



**MICROCHIP**

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## Section 33. Programming and Diagnostics

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### HIGHLIGHTS

This section of the manual contains the following topics:

33.1	Introduction .....	33-2
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33.4	Operation in Power-Saving Modes .....	33-13
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**Note:** This family reference manual section is meant to serve as a complement to device data sheets. Depending on the device variant, this manual section may not apply to all PIC32 devices.

Please consult the note at the beginning of the “**Special Features**” chapter in the current device data sheet to check whether this document supports the device you are using.

Device data sheets and family reference manual sections are available for download from the Microchip Worldwide Web site at: <http://www.microchip.com>

## 33.1 INTRODUCTION

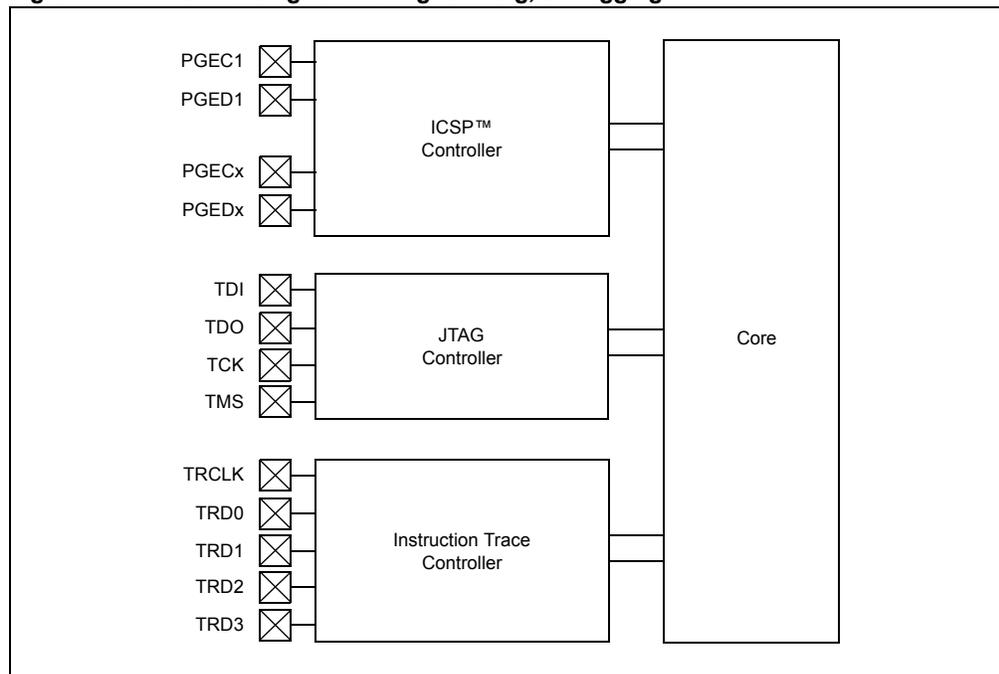
The PIC32 family of devices provides a complete range of programming and diagnostic features that can increase the flexibility of any application using them. These features allow system designers to include:

- Simplified field programming using 2-wire In-Circuit Serial Programming™ (ICSP™) interfaces
- Debugging using standard ICSP and Enhanced ICSP
- Programming and debugging capabilities using the Enhanced Joint Test Action Group (Enhanced JTAG) extension of Joint Test Action Group (JTAG) interfaces
- JTAG Boundary scan testing for device and board diagnostics

The PIC32 family of devices incorporates two programming and diagnostic modules, and a trace controller, which provide a range of functions to the application developer (see [Figure 33-1](#)). They are summarized in [Table 33-1](#).

**Note:** Not all programming and diagnostic features are available on all devices. Refer to the specific device data sheet for availability.

**Figure 33-1: Block Diagram of Programming, Debugging and Trace Ports**



**Table 33-1: Comparison of PIC32 Programming and Diagnostic Features**

Functions	Pins Used	Interface
Boundary Scan	TDI, TDO, TMS and TCK pins	JTAG
Programming and Debugging	TDI, TDO, TMS and TCK pins	Enhanced JTAG
Programming and Debugging	PGECx and PGEDx pins	ICSP™

## 33.2 OPERATION

This section provides a brief overview of operation for each programming option. For detailed information, refer to the “PIC32MX Flash Programming Specification” (DS61145). Also, for all device programming options, a minimum VDD requirement for Flash erase and programming operations is required. Refer to the specific device data sheet for further details.

### 33.2.1 Device Programming Options

#### 33.2.1.1 IN-CIRCUIT SERIAL PROGRAMMING™ (ICSP™)

ICSP is Microchip’s proprietary solution to providing microcontroller programming in the target application. ICSP is also the most direct method to program the device, whether the controller is embedded in a system or loaded into a device programmer.

##### 33.2.1.1.1 ICSP Interface

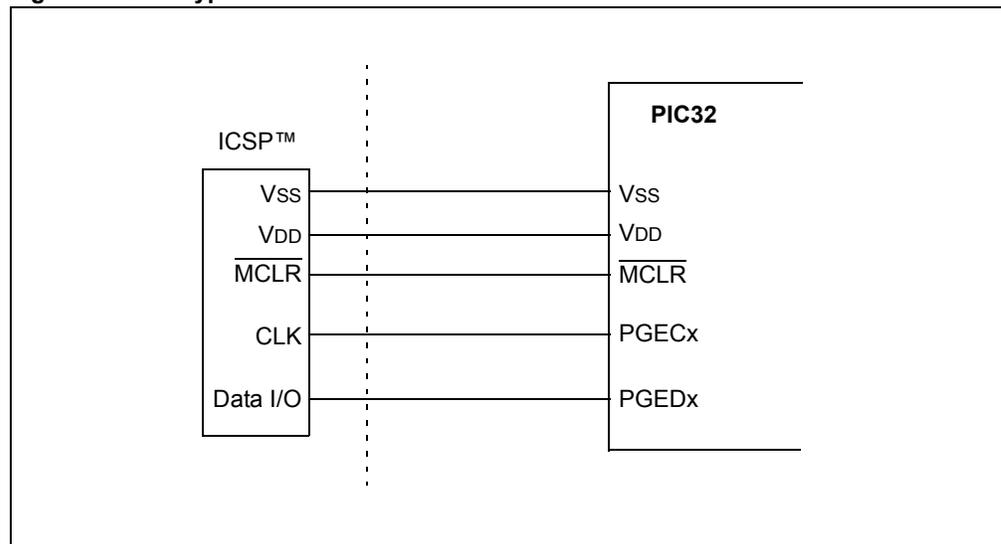
ICSP uses two pins as the core of its interface. The programming data line (PGD) functions as both an input and an output, allowing programming data to be read in and device information to be read out on command. The programming clock line (PGC) is used to clock in data and control the overall process.

