

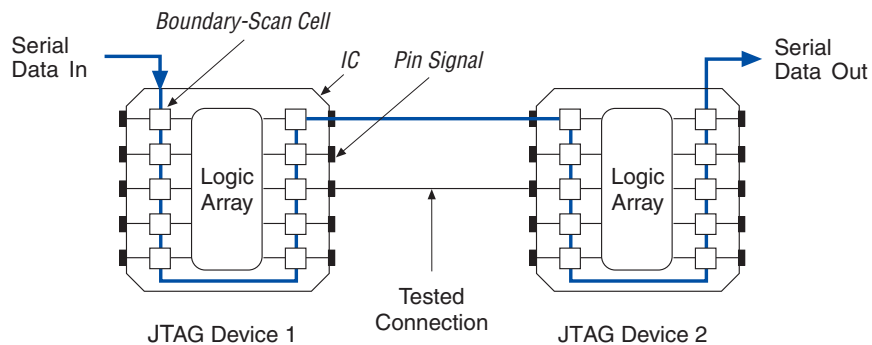
Introduction

As printed circuit boards (PCBs) become more complex, the need for thorough testing becomes increasingly important.

In the 1980s, the Joint Test Action Group (JTAG) developed a specification for boundary-scan testing that was later standardized as the IEEE Std. 1149.1 specification. This boundary-scan test (BST) architecture offers the capability to test efficiently components on PCBs with tight lead spacing.

BST architecture tests pin connections without using physical test probes and captures functional data while a device is operating normally. Boundary-scan cells in a device can force signals onto pins or capture data from pin or logic array signals. Forced test data is serially shifted into the boundary-scan cells. Captured data is serially shifted out and externally compared to expected results. [Figure 13–1](#) illustrates the concept of BST.

Figure 13–1. IEEE Std. 1149.1 Boundary-Scan Testing



This chapter discusses how to use the IEEE Std. 1149.1 BST circuitry in Stratix® III devices, including:

- [“IEEE Std. 1149.1 BST Architecture” on page 13–2](#)
- [“IEEE Std. 1149.1 Boundary-Scan Register” on page 13–4](#)
- [“IEEE Std. 1149.1 BST Operation Control” on page 13–6](#)
- [“I/O Voltage Support in JTAG Chain” on page 13–16](#)
- [“IEEE Std. 1149.1 BST Circuitry” on page 13–17](#)
- [“IEEE Std. 1149.1 BST for Configured Devices” on page 13–18](#)
- [“IEEE Std. 1149.1 BST Circuitry \(Disabling\)” on page 13–18](#)
- [“IEEE Std. 1149.1 BST Guidelines” on page 13–19](#)
- [“Boundary-Scan Description Language \(BSDL\) Support” on page 13–19](#)

In addition to BST, you can use the IEEE Std. 1149.1 controller for Stratix III device in-circuit reconfiguration (ICR). However, this chapter only discusses the BST feature of the IEEE Std. 1149.1 circuitry.

 For information about configuring Stratix III devices via the IEEE Std. 1149.1 circuitry, refer to the *Configuring Stratix III Devices, Hot Socketing and Power-On Reset in Stratix III Devices*, and the *Remote System Upgrades with Stratix III Devices* chapters in volume 1 of the *Stratix III Device Handbook*.

IEEE Std. 1149.1 BST Architecture

A Stratix III device operating in IEEE Std. 1149.1 BST mode uses four required pins, TDI, TDO, TMS, and TCK, and one optional pin, TRST. The TCK pin has an internal weak pull-down resistor; the TDI, TMS, and TRST pins have weak internal pull-ups. The TDO output pin and all of the JTAG input pins are powered by the 2.5-V/3.0-V/3.3-V V_{CCPD} supply of I/O Bank 1A. All user I/O pins are tri-stated during JTAG configuration.


 For recommendations about how to connect a JTAG chain with multiple voltages across the devices in the chain, refer to “I/O Voltage Support in JTAG Chain” on page 13–16.

Table 13–1 summarizes the functions of each of these pins.

Table 13–1. IEEE Std. 1149.1 Pin Descriptions

Pin	Description	Function
TDI	Test data input	Serial input pin for instructions as well as test and programming data. Signal applied to TDI is expected to change state at the falling edge of TCK. Data is shifted in on the rising edge of TCK.
TDO	Test data output	Serial data output pin for instructions as well as test and programming data. Data is shifted out on the falling edge of TCK. The pin is tri-stated if data is not being shifted out of the device.
TMS	Test mode select	Input pin that provides the control signal to determine the transitions of the test access port (TAP) controller state machine. Transitions within the state machine occur at the rising edge of TCK. Therefore, you must set up TMS before the rising edge of TCK. TMS is evaluated on the rising edge of TCK. During non-JTAG operation, Altera recommends you drive TMS high.
TCK	Test clock input	The clock input to the BST circuitry. Some operations occur at the rising edge, while others occur at the falling edge.
TRST (1)	Test reset input (optional)	Active-low input to asynchronously reset the boundary-scan circuit. You should drive this pin low when not in boundary-scan operation. For non-JTAG users, you should permanently tie the pin to GND.

Note to Table 13–1:

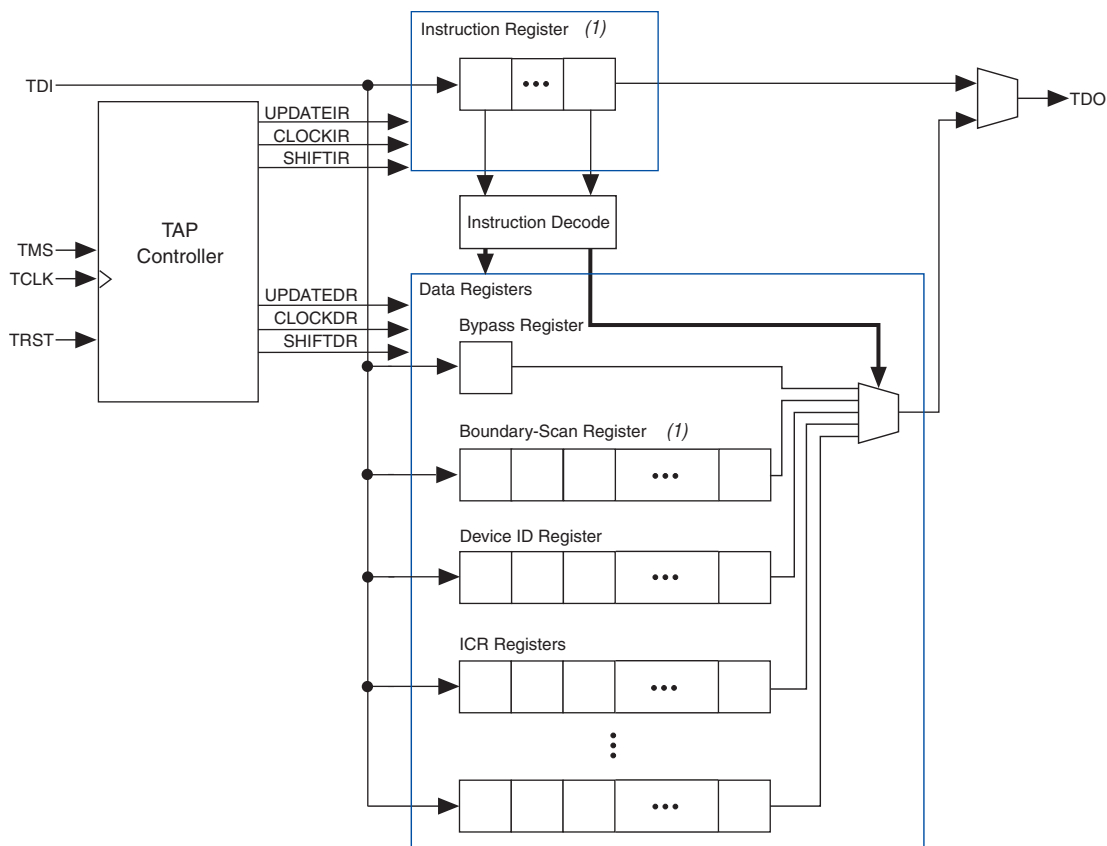
(1) The minimum TRST pulse width to reset the JTAG TAP controller is 60ns.

