



Cyclone Device Handbook, Volume 1



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Chapter Revision Dates

The chapters in this book, *Cyclone Device Handbook, Volume 1*, were revised on the following dates. Where chapters or groups of chapters are available separately, part numbers are listed.

Chapter 1. Introduction

Revised: *May 2003*
Part number: *C51001-1.0*

Chapter 2. Cyclone Architecture

Revised: *May 2003*
Part number: *C51002-1.0*

Chapter 3. Configuration & Testing

Revised: *May 2003*
Part number: *C51003-1.0*

Chapter 4. DC & Switching Characteristics

Revised: *May 2003*
Part number: *C51004-1.0*

Chapter 5. Reference & Ordering Information

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Part number: *C51005-1.0*

Chapter 6. Using PLLs in Cyclone Devices

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Chapter 7. On-Chip Memory Implementations Using Cyclone Memory Blocks

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Chapter 8. Using Selectable I/O Standards in Cyclone Devices

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Chapter 9. Implementing LVDS in Cyclone Devices

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Chapter 10. Implementing Double Data Rate I/O Signaling in Cyclone Devices

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Chapter 11. Using Cyclone Devices in Multiple-Voltage Systems

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Chapter 12. Designing with 1.5-V Devices

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Part number: *C51012-1.0*

Chapter 13. Configuring Cyclone FPGAs

Revised: *May 2003*
Part number: *C51013-1.0*

Chapter 14. Serial Configuration Devices (EPCS1 & EPCS4) Data Sheet

Revised: *May 2003*
Part number: *C51014-1.0*



About this Handbook

This handbook provides comprehensive information about the Altera® Cyclone™ family of devices.

How to Find Information

You can find more information in the following ways:

- The Adobe Acrobat Find feature, which searches the text of a PDF document. Click the binoculars toolbar icon to open the Find dialog box.
- Acrobat bookmarks, which serve as an additional table of contents in PDF documents.
- Thumbnail icons, which provide miniature previews of each page, provide a link to the pages.
- Numerous links, shown in green text, which allow you to jump to related information.

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Note to table:

(1) You can also contact your local Altera sales office or sales representative.

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Visual Cue	Meaning
Bold Type with Initial Capital Letters	Command names, dialog box titles, checkbox options, and dialog box options are shown in bold, initial capital letters. Example: Save As dialog box.
bold type	External timing parameters, directory names, project names, disk drive names, filenames, filename extensions, and software utility names are shown in bold type. Examples: f_{MAX} , qdesigns directory, d: drive, chiptrip.gdf file.
<i>Italic Type with Initial Capital Letters</i>	Document titles are shown in italic type with initial capital letters. Example: <i>AN 75: High-Speed Board Design</i> .
<i>Italic type</i>	Internal timing parameters and variables are shown in italic type. Examples: <i>t_{PIA}</i> , <i>n + 1</i> . Variable names are enclosed in angle brackets (< >) and shown in italic type. Example: <file name>, <project name>.pdf file.
Initial Capital Letters	Keyboard keys and menu names are shown with initial capital letters. Examples: Delete key, the Options menu.
“Subheading Title”	References to sections within a document and titles of on-line help topics are shown in quotation marks. Example: “Typographic Conventions.”
Courier type	Signal and port names are shown in lowercase Courier type. Examples: data1, tdi, input. Active-low signals are denoted by suffix n, e.g., resetn. Anything that must be typed exactly as it appears is shown in Courier type. For example: c:\qdesigns\tutorial\chiptrip.gdf. Also, sections of an actual file, such as a Report File, references to parts of files (e.g., the AHDL keyword SUBDESIGN), as well as logic function names (e.g., TRI) are shown in Courier.
1., 2., 3., and a., b., c., etc.	Numbered steps are used in a list of items when the sequence of the items is important, such as the steps listed in a procedure.
	Bullets are used in a list of items when the sequence of the items is not important.
	The checkmark indicates a procedure that consists of one step only.
	The hand points to information that requires special attention.
	The angled arrow indicates you should press the Enter key.
	The feet direct you to more information on a particular topic.



Section I. Cyclone FPGA Family Data Sheet

This section provides designers with the data sheet specifications for Cyclone devices. The chapters contain feature definitions of the internal architecture, configuration and JTAG boundary-scan testing information, DC operating conditions, AC timing parameters, a reference to power consumption, and ordering information for Cyclone devices.

This section contains the following chapters:

- Chapter 1. Introduction
- Chapter 2. Cyclone Architecture
- Chapter 3. Configuration & Testing
- Chapter 4. DC & Switching Characteristics
- Chapter 5. Reference & Ordering Information

Revision History

The table below shows the revision history for Chapters 1 through 5.

Chapter(s)	Date / Version	Changes Made
1 through 5	May 2003 v1.0	Added the EP1C4 device. Updated the "Timing Model" section.

Introduction

The Cyclone™ field programmable gate array family is based on a 1.5-V, 0.13-mm, all-layer copper SRAM process, with densities up to 20,060 logic elements (LEs) and up to 288 Kbits of RAM. With features like phase-locked loops (PLLs) for clocking and a dedicated double data rate (DDR) interface to meet DDR SDRAM and fast cycle RAM (FCRAM) memory requirements, Cyclone devices are a cost-effective solution for data-path applications. Cyclone devices support various I/O standards, including LVDS at data rates up to 311 megabits per second (Mbps) and 66-MHz, 32-bit peripheral component interconnect (PCI), for interfacing with and supporting ASSP and ASIC devices. Altera also offers new low-cost serial configuration devices to configure Cyclone devices.

The following shows the main sections in the Cyclone FPGA Family Data Sheet:

Section	Page
Features	1-2
Functional Description	2-1
Logic Array Blocks	2-3
Logic Elements	2-5
MultiTrack Interconnect	2-12
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Features

The Cyclone device family offers the following features:

- 2,910 to 20,060 LEs, see [Table 1-1](#)
- Up to 294,912 RAM bits (36,864 bytes)
- Supports configuration through low-cost serial configuration device
- Support for LVTTTL, LVCMOS, SSTL-2, and SSTL-3 I/O standards
- Support for 66-MHz, 32-bit PCI standard
- Low speed (311 Mbps) LVDS I/O support
- Up to two PLLs per device provide clock multiplication and phase shifting
- Up to eight global clock lines with six clock resources available per logic array block (LAB) row
- Support for external memory, including DDR SDRAM (133 MHz), FCRAM, and single data rate (SDR) SDRAM
- Support for multiple intellectual property (IP) cores, including Altera® MegaCore® functions and Altera Megafunctions Partners Program (AMPPSM) megafunctions.

Table 1-1. Cyclone Device Features

Feature	EP1C3	EP1C4	EP1C6	EP1C12	EP1C20
LEs	2,910	4,000	5,980	12,060	20,060
M4K RAM blocks (128 × 36 bits)	13	17	20	52	64
Total RAM bits	59,904	78,336	92,160	239,616	294,912
PLLs	1	2	2	2	2
Maximum user I/O pins (1)	104	301	185	249	301

Note to Table 1-1:

(1) This parameter includes global clock pins.

Cyclone devices are available in quad flat pack (QFP) and space-saving FineLine BGA® packages (see [Table 1–2](#) through [1–3](#)).

Table 1–2. Cyclone Package Options & I/O Pin Counts

Device	100-Pin TQFP (1)	144-Pin TQFP (1), (2)	240-Pin PQFP (1)	256-Pin FineLine BGA	324-Pin FineLine BGA	400-Pin FineLine BGA
EP1C3	65	104				
EP1C4					249	301
EP1C6		98	185	185		
EP1C12			173	185	249	
EP1C20					233	301

Notes to Table 1–2:

- (1) TQFP: thin quad flat pack.
PQFP: plastic quad flat pack.
- (2) Cyclone devices support vertical migration within the same package (i.e., designers can migrate between the EP1C3 device in the 144-pin TQFP package and the EP1C6 device in the same package)

Table 1–3. Cyclone QFP & FineLine BGA Package Sizes

Dimension	100-Pin TQFP	144-Pin TQFP	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA	400-Pin FineLine BGA
Pitch (mm)	0.5	0.5	0.5	1.0	1.0	1.0
Area (mm ²)	256	484	1,024	289	361	441
Length × width (mm × mm)	16 × 16	22 × 22	34.6 × 34.6	17 × 17	19 × 19	21 × 21

Functional Description

Cyclone devices contain a two-dimensional row- and column-based architecture to implement custom logic. Column and row interconnects of varying speeds provide signal interconnects between LABs and embedded memory blocks.

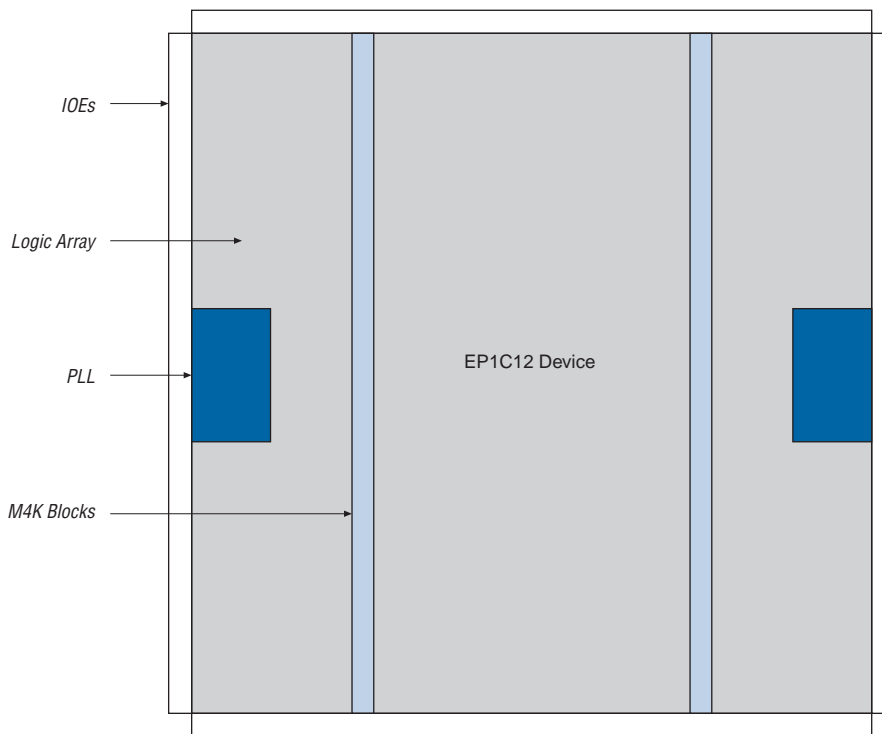
The logic array consists of LABs, with 10 LEs in each LAB. An LE is a small unit of logic providing efficient implementation of user logic functions. LABs are grouped into rows and columns across the device. Cyclone devices range between 2,910 to 20,060 LEs.

M4K RAM blocks are true dual-port memory blocks with 4K bits of memory plus parity (4,608 bits). These blocks provide dedicated true dual-port, simple dual-port, or single-port memory up to 36-bits wide at up to 200 MHz. These blocks are grouped into columns across the device in between certain LABs. Cyclone devices offer between 60 to 288 Kbits of embedded RAM.

Each Cyclone device I/O pin is fed by an I/O element (IOE) located at the ends of LAB rows and columns around the periphery of the device. I/O pins support various single-ended and differential I/O standards, such as the 66-MHz, 32-bit PCI standard and the LVDS I/O standard at up to 311 Mbps. Each IOE contains a bidirectional I/O buffer and three registers for registering input, output, and output-enable signals. Dual-purpose DQS, DQ, and DM pins along with delay chains (used to phase-align DDR signals) provide interface support with external memory devices such as DDR SDRAM, and FCRAM devices at up to 133 MHz (266 Mbps).

Cyclone devices provide a global clock network and up to two PLLs. The global clock network consists of eight global clock lines that drive throughout the entire device. The global clock network can provide clocks for all resources within the device, such as IOEs, LEs, and memory blocks. The global clock lines can also be used for control signals. Cyclone PLLs provide general-purpose clocking with clock multiplication and phase shifting as well as external outputs for high-speed differential I/O support.

Figure 2–1 shows a diagram of the Cyclone EP1C12 device.

Figure 2–1. Cyclone EP1C12 Device Block Diagram

The number of M4K RAM blocks, PLLs, rows, and columns vary per device. [Table 2–1](#) lists the resources available in each Cyclone device.

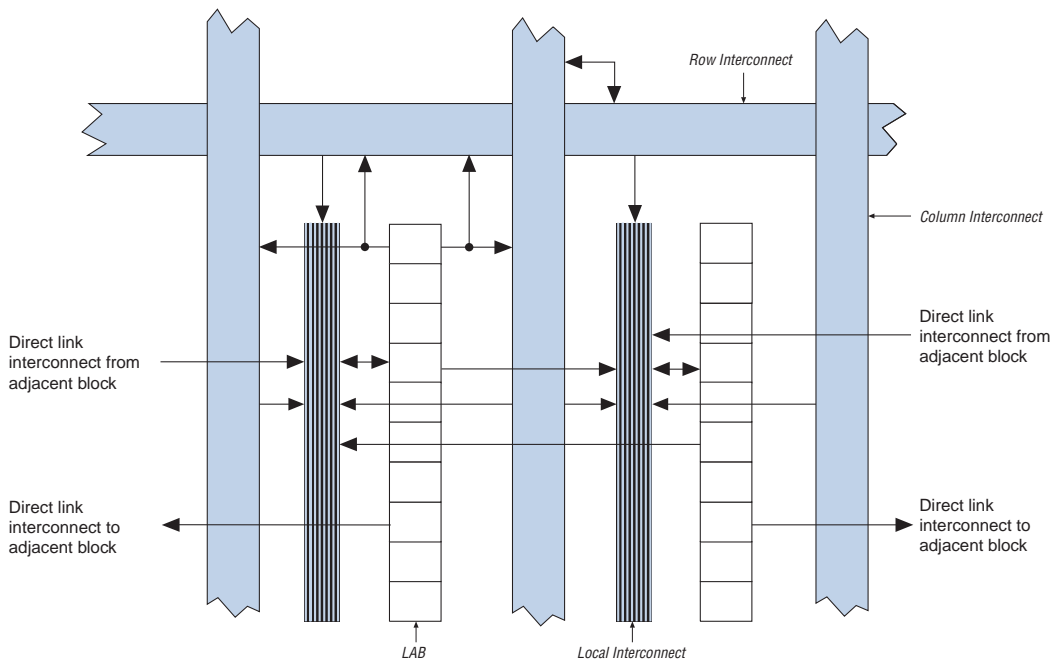
Table 2–1. Cyclone Device Resources

Device	M4K RAM		PLLs	LAB Columns	LAB Rows
	Columns	Blocks			
EP1C3	1	13	1	24	13
EP1C4	1	17	2	26	17
EP1C6	1	20	2	32	20
EP1C12	2	52	2	48	26
EP1C20	2	64	2	64	32

Logic Array Blocks

Each LAB consists of 10 LEs, LE carry chains, LAB control signals, a local interconnect, look-up table (LUT) chain, and register chain connection lines. The local interconnect transfers signals between LEs in the same LAB. LUT chain connections transfer the output of one LE's LUT to the adjacent LE for fast sequential LUT connections within the same LAB. Register chain connections transfer the output of one LE's register to the adjacent LE's register within an LAB. The Quartus II® Compiler places associated logic within an LAB or adjacent LABs, allowing the use of local, LUT chain, and register chain connections for performance and area efficiency. Figure 2-2 details the Cyclone LAB structure.

Figure 2-2. Cyclone LAB Structure

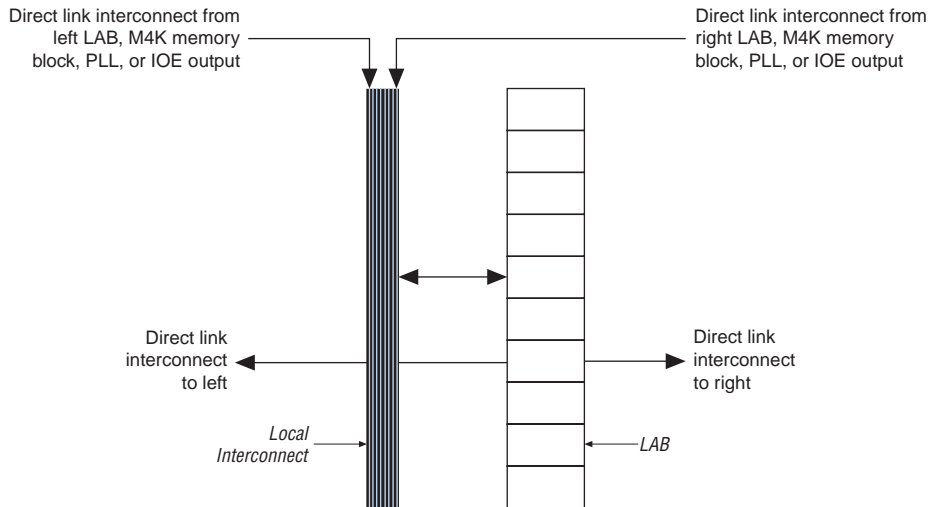


LAB Interconnects

The LAB local interconnect can drive LEs within the same LAB. The LAB local interconnect is driven by column and row interconnects and LE outputs within the same LAB. Neighboring LABs, PLLs, and M4K RAM blocks from the left and right can also drive an LAB's local interconnect through the direct link connection. The direct link connection feature minimizes the use of row and column interconnects, providing higher

performance and flexibility. Each LE can drive 30 other LEs through fast local and direct link interconnects. Figure 2-3 shows the direct link connection.

Figure 2-3. Direct Link Connection



LAB Control Signals

Each LAB contains dedicated logic for driving control signals to its LEs. The control signals include two clocks, two clock enables, two asynchronous clears, synchronous clear, asynchronous preset/load, synchronous load, and add/subtract control signals. This gives a maximum of 10 control signals at a time. Although synchronous load and clear signals are generally used when implementing counters, they can also be used with other functions.

Each LAB can use two clocks and two clock enable signals. Each LAB's clock and clock enable signals are linked. For example, any LE in a particular LAB using the `labclk1` signal will also use `labclkena1`. If the LAB uses both the rising and falling edges of a clock, it also uses both LAB-wide clock signals. De-asserting the clock enable signal will turn off the LAB-wide clock.

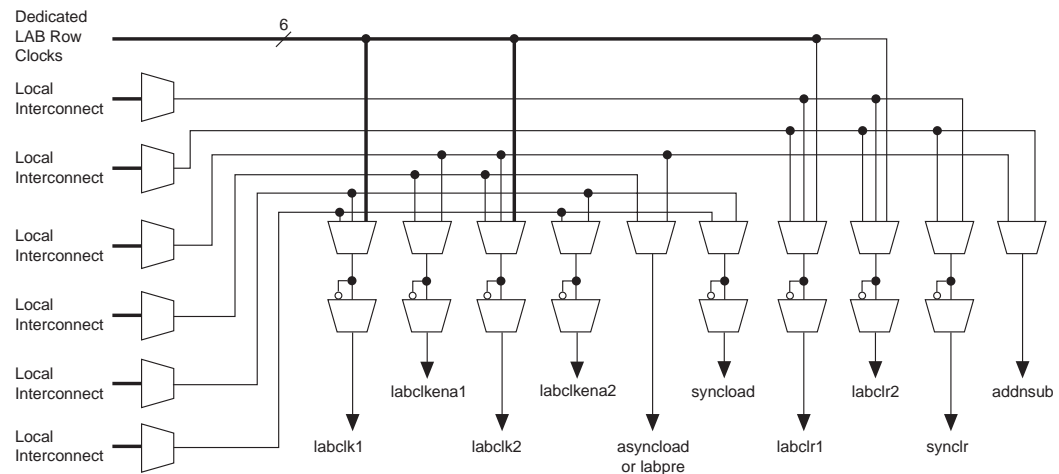
Each LAB can use two asynchronous clear signals and an asynchronous load/preset signal. The asynchronous load acts as a preset when the asynchronous load data input is tied high.