Most PIC32 devices have more than one pair of PGECx and PGEDx pins, which are multiplexed with other I/O or peripheral functions. Individual ICSP pin pairs are indicated by number, such as PGEC1/PGED1, and so on. The multiple PGECx/PGEDx pin pairs provide additional flexibility in system design by allowing users to incorporate ICSP on the pair of pins that is least constrained by the circuit design. All PGECx and PGEDx pins are functionally tied together and behave identically, and any one pair can be used for successful device programming. The only limitation is that both pins from the same pair must be used.

In addition to the PGECx and PGEDx pins, ICSP requires that all voltage supply (including the voltage regulator pin, ENVREG) and ground pins on the device must be connected. The MCLR pin, which is used with the PGECx pin to enter and control the programming process, must also be connected to the programmer.

A typical ICSP connection is shown in [Figure 33-2](#).

**Figure 33-2: Typical ICSP™ Connection**



## 33.2.1.1.2 ICSP Operation

ICSP uses a combination of internal hardware and external control to program the target device. Programming data and instructions are provided on the PGD. ICSP uses a special set of commands to control the overall process, combined with standard PIC32 instructions to execute the actual writing of the program memory. The PGD also returns data to the external programmer when responding to queries.

Control of the programming process is achieved by manipulating the PGC and  $\overline{\text{MCLR}}$ . Entry into and exit from Programming mode involves applying (or removing) voltage to  $\overline{\text{MCLR}}$  while supplying a code sequence to the PGD and a clock to the PGC. Any one of the PGECx/PGEDx pin pairs can be used to enter programming.

The internal process is regulated by a state machine built into the core logic of PIC32 devices; however, overall control of the process must be provided by the external programming device. Microchip programming devices, such as the MPLAB® PM 3 (used with MPLAB IDE software), include the necessary hardware and algorithms to manage the programming process for PIC32 devices. Users who are interested in a detailed description, or who are considering designing their own programming interface for PIC32 devices, should refer to the “*PIC32MX Flash Programming Specification*” (DS61145).

## 33.2.1.2 ENHANCED ICSP

The Enhanced ICSP protocol is an extension of the standard version of ICSP. It uses the same physical interface as the original, but changes the location and execution of programming control to a software application written to a PIC32 device. Use of Enhanced ICSP results in a significant decrease in overall programming time.

Standard ICSP uses a simple state machine to control each step of the programming process; however, that state machine is controlled by an external programmer. In contrast, Enhanced ICSP uses an on-board bootloader, known as the program executive, to manage the programming process. While overall device programming is still controlled by an external programmer, the program executive manages most of the tasks that must be directly controlled by the programmer in standard ICSP.

The program executive implements its own command set, wider in range than standard ICSP, that can directly erase, program and verify the device program memory. This avoids the need to repeatedly run ICSP command sequences to perform simple tasks. As a result, Enhanced ICSP is capable of programming or reprogramming a device faster than standard ICSP.

The program executive is not preprogrammed into a PIC32 device. If Enhanced ICSP is needed, the user must use standard ICSP to program the executive to the executive memory space in RAM. This can be done directly by the user, or automatically, using a compatible Microchip programming system. After the programming executive is written the device can be programmed using Enhanced ICSP.

For additional information on Enhanced ICSP and the program executive, refer to the “*PIC32MX Flash Programming Specification*” (DS61145).

## 33.2.1.3 DEVICE PROGRAMMING USING THE JTAG INTERFACE

The JTAG interface can also be used to program PIC32 devices in their target applications. The JTAG interface allows application designers to include a dedicated test and programming port into their applications, with a single 4-pin interface, without imposing the circuit constraints that the ICSP interface may require.

## 33.2.1.4 DEVICE PROGRAMMING USING THE ENHANCED JTAG INTERFACE

Enhanced JTAG programming uses the standard JTAG interface but utilizes a programming executive written to RAM. Use of the programming executive with the JTAG interface provides a significant improvement in programming speed.

### 33.2.2 Debugging

#### 33.2.2.1 ICSP AND IN-CIRCUIT DEBUGGING

ICSP also provides a hardware channel for the In-Circuit Debugger (ICD), which allows externally controlled debugging of software. Using the appropriate hardware interface and software environment, users can force the device to single-step through its code, track the actual content of multiple registers, and set software breakpoints.

To use ICD, an external system that supports ICD must load a debugger executive program into the microcontroller. This is automatically handled by many debugger tools, such as the MPLAB IDE. For PIC32 devices, the program is loaded into the last page of the boot Flash memory space. When not debugging, the application is free to use the last page of boot Flash memory.

ICSP for PIC32 devices supports standard debugging functions including memory and register viewing and modification. Breakpoints can be set and the program execution may be stopped or started. In addition to these functions, registers or memory contents can be viewed and modified while the CPU is running.

In contrast with programming, only one of the ICSP ports may be used for ICD. If more than one ICSP port is implemented, a Configuration bit determines which port is available. Depending on the particular PIC32 device, there may be two or more ICSP ports that can be selected for this function. The active ICSP debugger port is selected by the ICESEL Configuration bit(s). For information on a particular device, refer to the specific device data sheet.