The IEEE Std. 1149.1 BST circuitry requires the following registers:

- The instruction register determines the action to be performed and the data register to be accessed.
- The bypass register is a one-bit-long data register that provides a minimum-length serial path between TDI and TDO.
- The boundary-scan register is a shift register composed of all the boundary-scan cells of the device.

Figure 13–2 shows a functional model of the IEEE Std. 1149.1 circuitry.

Figure 13–2. IEEE Std. 1149.1 Circuitry



Note to Figure 13–2:

(1) For register lengths, refer to the device data sheet in the *Configuring Stratix III Devices* chapter in volume 1 of the *Stratix III Device Handbook*.

IEEE Std. 1149.1 boundary-scan testing is controlled by a TAP controller. For more information about the TAP controller, refer to “IEEE Std. 1149.1 BST Operation Control” on page 13–6. The TMS and TCK pins operate the TAP controller. The TDI and TDO pins provide the serial path for the data registers. The TDI pin also provides data to the instruction register, which then generates control logic for the data registers.

IEEE Std. 1149.1 Boundary-Scan Register

The boundary-scan register is a large serial shift register that uses the TDI pin as an input and the TDO pin as an output. The boundary-scan register consists of three-bit peripheral elements that are associated with Stratix III I/O pins. You can use the boundary-scan register to test external pin connections or to capture internal data.

For the Stratix III family device boundary-scan register lengths, refer to the *Configuring Stratix III Devices* chapter in volume 1 of the *Stratix III Device Handbook*.

Figure 13-3 shows how test data is serially shifted around the periphery of the IEEE Std. 1149.1 device.

Figure 13-3. Boundary-Scan Register

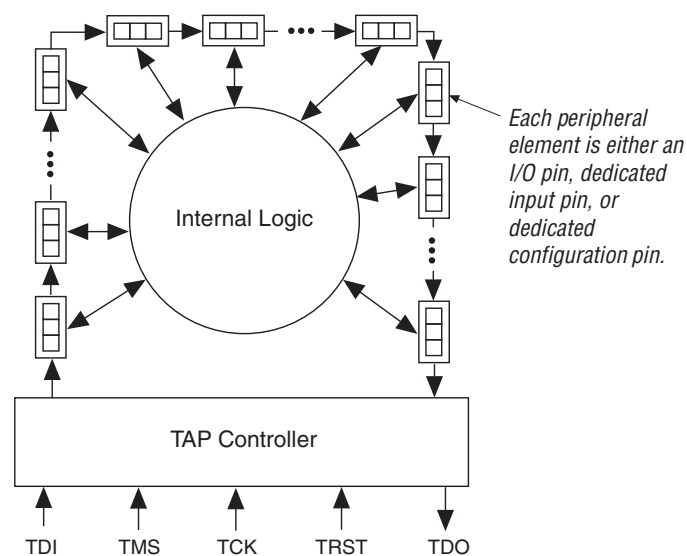


Table 13-2 shows the boundary-scan register length for Stratix III devices.

Table 13-2. Stratix III Boundary-Scan Register Length

Device	Boundary-Scan Register Length
EP3SL50	1506
EP3SL70	1506
EP3SL110	2274
EP3SL150ES	2274
EP3SL150	2274
EP3SL200	2970
EP3SL340	3402
EP3SE50	1506
EP3SE80	2274
EP3SE110	2274
EP3SE260	2970

Boundary-Scan Cells of a Stratix III Device I/O Pin

The Stratix III device three-bit boundary-scan cell (BSC) consists of a set of capture registers and a set of update registers. The capture registers can connect to internal device data via the OUTJ, OEJ, and PIN_IN signals, while the update registers connect to external data through the PIN_OUT, and PIN_OE signals.

The global control signals for the IEEE Std. 1149.1 BST registers (such as shift, clock, and update) are generated internally by the TAP controller. The MODE signal is generated by a decode of the instruction register. The HIGHZ signal is high when executing the HIGHZ instruction. The data signal path for the boundary-scan register runs from the serial data in (SDI) signal to the serial data out (SDO) signal. The scan register begins at the TDI pin and ends at the TDO pin of the device.

Figure 13-4 shows the Stratix III device's user I/O boundary-scan cell.

Figure 13-4. Stratix III Device's User I/O BSC with IEEE Std. 1149.1 BST Circuitry