With the LAB-wide `addnsub` control signal, a single LE can implement a one-bit adder and subtractor. This saves LE resources and improves performance for logic functions such as DSP correlators and signed multipliers that alternate between addition and subtraction depending on data.

The LAB row clocks [5..0] and LAB local interconnect generate the LAB-wide control signals. The MultiTrack™ interconnect's inherent low skew allows clock and control signal distribution in addition to data.

Figure 2-4 shows the LAB control signal generation circuit.

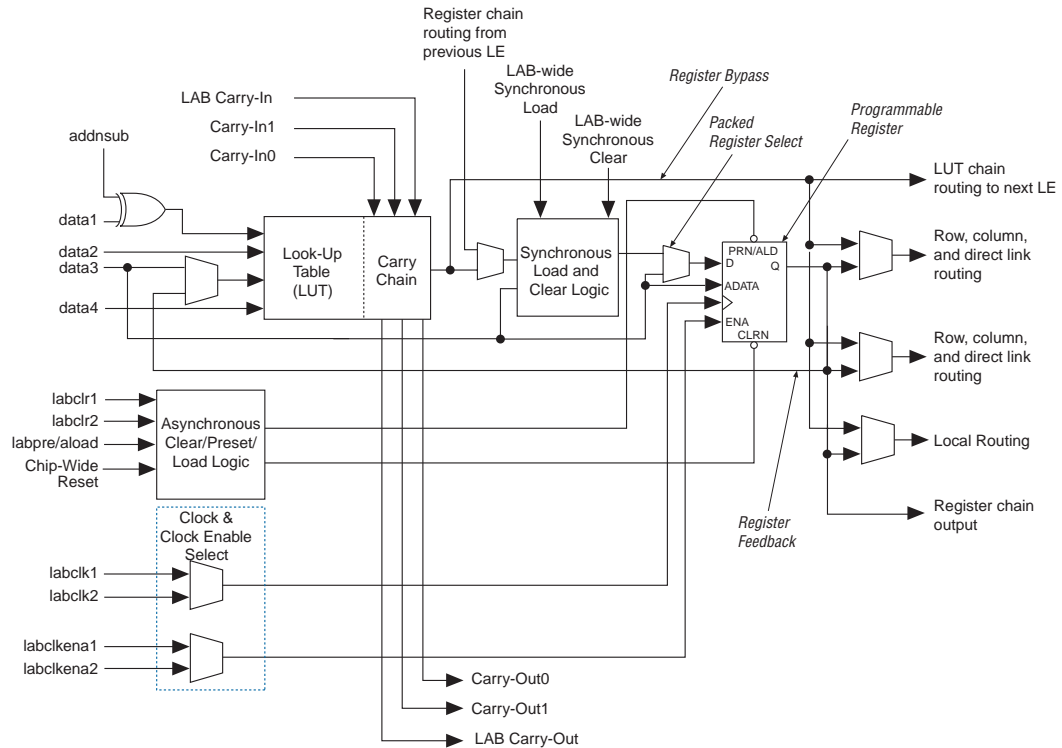
Figure 2-4. LAB-Wide Control Signals



Logic Elements

The smallest unit of logic in the Cyclone architecture, the LE, is compact and provides advanced features with efficient logic utilization. Each LE contains a four-input LUT, which is a function generator that can implement any function of four variables. In addition, each LE contains a programmable register and carry chain with carry select capability. A single LE also supports dynamic single bit addition or subtraction mode selectable by an LAB-wide control signal. Each LE drives all types of interconnects: local, row, column, LUT chain, register chain, and direct link interconnects. See Figure 2-5.

Figure 2-5. Cyclone LE



Each LE's programmable register can be configured for D, T, JK, or SR operation. Each register has data, true asynchronous load data, clock, clock enable, clear, and asynchronous load/preset inputs. Global signals, general-purpose I/O pins, or any internal logic can drive the register's clock and clear control signals. Either general-purpose I/O pins or internal logic can drive the clock enable, preset, asynchronous load, and asynchronous data. The asynchronous load data input comes from the data3 input of the LE. For combinatorial functions, the LUT output bypasses the register and drives directly to the LE outputs.

Each LE has three outputs that drive the local, row, and column routing resources. The LUT or register output can drive these three outputs independently. Two LE outputs drive column or row and direct link routing connections and one drives local interconnect resources. This allows the LUT to drive one output while the register drives another output. This feature, called register packing, improves device utilization because the device can use the register and the LUT for unrelated

functions. Another special packing mode allows the register output to feed back into the LUT of the same LE so that the register is packed with its own fan-out LUT. This provides another mechanism for improved fitting. The LE can also drive out registered and unregistered versions of the LUT output.

LUT Chain & Register Chain

In addition to the three general routing outputs, the LEs within an LAB have LUT chain and register chain outputs. LUT chain connections allow LUTs within the same LAB to cascade together for wide input functions. Register chain outputs allow registers within the same LAB to cascade together. The register chain output allows an LAB to use LUTs for a single combinatorial function and the registers to be used for an unrelated shift register implementation. These resources speed up connections between LABs while saving local interconnect resources. “[MultiTrack Interconnect](#)” on page 2–12 for more information on LUT chain and register chain connections.

addsub Signal

The LE's dynamic adder/subtractor feature saves logic resources by using one set of LEs to implement both an adder and a subtractor. This feature is controlled by the LAB-wide control signal `addsub`. The `addsub` signal sets the LAB to perform either $A + B$ or $A - B$. The LUT computes addition; subtraction is computed by adding the two's complement of the intended subtractor. The LAB-wide signal converts to two's complement by inverting the B bits within the LAB and setting carry-in = 1 to add one to the least significant bit (LSB). The LSB of an adder/subtractor must be placed in the first LE of the LAB, where the LAB-wide `addsub` signal automatically sets the carry-in to 1. The Quartus II® Compiler automatically places and uses the adder/subtractor feature when using adder/subtractor parameterized functions.

LE Operating Modes

The Cyclone LE can operate in one of the following modes:

- Normal mode
- Dynamic arithmetic mode

Each mode uses LE resources differently. In each mode, eight available inputs to the LE—the four data inputs from the LAB local interconnect, `carry-in0` and `carry-in1` from the previous LE, the LAB carry-in from the previous carry-chain LAB, and the register chain connection—are directed to different destinations to implement the

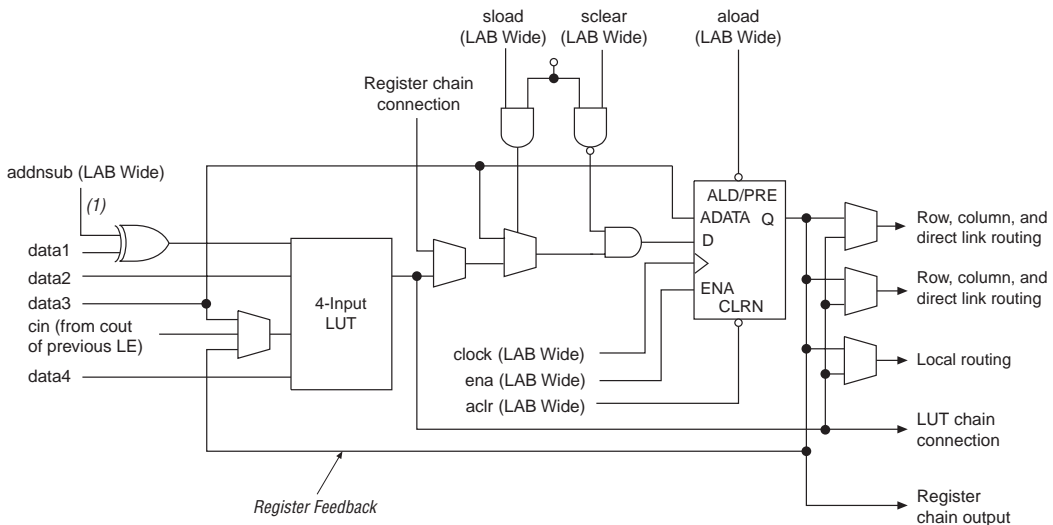
desired logic function. LAB-wide signals provide clock, asynchronous clear, asynchronous preset/load, synchronous clear, synchronous load, and clock enable control for the register. These LAB-wide signals are available in all LE modes. The `addnsub` control signal is allowed in arithmetic mode.

The Quartus II® software, in conjunction with parameterized functions such as library of parameterized modules (LPM) functions, automatically chooses the appropriate mode for common functions such as counters, adders, subtractors, and arithmetic functions. If required, the designer can also create special-purpose functions that specify which LE operating mode to use for optimal performance.

Normal Mode

The normal mode is suitable for general logic applications and combinatorial functions. In normal mode, four data inputs from the LAB local interconnect are inputs to a four-input LUT (see Figure 2–6). The Quartus II® Compiler automatically selects the carry-in or the `data3` signal as one of the inputs to the LUT. Each LE can use LUT chain connections to drive its combinatorial output directly to the next LE in the LAB. Asynchronous load data for the register comes from the `data3` input of the LE. LEs in normal mode support packed registers.

Figure 2–6. LE in Normal Mode



Note to Figure 2–6:

(1) This signal is only allowed in normal mode if the LE is at the end of an adder/subtractor chain.

Dynamic Arithmetic Mode

The dynamic arithmetic mode is ideal for implementing adders, counters, accumulators, wide parity functions, and comparators. An LE in dynamic arithmetic mode uses four 2-input LUTs configurable as a dynamic adder/subtractor. The first two 2-input LUTs compute two summations based on a possible carry-in of 1 or 0; the other two LUTs generate carry outputs for the two chains of the carry select circuitry. As shown in [Figure 2-7](#), the LAB carry-in signal selects either the `carry-in0` or `carry-in1` chain. The selected chain's logic level in turn determines which parallel sum is generated as a combinatorial or registered output. For example, when implementing an adder, the sum output is the selection of two possible calculated sums:

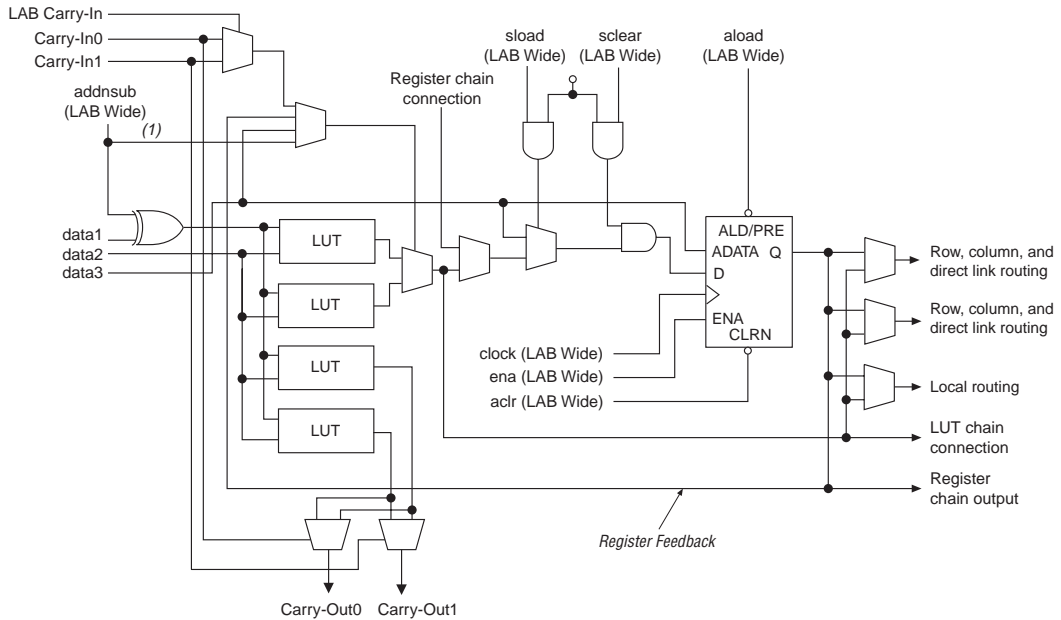
$$\text{data1} + \text{data2} + \text{carry-in0}$$

or

$$\text{data1} + \text{data2} + \text{carry-in1}$$

The other two LUTs use the `data1` and `data2` signals to generate two possible carry-out signals—one for a carry of 1 and the other for a carry of 0. The `carry-in0` signal acts as the carry select for the `carry-out0` output and `carry-in1` acts as the carry select for the `carry-out1` output. LEs in arithmetic mode can drive out registered and unregistered versions of the LUT output.

The dynamic arithmetic mode also offers clock enable, counter enable, synchronous up/down control, synchronous clear, synchronous load, and dynamic adder/subtractor options. The LAB local interconnect data inputs generate the counter enable and synchronous up/down control signals. The synchronous clear and synchronous load options are LAB-wide signals that affect all registers in the LAB. The Quartus II® software automatically places any registers that are not used by the counter into other LABs. The `addnsub` LAB-wide signal controls whether the LE acts as an adder or subtractor.

Figure 2-7. LE in Dynamic Arithmetic Mode**Note to Figure 2-7:**

(1) The addnsub signal is tied to the carry input for the first LE of a carry chain only.

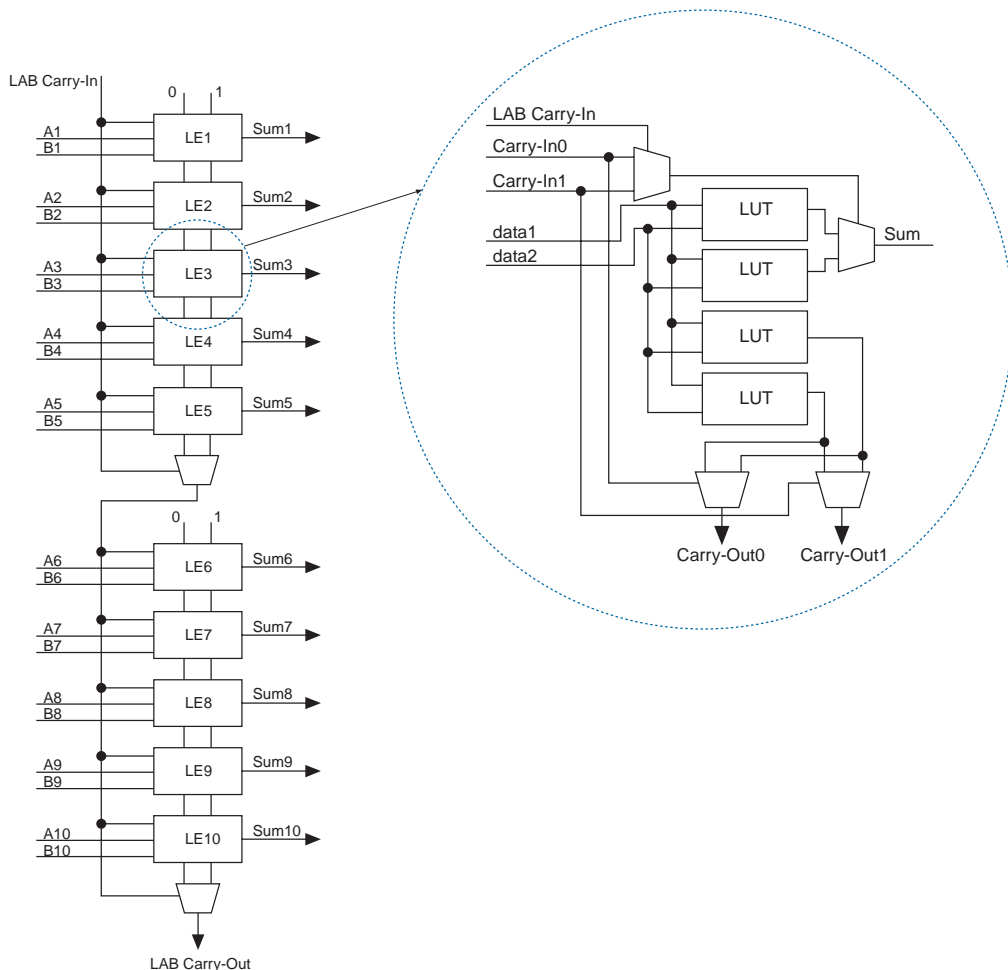
Carry-Select Chain

The carry-select chain provides a very fast carry-select function between LEs in dynamic arithmetic mode. The carry-select chain uses the redundant carry calculation to increase the speed of carry functions. The LE is configured to calculate outputs for a possible carry-in of 0 and carry-in of 1 in parallel. The carry-in0 and carry-in1 signals from a lower-order bit feed forward into the higher-order bit via the parallel carry chain and feed into both the LUT and the next portion of the carry chain. Carry-select chains can begin in any LE within an LAB.

The speed advantage of the carry-select chain is in the parallel pre-computation of carry chains. Since the LAB carry-in selects the precomputed carry chain, not every LE is in the critical path. Only the propagation delays between LAB carry-in generation (LE 5 and LE 10) are now part of the critical path. This feature allows the Cyclone architecture to implement high-speed counters, adders, multipliers, parity functions, and comparators of arbitrary width.

Figure 2–8 shows the carry-select circuitry in an LAB for a 10-bit full adder. One portion of the LUT generates the sum of two bits using the input signals and the appropriate carry-in bit; the sum is routed to the output of the LE. The register can be bypassed for simple adders or used for accumulator functions. Another portion of the LUT generates carry-out bits. An LAB-wide carry-in bit selects which chain is used for the addition of given inputs. The carry-in signal for each chain, `carry-in0` or `carry-in1`, selects the carry-out to carry forward to the carry-in signal of the next-higher-order bit. The final carry-out signal is routed to an LE, where it is fed to local, row, or column interconnects.

Figure 2–8. Carry Select Chain



The Quartus II® Compiler automatically creates carry chain logic during design processing, or the designer can create it manually during design entry. Parameterized functions such as LPM functions automatically take advantage of carry chains for the appropriate functions.

The Quartus II® Compiler creates carry chains longer than 10 LEs by linking LABs together automatically. For enhanced fitting, a long carry chain runs vertically allowing fast horizontal connections to M4K memory blocks. A carry chain can continue as far as a full column.

Clear & Preset Logic Control

LAB-wide signals control the logic for the register's clear and preset signals. The LE directly supports an asynchronous clear and preset function. The register preset is achieved through the asynchronous load of a logic high. The direct asynchronous preset does not require a NOT-gate push-back technique. Cyclone devices support simultaneous preset/asynchronous load and clear signals. An asynchronous clear signal takes precedence if both signals are asserted simultaneously. Each LAB supports up to two clears and one preset signal.

In addition to the clear and preset ports, Cyclone devices provide a chip-wide reset pin (`DEV_CLRn`) that resets all registers in the device. An option set before compilation in the Quartus II® software controls this pin. This chip-wide reset overrides all other control signals.

MultiTrack Interconnect

In the Cyclone architecture, connections between LEs, M4K memory blocks, and device I/O pins are provided by the MultiTrack interconnect structure with DirectDrive™ technology. The MultiTrack interconnect consists of continuous, performance-optimized routing lines of different speeds used for inter- and intra-design block connectivity. The Quartus II® Compiler automatically places critical design paths on faster interconnects to improve design performance.

DirectDrive technology is a deterministic routing technology that ensures identical routing resource usage for any function regardless of placement within the device. The MultiTrack interconnect and DirectDrive technology simplify the integration stage of block-based designing by eliminating the re-optimization cycles that typically follow design changes and additions.