#### 33.2.2.2 ENHANCED JTAG DEBUGGING

The industry standard Enhanced JTAG interface allows third-party Enhanced JTAG tools to be used for debugging. Using the Enhanced JTAG interface, memory and registers can be viewed and modified. Breakpoints can be set and the program execution may be stopped, started or single-stepped.

### 33.2.3 JTAG Boundary Scan

As the complexity and density of board designs increases, testing electrical connections between the components on fully assembled circuit boards poses many challenges. To address these challenges, a method for boundary scan testing was developed by the Joint Test Action Group that was later standardized as IEEE 1149.1-2001, "*IEEE Standard Test Access Port and Boundary Scan Architecture*". Since its adoption, many microcontroller manufacturers have added device programming to the capabilities of the test port.

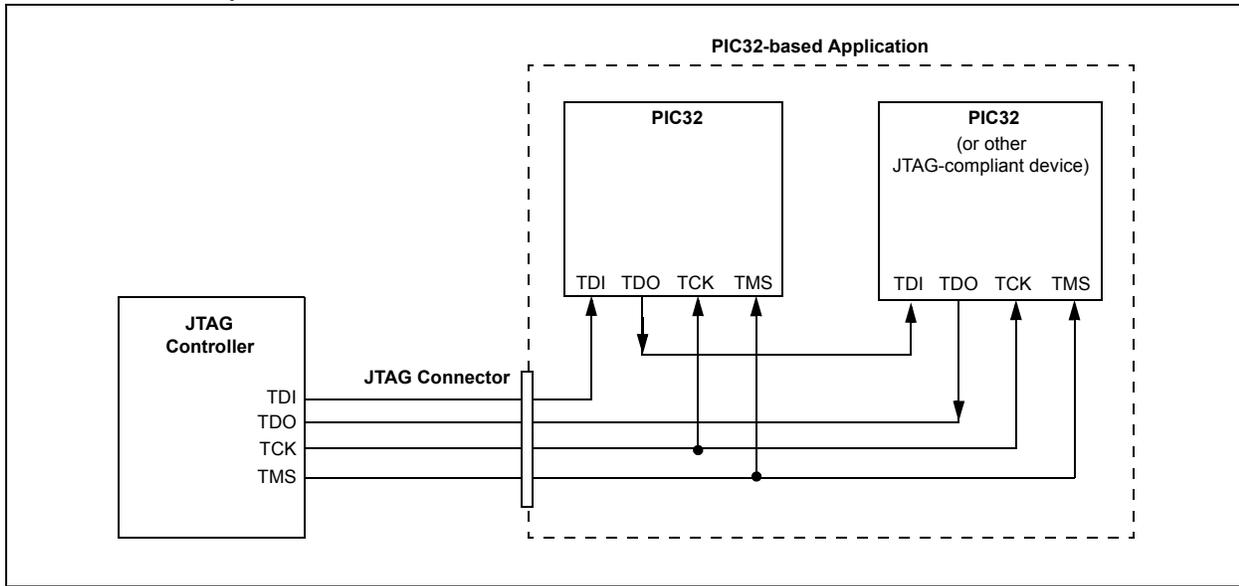
The JTAG boundary scan method is the process of adding a shift register stage adjacent to each of the component's I/O pins. This permits signals at the component boundaries to be controlled and observed, using a defined set of scan test principles. An external tester or controller provides instructions and reads the results in a serial fashion. The external device also provides common clock and control signals. Depending on the implementation, access to all test signals is provided through a standardized 4-pin interface.

In system-level applications, individual JTAG-enabled components are connected through their individual testing interfaces (in addition to their more standard application-specific connections). Devices are connected in a series or daisy-chained fashion, with the test output of one device connected exclusively to the test input of the next device in the chain. Instructions in the JTAG boundary scan protocol allow the testing of any one device in the chain, or any combination of devices, without testing the entire chain. In this method, connections between components, as well as connections at the boundary of the application, may be tested.

A typical application incorporating the JTAG boundary scan interface is shown in [Figure 33-3](#). In this example, a PIC32 family microcontroller is daisy-chained to a second JTAG-compliant device. Note that the TDI line from the external tester supplies data to the TDI pin of the first device in the chain (in this case, the microcontroller). The resulting test data for this two-device chain is provided from the TDO pin of the second device to the TDO line of the tester.