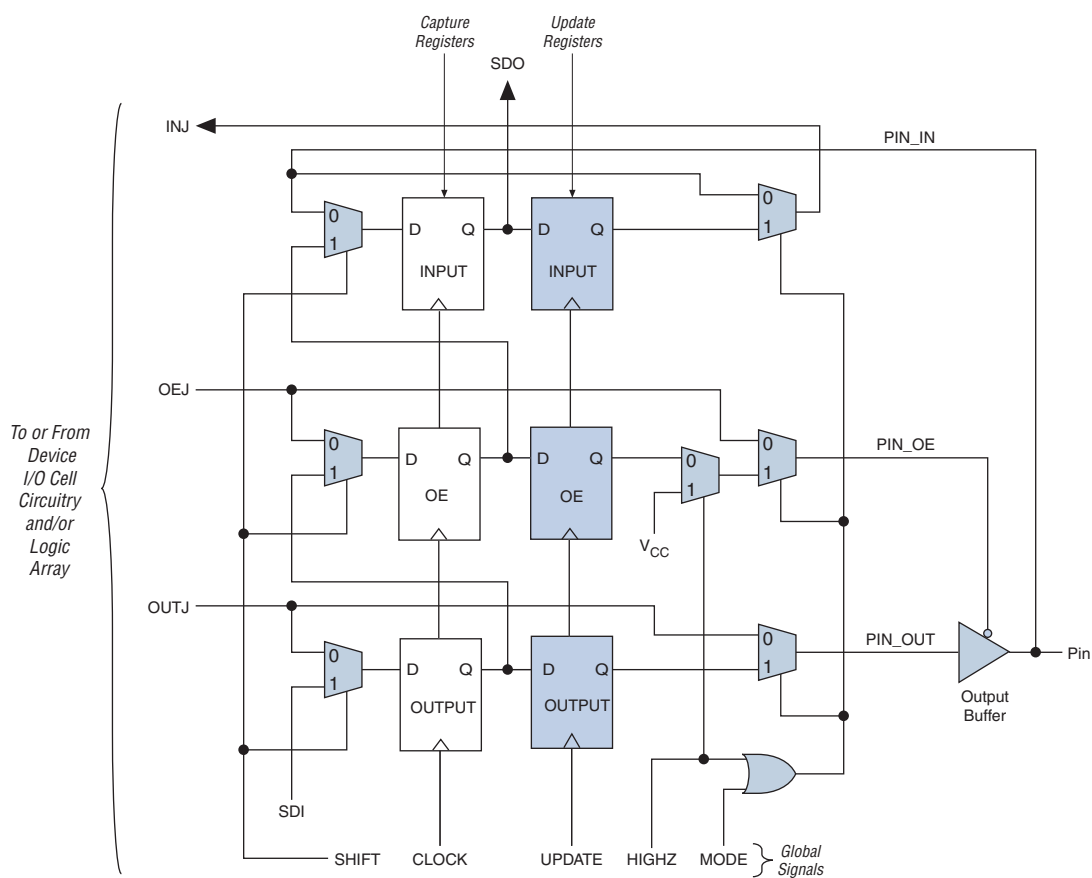


Table 13-3 describes the capture and update register capabilities of all boundary-scan cells within Stratix III devices.

Table 13-3. Stratix III Device Boundary Scan Cell Descriptions (Note 1)

Pin Type	Captures			Drives			Comments
	Output Capture Register	OE Capture Register	Input Capture Register	Output Update Register	OE Update Register	Input Update Register	
User I/O pins	OUTJ	OEJ	PIN_IN	PIN_OUT	PIN_OE	INJ	NA
Dedicated clock input	0	1	PIN_IN	—	—	—	PIN_IN drives to clock network or logic array
Dedicated input (2)	0	1	PIN_IN	—	—	—	PIN_IN drives to control logic
Dedicated bidirectional (open drain) (3)	0	OEJ	PIN_IN	—	—	—	PIN_IN drives to configuration control
Dedicated bidirectional (4)	OUTJ	OEJ	PIN_IN	—	—	—	PIN_IN drives to configuration control and OUTJ drives to output buffer
Dedicated output (5)	OUTJ	0	0	—	—	—	OUTJ drives to output buffer

Notes to Table 13-3:

- (1) TDI, TDO, TMS, TCK, TRST, all V_{CC} and GND pin types, VREF, and TEMP_DIODE pins do not have BSCs.
- (2) This includes pins PLL_ENA, nCONFIG, MSEL0, MSEL1, MSEL2, nCE, PORSEL, and nIO_PULLUP.
- (3) This includes pins CONF_DONE and nSTATUS.
- (4) This includes pin DCLK.
- (5) This includes pin nCEO.

IEEE Std. 1149.1 BST Operation Control

Stratix III devices support the IEEE Std. 1149.1 (JTAG) instructions shown in Table 13-4.

Table 13-4. Stratix III JTAG Instructions

JTAG Instruction	Instruction Code	Description
SAMPLE / PRELOAD	00 0000 0101	Allows a snapshot of signals at the device pins to be captured and examined during normal device operation, and permits an initial data pattern to be output at the device pins. Also used by the SignalTap® II embedded logic analyzer.
EXTEST (1)	00 0000 1111	Allows the external circuitry and board-level interconnects to be tested by forcing a test pattern at the output pins and capturing test results at the input pins.
BYPASS	11 1111 1111	Places the 1-bit bypass register between the TDI and TDO pins, which allows the BST data to pass synchronously through selected devices to adjacent devices during normal device operation.

Table 13-4. Stratix III JTAG Instructions

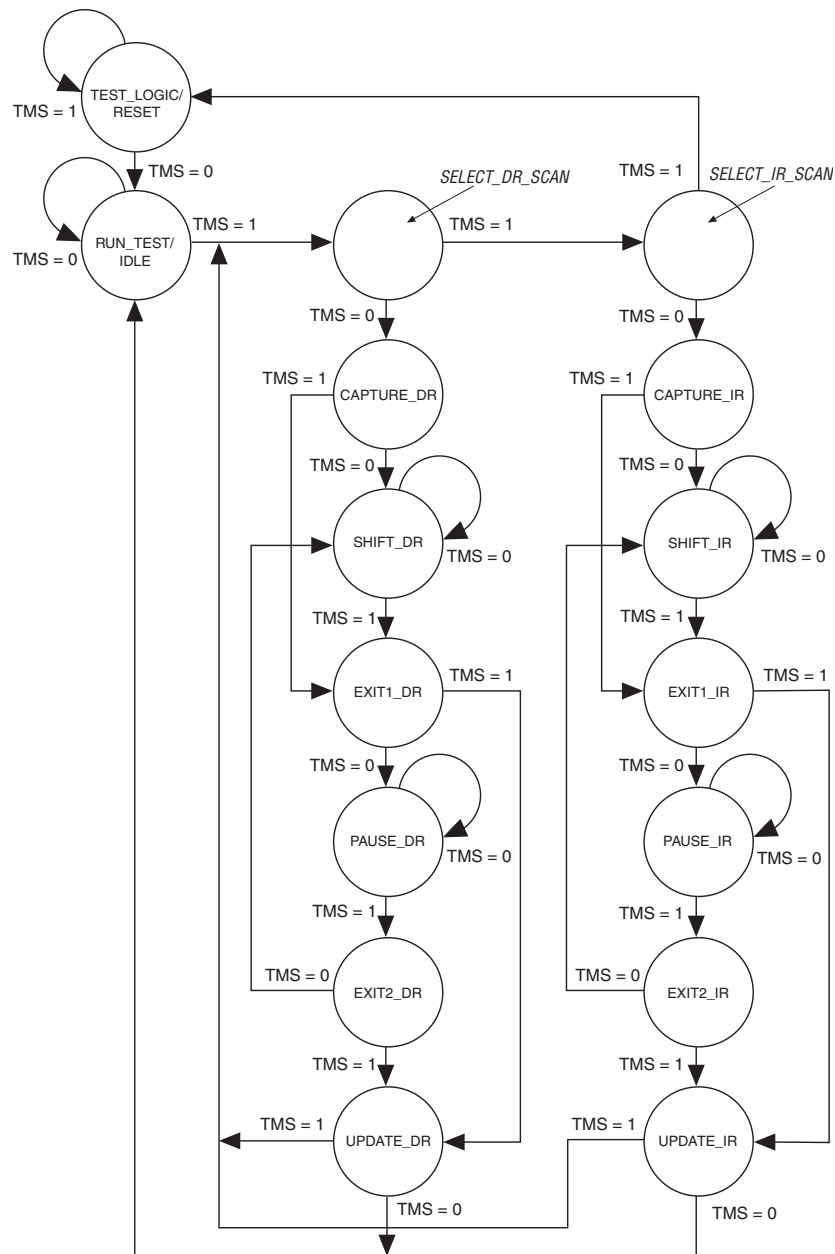
JTAG Instruction	Instruction Code	Description
USERCODE	00 0000 0111	Places the 32-bit device identification register between TDI and TDO. The USERCODE value will be loaded into this Device ID register for shifting out via TDO.
IDCODE	00 0000 0110	Selects the IDCODE register and places it between TDI and TDO, allowing the IDCODE to be serially shifted out of TDO.
HIGHZ (1)	00 0000 1011	Places the 1-bit bypass register between the TDI and TDO pins, which allows the BST data to pass synchronously through selected devices to adjacent devices during normal device operation, while tri-stating all of the I/O pins.
CLAMP (1)	00 0000 1010	Places the 1-bit bypass register between the TDI and TDO pins, which allows the BST data to pass synchronously through selected devices to adjacent devices during normal device operation while holding I/O pins to a state defined by the data in the boundary-scan register.
ICR instructions	—	Used when configuring a Stratix III device via the JTAG port with a USB Blaster™, ByteBlaster™ II, MasterBlaster™ or ByteBlasterMV™ download cable, or when using a Jam File, or JBC File via an embedded processor.
PULSE_NCONFIG	00 0000 0001	Emulates pulsing the nCONFIG pin low to trigger reconfiguration even though the physical pin is unaffected.
CONFIG_IO	00 0000 1101	Allows I/O reconfiguration through JTAG ports using the IOCSR for JTAG testing. Can be executed before, after, or during configurations.