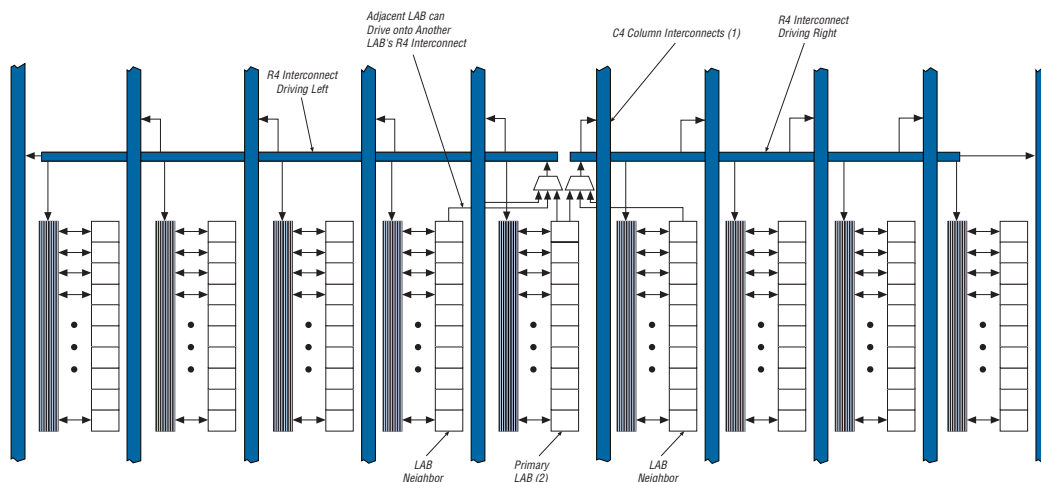
The MultiTrack interconnect consists of row and column interconnects that span fixed distances. A routing structure with fixed length resources for all devices allows predictable and repeatable performance when

migrating through different device densities. Dedicated row interconnects route signals to and from LABs, PLLs, and M4K memory blocks within the same row. These row resources include:

- Direct link interconnects between LABs and adjacent blocks
- R4 interconnects traversing four blocks to the right or left

The direct link interconnect allows an LAB or M4K memory block to drive into the local interconnect of its left and right neighbors. Only one side of a PLL block interfaces with direct link and row interconnects. The direct link interconnect provides fast communication between adjacent LABs and/or blocks without using row interconnect resources.

The R4 interconnects span four LABs, or two LABs and one M4K RAM block. These resources are used for fast row connections in a four-LAB region. Every LAB has its own set of R4 interconnects to drive either left or right. [Figure 2-9](#) shows R4 interconnect connections from an LAB. R4 interconnects can drive and be driven by M4K memory blocks, PLLs, and row IOEs. For LAB interfacing, a primary LAB or LAB neighbor can drive a given R4 interconnect. For R4 interconnects that drive to the right, the primary LAB and right neighbor can drive on to the interconnect. For R4 interconnects that drive to the left, the primary LAB and its left neighbor can drive on to the interconnect. R4 interconnects can drive other R4 interconnects to extend the range of LABs they can drive. R4 interconnects can also drive C4 interconnects for connections from one row to another.

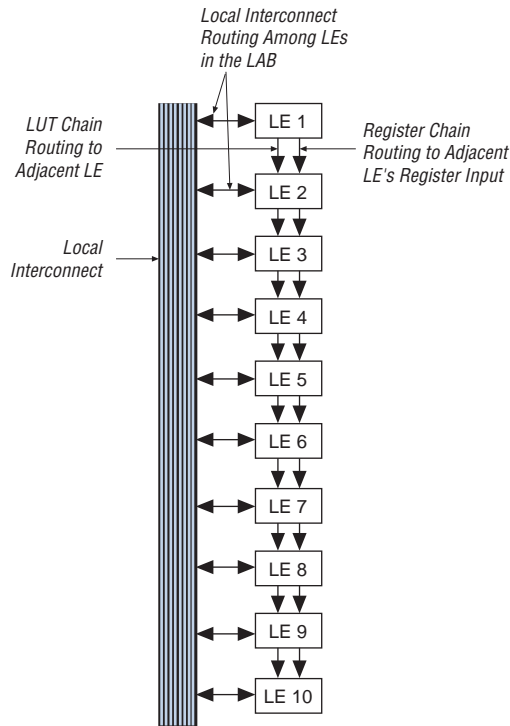
Figure 2–9. R4 Interconnect Connections**Notes to Figure 2–9:**

- (1) C4 interconnects can drive R4 interconnects.
- (2) This pattern is repeated for every LAB in the LAB row.

The column interconnect operates similarly to the row interconnect. Each column of LABs is served by a dedicated column interconnect, which vertically routes signals to and from LABs, M4K memory blocks, and row and column IOEs. These column resources include:

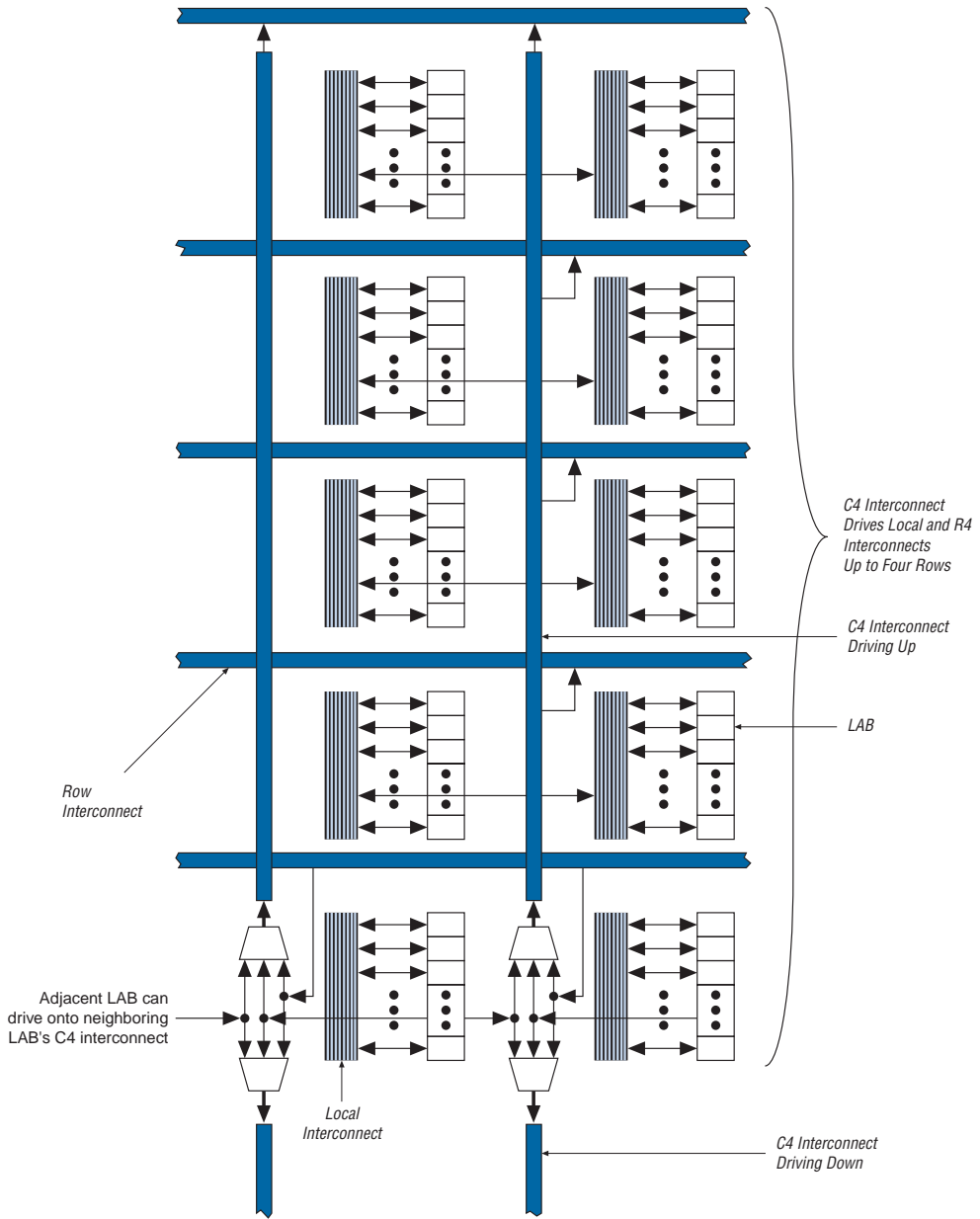
- LUT chain interconnects within an LAB
- Register chain interconnects within an LAB
- C4 interconnects traversing a distance of four blocks in an up and down direction

Cyclone devices include an enhanced interconnect structure within LABs for routing LE output to LE input connections faster using LUT chain connections and register chain connections. The LUT chain connection allows the combinatorial output of an LE to directly drive the fast input of the LE right below it, bypassing the local interconnect. These resources can be used as a high-speed connection for wide fan-in functions from LE 1 to LE 10 in the same LAB. The register chain connection allows the register output of one LE to connect directly to the register input of the next LE in the LAB for fast shift registers. The Quartus II® Compiler automatically takes advantage of these resources to improve utilization and performance. Figure 2–10 shows the LUT chain and register chain interconnects.

Figure 2–10. LUT Chain & Register Chain Interconnects

The C4 interconnects span four LABs or M4K blocks up or down from a source LAB. Every LAB has its own set of C4 interconnects to drive either up or down. [Figure 2–11](#) shows the C4 interconnect connections from an LAB in a column. The C4 interconnects can drive and be driven by all types of architecture blocks, including PLLs, M4K memory blocks, and column and row IOEs. For LAB interconnection, a primary LAB or its LAB neighbor can drive a given C4 interconnect. C4 interconnects can drive each other to extend their range as well as drive row interconnects for column-to-column connections.

Figure 2-11. C4 Interconnect Connections *Note (1)*



Note to Figure 2-11:

- (1) Each C4 interconnect can drive either up or down four rows.

All embedded blocks communicate with the logic array similar to LAB-to-LAB interfaces. Each block (i.e., M4K memory or PLL) connects to row and column interconnects and has local interconnect regions driven by row and column interconnects. These blocks also have direct link interconnects for fast connections to and from a neighboring LAB.

Table 2–2 shows the Cyclone device's routing scheme.

Table 2–2. Cyclone Device Routing Scheme

Source	Destination										
	LUT Chain	Register Chain	Local Interconnect	Direct Link Interconnect	R4 Interconnect	C4 Interconnect	LE	M4K RAM Block	PLL	Column IOE	Row IOE
LUT Chain							✓				
Register Chain							✓				
Local Interconnect							✓	✓	✓	✓	✓
Direct Link Interconnect			✓								
R4 Interconnect			✓		✓	✓					
C4 Interconnect			✓		✓	✓					
LE	✓	✓	✓	✓	✓	✓					
M4K RAM Block			✓	✓	✓	✓					
PLL				✓	✓	✓					
Column IOE						✓					
Row IOE				✓	✓	✓					

Embedded Memory

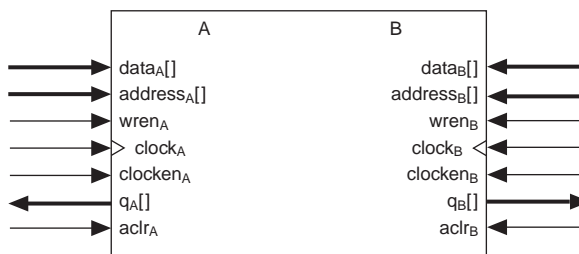
The Cyclone embedded memory consists of columns of M4K memory blocks. EP1C3 and EP1C6 devices have one column of M4K blocks, while EP1C12 and EP1C20 devices have two columns (see [Table 1-1 on page 1-2](#) for total RAM bits per density). Each M4K block can implement various types of memory with or without parity, including true dual-port, simple dual-port, and single-port RAM, ROM, and FIFO buffers. The M4K blocks support the following features:

- 4,608 RAM bits
- 200 MHz performance
- True dual-port memory
- Simple dual-port memory
- Single-port memory
- Byte enable
- Parity bits
- Shift register
- FIFO buffer
- ROM
- Mixed clock mode

Memory Modes

The M4K memory blocks include input registers that synchronize writes and output registers to pipeline designs and improve system performance. M4K blocks offer a true dual-port mode to support any combination of two-port operations: two reads, two writes, or one read and one write at two different clock frequencies. [Figure 2-12](#) shows true dual-port memory.

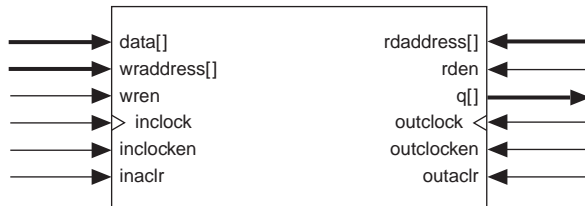
Figure 2-12. True Dual-Port Memory Configuration



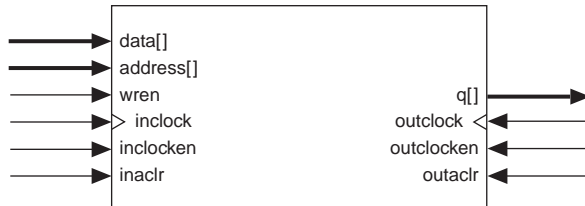
In addition to true dual-port memory, the M4K memory blocks support simple dual-port and single-port RAM. Simple dual-port memory supports a simultaneous read and write. Single-port memory supports non-simultaneous reads and writes. [Figure 2-13](#) shows these different M4K RAM memory port configurations.

Figure 2–13. Simple Dual-Port & Single-Port Memory Configurations

Simple Dual-Port Memory



Single-Port Memory (1)



Note to Figure 2–13:

- (1) Two single-port memory blocks can be implemented in a single M4K block as long as each of the two independent block sizes is equal to or less than half of the M4K block size.

The memory blocks also enable mixed-width data ports for reading and writing to the RAM ports in dual-port RAM configuration. For example, the memory block can be written in $\times 1$ mode at port A and read out in $\times 16$ mode from port B.

The Cyclone memory architecture can implement fully synchronous RAM by registering both the input and output signals to the M4K RAM block. All M4K memory block inputs are registered, providing synchronous write cycles. In synchronous operation, the memory block generates its own self-timed strobe write enable (*wren*) signal derived from a global clock. In contrast, a circuit using asynchronous RAM must generate the RAM *wren* signal while ensuring its data and address signals meet setup and hold time specifications relative to the *wren* signal. The output registers can be bypassed. Pseudo-asynchronous reading is possible in the simple dual-port mode of M4K blocks by clocking the read enable and read address registers on the negative clock edge and bypassing the output registers.

When configured as RAM or ROM, the designer can use an initialization file to pre-load the memory contents.

Two single-port memory blocks can be implemented in a single M4K block as long as each of the two independent block sizes is equal to or less than half of the M4K block size.

The Quartus II® software automatically implements larger memory by combining multiple M4K memory blocks. For example, two 256×16-bit RAM blocks can be combined to form a 256×32-bit RAM block. Memory performance does not degrade for memory blocks using the maximum number of words allowed. Logical memory blocks using less than the maximum number of words use physical blocks in parallel, eliminating any external control logic that would increase delays. To create a larger high-speed memory block, the Quartus II® software automatically combines memory blocks with LE control logic.

Parity Bit Support

The M4K blocks support a parity bit for each byte. The parity bit, along with internal LE logic, can implement parity checking for error detection to ensure data integrity. Designers can also use parity-size data words to store user-specified control bits. Byte enables are also available for data input masking during write operations.

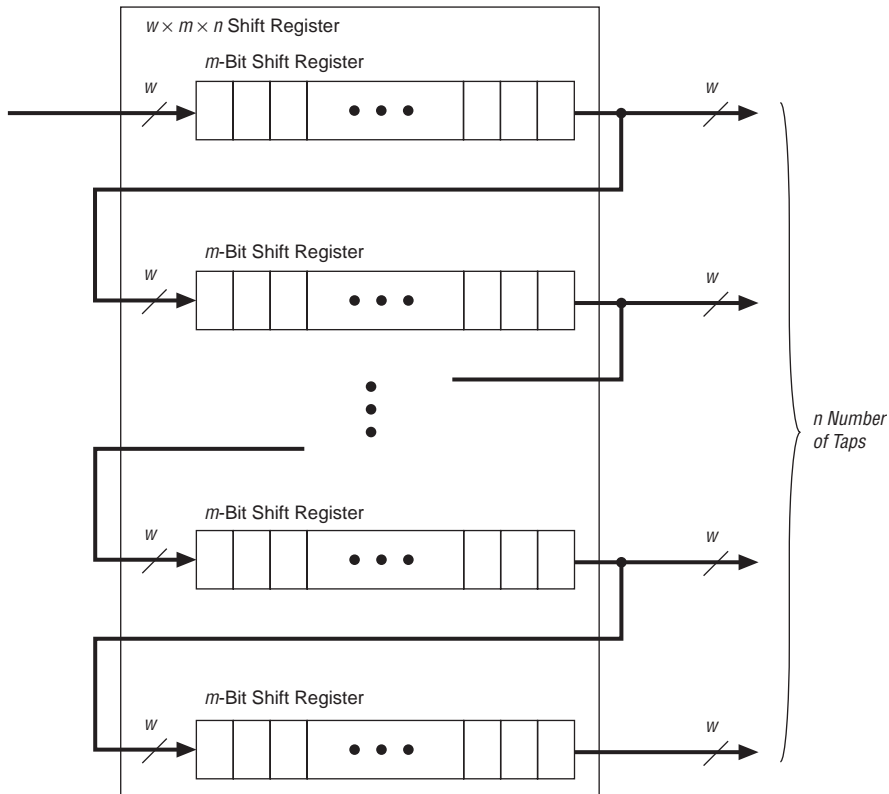
Shift Register Support

The designer can configure M4K memory blocks to implement shift registers for DSP applications such as pseudo-random number generators, multi-channel filtering, auto-correlation, and cross-correlation functions. These and other DSP applications require local data storage, traditionally implemented with standard flip-flops, which can quickly consume many logic cells and routing resources for large shift registers. A more efficient alternative is to use embedded memory as a shift register block, which saves logic cell and routing resources and provides a more efficient implementation with the dedicated circuitry.

The size of a $w \times m \times n$ shift register is determined by the input data width (w), the length of the taps (m), and the number of taps (n). The size of a $w \times m \times n$ shift register must be less than or equal to the maximum number of memory bits in the M4K block (4,608 bits). The total number of shift register outputs (number of taps $n \times$ width w) must be less than the maximum data width of the M4K RAM block (×36). To create larger shift registers, multiple memory blocks are cascaded together.

Data is written into each address location at the falling edge of the clock and read from the address at the rising edge of the clock. The shift register mode logic automatically controls the positive and negative edge clocking to shift the data in one clock cycle. Figure 2-14 shows the M4K memory block in the shift register mode.

Figure 2-14. Shift Register Memory Configuration



Memory Configuration Sizes

The memory address depths and output widths can be configured as $4,096 \times 1$, $2,048 \times 2$, $1,024 \times 4$, 512×8 (or 512×9 bits), 256×16 (or 256×18 bits), and 128×32 (or 128×36 bits). The 128×32 - or 36 -bit configuration

is not available in the true dual-port mode. Mixed-width configurations are also possible, allowing different read and write widths. Tables 2-3 and 2-4 summarize the possible M4K RAM block configurations.

Table 2-3. M4K RAM Block Configurations (Simple Dual-Port)

Read Port	Write Port								
	4K × 1	2K × 2	1K × 4	512 × 8	256 × 16	128 × 32	512 × 9	256 × 18	128 × 36
4K × 1	✓	✓	✓	✓	✓	✓			
2K × 2	✓	✓	✓	✓	✓	✓			
1K × 4	✓	✓	✓	✓	✓	✓			
512 × 8	✓	✓	✓	✓	✓	✓			
256 × 16	✓	✓	✓	✓	✓	✓			
128 × 32	✓	✓	✓	✓	✓	✓			
512 × 9							✓	✓	✓
256 × 18							✓	✓	✓
128 × 36							✓	✓	✓

Table 2-4. M4K RAM Block Configurations (True Dual-Port)

Port A	Port B						
	4K × 1	2K × 2	1K × 4	512 × 8	256 × 16	512 × 9	256 × 18
4K × 1	✓	✓	✓	✓	✓		
2K × 2	✓	✓	✓	✓	✓		
1K × 4	✓	✓	✓	✓	✓		
512 × 8	✓	✓	✓	✓	✓		
256 × 16	✓	✓	✓	✓	✓		
512 × 9						✓	✓
256 × 18						✓	✓

When the M4K RAM block is configured as a shift register block, the designer can create a shift register up to 4,608 bits ($w \times m \times n$).