# PIC32 Family Reference Manual

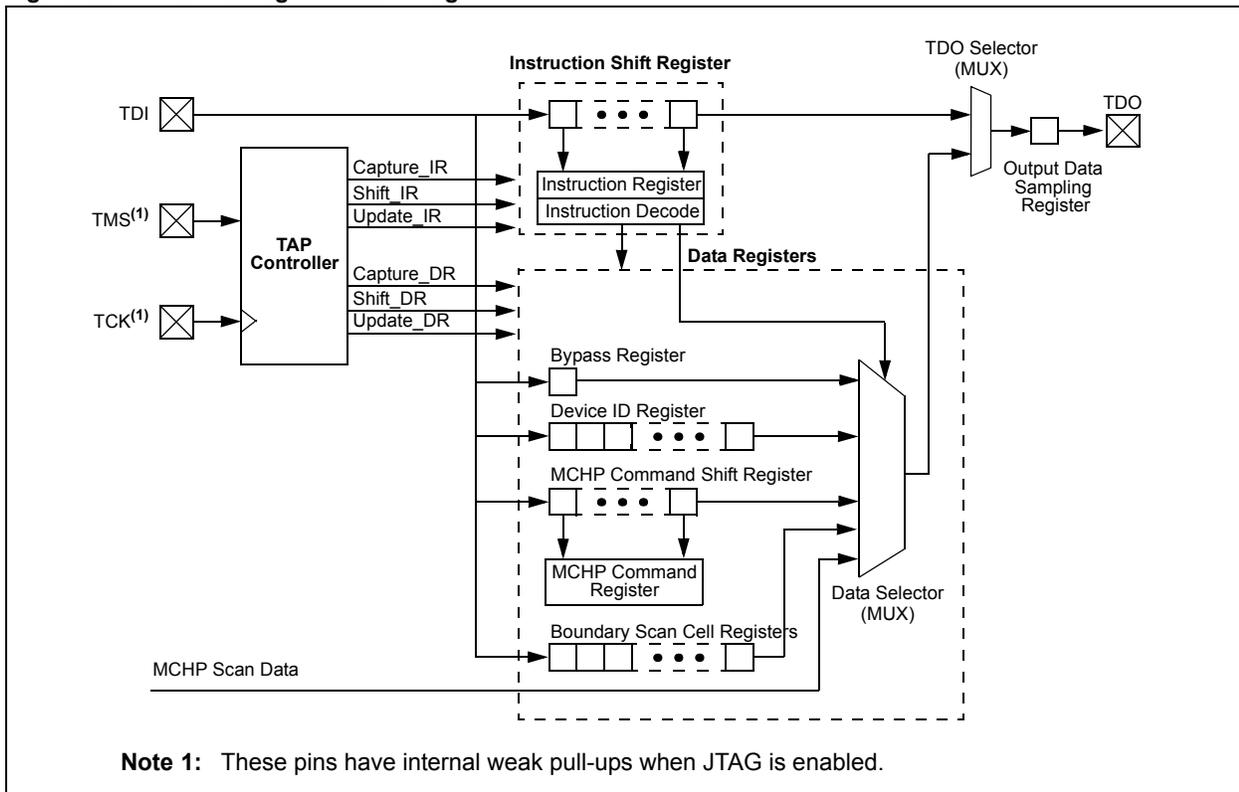
**Figure 33-3: Overview of PIC32 Family-based JTAG-compliant Application Showing Daisy-chaining of Components**



In PIC32 devices, the hardware for the JTAG boundary scan is implemented as a peripheral module (i.e., outside of the CPU core) with additional integrated logic in all I/O ports. A logical block diagram of the JTAG module is shown in [Figure 33-4](#). It consists of the following key elements:

- Test Access Port (TAP) Interface Pins (TDI, TMS, TCK and TDO)
- TAP Controller
- Instruction Shift Register and Instruction Register (IR)
- Data Registers (DR)

**Figure 33-4: JTAG Logical Block Diagram**



## 33.2.3.1 TEST ACCESS PORT (TAP) AND TAP CONTROLLER

The Test Access Port (TAP) on the PIC32 family of devices is a general purpose port that provides test access to many built-in support functions and test logic defined in the IEEE Standard 1149.1.

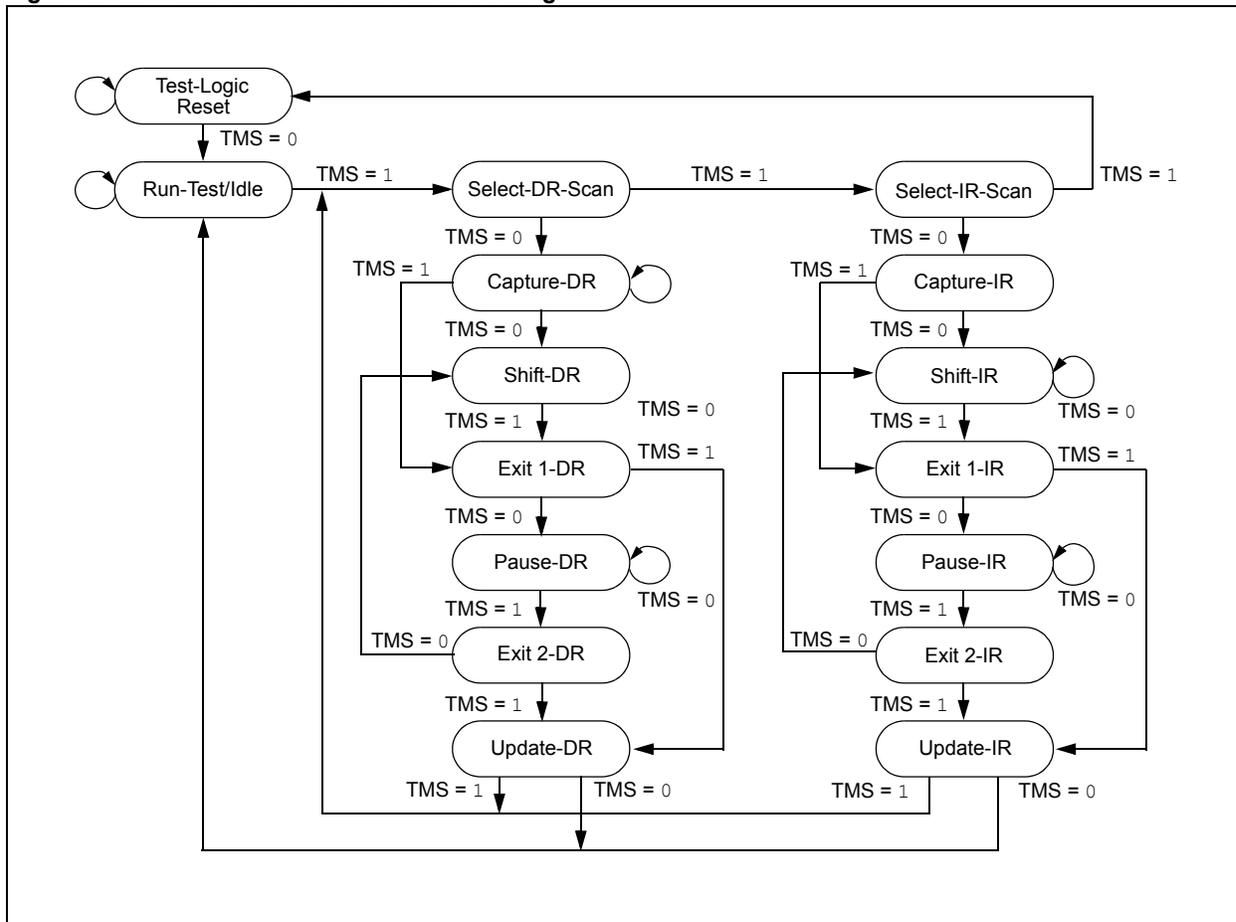
The PIC32 family of devices implements a 4-pin JTAG interface with these pins:

- TCK (Test Clock Input): Provides the clock for test logic
- TMS (Test Mode Select Input): Used by the TAP to control test operations
- TDI (Test Data Input): Serial input for test instructions and data
- TDO (Test Data Output): Serial output for test instructions and data

To minimize I/O loss due to JTAG, the optional TAP reset input pin, specified in the standard, is not implemented on the PIC32 family of devices. For convenience, a “soft” TAP reset has been included in the TAP controller, using the TMS and TCK pins. To force a port reset, apply a logic high to the TMS pin for at least five rising edges of TCK. Note that device Resets (including POR) do not automatically result in a TAP reset; this must be done by the external JTAG controller using the soft TAP reset.

The TAP controller on the PIC32 family of devices is a synchronous finite state machine that implements the standard 16 states for JTAG. Figure 33-5 shows all of the module states of the TAP controller. All Boundary Scan Testing (BST) instructions and test results are communicated through the TAP via the TDI pin in a serial format, Least Significant bit (LSb) first.

**Figure 33-5: TAP Controller Module State Diagram**



By manipulating the state of TMS and the clock pulses on TCK, the TAP controller can be moved through all of the defined module states to capture, shift, and update various instruction and/or data registers. Figure 33-5 shows the state changes on TMS as the controller cycles through its state machine. Figure 33-6 shows the timing of TMS and TCK while transitioning the controller through the appropriate module states for shifting in an instruction. In this example, the sequence shown demonstrates how an instruction is read by the TAP controller.

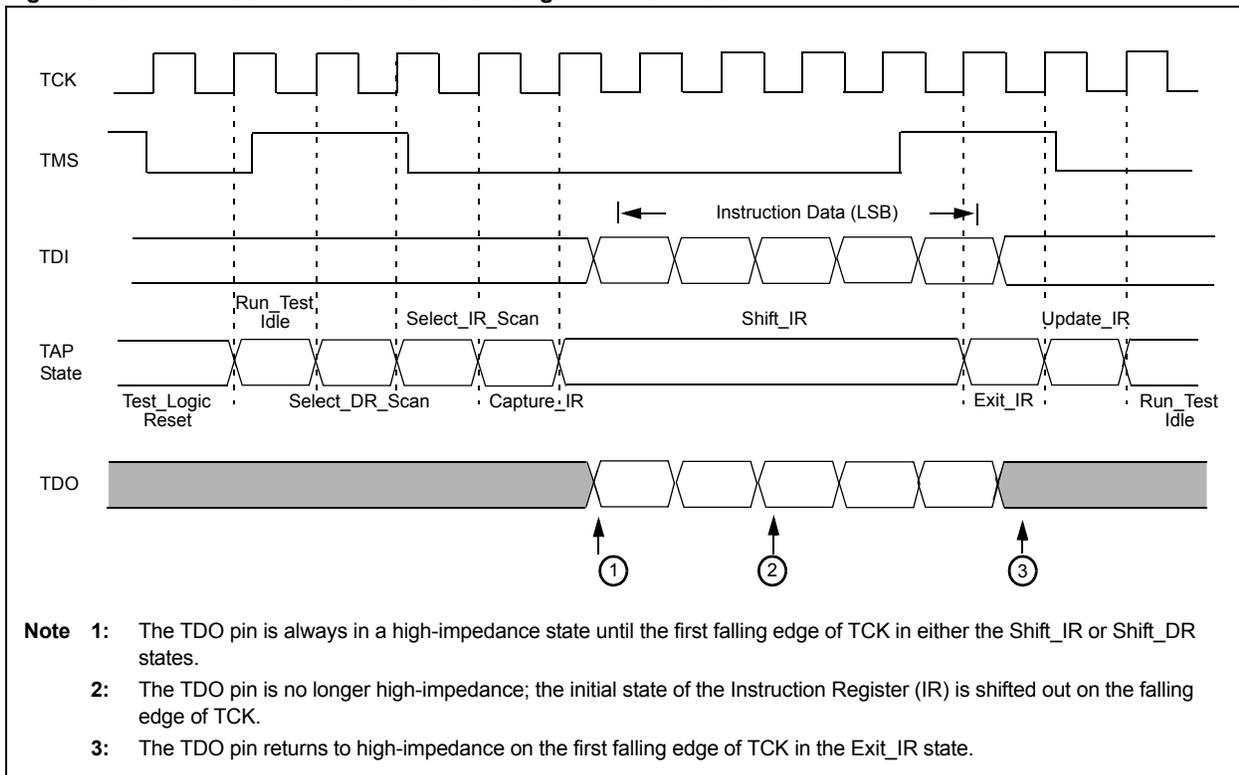
All TAP controller states are entered on the rising edge of the TCK pin. In this example, the TAP controller starts in the Test\_Logic Reset state. Since the state of the TAP controller is dependent on the previous instruction, and therefore could be unknown, it is good programming practice to begin in the Test\_Logic Reset state.

When TMS is asserted low on the next rising edge of TCK, the TAP controller will move into the Run\_Test/Idle state. On the next two rising edges of TCK, TMS is high, which moves the TAP controller to the Select\_IR\_Scan state.

On the next two rising edges of TCK, TMS is held low, which moves the TAP controller into the Shift\_IR state. An instruction is shifted into the instruction register (IR) via the TDI on the next four rising edges of TCK. After the TAP controller enters this state, the TDO pin goes from a high-impedance state to active. The controller shifts out the initial state of the IR on the TDO pin, on the falling edges of TCK, and continues to shift out the contents of the instruction register while in the Shift\_IR state. The TDO returns to the high-impedance state on the first falling edge of TCK upon exiting the shift state.