Note to Table 13-4:

(1) Bus hold and weak pull-up resistor features override the high-impedance state of the HIGHZ, CLAMP, and EXTEST instruction.

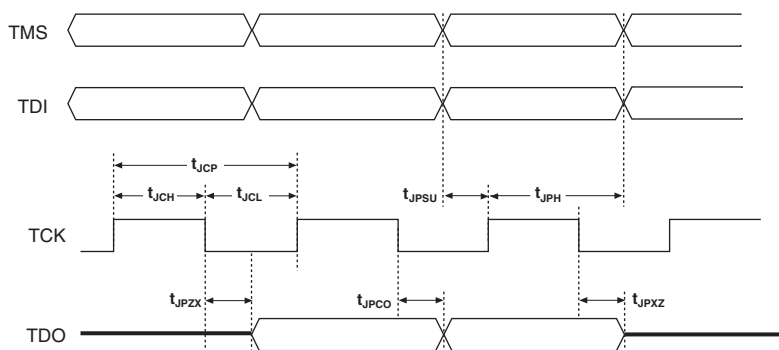
The IEEE Std. 1149.1 TAP controller, a 16-state machine clocked on the rising edge of TCK, uses the TMS pin to control IEEE Std. 1149.1 operation in the device. Figure 13-5 shows the TAP controller state machine.

Figure 13-5. IEEE Std. 1149.1 TAP Controller State Machine



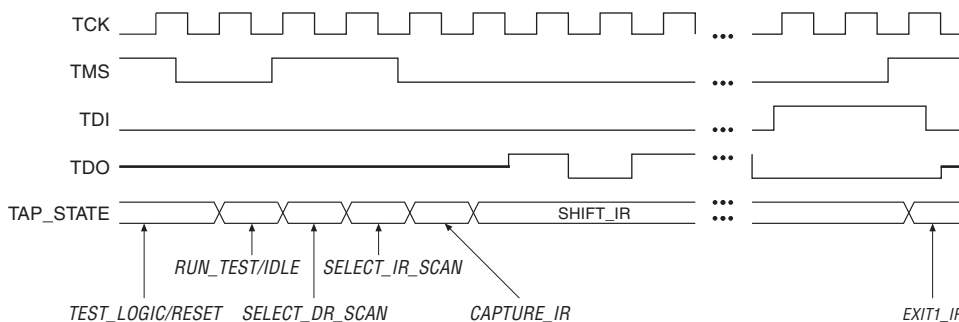
When the TAP controller is in the TEST_LOGIC/RESET state, the BST circuitry is disabled, the device is in normal operation, and the instruction register is initialized with IDCODE as the initial instruction. At device power-up, the TAP controller starts in this TEST_LOGIC/RESET state. In addition, forcing the TAP controller to the TEST_LOGIC/RESET state is achieved by holding TMS high for five TCK clock cycles, or by holding the TRST pin low. Once in the TEST_LOGIC/RESET state, the TAP controller remains in this state as long as TMS is held high (while TCK is clocked) or TRST is held low. Figure 13-6 shows the timing requirements for the IEEE Std. 1149.1 signals.

Figure 13-6. IEEE Std. 1149.1 Timing Waveforms



To start IEEE Std. 1149.1 operation, select an instruction mode by advancing the TAP controller to the shift instruction register (SHIFT_IR) state and shift in the appropriate instruction code on the TDI pin. The waveform diagram in Figure 13-7 represents the entry of the instruction code into the instruction register. It also shows the values of TCK, TMS, TDI, TDO, and the states of the TAP controller. From the RESET state, TMS is clocked with the pattern 01100 to advance the TAP controller to SHIFT_IR.

Figure 13-7. Selecting the Instruction Mode



The TDO pin is tri-stated in all states except in the SHIFT_IR and SHIFT_DR states. The TDO pin is activated at the first falling edge of TCK after entering either of the shift states and is tri-stated at the first falling edge of TCK after leaving either of the shift states.

When the SHIFT_IR state is activated, TDO is no longer tri-stated, and the initial state of the instruction register is shifted out on the falling edge of TCK. TDO continues to shift out the contents of the instruction register as long as the SHIFT_IR state is active. The TAP controller remains in the SHIFT_IR state as long as TMS remains low.

During the SHIFT_IR state, an instruction code is entered by shifting data on the TDI pin on the rising edge of TCK. The last bit of the instruction code is clocked at the same time that the next state, EXIT1_IR, is activated. Set TMS high to activate the EXIT1_IR state. Once in the EXIT1_IR state, TDO becomes tri-stated again. TDO is always tri-stated except in the SHIFT_IR and SHIFT_DR states. After an instruction code is entered correctly, the TAP controller advances to serially shift test data in one of three modes.