Byte Enables

M4K blocks support byte writes when the write port has a data width of 16, 18, 32, or 36 bits. The byte enables allow the input data to be masked so the device can write to specific bytes. The unwritten bytes retain the previous written value. [Table 2-5](#) summarizes the byte selection.

<i>Table 2-5. Byte Enable for M4K Blocks</i> <i>Notes (1), (2)</i>		
byteena[3..0]	datain × 18	datain × 36
[0] = 1	[8..0]	[8..0]
[1] = 1	[17..9]	[17..9]
[2] = 1	–	[26..18]
[3] = 1	–	[35..27]

Notes to [Table 2-5](#):

- (1) Any combination of byte enables is possible.
- (2) Byte enables can be used in the same manner with 8-bit words, i.e., in ×16 and ×32 modes.

Control Signals & M4K Interface

The M4K blocks allow for different clocks on their inputs and outputs. Either of the two clocks feeding the block can clock M4K block registers (*renwe*, *address*, *byte enable*, *datain*, and output registers). Only the output register can be bypassed. The six *labclk* signals or local interconnects can drive the control signals for the A and B ports of the M4K block. LEs can also control the *clock_a*, *clock_b*, *renwe_a*, *renwe_b*, *clr_a*, *clr_b*, *clocken_a*, and *clocken_b* signals, as shown in [Figure 2-15](#).

The R4, C4, and direct link interconnects from adjacent LABs drive the M4K block local interconnect. The M4K blocks can communicate with LABs on either the left or right side through these row resources or with LAB columns on either the right or left with the column resources. Up to 10 direct link input connections to the M4K block are possible from the left adjacent LABs and another 10 possible from the right adjacent LAB. M4K block outputs can also connect to left and right LABs through 10 direct link interconnects each. [Figure 2-16](#) shows the M4K block to logic array interface.

Figure 2-15. M4K RAM Block Control Signals

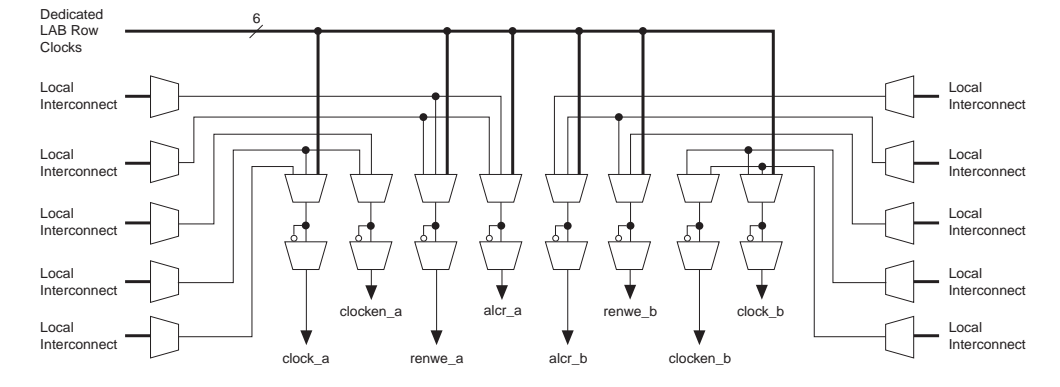
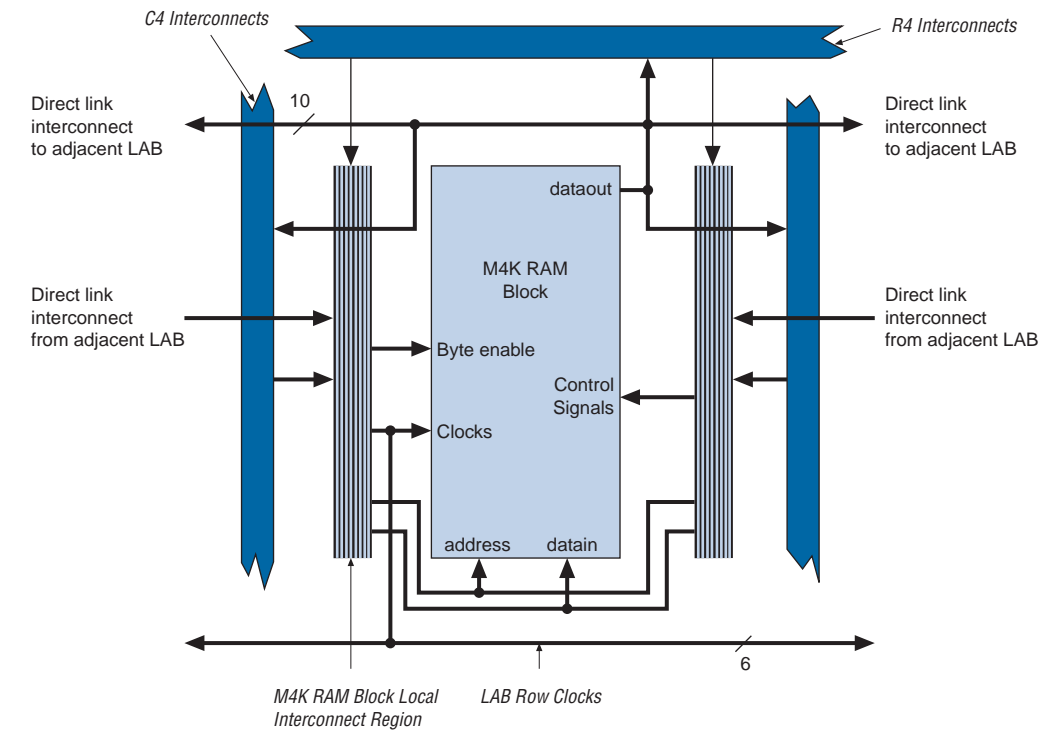


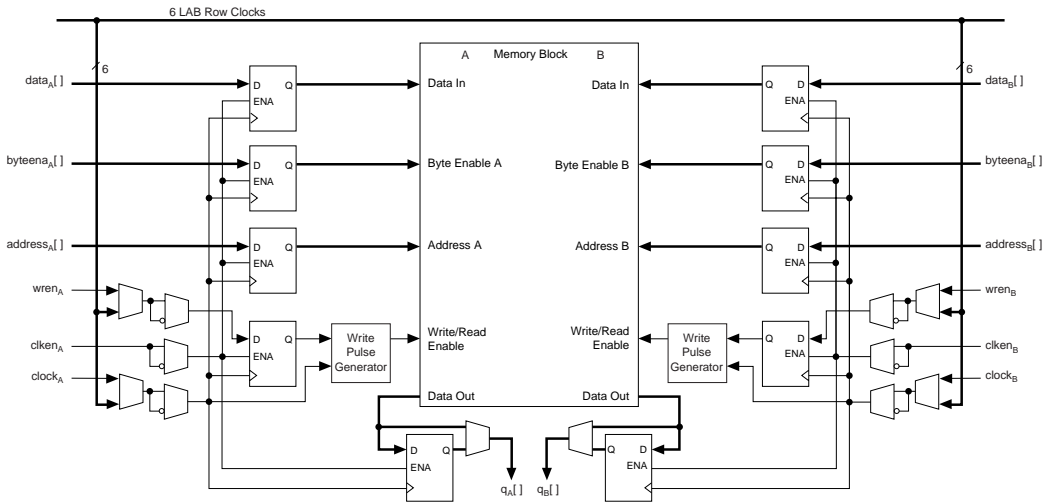
Figure 2-16. M4K RAM Block LAB Row Interface



Independent Clock Mode

The M4K memory blocks implement independent clock mode for true dual-port memory. In this mode, a separate clock is available for each port (ports A and B). Clock A controls all registers on the port A side, while clock B controls all registers on the port B side. Each port, A and B, also supports independent clock enables and asynchronous clear signals for port A and B registers. Figure 2-17 shows an M4K memory block in independent clock mode.

Figure 2-17. Independent Clock Mode Note (1)



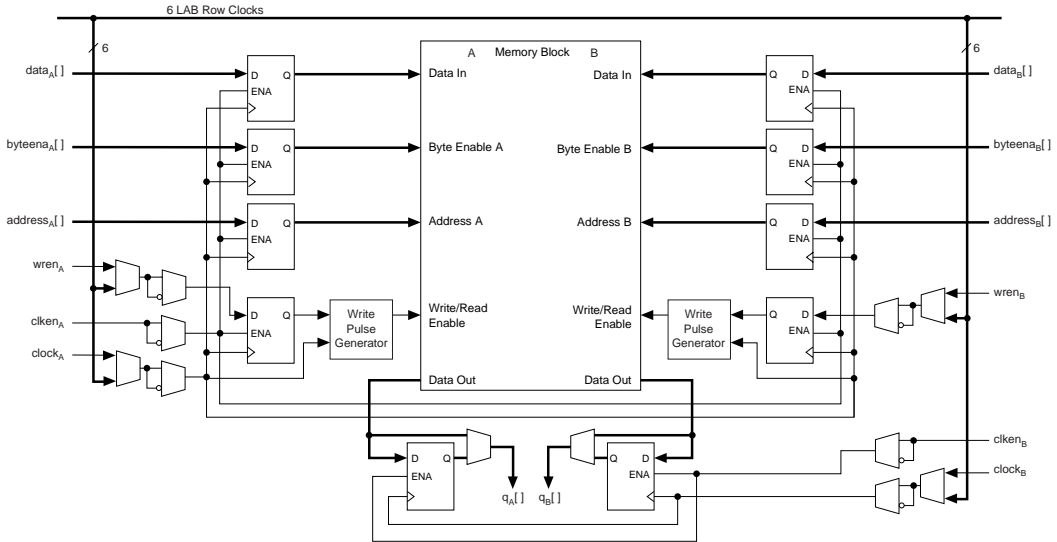
Note to Figure 2-17:

(1) All registers shown have asynchronous clear ports.

Input/Output Clock Mode

Input/output clock mode can be implemented for both the true and simple dual-port memory modes. On each of the two ports, A or B, one clock controls all registers for inputs into the memory block: data input, wren, and address. The other clock controls the block's data output registers. Each memory block port, A or B, also supports independent clock enables and asynchronous clear signals for input and output registers. Figures 2-18 and 2-19 show the memory block in input/output clock mode.

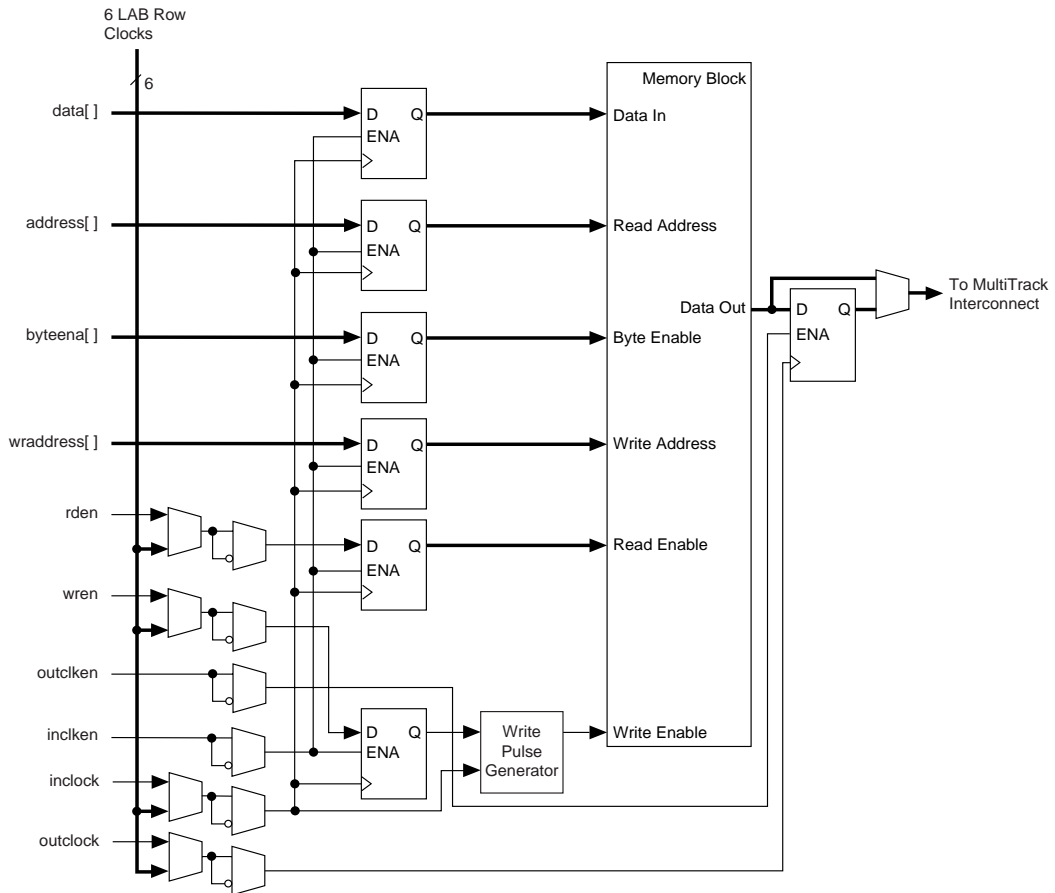
Figure 2-18. Input/Output Clock Mode in True Dual-Port Mode *Note (1)*



Note to Figure 2-18:

(1) All registers shown have asynchronous clear ports.

Figure 2–19. Input/Output Clock Mode in Simple Dual-Port Mode *Note (1)*

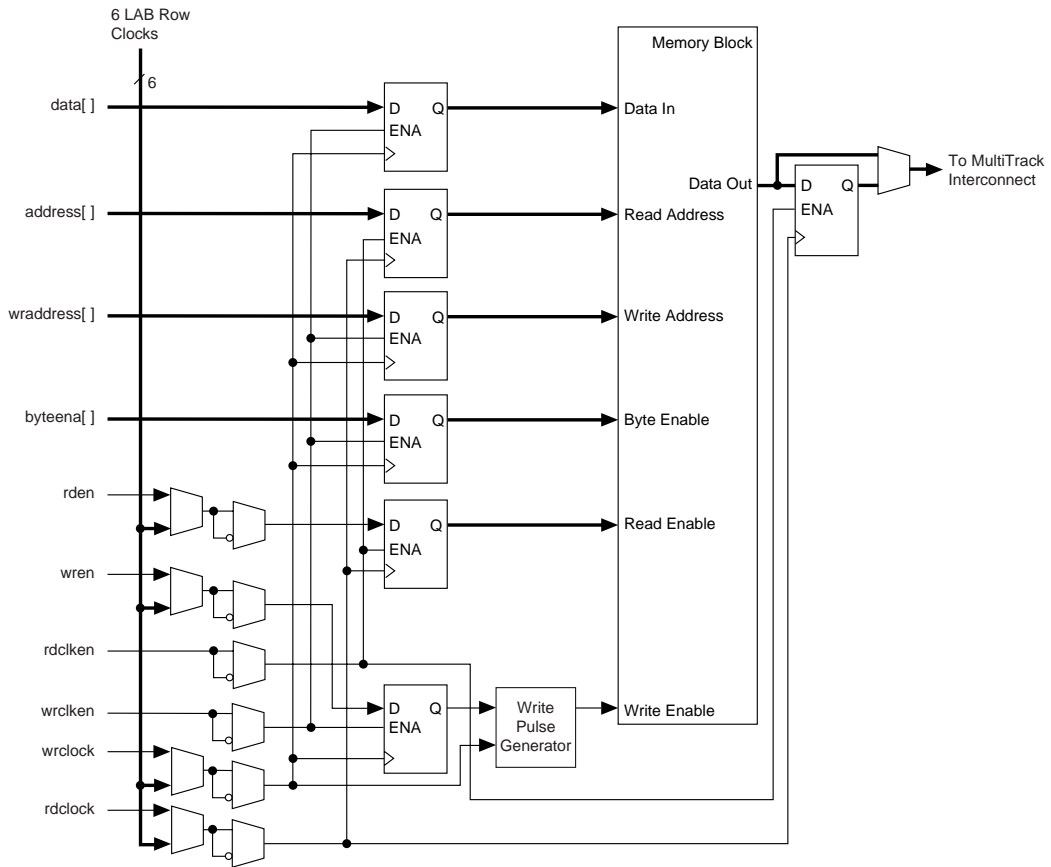


Note to Figure 2–19:

(1) All registers shown except the rden register have asynchronous clear ports.

Read/Write Clock Mode

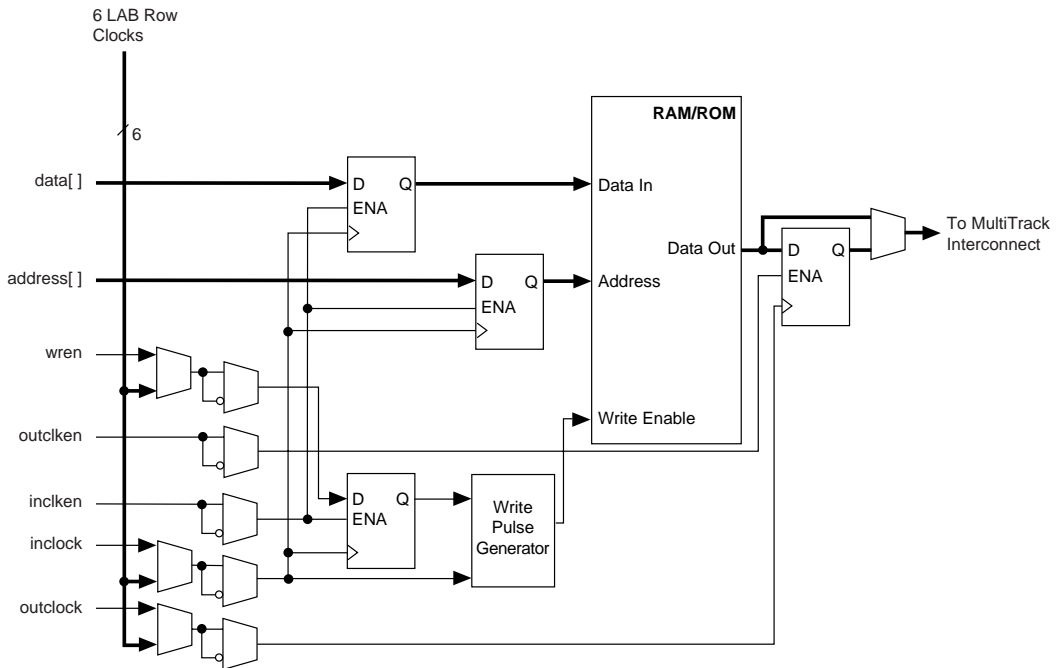
The M4K memory blocks implement read/write clock mode for simple dual-port memory. The designer can use up to two clocks in this mode. The write clock controls the block's data inputs, *waddress*, and *wren*. The read clock controls the data output, *rdaddress*, and *rden*. The memory blocks support independent clock enables for each clock and asynchronous clear signals for the read- and write-side registers. [Figure 2–20](#) shows a memory block in read/write clock mode.

Figure 2–20. Read/Write Clock Mode in Simple Dual-Port Mode *Note (1)***Note to Figure 2–20:**

(1) All registers shown except the rden register have asynchronous clear ports.

Single-Port Mode

The M4K memory blocks also support single-port mode, used when simultaneous reads and writes are not required. See [Figure 2–21](#). A single M4K memory block can support up to two single-port mode RAM blocks if each RAM block is less than or equal to 2K bits in size.

Figure 2–21. Single-Port Mode

Global Clock Network & Phase-Locked Loops

Cyclone devices provide a global clock network and up to two PLLs for a complete clock management solution.