On the next three rising edges of TCK, the TAP controller exits the Shift\_IR state, updates the Instruction Register and then moves back to the Run\_Test/Idle state. Data, or another instruction, can now be shifted into the appropriate data or instruction register.

**Figure 33-6: TAP State Transitions for Shifting in an Instruction**



### 33.2.3.2 JTAG REGISTERS

The JTAG module uses a number of registers of various sizes as part of its operation. In terms of bit count, most of the JTAG registers are single-bit register cells, integrated into the I/O ports. Regardless of their location within the module, none of the JTAG registers are located within the device data memory space, and cannot be directly accessed by the user in normal operating modes.

#### 33.2.3.2.1 Instruction Register

The instruction register is a 5-bit shift register used for selecting the actions to be performed and/or what data registers to be accessed. Instructions are shifted in, Least Significant bit first, and then decoded.

A list and description of implemented instructions are provided in [33.2.3.4 “JTAG Instructions”](#).

#### 33.2.3.2.2 Data Registers

Once an instruction is shifted in and updated into the instruction register, the TAP controller places certain data registers between the TDI and TDO pins. Additional data values can then be shifted into these data registers as needed.

The PIC32 family of devices supports three data registers:

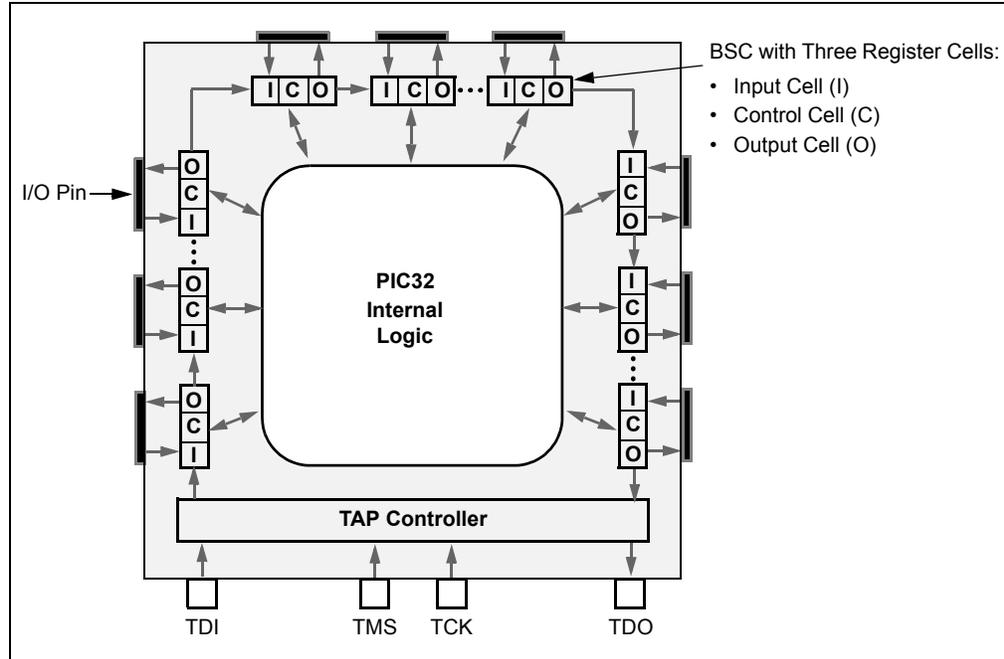
- **BYPASS Register:** A single-bit register which allows the boundary scan test data to pass through the selected device to adjacent devices. The BYPASS register is placed between the TDI and TDO pins when the `BYPASS` instruction is active.
- **Device ID Register:** A 32-bit part identifier. It consists of an 11-bit manufacturer ID assigned by the IEEE (0x29 for Microchip Technology), device part number and device revision identifier. When the `IDCODE` instruction is active, the device ID register is placed between the TDI and TDO pins. The device data ID is then shifted out on to the TDO pin, on the next 32 falling edges of TCK, after the TAP controller is in the `Shift_DR`.
- **MCHP Command Shift Register:** An 8-bit shift register that is placed between the TDI and TDO pins when the `MCHP_CMD` instruction is active. This shift register is used to shift in Microchip commands.

#### 33.2.3.3 BOUNDARY SCAN REGISTER (BSR)

The BSR is a large shift register that is comprised of all the I/O Boundary Scan Cells (BSCs), daisy-chained together ([Figure 33-7](#)). Each I/O pin has one BSC, each containing three BSC registers: an input cell, an output cell, and a control cell. When the `SAMPLE/PRELOAD` or `EXTEST` instructions are active, the BSR is placed between the TDI and TDO pins, with the TDI pin as the input and the TDO pin as the output.

The size of the BSR depends on the number of I/O pins on the device. For example, the 100-pin PIC32 general purpose devices have 82 I/O pins. With three BSC registers for each of the 82 I/Os, this yields a Boundary Scan register length of 244 bits. This is due to the `MCLR` pin being an input-only BSR cell. Information on the I/O port pin count of other PIC32 devices can be found in their specific device data sheets.