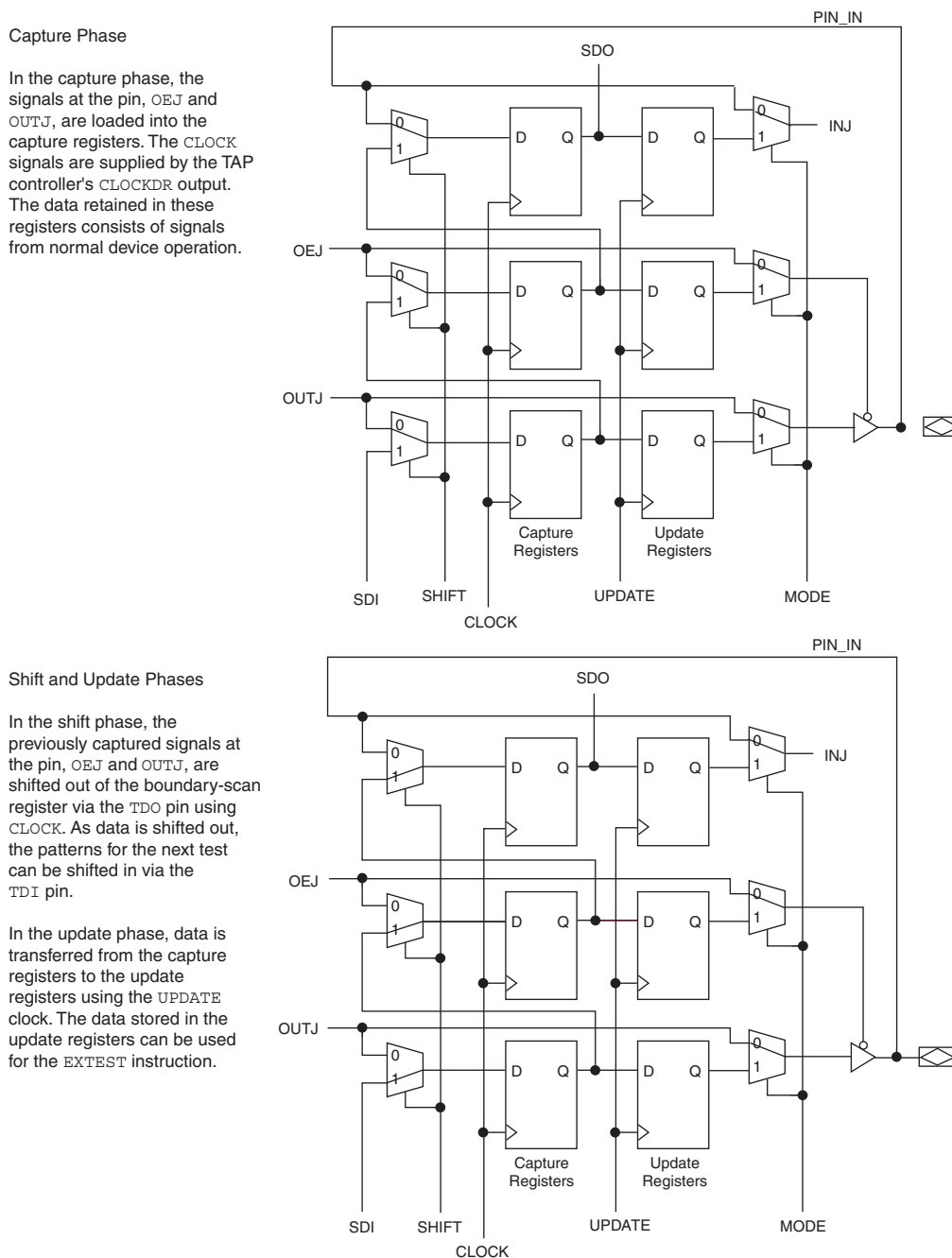
The three serially shift test data instruction modes are discussed in the following sections:

- “SAMPLE/PRELOAD Instruction Mode” on page 13-10
- “EXTEST Instruction Mode” on page 13-12
- “BYPASS Instruction Mode” on page 13-14

SAMPLE/PRELOAD Instruction Mode

The SAMPLE/PRELOAD instruction mode allows you to take a snapshot of device data without interrupting normal device operation. However, this instruction is most often used to preload the test data into the update registers prior to loading the EXTEST instruction. Figure 13-8 shows the capture, shift, and update phases of the SAMPLE/PRELOAD mode.

Figure 13-8. IEEE Std. 1149.1 BST SAMPLE/PRELOAD Mode

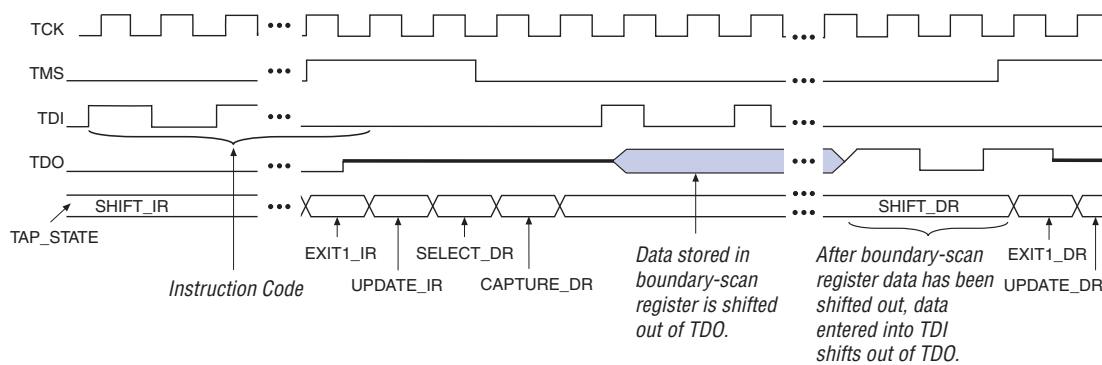


During the capture phase, multiplexers preceding the capture registers select the active device data signals. This data is then clocked into the capture registers. The multiplexers at the outputs of the update registers also select active device data to prevent functional interruptions to the device. During the shift phase, the boundary-scan shift register is formed by clocking data through the capture registers

around the device periphery and then out of the TDO pin. The device can simultaneously shift new test data into TDI and replace the contents of the capture registers. During the update phase, data in the capture registers is transferred to the update registers. You can then use this data in the EXTEST instruction mode. Refer to “EXTEST Instruction Mode” on page 13-12 for more information.

Figure 13-9 shows the SAMPLE/PRELOAD waveforms. The SAMPLE/PRELOAD instruction code is shifted in through the TDI pin. The TAP controller advances to the CAPTURE_DR state and then to the SHIFT_DR state, where it remains if TMS is held low. The data that was present in the capture registers after the capture phase is shifted out of the TDO pin. New test data shifted into the TDI pin appears at the TDO pin after being clocked through the entire boundary-scan register. If TMS is held high on two consecutive TCK clock cycles, the TAP controller advances to the UPDATE_DR state for the update phase.

Figure 13-9. SAMPLE/PRELOAD Shift Data Register Waveforms



EXTEST Instruction Mode

Use the EXTEST instruction mode primarily to check external pin connections between devices. Unlike the SAMPLE/PRELOAD mode, EXTEST allows test data to be forced onto the pin signals. By forcing known logic high and low levels on output pins, you can detect opens and shorts at pins of any device in the scan chain.