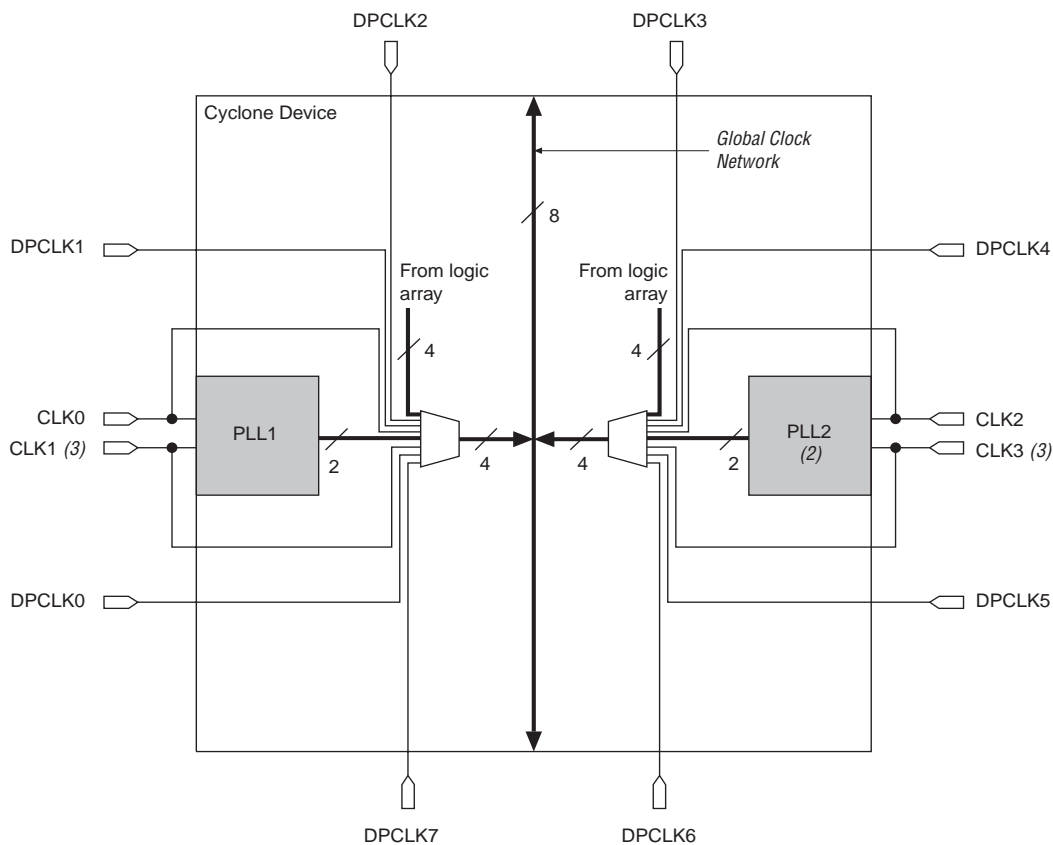
Global Clock Network

There are four dedicated clock pins (CLK [3 . . 0]), two pins on the left side and two pins on the right side) that drive the global clock network, as shown in [Figure 2–22](#). PLL outputs, logic array, and dual-purpose clock (DPCLK [7 . . 0]) pins can also drive the global clock network.

The eight global clock lines in the global clock network drive throughout the entire device. The global clock network can provide clocks for all resources within the device — IOEs, LEs, and memory blocks. The global clock lines can also be used for control signals, such as clock enables and synchronous or asynchronous clears fed from the external pin, or DQS signals for DDR SDRAM or FCRAM interfaces. Internal logic can also drive the global clock network for internally generated global clocks and

asynchronous clears, clock enables, or other control signals with large fanout. Figure 2-22 shows the various sources that drive the global clock network.

Figure 2-22. Global Clock Generation *Note (1)*



Notes to Figure 2-22:

- (1) The EP1C3 device in the 100-pin TQFP package has five DPCLK pins (DPCLK2, DPCLK3, DPCLK4, DPCLK6, and DPCLK7).
- (2) EP1C3 devices only contain one PLL (PLL 1).
- (3) The EP1C3 device in the 100-pin TQFP package does not have dedicated clock pins CLK1 and CLK3.

Dual-Purpose Clock Pins

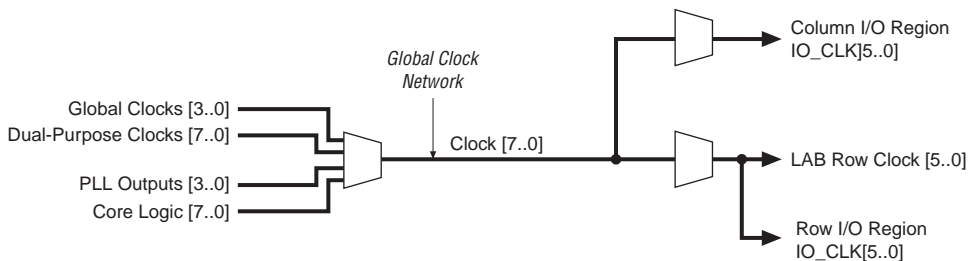
Each Cyclone device except the EP1C3 device has eight dual-purpose clock pins, DPCLK[7..0] (two on each I/O bank). EP1C3 devices have five DPCLK pins in the 100-pin TQFP package. These dual-purpose pins

can connect to the global clock network (see [Figure 2-22](#)) for high-fanout control signals such as clocks, asynchronous clears, presets, and clock enables, or protocol control signals such as `TRDY` and `IRDY` for PCI, or `DQS` signals for external memory interfaces.

Combined Resources

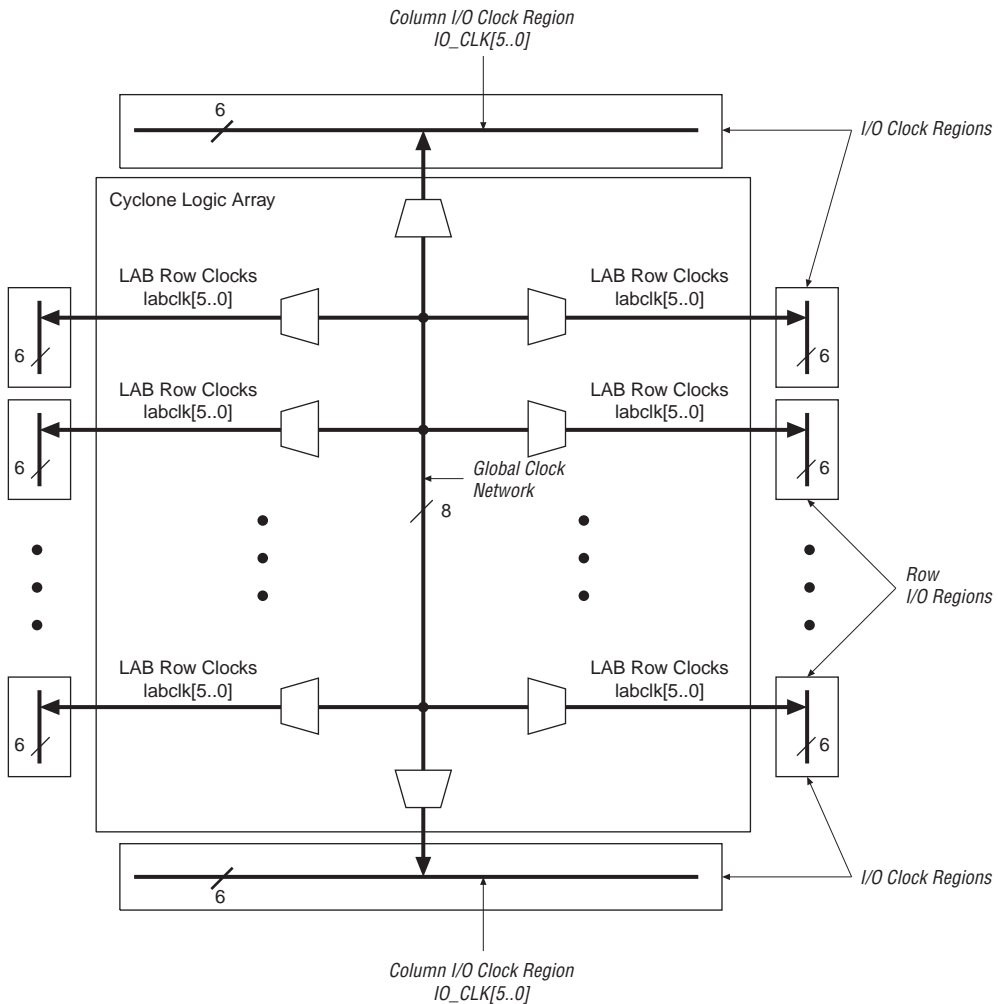
Each Cyclone device contains eight distinct dedicated clocking resources. The device uses multiplexers with these clocks to form six-bit buses to drive LAB row clocks, column IOE clocks, or row IOE clocks. See [Figure 2-23](#). Another multiplexer at the LAB level selects two of the six LAB row clocks to feed the LE registers within the LAB.

Figure 2-23. Global Clock Network Multiplexers



IOE clocks have row and column block regions. Six of the eight global clock resources feed to these row and column regions. [Figure 2-24](#) shows the I/O clock regions.

Figure 2–24. I/O Clock Regions



PLLs

Cyclone PLLs provide general-purpose clocking with clock multiplication and phase shifting as well as outputs for differential I/O support. Cyclone devices contain two PLLs, except for the EP1C3 device, which contains one PLL.

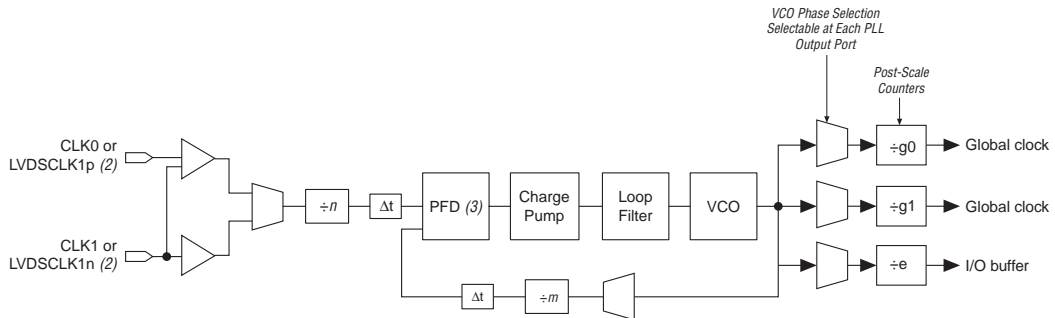
Table 2–6 shows the PLL features in Cyclone devices. Figure 2–25 shows a Cyclone PLL.

Feature	PLL Support
Clock multiplication and division	$m/(n \times \text{post-scale counter})$ (1)
Phase shift	Down to 156-ps increments (2), (3)
Programmable duty cycle	Yes
Number of internal clock outputs	2
Number of external clock outputs	One differential or one single-ended (4)

Notes to Table 2–6:

- (1) The m counter ranges from 2 to 32. The n counter and the post-scale counters range from 1 to 32.
- (2) The smallest phase shift is determined by the voltage-controlled oscillator (VCO) period divided by 8.
- (3) For degree increments, Cyclone devices can shift all output frequencies in increments of 45°. Smaller degree increments are possible depending on the frequency and divide parameters.
- (4) The EP1C3 device in the 100-pin TQFP package does not support external clock output. The EP1C6 device in the 144-pin TQFP package does not support external clock output from PLL2.

Figure 2–25. Cyclone PLL Note (1)

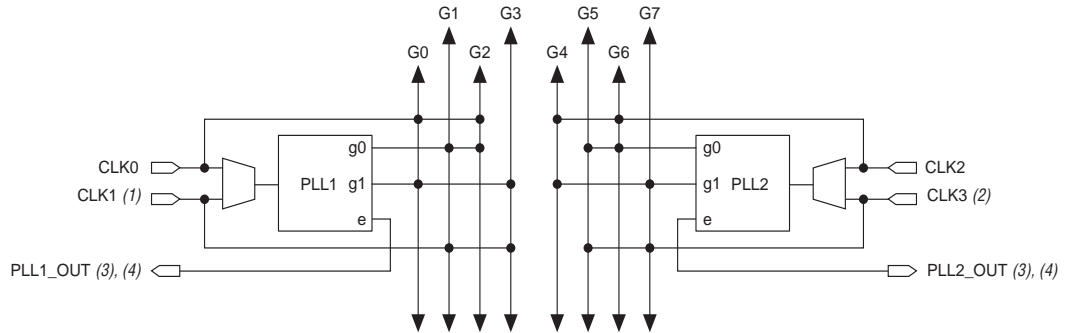


Notes to Figure 2–25:

- (1) The EP1C3 device in the 100-pin TQFP package does not support external outputs or LVDS inputs. The EP1C6 device in the 144-pin TQFP package does not support external output from PLL2.
- (2) LVDS input is supported via the secondary function of the dedicated clock pins. For PLL 1, the CLK0 pin's secondary function is LVDSCLK1p and the CLK1 pin's secondary function is LVDSCLK1n. For PLL 2, the CLK2 pin's secondary function is LVDSCLK2p and the CLK3 pin's secondary function is LVDSCLK2n.
- (3) PFD: phase frequency detector.

Figure 2–26 shows the PLL global clock connections.

Figure 2–26. Cyclone PLL Global Clock Connections



Notes to Figure 2–26:

- (1) PLL 1 supports one single-ended or LVDS input via pins CLK0 and CLK1.
- (2) PLL2 supports one single-ended or LVDS input via pins CLK2 and CLK3.
- (3) PLL1_OUT and PLL2_OUT support single-ended or LVDS output. If external output is not required, these pins are available as regular user I/O pins.
- (4) The EP1C3 device in the 100-pin TQFP package does not support external clock output. The EP1C6 device in the 144-pin TQFP package does not support external clock output from PLL2.

Table 2–7 shows the global clock network sources available in Cyclone devices.

Source		GCLK0	GCLK1	GCLK2	GCLK3	GCLK4	GCLK5	GCLK6	GCLK7
PLL Counter Output	PLL1 G0		✓	✓					
	PLL1 G1	✓			✓				
	PLL2 G0 (1)						✓	✓	
	PLL2 G1 (1)					✓			✓
Dedicated Clock Input Pins	CLK0	✓		✓					
	CLK1 (2)		✓		✓				
	CLK2					✓		✓	
	CLK3 (2)						✓		✓

Table 2–7. Global Clock Network Sources (Part 2 of 2)

Source		GCLK0	GCLK1	GCLK2	GCLK3	GCLK4	GCLK5	GCLK6	GCLK7
Dual-Purpose Clock Pins	DPCLK0 (3)				✓				
	DPCLK1 (3)			✓					
	DPCLK2	✓							
	DPCLK3					✓			
	DPCLK4							✓	
	DPCLK5 (3)								✓
	DPCLK6						✓		
	DPCLK7		✓						

Notes to Table 2–7:

- (1) EP1C3 devices only have one PLL (PLL 1).
- (2) EP1C3 devices in the 100-pin TQFP package do not have dedicated clock pins CLK1 and CLK3.
- (3) EP1C3 devices in the 100-pin TQFP package do not have the DPCLK0, DPCLK1, or DPCLK5 pins.

Clock Multiplication & Division

Cyclone PLLs provide clock synthesis for PLL output ports using $m/(n \times$ post scale counter) scaling factors. The input clock is divided by a pre-scale divider, n , and is then multiplied by the m feedback factor. The control loop drives the VCO to match $f_{IN} \times (m/n)$. Each output port has a unique post-scale counter to divide down the high-frequency VCO. For multiple PLL outputs with different frequencies, the VCO is set to the least-common multiple of the output frequencies that meets its frequency specifications. Then, the post-scale dividers scale down the output frequency for each output port. For example, if the output frequencies required from one PLL are 33 and 66 MHz, the VCO is set to 330 MHz (the least-common multiple in the VCO's range).

Each PLL has one pre-scale divider, n , that can range in value from 1 to 32. Each PLL also has one multiply divider, m , that can range in value from 2 to 32. Global clock outputs have two post scale G dividers for global clock outputs, and external clock outputs have an E divider for external clock output, both ranging from 1 to 32. The Quartus II® software automatically chooses the appropriate scaling factors according to the input frequency, multiplication, and division values entered.

External Clock Inputs

Each PLL supports single-ended or differential inputs for source-synchronous receivers or for general-purpose use. The dedicated clock pins (CLK [3..0]) feed the PLL inputs. These dual-purpose pins can also act as LVDS input pins. See [Figure 2-25](#).

[Table 2-8](#) shows the I/O standards supported by PLL input and output pins.

I/O Standard	CLK Input	EXTCLK Output
3.3-V LVTTTL/LVCMOS	✓	✓
2.5-V LVTTTL/LVCMOS	✓	✓
1.8-V LVTTTL/LVCMOS	✓	✓
1.5-V LVCMOS	✓	✓
3.3-V PCI	✓	✓
LVDS	✓	✓
SSTL-2 class I	✓	✓
SSTL-2 class II	✓	✓
SSTL-3 class I	✓	✓
SSTL-3 class II	✓	✓
Differential SSTL-2		✓

For more information on LVDS I/O support, see “LVDS I/O Pins” on [page 2-54](#).

External Clock Outputs

Each PLL supports one differential or one single-ended output for source-synchronous transmitters or for general-purpose external clocks. If the PLL does not use these PLL_OUT pins, the pins are available for use as general-purpose I/O pins. The PLL_OUT pins support all I/O standards shown in [Table 2-8](#).

The external clock outputs do not have their own V_{CC} and ground voltage supplies. Therefore, to minimize jitter, do not place switching I/O pins next to these output pins. The EP1C3 device in the 100-pin TQFP package

does not have dedicated clock output pins. The EP1C6 device in the 144-pin TQFP package only supports dedicated clock outputs from PLL 1.

Clock Feedback

Cyclone PLLs have three modes for multiplication and/or phase shifting:

- Zero delay buffer mode—The external clock output pin is phase-aligned with the clock input pin for zero delay.
- Normal mode—If the design uses an internal PLL clock output, the normal mode compensates for the internal clock delay from the input clock pin to the IOE registers. The external clock output pin is phase shifted with respect to the clock input pin if connected in this mode. The designer defines which internal clock output from the PLL should be phase-aligned to compensate for internal clock delay.
- No compensation mode—In this mode, the PLL will not compensate for any clock networks.

Phase Shifting

Cyclone PLLs have an advanced clock shift capability that enables programmable phase shifts. Designers can enter a phase shift (in degrees or time units) for each PLL clock output port or for all outputs together in one shift. Designers can perform phase shifting in time units with a resolution range of 156 to 417 ps. The finest resolution equals one eighth of the VCO period. The VCO period is a function of the frequency input and the multiplication and division factors. Each clock output counter can choose a different phase of the VCO period from up to eight taps. Designers can use this clock output counter along with an initial setting on the post-scale counter to achieve a phase-shift range for the entire period of the output clock. The phase tap feedback to the m counter can shift all outputs to a single phase. The Quartus II® software automatically sets the phase taps and counter settings according to the phase shift entered.

Lock Detect Signal

The lock output indicates that there is a stable clock output signal in phase with the reference clock. Without any additional circuitry, the lock signal may toggle as the PLL begins tracking the reference clock. Therefore, the designer may need to gate the lock signal for use as a system-control signal.

Programmable Duty Cycle

The programmable duty cycle allows PLLs to generate clock outputs with a variable duty cycle. This feature is supported on each PLL post-scale counter (g0, g1, e). The duty cycle setting is achieved by a low- and high-time count setting for the post-scale dividers. The Quartus II® software uses the frequency input and the required multiply or divide rate to determine the duty cycle choices.

Control Signals

There are three control signals for clearing and enabling PLLs and their outputs. The designer can use these signals to control PLL resynchronization and the ability to gate PLL output clocks for low-power applications.

The `pllenable` signal enables and disables PLLs. When the `pllenable` signal is low, the clock output ports are driven by ground and all the PLLs go out of lock. When the `pllenable` signal goes high again, the PLLs relock and resynchronize to the input clocks. An input pin or LE output can drive the `pllenable` signal.

The `areset` signals are reset/resynchronization inputs for each PLL. Cyclone devices can drive these input signals from input pins or from LEs. When `areset` is driven high, the PLL counters will reset, clearing the PLL output and placing the PLL out of lock. When driven low again, the PLL will resynchronize to its input as it relocks.