**Figure 33-7: Daisy-chained Boundary Scan Cell Registers on a PIC32 Microcontroller**



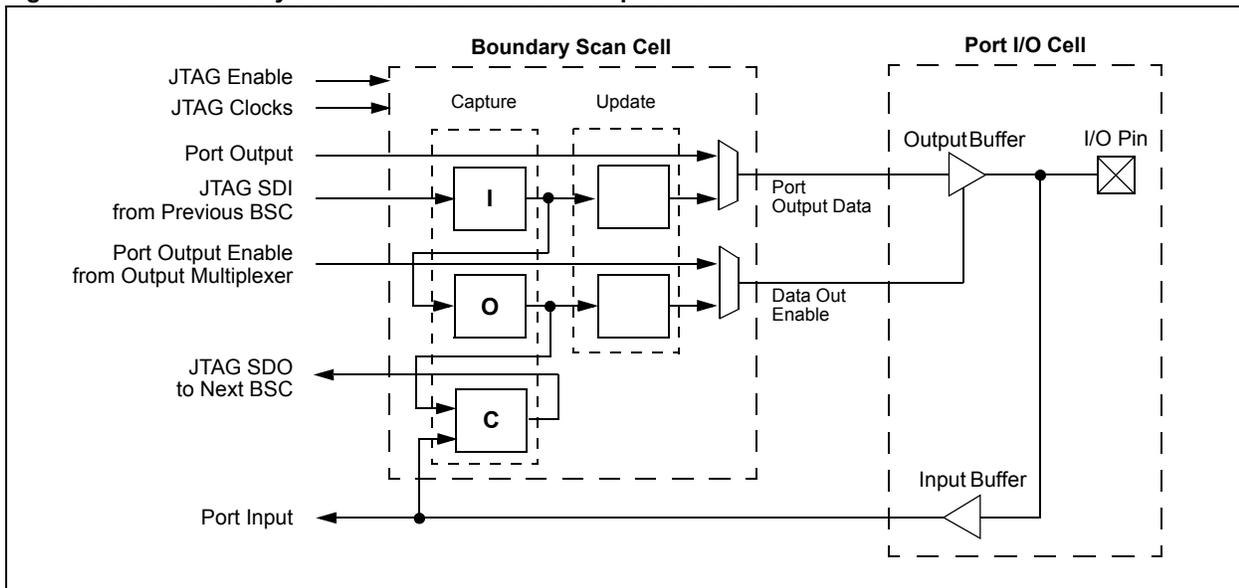
### 33.2.3.3.1 Boundary Scan Cell (BSC)

The function of the BSC is to capture and override I/O data values when JTAG is active. The BSC consists of three single-bit capture register cells and two single-bit holding register cells. The capture cells are daisy-chained to capture the port's input, output, and control (output-enable) data, as well as pass JTAG data along the Boundary Scan register. Command signals from the TAP controller determine if the port of JTAG data is captured, and how and when it is clocked out of the BSC.

The first register either captures internal data destined to the output driver, or provides serially scanned in data for the output driver. The second register captures internal output-enable control from the output driver and also provides serially scanned in output-enable values. The third register captures the input data from the I/O's input buffer.

Figure 33-8 shows a typical BSC and its relationship to the I/O port's structure.

**Figure 33-8: Boundary Scan Cell and Its Relationship to the I/O Port**



## 33.2.3.4 JTAG INSTRUCTIONS

The PIC32 family of devices supports the mandatory instruction set specified by IEEE 1149.1, as well as several optional public instructions defined in the specification. These devices also implement instructions that are specific to Microchip devices.

The mandatory JTAG instructions are:

- **BYPASS** (0x1F): Used for bypassing a device in a test chain, which allows the testing of off-chip circuitry and board-level interconnections
- **SAMPLE/PRELOAD** (0x02): Captures the I/O states of the component, providing a snapshot of its operation
- **EXTEST** (0x06): Allows the external circuitry and interconnections to be tested, by either forcing various test patterns on the output pins, or capturing test results from the input pins

Microchip has implemented optional JTAG instructions and manufacturer-specific JTAG commands in the PIC32 family of devices. For more information, refer to [Table 33-2](#), [Table 33-3](#), [Table 33-4](#), and [Table 33-5](#).

**Table 33-2: JTAG Commands**

OPCODE	Name	Device Integration
0x1F	Bypass	Bypasses device in test chain.
0x00	HIGHZ	Places device in a high-impedance state, all pins are forced to inputs.
0x01	ID Code	Shifts out the device's ID code.
0x02	Sample/Preload	Samples all pins or loads a specific value into output latch.
0x06	EXTEST	Boundary Scan.

**Table 33-3: Microchip TAP IR Commands**

OPCODE	Name	Device Integration
0x01	MTAP_IDCODE	Shifts out the device's ID code.
0x07	MTAP_COMMAND	Configure Microchip TAP controller for DR commands.
0x04	MTAP_SW_MTAP	Select Microchip TAP controller.
0x05	MTAP_SW_ETAP	Select Enhanced JTAG TAP controller.

**Table 33-4: Microchip TAP 8-bit DR Commands**

OPCODE	Name	Device Integration
0x00	MCHP_STATUS	Perform NOP and return status.
0xD1	MCHP_ASERT_RST	Request assert device Reset.
0xD0	MCHP_DE_ASSERT_RST	Request deassert device Reset.
0xFC	MCHP_ERASE	Perform a Chip Erase.
0xFE	MCHP_FLASH_ENABLE	Enables fetches and loads to the Flash from the CPU.
0xFD	MCHP_FLASH_DISABLE	Disables fetches and loads to the Flash from the CPU.
0xFF	MCHP_READ_CONFIG	Forces device to reread the configuration settings and initialize accordingly.

**Table 33-5: Enhanced JTAG Commands**

OPCODE	Name	Device Integration	Data Length for the Following DR
0x00	—	Not used.	—
0x01	IDCODE	Selects the device's ID code register.	32 bits
0x02	—	Not used.	—
0x03	IMPCODE	Selects the implementation register.	—
0x04 <sup>(2)</sup>	MTAP_SW_MTAP	Selects the Microchip TAP controller.	—
0x05 <sup>(2)</sup>	MTAP_SW_ETAP	Selects the Enhanced JTAG TAP controller.	—
0x06-0x07	—	Not used.	—
0x08	ADDRESS	Selects the address register.	32 bits
0x09	DATA	Selects the data register.	32 bits
0x0A	CONTROL	Selects the Enhanced JTAG control register	32 bits
0x0B	ALL	Selects the address, data, and Enhanced JTAG control registers.	96 bits
0x0C	EJTAGBOOT	Forces the CPU to take a debug exception after a boot.	1-bit
0x0D	NORMALBOOT	Makes the CPU execute the reset handler after a boot.	1-bit
0x0E	FASTDATA	Selects the data and fast data registers.	1-bit
0x0F-0x1B	—	Reserved.	—
0x1C-0xFE	—	Not used.	—
0xFF	—	Selects the BYPASS register.	—

**Note 1:** Refer to the Enhanced JTAG Specification for information about this protocol and its commands, which is available from MIPS Technologies ([www.mips.com](http://www.mips.com)).