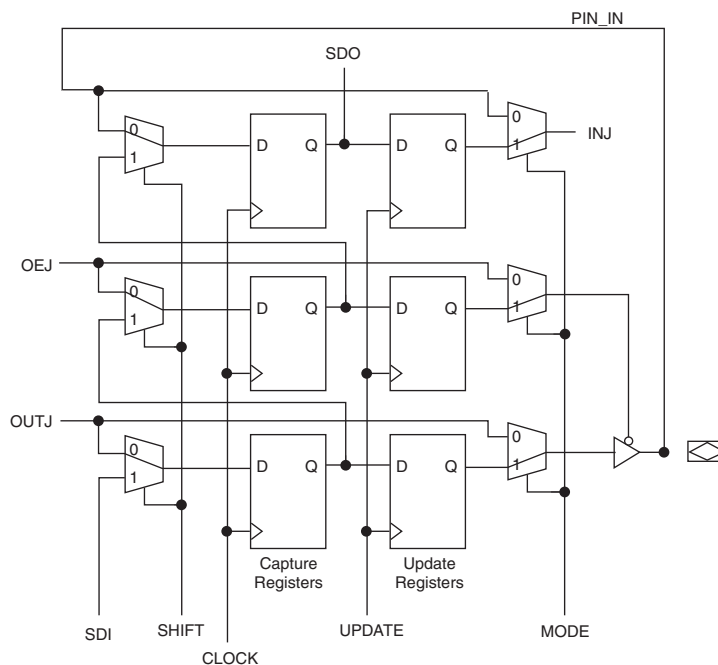
Figure 13-10 shows the capture, shift, and update phases of the EXTEST mode.

Figure 13-10. IEEE Std. 1149.1 BST EXTEST Mode

Capture Phase

In the capture phase, the signals at the pin, \overline{OEJ} and $OUTJ$, are loaded into the capture registers. The $CLOCK$ signals are supplied by the TAP controller's $CLOCKDR$ output. Previously retained data in the update registers drive the PIN_OUT , INJ , and allows the I/O pin to tri-state or drive a signal out.

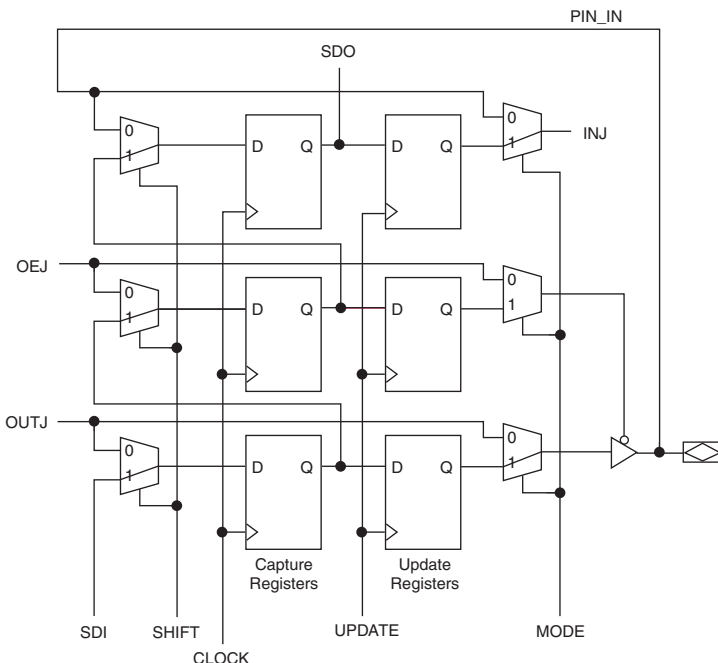
A "1" in the \overline{OEJ} update register tri-states the output buffer.



Shift and Update Phases

In the shift phase, the previously captured signals at the pin, \overline{OEJ} and $OUTJ$, are shifted out of the boundary-scan register via the TDO pin using $CLOCK$. As data is shifted out, the patterns for the next test can be shifted in via the TDI pin.

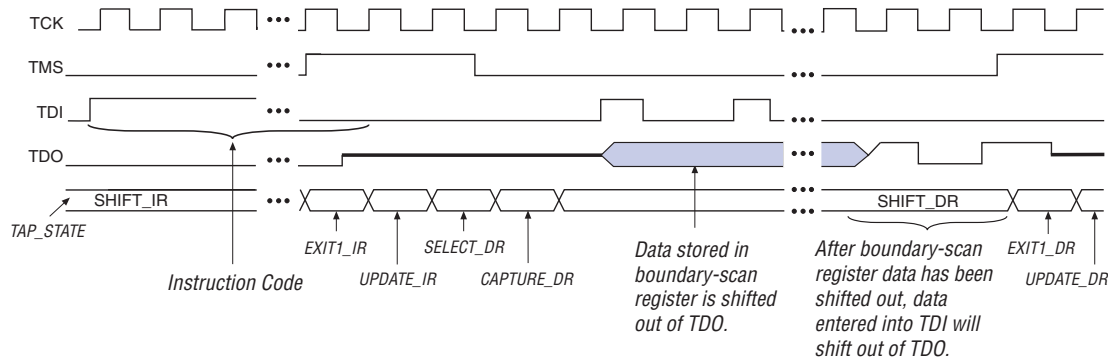
In the update phase, data is transferred from the capture registers to the update registers using the $UPDATE$ clock. The update registers then drive the PIN_OUT , INJ , and allow the I/O pin to tri-state or drive a signal out.



EXTEST mode selects data differently than SAMPLE/PRELOAD mode. EXTEST chooses data from the update registers as the source of the output and output-enable signals. Once the EXTEST instruction code is entered, the multiplexers select the update register data. Therefore, data stored in these registers from a previous EXTEST or SAMPLE/PRELOAD test cycle can be forced onto the pin signals. In the capture phase, the results of this test data are stored in the capture registers and then shifted out of TDO during the shift phase. You can then store new test data in the update registers during the update phase.

The EXTEST waveform diagram in Figure 13-11 resembles the SAMPLE/PRELOAD waveform diagram, except for the instruction code. The data shifted out of TDO consists of the data that was present in the capture registers after the capture phase. New test data shifted into the TDI pin appears at the TDO pin after being clocked through the entire boundary-scan register.

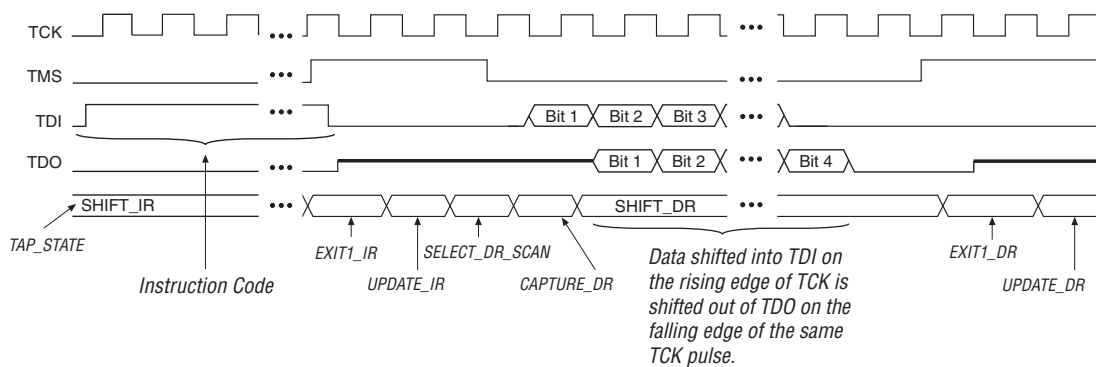
Figure 13-11. EXTEST Shift Data Register Waveforms



BYPASS Instruction Mode

The BYPASS mode is activated when an instruction code of all ones is loaded in the instruction register. This mode allows the boundary scan data to pass the selected device synchronously to adjacent devices when no test operation of the device is needed at the board level. The waveforms in Figure 13-12 show how scan data passes through a device once the TAP controller is in the SHIFT_DR state. In this state, data signals are clocked into the bypass register from TDI on the rising edge of TCK and out of TDO on the falling edge of the same clock pulse.

