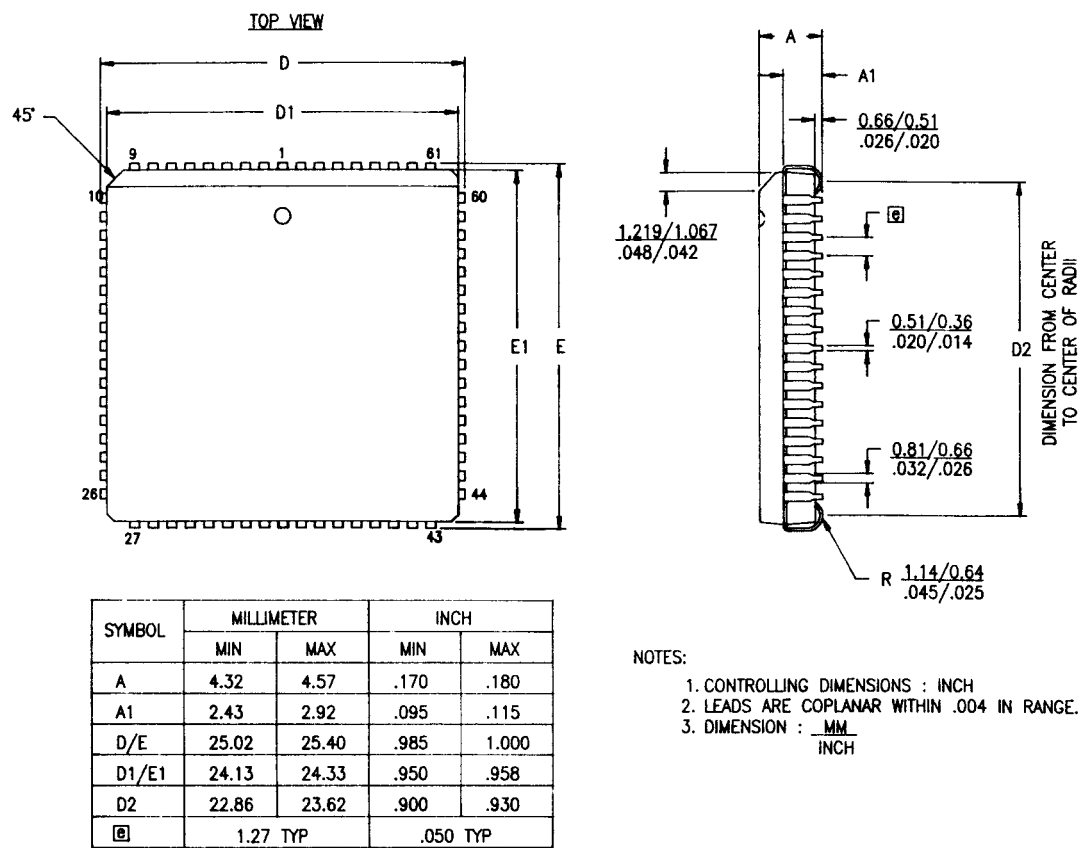


Figure 47. 68-Pin PLCC Package Diagram

# PACKAGE INFORMATION (Continued)

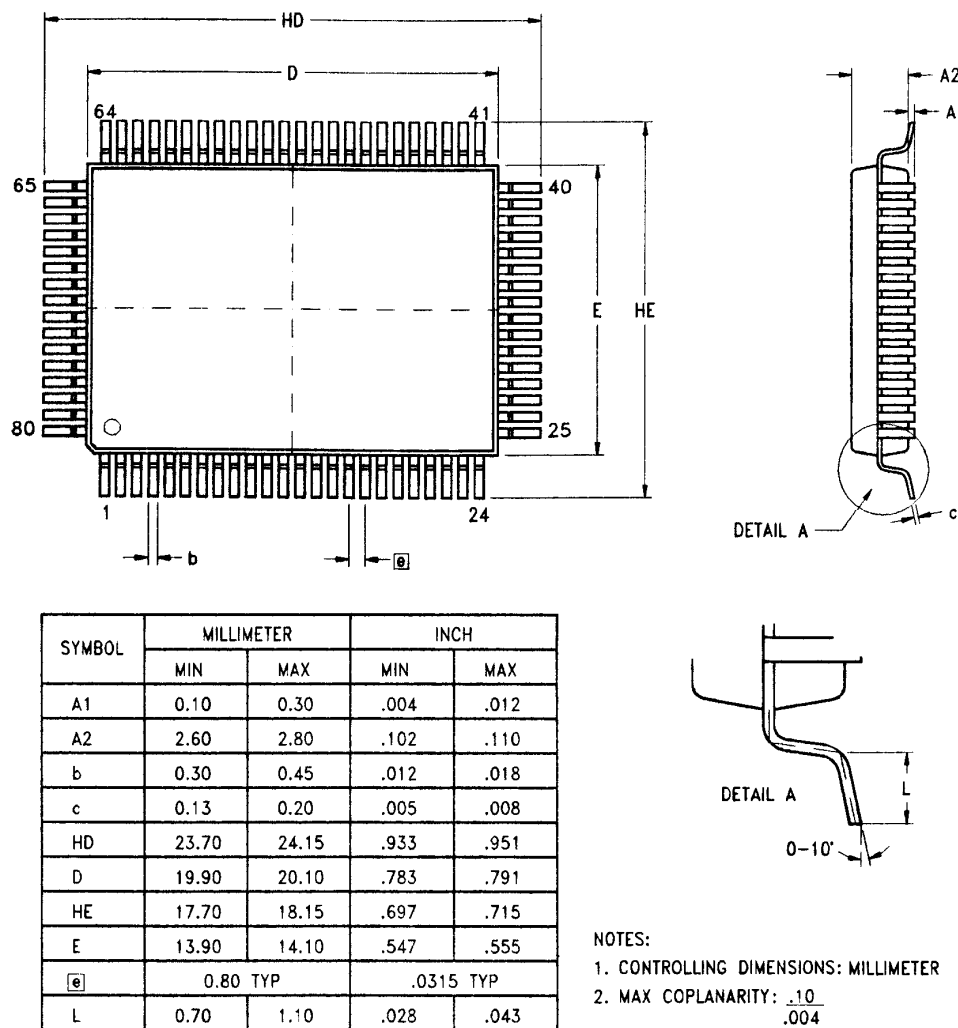


Figure 48. 80-Pin PQFP Package Diagram

ORDERING INFORMATION

| Package Type | ROM         | OTP         |
|--------------|-------------|-------------|
| 44-Pin PLCC  | Z8922320VSC | Z8927320VSC |
|              | Z8922320VEC |             |
| 44-Pin PQFP  | Z8922320FSC |             |
|              | Z8922320FEC |             |
| 64-Pin TQFP  | Z8932320ASC | Z8937320ASC |
|              | Z8932320AEC |             |
| 68-Pin PLCC  | Z8932320VSC | Z8937320VSC |
|              | Z8932320VEC |             |
| 80-Pin PQFP  | Z8932320FSC | Z8937320FSC |
|              | Z8932320FEC |             |

For fast results, contact your local ZiLOG sales office for assistance in ordering the part required.

CODES

|               |                      |
|---------------|----------------------|
| Package       | V = PLCC             |
|               | A = TQFP             |
|               | F = PQFP             |
| Temperature   | S = 0°C to +70°C     |
|               | E = -40°C to 85°C    |
| Speed         | 20 = 20 MHz          |
| Environmental | C = Plastic Standard |

Example:

Z

89323

20

V

S

C

is a Z89323, 20 MHz, PLCC, 0°C to +70°C, Plastic Standard Flow

Environmental Flow

Temperature

Package

Speed/Bond Out Option

Product Number

ZiLOG Prefix

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