The `pfdena` signals control the phase frequency detector (PFD) output with a programmable gate. If you disable the PFD, the VCO will operate at its last set value of control voltage and frequency with some drift, and the system will continue running when the PLL goes out of lock or the input clock disables. By maintaining the last locked frequency, the system has time to store its current settings before shutting down. The designer can either use their own control signal or gated locked status signals to trigger the `pfdena` signal.



For more information on Cyclone PLLs, see [Chapter 6, Using PLLs in Cyclone Devices](#).

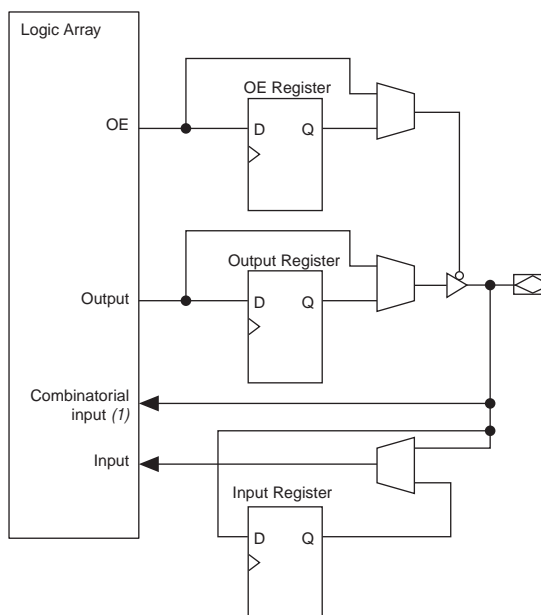
I/O Structure

IOEs support many features, including:

- Differential and single-ended I/O standards
- 3.3-V, 32-bit, 66-MHz PCI compliance
- Joint Test Action Group (JTAG) boundary-scan test (BST) support
- Output drive strength control
- Weak pull-up resistors during configuration
- Slew-rate control
- Tri-state buffers
- Bus-hold circuitry
- Programmable pull-up resistors in user mode
- Programmable input and output delays
- Open-drain outputs
- DQ and DQS I/O pins

Cyclone device IOEs contain a bidirectional I/O buffer and three registers for complete embedded bidirectional single data rate transfer.

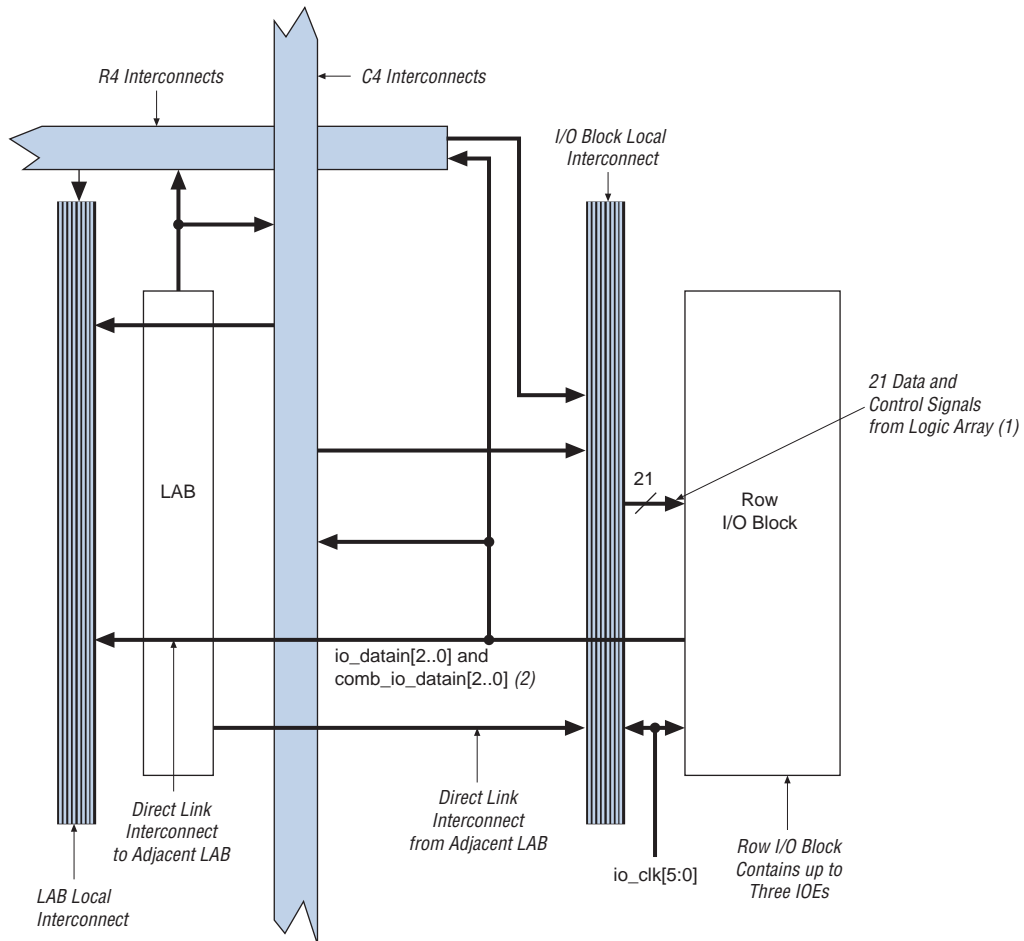
Figure 2–27 shows the Cyclone IOE structure. The IOE contains one input register, one output register, and one output enable register. The designer can use the input registers for fast setup times and output registers for fast clock-to-output times. Additionally, the designer can use the output enable (OE) register for fast clock-to-output enable timing. The Quartus®II software automatically duplicates a single OE register that controls multiple output or bidirectional pins. IOEs can be used as input, output, or bidirectional pins.

Figure 2–27. Cyclone IOE Structure**Note to Figure 2–27:**

- (1) There are two paths available for combinatorial inputs to the logic array. Each path contains a unique programmable delay chain.

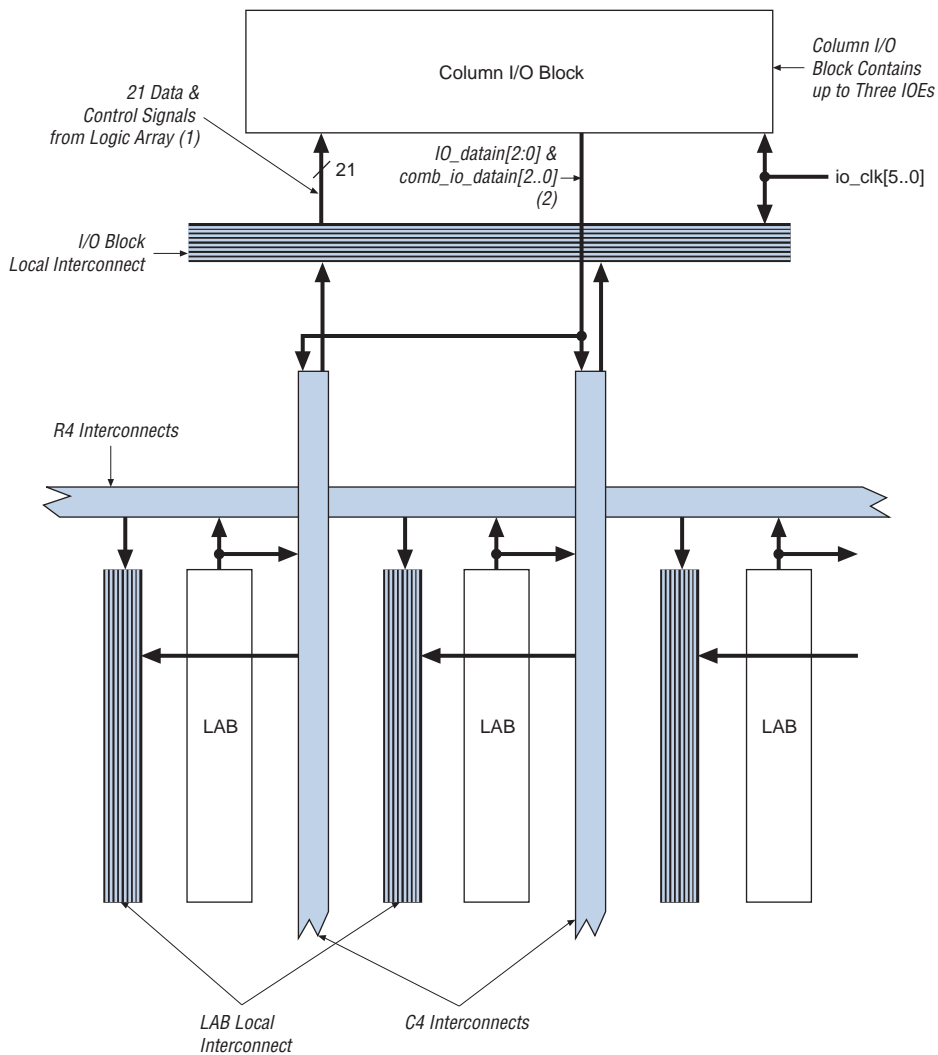
The IOEs are located in I/O blocks around the periphery of the Cyclone device. There are up to three IOEs per row I/O block and up to three IOEs per column I/O block (column I/O blocks span two columns). The row I/O blocks drive row, column, or direct link interconnects. The column I/O blocks drive column interconnects. [Figure 2–28](#) shows how a row I/O block connects to the logic array. [Figure 2–29](#) shows how a column I/O block connects to the logic array.

Figure 2–28. Row I/O Block Connection to the Interconnect

**Notes to Figure 2–28:**

- (1) The 21 data and control signals consist of three data out lines, `io_dataout[2..0]`, three output enables, `io_coe[2..0]`, three input clock enables, `io_cce_in[2..0]`, three output clock enables, `io_cce_out[2..0]`, three clocks, `io_cclk[2..0]`, three asynchronous clear signals, `io_caclr[2..0]`, and three synchronous clear signals, `io_csclr[2..0]`.
- (2) Each of the three IOEs in the row I/O block can have one `io_datain` input (combinatorial or registered) and one `comb_io_datain` (combinatorial) input.

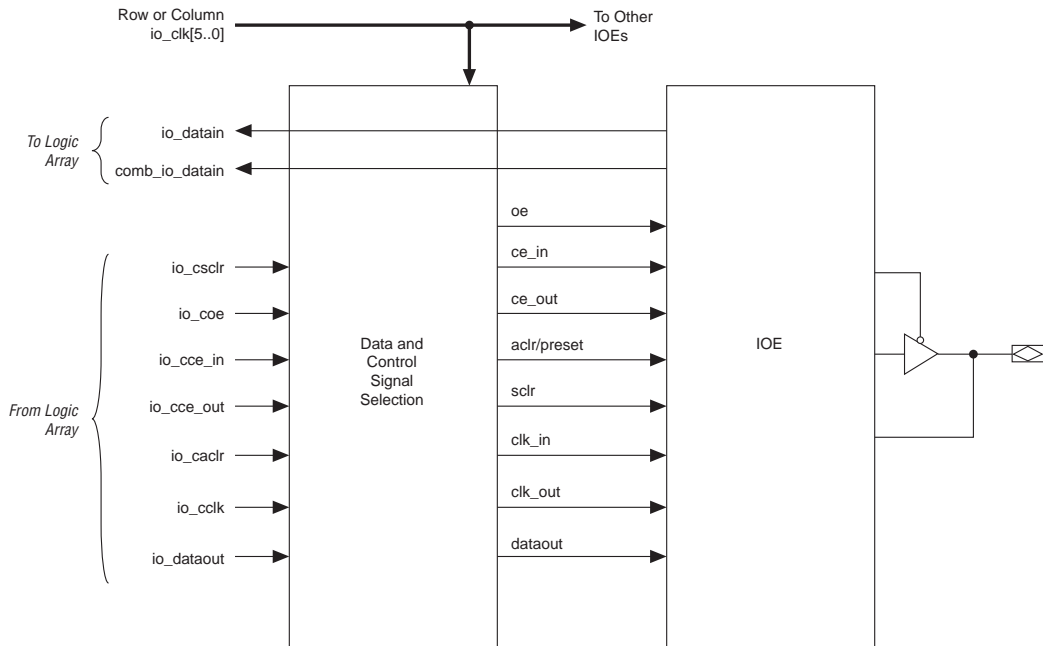
Figure 2–29. Column I/O Block Connection to the Interconnect

**Notes to Figure 2–29:**

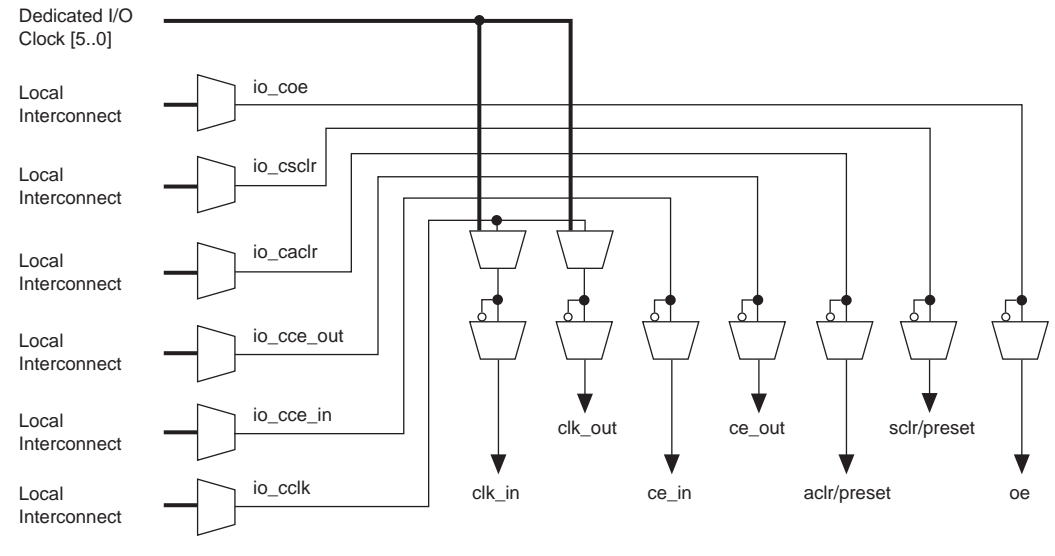
- (1) The 21 data and control signals consist of three data out lines, `io_dataout[2..0]`, three output enables, `io_coe[2..0]`, three input clock enables, `io_cce_in[2..0]`, three output clock enables, `io_cce_out[2..0]`, three clocks, `io_cclk[2..0]`, three asynchronous clear signals, `io_caclr[2..0]`, and three synchronous clear signals, `io_csclr[2..0]`.
- (2) Each of the three IOEs in the column I/O block can have one `io_datain` input (combinatorial or registered) and one `comb_io_datain` (combinatorial) input.

The pin's datain signals can drive the logic array. The logic array drives the control and data signals, providing a flexible routing resource. The row or column IOE clocks, `io_clk[5..0]`, provide a dedicated routing resource for low-skew, high-speed clocks. The global clock network generates the IOE clocks that feed the row or column I/O regions (see “Global Clock Network & Phase-Locked Loops” on page 2–29). Figure 2–30 illustrates the signal paths through the I/O block.

Figure 2–30. Signal Path through the I/O Block

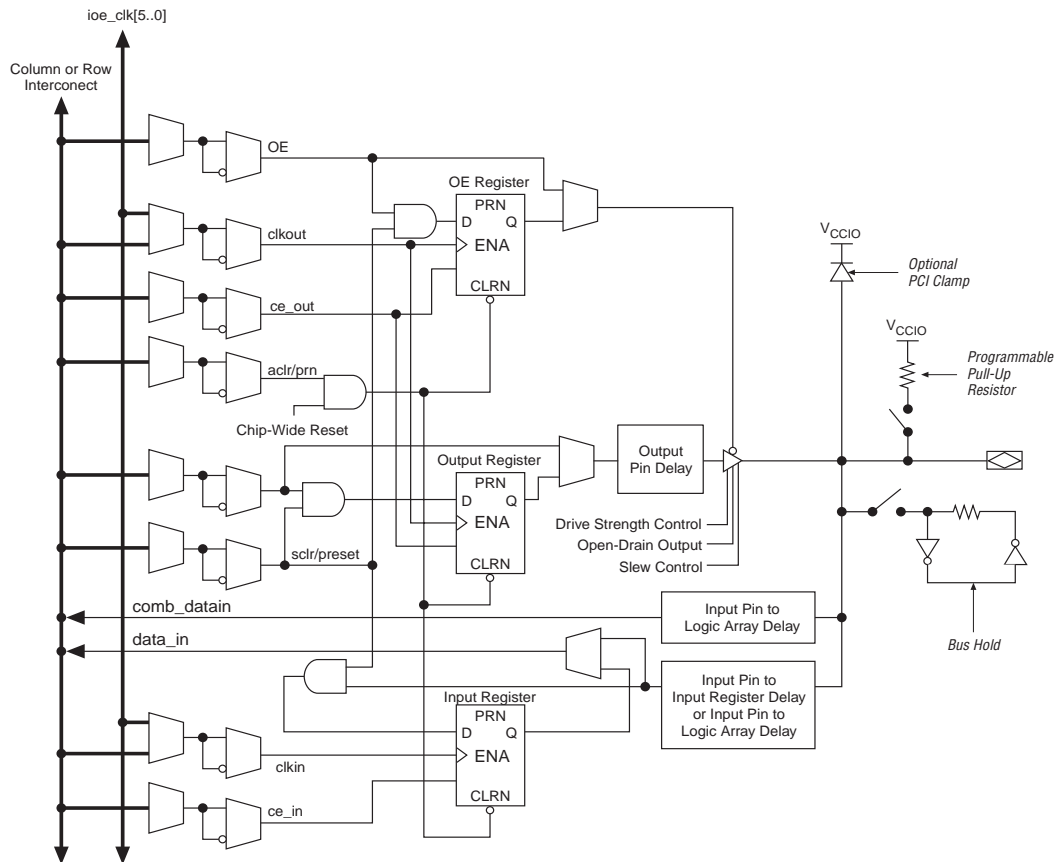


Each IOE contains its own control signal selection for the following control signals: `oe`, `ce_in`, `ce_out`, `aclr/preset`, `sclr/preset`, `clk_in`, and `clk_out`. Figure 2–31 illustrates the control signal selection.

Figure 2–31. Control Signal Selection per IOE

In normal bidirectional operation, the designer can use the input register for input data requiring fast setup times. The input register can have its own clock input and clock enable separate from the OE and output registers. The output register can be used for data requiring fast clock-to-output performance. The OE register is available for fast clock-to-output enable timing. The OE and output register share the same clock source and the same clock enable source from the local interconnect in the associated LAB, dedicated I/O clocks, or the column and row interconnects. [Figure 2–32](#) shows the IOE in bidirectional configuration.

Figure 2–32. Cyclone IOE in Bidirectional I/O Configuration



The Cyclone device IOE includes programmable delays to ensure zero hold times, minimize setup times, or increase clock to output times.

A path in which a pin directly drives a register may require a programmable delay to ensure zero hold time, whereas a path in which a pin drives a register through combinatorial logic may not require the delay. Programmable delays decrease input-pin-to-logic-array and IOE input register delays. The Quartus II® Compiler can program these delays to automatically minimize setup time while providing a zero hold

time. Programmable delays can increase the register-to-pin delays for output registers. Table 2-9 shows the programmable delays for Cyclone devices.

Programmable Delays	Quartus II® Logic Option
Input pin to logic array delay	Decrease input delay to internal cells
Input pin to input register delay	Decrease input delay to input registers
Output pin delay	Increase delay to output pin

There are two paths in the IOE for a combinatorial input to reach the logic array. Each of the two paths can have a different delay. This allows the designer to adjust delays from the pin to internal LE registers that reside in two different areas of the device. The designer sets the two combinatorial input delays by selecting different delays for two different paths under the **Decrease input delay to internal cells** logic option in the Quartus II® software. When the input signal requires two different delays for the combinatorial input, the input register in the IOE is no longer available.