Figure 13-12. BYPASS Shift Data Register Waveforms



IDCODE Instruction Mode

Use the IDCODE instruction mode to identify the devices in an IEEE Std. 1149.1 chain. When IDCODE is selected, the device identification register is loaded with the 32-bit vendor-defined identification code. The device ID register is connected between the TDI and TDO ports, and the device IDCODE is shifted out. Table 13-5 shows the IDCODE information for Stratix III devices.

Table 13-5. 32-Bit Stratix III Device IDCODE

Device	IDCODE (32 Bits) (1)			
	Version (4 Bits)	Part Number (16 Bits)	Manufacturer Identity (11 Bits)	LSB (1 Bit) (2)
EP3SL50	0000	0010 0001 0000 1000	000 0110 1110	1
EP3SL70	0000	0010 0001 0000 0001	000 0110 1110	1
EP3SL110	0000	0010 0001 0000 1001	000 0110 1110	1
EP3SL150ES	0000	0010 0001 0000 0010	000 0110 1110	1
EP3SL150	0001	0010 0001 0000 0010	000 0110 1110	1
EP3SL200	0000	0010 0001 0000 0011	000 0110 1110	1
EP3SL340	0000	0010 0001 0000 0101	000 0110 1110	1
EP3SE50	0000	0010 0001 0000 0110	000 0110 1110	1
EP3SE80	0000	0010 0001 0000 1010	000 0110 1110	1
EP3SE110	0000	0010 0001 0000 0111	000 0110 1110	1
EP3SE260	0000	0010 0001 0000 0100	000 0110 1110	1

Notes to Table 13-5:

- (1) The most significant bit (MSB) is on the left.
- (2) The IDCODE's least significant bit (LSB) is always 1.

USERCODE Instruction Mode

Use the USERCODE instruction mode to examine the user electronic signature (UES) within the devices along an IEEE Std. 1149.1 chain. When you select this instruction, the device identification register is connected between the TDI and TDO ports. The user-defined UES is shifted into the device ID register in parallel from the 32-bit USERCODE register. The UES is then shifted out through the device ID register.



The UES value is not user defined until after the device is configured. This is because the value is stored in the programmer object file (.pof) and only loaded to the device during configuration. Before configuration, the UES value is set to the default value.

CLAMP Instruction Mode

Use the CLAMP instruction mode to allow the state of the signals driven from the pins to be determined from the boundary-scan register while the bypass register is selected as the serial path between the TDI and TDO ports. The states of all signals driven from the pins are completely defined by the data held in the boundary-scan register.

HIGHZ Instruction Mode

The HIGHZ instruction mode sets all of the user I/O pins to an inactive drive state. These pins are tri-stated until a new JTAG instruction is executed. When this instruction is loaded into the instruction register, the bypass register is connected between the TDI and TDO ports.

I/O Voltage Support in JTAG Chain

The JTAG chain supports several devices. However, you should use caution if the chain contains devices that have different V_{CCIO} levels. The output voltage level of the TDO pin must meet the specifications of the TDI pin it drives. The TDI and TDO pins of Stratix III device are powered by the V_{CCPD} (2.5 V / 3.0 V / 3.3 V) of I/O Bank 1A. You should connect V_{CCPD} according to the I/O standard used in the same bank. For 3.3-V I/O standards, you should connect V_{CCPD} to 3.3 V. For 3.0-V I/O standards, you should connect V_{CCPD} to 3.0 V; for 2.5-V and below I/O standards, you should connect V_{CCPD} to 2.5 V. Table 13-6 shows board design recommendations to ensure proper JTAG chain operation.

Table 13-6. Supported TDO/TDI Voltage Combinations

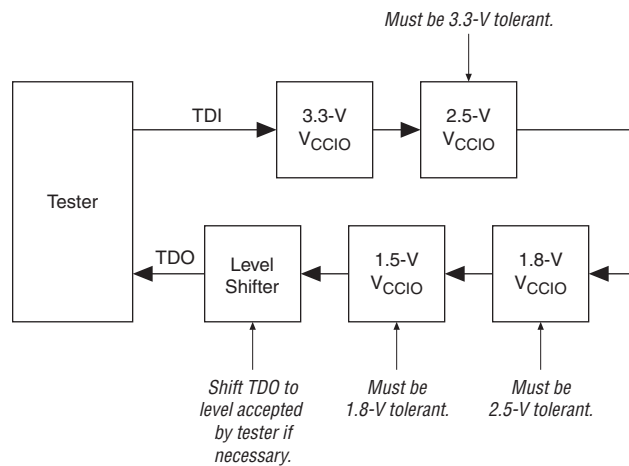
Device	TDI Input Buffer Power	Stratix III TDO V_{CCPD}		
		$V_{CCPD} = 3.3\text{ V}$ (1)	$V_{CCPD} = 3.0\text{ V}$ (1)	$V_{CCPD} = 2.5\text{ V}$ (2)
Stratix III	$V_{CCPD} = 3.3\text{V}$	✓	✓	✓
	$V_{CCPD} = 3.0\text{V}$	✓	✓	✓
	$V_{CCPD} = 2.5\text{V}$	✓	✓	✓
Non-Stratix III	$V_{CC} = 3.3\text{ V}$	✓ (3)	✓ (4)	✓ (5)
	$V_{CC} = 2.5\text{ V}$	✓ (3)	✓ (4)	✓ (5)
	$V_{CC} = 1.8\text{ V}$	✓ (3)	✓ (4)	✓ (5)
	$V_{CC} = 1.5\text{ V}$	✓ (3)	✓ (4)	✓ (5)

Notes to Table 13-6:

- (1) The TDO output buffer meets $V_{OH}(\text{MIN}) = 2.4\text{ V}$.
- (2) The TDO output buffer meets $V_{OH}(\text{MIN}) = 2.0\text{ V}$.
- (3) Input buffer must be 3.3-V tolerant.
- (4) Input buffer must be 3.0-V tolerant.
- (5) Input buffer must be 2.5-V tolerant.

You can interface the TDI and TDO lines of the devices that have different V_{CCIO} levels by inserting a level shifter between the devices. If possible, you should build the JTAG chain in such a way that a device with a higher V_{CCIO} level drives to a device with an equal or lower V_{CCIO} level. This way, a level shifter is used only to shift the TDO level to a level acceptable to the JTAG tester. Figure 13-13 shows the JTAG chain of mixed voltages and how a level shifter is inserted in the chain.


Figure 13-13. JTAG Chain of Mixed Voltages



IEEE Std. 1149.1 BST Circuitry


Stratix III devices have dedicated JTAG pins and the IEEE Std. 1149.1 BST circuitry is enabled upon device power-up. You can perform BST on Stratix III FPGAs before, during, and after configuration. Stratix III FPGAs support the `BYPASS`, `IDCODE`, and `SAMPLE` instructions during configuration without interrupting configuration. To send all other JTAG instructions, you must interrupt configuration using the `CONFIG_IO` instruction.