**2:** This opcode is not an Enhanced JTAG command, but is recognized by the Microchip implementation.

### 33.2.4 Boundary Scan Testing (BST)

BST is the method of controlling and observing the boundary pins of the JTAG-compliant device, such as PIC32 devices, utilizing software control. BST can be used to test connectivity between devices by daisy-chaining JTAG compliant devices to form a single scan chain. Several scan chains can exist on a PCB to form multiple scan chains. These multiple scan chains can then be driven simultaneously to test many components in parallel. Scan chains can contain both JTAG-compliant devices and non-JTAG-compliant devices.

A key advantage of BST is that it can be implemented without physical test probes; all that is needed is a 4-wire interface and an appropriate test platform. Since JTAG boundary scan has been available for many years, many software tools exist for testing scan chains without the need for extensive physical probing. The main drawback to BST is that it can only evaluate digital signals and circuit continuity; it cannot measure input or output voltage levels or currents.

#### 33.2.4.1 RELATED JTAG FILES

To implement BST, all JTAG test tools will require a Boundary Scan Description Language (BSDL) file. BSDL is a subset of VHDL (VHSIC Hardware Description Language), and is described as part of IEEE Std. 1149.1. The device-specific BSDL file describes how the standard is implemented on a particular device and how it operates.

The BSDL file for a particular device includes the following:

- The pinout and package configuration for the particular device
- The physical location of the TAP pins
- The Device ID register and the device ID
- The length of the Instruction Register
- The supported BST instructions and their binary codes
- The length and structure of the Boundary Scan register
- The boundary scan cell definition

### 33.3 INTERRUPTS

Programming and debugging operations are not performed during code execution and are therefore not affected by interrupts. Trace operations will report the change in code execution when an interrupt occurs but the trace controller is not affected by interrupts.

### 33.4 OPERATION IN POWER-SAVING MODES

PIC32 devices must be awake for all programming and debugging operations.

### 33.5 EFFECTS OF RESETS

#### 33.5.1 Device Reset

A device Reset by asserting  $\overline{\text{MCLR}}$  while in ICSP mode will force the ICSP to exit. Asserting  $\overline{\text{MCLR}}$  will force an exit from Enhanced JTAG mode.

#### 33.5.2 Watchdog Timer Reset

A Watchdog Timer (WDT) Reset during erase will not abort the erase cycle. The WDT event flag will be set to show that a WDT Reset has occurred.

A WDT Reset during an Enhanced JTAG session will reset the TAP controller to the Microchip TAP controller.

A WDT Reset during programming will abort the programming sequence.

## 33.6 RELATED APPLICATION NOTES

This section lists application notes that are related to this section of the manual. These application notes may not be written specifically for the PIC32 family of devices, but the concepts are pertinent and could be used with modification and possible limitations. The current application notes related to Programming and Diagnostics are:

Title	Application Note #
No related application notes at this time.	N/A

**Note:** Please visit the Microchip web site ([www.microchip.com](http://www.microchip.com)) for additional application notes and code examples for the PIC32 family of devices.

## 33.7 REVISION HISTORY

### Revision A (September 2007)

This is the initial released version of this document.

### Revision B (October 2007)

Updated document to remove Confidential status.

### Revision C (April 2008)

Revised document status to Preliminary; Revised U-0 to r-x.

### Revision D (June 2008)

This revision includes the following updates:

- Added a Note to **33.3.1 “Device Programming Options”**
- Revised **33.3.2.1 “ICSP and In-Circuit Debugging”**
- Revised Table 33-7
- Change Reserved bits from “Maintain as” to “Write” in all registers

### Revision E (August 2009)

This revision includes the following updates:

- Minor updates to text and formatting have been incorporated throughout the document
- Added the FJTAGEN bit and removed bits DDPU1, DDPU2 and DDPSP11 from Table 33-2: Programming and Diagnostics SFR Summary
- Added FJTAGEN bit and removed bits DDPUSB, DDPU1, DDPU2 and DDPSP11 from Register 33-1: DDPCON: Debug Data Port Control Register

### Revision F (February 2012)

This revision includes the following updates:

- Updated the Programming, Debugging, and Trace Ports Block Diagram (see [Figure 33-1](#))
- Added Note 1 to the JTAG Logical Block Diagram (see [Figure 33-4](#))
- Removed the Programming and Diagnostics SFR Summary (Table 33-2)
- Removed the DDPCON and DEVCFG0 registers (Register 33-1 and Register 33-2)
- Removed **33.3.3 “Special Debug Modes for Select Communication Peripherals”**
- Updated the first paragraph of **33.2.3.1 “Test Access Port (TAP) and TAP Controller”**
- Updated **33.2.4.1 “Related JTAG Files”**
- Removed **33.2 “Control Registers”**
- Removed **33.5 “I/O Pins”**
- Removed **33.8 “Application Ideas”**
- All references to the PGC and PGD pins have been updated to: PGECx and PGEDx
- All references to EJTAG were updated to: Enhanced JTAG
- All references to EICSP were updated to: Enhanced ICSP
- All occurrences of PIC32MX have been replaced with PIC32, with the exception of references to the *“PIC32MX Flash Programming Specification”* (DS61145)
- Formatting modifications and text updates were incorporated throughout the document

NOTES:

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**Note the following details of the code protection feature on Microchip devices:**

- Microchip products meet the specification contained in their particular Microchip Data Sheet.
- Microchip believes that its family of products is one of the most secure families of its kind on the market today, when used in the intended manner and under normal conditions.
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