The IOE registers in Cyclone devices share the same source for clear or preset. The designer can program preset or clear for each individual IOE. The designer can also program the registers to power up high or low after configuration is complete. If programmed to power up low, an asynchronous clear can control the registers. If programmed to power up high, an asynchronous preset can control the registers. This feature prevents the inadvertent activation of another device's active-low input upon power up. If one register in an IOE uses a preset or clear signal then all registers in the IOE must use that same signal if they require preset or clear. Additionally a synchronous reset signal is available to the designer for the IOE registers.

External RAM Interfacing

Cyclone devices support DDR SDRAM and FCRAM interfaces at up to 133 MHz through dedicated circuitry.

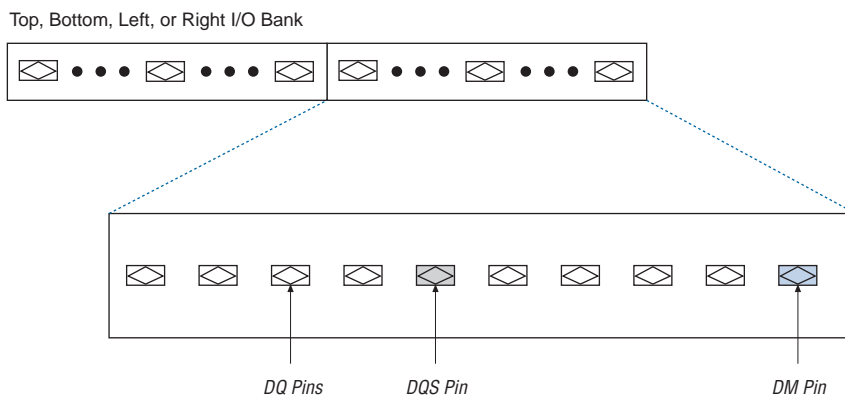
DDR SDRAM & FCRAM

Cyclone devices have dedicated circuitry for interfacing with DDR SDRAM. All I/O banks support DDR SDRAM and FCRAM I/O pins. However, the configuration input pins in bank 1 must operate at 2.5 V because the SSTL-2 V_{CCIO} level is 2.5 V. Additionally, the configuration

output pins (`nSTATUS` and `CONF_DONE`) and all the JTAG pins in I/O bank 3 must operate at 2.5 V because the V_{CCIO} level of SSTL-2 is 2.5 V. I/O banks 1, 2, 3, and 4 support DQS signals with DQ bus modes of $\times 8$.

For $\times 8$ mode, there are up to eight groups of programmable DQS and DQ pins, I/O banks 1, 2, 3, and 4 each have two groups in the 324-pin and 400-pin FineLine BGA packages. Each group consists of one DQS pin, a set of eight DQ pins, and one DM pin (see Figure 2–33). Each DQS pin drives the set of eight DQ pins within that group.

Figure 2–33. Cyclone Device DQ & DQS Groups in $\times 8$ Mode *Note (1)*



Note to Figure 2–33:

- (1) Each DQ group consists of one DQS pin, eight DQ pins, and one DM pin.

Table 2–10 shows the number of DQ pin groups per device.

Device	Package	Number of $\times 8$ DQ Pin Groups	Total DQ Pin Count
EP1C3	100-pin TQFP (1)	3	24
	144-pin TQFP	4	32
EP1C4	324-pin FineLine BGA	8	64
	400-pin FineLine BGA	8	64

Device	Package	Number of × 8 DQ Pin Groups	Total DQ Pin Count
EP1C6	144-pin TQFP	4	32
	240-pin PQFP	4	32
	256-pin FineLine BGA	4	32
EP1C12	240-pin PQFP	4	32
	256-pin FineLine BGA	4	32
	324-pin FineLine BGA	8	64
EP1C20	324-pin FineLine BGA	8	64
	400-pin FineLine BGA	8	64

Note to Table 2–10:

- (1) EP1C3 devices in the 100-pin TQFP package do not have any DQ pin groups in I/O bank 1.

A programmable delay chain on each DQS pin allows for either a 90° phase shift (for DDR SDRAM), or a 72° phase shift (for FCRAM) which automatically center-aligns input DQS synchronization signals within the data window of their corresponding DQ data signals. The phase-shifted DQS signals drive the global clock network. This global DQS signal clocks DQ signals on internal LE registers.

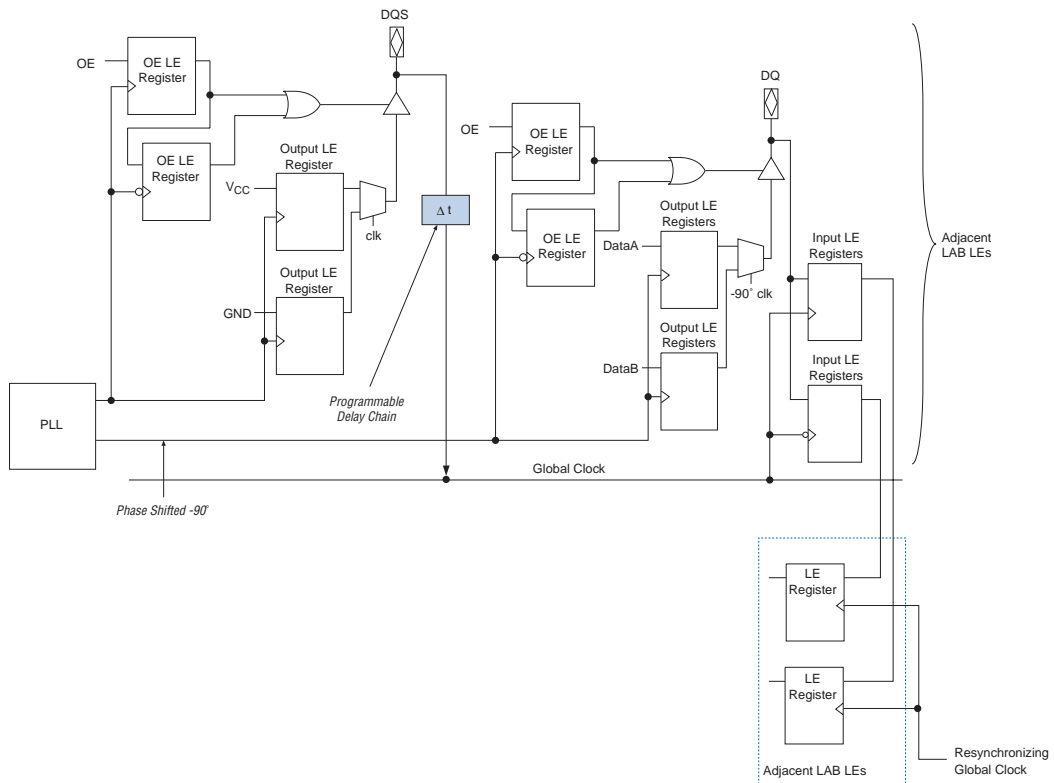
These DQS delay elements combine with the PLL's clocking and phase shift ability to provide a complete hardware solution for interfacing to high-speed memory.

The clock phase shift allows the PLL to clock the DQ output enable and output paths. The designer should use the following guidelines to meet 133 MHz performance for DDR SDRAM and FCRAM interfaces:

- The DQS signal must be in the middle of the DQ group it clocks
- Resynchronize the incoming data to the logic array clock using successive LE registers or FIFO buffers
- LE registers must be placed in the LAB adjacent to the DQ I/O pin column it is fed by

Figure 2–34 illustrates DDR SDRAM and FCRAM interfacing from the I/O through the dedicated circuitry to the logic array.

Figure 2–34. DDR SDRAM & FCRAM Interfacing



Programmable Drive Strength

The output buffer for each Cyclone device I/O pin has a programmable drive strength control for certain I/O standards. The LVTTTL and LVCMOS standards have several levels of drive strength that the designer can control. SSTL-3 class I and II, and SSTL-2 class I and II support a minimum setting, the lowest drive strength that guarantees the I_{OH}/I_{OL} of the standard. Using minimum settings provides signal slew

rate control to reduce system noise and signal overshoot. [Table 2–11](#) shows the possible settings for the I/O standards with drive strength control.

Table 2–11. Programmable Drive Strength

I/O Standard	I _{OH} /I _{OL} Current Strength Setting (mA)
LVTTTL (3.3 V)	4
	8
	12
	16
	24
LVCMOS (3.3 V)	2
	4
	8
	12
LVTTTL (2.5 V)	2
	8
	12
	16
LVTTTL (1.8 V)	2
	8
	12
LVCMOS (1.5 V)	2
	4
	8

Open-Drain Output

Cyclone devices provide an optional open-drain (equivalent to an open-collector) output for each I/O pin. This open-drain output enables the device to provide system-level control signals (e.g., interrupt and write-enable signals) that can be asserted by any of several devices.

Slew-Rate Control

The output buffer for each Cyclone device I/O pin has a programmable output slew-rate control that can be configured for low noise or high-speed performance. A faster slew rate provides high-speed transitions for high-performance systems. However, these fast transitions may introduce noise transients into the system. A slow slew rate reduces

system noise, but adds a nominal delay to rising and falling edges. Each I/O pin has an individual slew-rate control, allowing the designer to specify the slew rate on a pin-by-pin basis. The slew-rate control affects both the rising and falling edges.

Bus Hold

Each Cyclone device I/O pin provides an optional bus-hold feature. The bus-hold circuitry can hold the signal on an I/O pin at its last-driven state. Since the bus-hold feature holds the last-driven state of the pin until the next input signal is present, an external pull-up or pull-down resistor is not necessary to hold a signal level when the bus is tri-stated.

The bus-hold circuitry also pulls undriven pins away from the input threshold voltage where noise can cause unintended high-frequency switching. The designer can select this feature individually for each I/O pin. The bus-hold output will drive no higher than V_{CCIO} to prevent overdriving signals. If the bus-hold feature is enabled, the device cannot use the programmable pull-up option. Disable the bus-hold feature when the I/O pin is configured for differential signals.

The bus-hold circuitry uses a resistor with a nominal resistance (RBH) of approximately 7 k Ω to pull the signal level to the last-driven state. [Table 4-15 on page 4-6](#) gives the specific sustaining current for each V_{CCIO} voltage level driven through this resistor and overdrive current used to identify the next-driven input level.

The bus-hold circuitry is only active after configuration. When going into user mode, the bus-hold circuit captures the value on the pin present at the end of configuration.

Programmable Pull-Up Resistor

Each Cyclone device I/O pin provides an optional programmable pull-up resistor during user mode. If the designer enables this feature for an I/O pin, the pull-up resistor (typically 25 k Ω) holds the output to the V_{CCIO} level of the output pin's bank.

Advanced I/O Standard Support

Cyclone device IOEs support the following I/O standards:

- 3.3-V LVTTTL/LVCMOS
- 2.5-V LVTTTL/LVCMOS
- 1.8-V LVTTTL/LVCMOS
- 1.5-V LVCMOS
- 3.3-V PCI
- LVDS
- SSTL-2 class I and II
- SSTL-3 class I and II
- Differential SSTL-2 class II (on output clocks only)

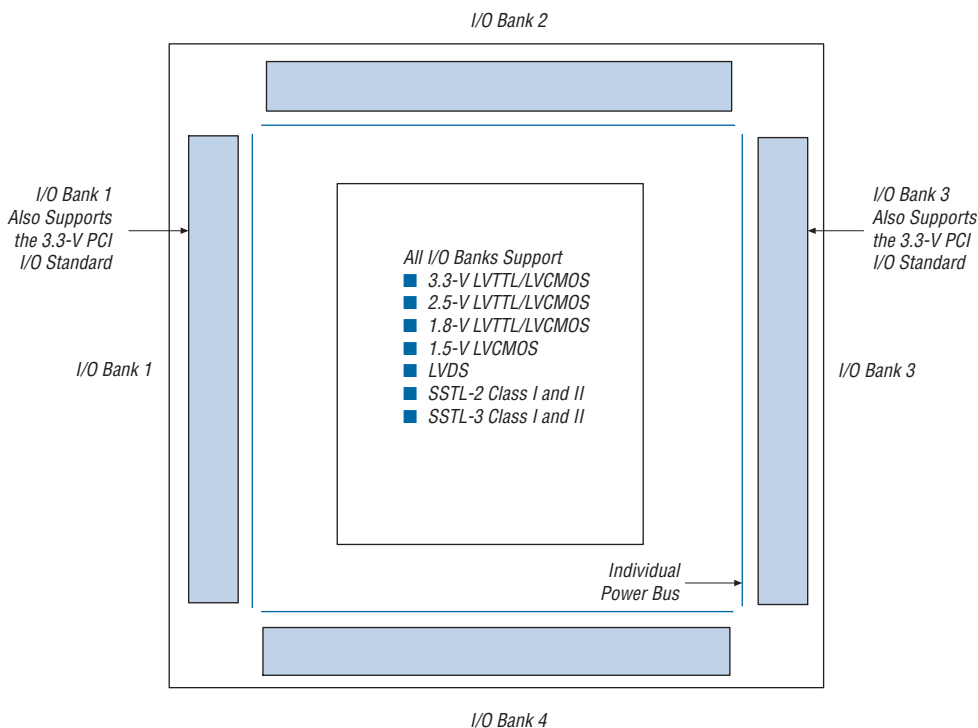
Table 2–12 describes the I/O standards supported by Cyclone devices.

I/O Standard	Type	Input Reference Voltage (V_{REF}) (V)	Output Supply Voltage (V_{CCIO}) (V)	Board Termination Voltage (V_{TT}) (V)
3.3-V LVTTTL/LVCMOS	Single-ended	N/A	3.3	N/A
2.5-V LVTTTL/LVCMOS	Single-ended	N/A	2.5	N/A
1.8-V LVTTTL/LVCMOS	Single-ended	N/A	1.8	N/A
1.5-V LVCMOS	Single-ended	N/A	1.5	N/A
3.3-V PCI (1)	Single-ended	N/A	3.3	N/A
LVDS (2)	Differential	N/A	2.5	N/A
SSTL-2 class I and II	Voltage-referenced	1.25	2.5	1.25
SSTL-3 class I and II	Voltage-referenced	1.5	3.3	1.5
Differential SSTL-2 (3)	Differential	1.25	2.5	1.25

Notes to Table 2–12:

- (1) EP1C3 devices do not support PCI.
- (2) EP1C3 devices in the 100-pin TQFP package do not support the LVDS I/O standard.
- (3) This I/O standard is only available on output clock pins (PLL_OUT pins).

Cyclone devices contain four I/O banks, as shown in Figure 2–35. I/O banks 1 and 3 support all the I/O standards listed in Table 2–12. I/O banks 2 and 4 support all the I/O standards listed in Table 2–12 except the 3.3-V PCI standard. I/O banks 2 and 4 contain dual-purpose DQS, DQ, and DM pins to support a DDR SDRAM or FCRAM interface. I/O bank 1 can also support a DDR SDRAM or FCRAM interface, however, the configuration input pins in I/O bank 1 must operate at 2.5 V. I/O bank 3 can also support a DDR SDRAM or FCRAM interface, however, all the JTAG pins in I/O bank 3 must operate at 2.5 V.

Figure 2–35. Cyclone I/O Banks Notes (1), (2)

Notes to Figure 2–35:

- (1) Figure 2–35 is a top view of the silicon die.
- (2) Figure 2–35 is a graphic representation only. Refer to the pin list and the Quartus II® software for exact pin locations.

Each I/O bank has its own V_{CCIO} pins. A single device can support 1.5-V, 1.8-V, 2.5-V, and 3.3-V interfaces; each individual bank can support a different standard with different I/O voltages. Each bank also has dual-purpose V_{REF} pins to support any one of the voltage-referenced standards (e.g., SSTL-3) independently. If an I/O bank does not use voltage-referenced standards, the V_{REF} pins are available as user I/O pins.

Each I/O bank can support multiple standards with the same V_{CCIO} for input and output pins. For example, when V_{CCIO} is 3.3-V, a bank can support LVTTTL, LVCMOS, 3.3-V PCI, and SSTL-3 for inputs and outputs.

LVDS I/O Pins

A subset of pins in all four I/O banks supports LVDS interfacing. These dual-purpose LVDS pins require an external-resistor network at the transmitter channels in addition to 100- Ω termination resistors on receiver channels. These pins do not contain dedicated serialization or deserialization circuitry; therefore, internal logic performs serialization and deserialization functions.

Table 2–13 shows the total number of supported LVDS channels per device density.

Device	Pin Count	Number of LVDS Channels
EP1C3	100	(1)
	144	34
EP1C4	324	103
	400	129
EP1C6	144	29
	240	72
	256	72
EP1C12	240	66
	256	72
	324	103
EP1C20	324	95
	400	129

Note to Table 2–13:

- (1) EP1C3 devices in the 100-pin TQFP package do not support the LVDS I/O standard.

MultiVolt I/O Interface

The Cyclone architecture supports the MultiVolt I/O interface feature, which allows Cyclone devices in all packages to interface with systems of different supply voltages. The devices have one set of V_{CC} pins for internal operation and input buffers (V_{CCINT}), and four sets for I/O output drivers (V_{CCIO}).

The Cyclone V_{CCINT} pins must always be connected to a 1.5-V power supply. If the V_{CCINT} level is 1.5 V, then input pins are 1.5-V, 1.8-V, 2.5-V, and 3.3-V tolerant. The V_{CCIO} pins can be connected to either a 1.5-V,

1.8-V, 2.5-V, or 3.3-V power supply, depending on the output requirements. The output levels are compatible with systems of the same voltage as the power supply (i.e., when V_{CCIO} pins are connected to a 1.5-V power supply, the output levels are compatible with 1.5-V systems). When V_{CCIO} pins are connected to a 3.3-V power supply, the output high is 3.3-V and is compatible with 3.3-V or 5.0-V systems. Table 2-14 summarizes Cyclone MultiVolt I/O support.

Table 2-14. Cyclone MultiVolt I/O Support *Note (1)*

V_{CCIO} (V)	Input Signal					Output Signal				
	1.5 V	1.8 V	2.5 V	3.3 V	5.0 V	1.5 V	1.8 V	2.5 V	3.3 V	5.0 V
1.5	✓	✓	✓ (2)	✓ (2)		✓				
1.8		✓	✓	✓		✓ (3)	✓			
2.5			✓	✓		✓ (5)	✓ (5)	✓		
3.3			✓ (4)	✓	✓ (6)	✓ (7)	✓ (7)	✓ (7)	✓	✓ (8)

Notes to Table 2-14:

- (1) The PCI clamping diode must be disabled to drive an input with voltages higher than V_{CCIO} .
- (2) When $V_{CCIO} = 1.5\text{-V}$ and a 2.5-V or 3.3-V input signal feeds an input pin, higher pin leakage current is expected.
- (3) When $V_{CCIO} = 1.8\text{-V}$, a Cyclone device can drive a 1.5-V device with 1.8-V tolerant inputs.
- (4) When $V_{CCIO} = 3.3\text{-V}$ and a 2.5-V input signal feeds an input pin, the V_{CCIO} supply current will be slightly larger than expected.
- (5) When $V_{CCIO} = 2.5\text{-V}$, a Cyclone device can drive a 1.5-V or 1.8-V device with 2.5-V tolerant inputs.
- (6) Cyclone devices can be 5.0-V tolerant with the use of an external resistor and the internal PCI clamp diode.
- (7) When $V_{CCIO} = 3.3\text{-V}$, a Cyclone device can drive a 1.5-V, 1.8-V, or 2.5-V device with 3.3-V tolerant inputs.
- (8) When $V_{CCIO} = 3.3\text{-V}$, a Cyclone device can drive a device with 5.0-V LVTTTL inputs but not 5.0-V LVCMOS inputs.

Power Sequencing & Hot Socketing

Because Cyclone devices can be used in a mixed-voltage environment, they have been designed specifically to tolerate any possible power-up sequence. Therefore, the V_{CCIO} and V_{CCINT} power supplies may be powered in any order.