The `CONFIG_IO` instruction allows you to configure I/O buffers via the JTAG port, and when issued, interrupts configuration. This instruction allows you to perform board-level testing prior to configuring the Stratix III FPGA or you can wait for the configuration device to complete configuration. Once configuration is interrupted and JTAG BST is complete, you must reconfigure the part via JTAG (`PULSE_CONFIG` instruction) or by pulsing `nCONFIG` low.

 When you perform JTAG boundary-scan testing before configuration, the `nCONFIG` pin must be held low.

The chip-wide reset (`DEV_CLRn`) and chip-wide output enable (`DEV_OE`) pins on Stratix III devices do not affect JTAG boundary-scan or configuration operations. Toggling these pins does not disrupt BST operation (other than the expected BST behavior).

When you design a board for JTAG configuration of Stratix III devices, you need to consider the connections for the dedicated configuration pins.

 For more information about using the IEEE Std.1149.1 circuitry for device configuration, refer to the *Configuring Stratix III Devices* chapter in volume 1 of the *Stratix III Device Handbook*.

IEEE Std. 1149.1 BST for Configured Devices

For a configured device, the input buffers are turned off by default for I/O pins that are set as output only in the design file. Nevertheless, executing the `SAMPLE` instruction will turn on the input buffers in the output pins for sample operation. You can set the Quartus® II software to always enable the input buffers on a configured device so it behaves the same as an unconfigured device for boundary-scan testing, allowing sample function on output pins in the design. This aspect can cause a slight increase in standby current because the unused input buffer is always on.

In the Quartus II software, preform the following steps:

1. On the assignments menu, select Settings. The **Settings** dialog box appears.
2. Under the Category list, click **Assembler**.
3. Turn on **Always Enable Input Buffers**.
4. Click **OK**.



If you use the default setting with input disabled, you need to convert the default BSDL file to the design-specific BSDL file using the BSDL Customizer script.

For more information about the BSDL file, refer to [“Boundary-Scan Description Language \(BSDL\) Support” on page 13-19](#).

IEEE Std. 1149.1 BST Circuitry (Disabling)

The IEEE Std. 1149.1 BST circuitry for Stratix III devices is enabled upon device power-up. Because the IEEE Std. 1149.1 BST circuitry is used for BST or in-circuit reconfiguration, you must enable the circuitry only at specific times as mentioned in, [“IEEE Std. 1149.1 BST Circuitry” on page 13-17](#).



If you are not using the IEEE Std. 1149.1 circuitry in Stratix III, you should permanently disable the circuitry to ensure that you do not inadvertently enable it when it is not required.

[Table 13-7](#) shows the pin connections necessary for disabling the IEEE Std. 1149.1 circuitry in Stratix III devices.

Table 13-7. Disabling IEEE Std. 1149.1 Circuitry

JTAG Pins (1)	Connection for Disabling
TMS	V_{CCPD} supply of Bank 1A
TCK	GND
TDI	V_{CCPD} supply of Bank 1A
TDO	Leave open
TRST	GND

Note to Table 13-7:

- (1) There is no software option to disable JTAG in Stratix III devices. The JTAG pins are dedicated.

IEEE Std. 1149.1 BST Guidelines

Use the following guidelines when performing boundary-scan testing with IEEE Std. 1149.1 devices:


- If the “10...” pattern does not shift out of the instruction register via the TDO pin during the first clock cycle of the `SHIFT_IR` state, the TAP controller did not reach the proper state. To solve this problem, try one of the following procedures:
 - Verify that the TAP controller has reached the `SHIFT_IR` state correctly. To advance the TAP controller to the `SHIFT_IR` state, return to the `RESET` state and send the code `01100` to the TMS pin.
 - Check the connections to the V_{CC} , GND, JTAG, and dedicated configuration pins on the device.

Do NOT use the following private instructions as they may render the device inoperable:

```
11 0001 0000
00 1100 1001
11 0001 0011
11 0001 0111
```


You should take precautions not to invoke these instructions at any time.

- Perform a `SAMPLE/PRELOAD` test cycle prior to the first `EXTEST` test cycle to ensure that known data is present at the device pins when you enter the `EXTEST` mode. If the `OEJ` update register contains a 0, the data in the `OUTJ` update register is driven out. The state must be known and correct to avoid contention with other devices in the system.
- Do not perform `EXTEST` testing during `ICR`. This instruction is supported before or after `ICR`, but not during `ICR`. Use the `CONFIG_IO` instruction to interrupt configuration and then perform testing, or wait for configuration to complete.
- If performing testing before configuration, hold the `nCONFIG` pin low.

 For more information about boundary scan testing, contact Altera Application at www.altera.com.

Boundary-Scan Description Language (BSDL) Support

The Boundary-Scan Description Language (BSDL), a subset of VHDL, provides a syntax that allows you to describe the features of an IEEE Std. 1149.1 BST-capable device that can be tested. Test software development systems then use the BSDL files for test generation, analysis, and failure diagnostics.

 For more information on BSDL files for IEEE Std. 1149.1-compliant Stratix III devices and the BSDL Customizer script, visit the Altera® website at www.altera.com.

Conclusion

The IEEE Std. 1149.1 BST circuitry available in Stratix III devices provides a cost-effective and efficient way to test systems that contain devices with tight lead spacing. Circuit boards with Altera and other IEEE Std. 1149.1-compliant devices can use the EXTTEST, SAMPLE/PRELOAD, and BYPASS modes to create serial patterns that internally test the pin connections between devices and check device operation.

Chapter Revision History

Table 13–8 shows the revision history for this document.

Table 13–8. Chapter Revision History

Date and Revision	Changes Made	Summary of Changes
May 2009, version 1.7	<ul style="list-style-type: none"> ■ Updated Table 13–1. ■ Updated “I/O Voltage Support in JTAG Chain” and “IEEE Std. 1149.1 BST Circuitry” sections. 	—
February 2009, version 1.6	Removed “Referenced Documents” section.	—
October 2008, version 1.5	<ul style="list-style-type: none"> ■ Updated Table 13–4. ■ Updated New Document Format. 	—
May 2008, version 1.4	<ul style="list-style-type: none"> ■ Updated Table 13–2 and Table 13–5 with EP3SL150ES information. ■ Updated Table 13–6. ■ Updated Figure 13–6. 	—
November 2007, version 1.3	Updated Table 13–2.	Minor update.
October 2007, version 1.2	<ul style="list-style-type: none"> ■ Added new section “Referenced Documents”. ■ Added live links for references. 	Minor update.
May 2007, version 1.1	<ul style="list-style-type: none"> ■ Updated Note 3 to Table 13–3. Updated Figure 13–6. ■ Added Table 13–2, Table 13–4, Table 13–5, and Table 13–7. ■ Removed opening paragraph and footnote for “IEEE Std. 1149.1 BST Operation Control” on page 13–9. ■ Added warning on page 13-22. 	Minor updates.
November 2006, version 1.0	Initial Release.	—