Signals can be driven into Cyclone devices before and during power up without damaging the device. In addition, Cyclone devices do not drive out during power up. Once operating conditions are reached and the device is configured, Cyclone devices operate as specified by the user.

IEEE Std. 1149.1 (JTAG) Boundary Scan Support

All Cyclone devices provide JTAG BST circuitry that complies with the IEEE Std. 1149.1a-1990 specification. JTAG boundary-scan testing can be performed either before or after, but not during configuration. Cyclone devices can also use the JTAG port for configuration together with either the Quartus II® software or hardware using either Jam Files (.jam) or Jam Byte-Code Files (.jbc).

Cyclone devices support reconfiguring the I/O standard settings on the IOE through the JTAG BST chain. The JTAG chain can update the I/O standard for all input and output pins any time before or during user mode. Designers can use this ability for JTAG testing before configuration when some of the Cyclone pins drive or receive from other devices on the board using voltage-referenced standards. Since the Cyclone device might not be configured before JTAG testing, the I/O pins might not be configured for appropriate electrical standards for chip-to-chip communication. Programming those I/O standards via JTAG allows designers to fully test I/O connection to other devices.

The JTAG pins support 1.5-V/1.8-V or 2.5-V/3.3-V I/O standards. The TDO pin voltage is determined by the V_{CCIO} of the bank where it resides. The bank V_{CCIO} selects whether the JTAG inputs are 1.5-V, 1.8-V, 2.5-V, or 3.3-V compatible.

Cyclone devices also use the JTAG port to monitor the operation of the device with the SignalTap® II embedded logic analyzer. Cyclone devices support the JTAG instructions shown in [Table 3-1](#).

Table 3-1. Cyclone JTAG Instructions (Part 1 of 2)

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 0000	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 3–1. Cyclone JTAG Instructions (Part 2 of 2)		
JTAG Instruction	Instruction Code	Description
USERCODE	00 0000 0111	Selects the 32-bit USERCODE register and places it between the TDI and TDO pins, allowing the USERCODE to be serially shifted out of 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 Cyclone device via the JTAG port with a MasterBlaster™ or ByteBlasterMV™ download cable, or when using a Jam File or Jam Byte-Code 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 configuration of I/O standards through the JTAG chain for JTAG testing. Can be executed before, after, or during configuration. Stops configuration if executed during configuration. Once issued, the CONFIG_IO instruction will hold nSTATUS low to reset the configuration device. nSTATUS is held low until the device is reconfigured.
SignalTap II instructions		Monitors internal device operation with the SignalTap II embedded logic analyzer.

Note to Table 3–1:

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

The Cyclone device instruction register length is 10 bits and the USERCODE register length is 32 bits. Tables 3–2 and 3–3 show the boundary-scan register length and device IDCODE information for Cyclone devices.

Device	Boundary-Scan Register Length
EP1C3	339
EP1C4	930
EP1C6	582
EP1C12	774
EP1C20	930

Device	IDCODE (32 bits) (1)			
	Version (4 Bits)	Part Number (16 Bits)	Manufacturer Identity (11 Bits)	LSB (1 Bit) (2)
EP1C3	0000	0010 0000 1000 0001	000 0110 1110	1
EP1C4	0000	0010 0000 1000 0101	000 0110 1110	1
EP1C6	0000	0010 0000 1000 0010	000 0110 1110	1
EP1C12	0000	0010 0000 1000 0011	000 0110 1110	1
EP1C20	0000	0010 0000 1000 0100	000 0110 1110	1

Notes to Table 3–3:

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

Figure 3-1 shows the timing requirements for the JTAG signals.

Figure 3-1. Cyclone JTAG Waveforms

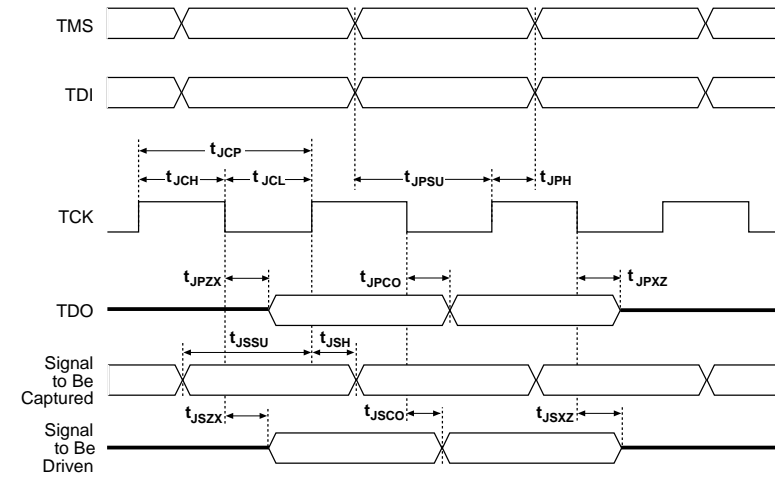


Table 3-4 shows the JTAG timing parameters and values for Cyclone devices.

Symbol	Parameter	Min	Max	Unit
t_{JCP}	TCK clock period	100		ns
t_{JCH}	TCK clock high time	50		ns
t_{JCL}	TCK clock low time	50		ns
t_{JPSU}	JTAG port setup time	20		ns
t_{JPH}	JTAG port hold time	45		ns
t_{JPCO}	JTAG port clock to output		25	ns
t_{JPZX}	JTAG port high impedance to valid output		25	ns
t_{JPXZ}	JTAG port valid output to high impedance		25	ns
t_{JSSU}	Capture register setup time	20		ns
t_{JSH}	Capture register hold time	45		ns
t_{JSCO}	Update register clock to output		35	ns
t_{JSZX}	Update register high impedance to valid output		35	ns
t_{JSXZ}	Update register valid output to high impedance		35	ns



For more information on JTAG, see the following documents:

- *Application Note 39 (IEEE Std. 1149.1 (JTAG) Boundary-Scan Testing in Altera Devices)*
- *Jam Programming & Test Language Specification*

SignalTap II Embedded Logic Analyzer

Cyclone devices feature the SignalTap II embedded logic analyzer, which monitors design operation over a period of time through the IEEE Std. 1149.1 (JTAG) circuitry. A designer can analyze internal logic at speed without bringing internal signals to the I/O pins. This feature is particularly important for advanced packages, such as FineLine BGA packages, because it can be difficult to add a connection to a pin during the debugging process after a board is designed and manufactured.

Configuration

The logic, circuitry, and interconnects in the Cyclone architecture are configured with CMOS SRAM elements. Cyclone devices are reconfigurable and are 100% tested prior to shipment. As a result, the designer does not have to generate test vectors for fault coverage purposes, and can instead focus on simulation and design verification. In addition, the designer does not need to manage inventories of different ASIC designs. Cyclone devices can be configured on the board for the specific functionality required.

Cyclone devices are configured at system power-up with data stored in an Altera configuration device or provided by a system controller. The Cyclone device's optimized interface allows the device to act as controller in an active serial configuration scheme with the new low-cost serial configuration device. Cyclone devices can be configured in under 120 ms using serial data at 20 MHz. The serial configuration device can be programmed via the ByteBlaster II download cable, the Altera Programming Unit (APU), or third-party programmers.

In addition to the new low-cost serial configuration device, Altera offers in-system programmability (ISP)-capable configuration devices that can configure Cyclone devices via a serial data stream. The interface also enables microprocessors to treat Cyclone devices as memory and configure them by writing to a virtual memory location, making reconfiguration easy. After a Cyclone device has been configured, it can be reconfigured in-circuit by resetting the device and loading new data. Real-time changes can be made during system operation, enabling innovative reconfigurable computing applications.

Operating Modes

The Cyclone architecture uses SRAM configuration elements that require configuration data to be loaded each time the circuit powers up. The process of physically loading the SRAM data into the device is called configuration. During initialization, which occurs immediately after configuration, the device resets registers, enables I/O pins, and begins to operate as a logic device. Together, the configuration and initialization processes are called command mode. Normal device operation is called user mode.

SRAM configuration elements allow Cyclone devices to be reconfigured in-circuit by loading new configuration data into the device. With real-time reconfiguration, the device is forced into command mode with a device pin. The configuration process loads different configuration data, reinitializes the device, and resumes user-mode operation. Designers can perform in-field upgrades by distributing new configuration files either within the system or remotely.

A built-in weak pull-up resistor pulls all user I/O pins to V_{CCIO} before and during device configuration.

The configuration pins support 1.5-V/1.8-V or 2.5-V/3.3-V I/O standards. The voltage level of the configuration output pins is determined by the V_{CCIO} of the bank where the pins reside. The bank V_{CCIO} selects whether the configuration inputs are 1.5-V, 1.8-V, 2.5-V, or 3.3-V compatible.

Configuration Schemes

Designers can load the configuration data for a Cyclone device with one of three configuration schemes (see [Table 3–5](#)), chosen on the basis of the target application. Designers can use a configuration device, intelligent controller, or the JTAG port to configure a Cyclone device. A low-cost configuration device can automatically configure a Cyclone device at system power-up.

Multiple Cyclone devices can be configured in any of the three configuration schemes by connecting the configuration enable (nCE) and configuration enable output ($nCEO$) pins on each device.

Configuration Scheme	Data Source
Active serial	Low-cost serial configuration device
Passive serial (PS)	Enhanced or EPC2 configuration device, MasterBlaster or ByteBlasterMV download cable, or serial data source
JTAG	MasterBlaster or ByteBlasterMV download cable or a microprocessor with a Jam or JBC file

Operating Conditions

Cyclone devices are offered in both commercial and industrial grades. However, industrial-grade devices may have limited speed-grade availability.

Tables 4–1 through 4–16 provide information on absolute maximum ratings, recommended operating conditions, DC operating conditions, and capacitance for Cyclone devices.

Table 4–1. Cyclone Device Absolute Maximum Ratings *Notes (1), (2)*

Symbol	Parameter	Conditions	Minimum	Maximum	Unit
V _{CCINT}	Supply voltage	With respect to ground (3)	–0.5	2.4	V
V _{CCIO}			–0.5	4.6	V
V _I	DC input voltage		–0.5	4.6	V
I _{OUT}	DC output current, per pin		–25	25	mA
T _{STG}	Storage temperature	No bias	–65	150	°C
T _{AMB}	Ambient temperature	Under bias	–65	135	°C
T _J	Junction temperature	BGA packages under bias		135	°C

Table 4–2. Cyclone Device Recommended Operating Conditions (Part 1 of 2)

Symbol	Parameter	Conditions	Minimum	Maximum	Unit
V _{CCINT}	Supply voltage for internal logic and input buffers	(4)	1.425	1.575	V
V _{CCIO}	Supply voltage for output buffers, 3.3-V operation	(4)	3.00	3.60	V
	Supply voltage for output buffers, 2.5-V operation	(4)	2.375	2.625	V
	Supply voltage for output buffers, 1.8-V operation	(4)	1.71	1.89	V
	Supply voltage for output buffers, 1.5-V operation	(4)	1.4	1.6	V
V _I	Input voltage	(3), (5)	–0.5	4.1	V

Table 4–2. Cyclone Device Recommended Operating Conditions (Part 2 of 2)

Symbol	Parameter	Conditions	Minimum	Maximum	Unit
V_O	Output voltage		0	V_{CCIO}	V
T_J	Operating junction temperature	For commercial use	0	85	° C
		For industrial use	–40	100	° C
t_R	Input rise time			40	ns
t_F	Input fall time			40	ns

Table 4–3. Cyclone Device DC Operating Conditions *Note (6)*

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
I_I	Input pin leakage current	$V_I = V_{CCIOmax}$ to 0 V (7)	–10		10	μ A
I_{OZ}	Tri-stated I/O pin leakage current	$V_O = V_{CCIOmax}$ to 0 V (7)	–10		10	μ A
I_{CC0}	V_{CC} supply current (standby) (All M4K blocks in power-down mode)	$V_I =$ ground, no load, no toggling inputs		10		mA
R_{CONF}	Value of I/O pin pull-up resistor before and during configuration	$V_{CCIO} = 3.0$ V (8)	20		50	k Ω
		$V_{CCIO} = 2.375$ V (8)	30		80	k Ω
		$V_{CCIO} = 1.71$ V (8)	60		150	k Ω

Table 4–4. LVTTL Specifications

Symbol	Parameter	Conditions	Minimum	Maximum	Unit
V_{CCIO}	Output supply voltage		3.0	3.6	V
V_{IH}	High-level input voltage		1.7	4.1	V
V_{IL}	Low-level input voltage		–0.5	0.7	V
V_{OH}	High-level output voltage	$I_{OH} = -4$ to -24 mA (9)	2.4		V
V_{OL}	Low-level output voltage	$I_{OL} = 4$ to 24 mA (9)		0.45	V

Table 4–5. LVCMOS Specifications

Symbol	Parameter	Conditions	Minimum	Maximum	Unit
V_{CCIO}	Output supply voltage		3.0	3.6	V
V_{IH}	High-level input voltage		1.7	4.1	V
V_{IL}	Low-level input voltage		-0.5	0.7	V
V_{OH}	High-level output voltage	$V_{CCIO} = 3.0$, $I_{OH} = -0.1$ mA	$V_{CCIO} - 0.2$		V
V_{OL}	Low-level output voltage	$V_{CCIO} = 3.0$, $I_{OL} = 0.1$ mA		0.2	V

Table 4–6. 2.5-V I/O Specifications *Note (9)*

Symbol	Parameter	Conditions	Minimum	Maximum	Unit
V_{CCIO}	Output supply voltage		2.375	2.625	V
V_{IH}	High-level input voltage		1.7	4.1	V
V_{IL}	Low-level input voltage		-0.5	0.7	V
V_{OH}	High-level output voltage	$I_{OH} = -0.1$ mA	2.1		V
		$I_{OH} = -1$ mA	2.0		V
		$I_{OH} = -2$ to -16 mA (9)	1.7		V
V_{OL}	Low-level output voltage	$I_{OL} = 0.1$ mA		0.2	V
		$I_{OH} = 1$ mA		0.4	V
		$I_{OH} = 2$ to 16 mA (9)		0.7	V

Table 4–7. 1.8-V I/O Specifications

Symbol	Parameter	Conditions	Minimum	Maximum	Unit
V_{CCIO}	Output supply voltage		1.65	1.95	V
V_{IH}	High-level input voltage		$0.65 \times V_{CCIO}$	2.25	V
V_{IL}	Low-level input voltage		-0.3	$0.35 \times V_{CCIO}$	V
V_{OH}	High-level output voltage	$I_{OH} = -2$ to -8 mA (9)	$V_{CCIO} - 0.45$		V
V_{OL}	Low-level output voltage	$I_{OL} = 2$ to 8 mA (9)		0.45	V

Table 4–8. 1.5-V I/O Specifications

Symbol	Parameter	Conditions	Minimum	Maximum	Unit
V_{CCIO}	Output supply voltage		1.4	1.6	V
V_{IH}	High-level input voltage		$0.65 \times V_{CCIO}$	$V_{CCIO} + 0.3$	V
V_{IL}	Low-level input voltage		-0.3	$0.35 \times V_{CCIO}$	V
V_{OH}	High-level output voltage	$I_{OH} = -2 \text{ mA}$ (9)	$0.75 \times V_{CCIO}$		V
V_{OL}	Low-level output voltage	$I_{OL} = 2 \text{ mA}$ (9)		$0.25 \times V_{CCIO}$	V

Table 4–9. 2.5-V LVDS I/O Specifications Note (10)

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{CCIO}	I/O supply voltage		2.375	2.5	2.625	V
V_{OD}	Differential output voltage	$R_L = 100 \Omega$	250		550	mV
ΔV_{OD}	Change in V_{OD} between high and low	$R_L = 100 \Omega$			50	mV
V_{OS}	Output offset voltage	$R_L = 100 \Omega$	1.125	1.25	1.375	V
ΔV_{OS}	Change in V_{OS} between high and low	$R_L = 100 \Omega$			50	mV
V_{TH}	Differential input threshold	$V_{CM} = 1.2 \text{ V}$	-100		100	mV
V_{IN}	Receiver input voltage range		0.0		2.4	V
R_L	Receiver differential input resistor		90	100	110	W

Table 4–10. 3.3-V PCI Specifications

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{CCIO}	Output supply voltage		3.0	3.3	3.6	V
V_{IH}	High-level input voltage		$0.5 \times V_{CCIO}$		$V_{CCIO} + 0.5$	V
V_{IL}	Low-level input voltage		-0.5		$0.3 \times V_{CCIO}$	V
V_{OH}	High-level output voltage	$I_{OUT} = -500 \mu\text{A}$	$0.9 \times V_{CCIO}$			V
V_{OL}	Low-level output voltage	$I_{OUT} = 1,500 \mu\text{A}$			$0.1 \times V_{CCIO}$	V

Table 4–11. SSTL-2 Class I Specifications

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{CCIO}	Output supply voltage		2.375	2.5	2.625	V
V_{TT}	Termination voltage		$V_{REF} - 0.04$	V_{REF}	$V_{REF} + 0.04$	V
V_{REF}	Reference voltage		1.15	1.25	1.35	V
V_{IH}	High-level input voltage		$V_{REF} + 0.18$		3.0	V
V_{IL}	Low-level input voltage		-0.3		$V_{REF} - 0.18$	V
V_{OH}	High-level output voltage	$I_{OH} = -8.1 \text{ mA}$ (9)	$V_{TT} + 0.57$			V
V_{OL}	Low-level output voltage	$I_{OL} = 8.1 \text{ mA}$ (9)			$V_{TT} - 0.57$	V

Table 4–12. SSTL-2 Class II Specifications

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{CCIO}	Output supply voltage		2.3	2.5	2.7	V
V_{TT}	Termination voltage		$V_{REF} - 0.04$	V_{REF}	$V_{REF} + 0.04$	V
V_{REF}	Reference voltage		1.15	1.25	1.35	V
V_{IH}	High-level input voltage		$V_{REF} + 0.18$		$V_{CCIO} + 0.3$	V
V_{IL}	Low-level input voltage		-0.3		$V_{REF} - 0.18$	V
V_{OH}	High-level output voltage	$I_{OH} = -16.4 \text{ mA}$ (9)	$V_{TT} + 0.76$			V
V_{OL}	Low-level output voltage	$I_{OL} = 16.4 \text{ mA}$ (9)			$V_{TT} - 0.76$	V

Table 4–13. SSTL-3 Class I Specifications

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{CCIO}	Output supply voltage		3.0	3.3	3.6	V
V_{TT}	Termination voltage		$V_{REF} - 0.05$	V_{REF}	$V_{REF} + 0.05$	V
V_{REF}	Reference voltage		1.3	1.5	1.7	V
V_{IH}	High-level input voltage		$V_{REF} + 0.2$		$V_{CCIO} + 0.3$	V
V_{IL}	Low-level input voltage		-0.3		$V_{REF} - 0.2$	V
V_{OH}	High-level output voltage	$I_{OH} = -8 \text{ mA}$ (9)	$V_{TT} + 0.6$			V
V_{OL}	Low-level output voltage	$I_{OL} = 8 \text{ mA}$ (9)			$V_{TT} - 0.6$	V

Table 4–14. SSTL-3 Class II Specifications

Symbol	Parameter	Conditions	Minimum	Typical	Maximum	Unit
V_{CCIO}	Output supply voltage		3.0	3.3	3.6	V
V_{TT}	Termination voltage		$V_{REF} - 0.05$	V_{REF}	$V_{REF} + 0.05$	V
V_{REF}	Reference voltage		1.3	1.5	1.7	V
V_{IH}	High-level input voltage		$V_{REF} + 0.2$		$V_{CCIO} + 0.3$	V
V_{IL}	Low-level input voltage		-0.3		$V_{REF} - 0.2$	V
V_{OH}	High-level output voltage	$I_{OH} = -16 \text{ mA}$ (9)	$V_{TT} + 0.8$			V
V_{OL}	Low-level output voltage	$I_{OL} = 16 \text{ mA}$ (9)			$V_{TT} - 0.8$	V

Table 4–15. Bus Hold Parameters

Parameter	Conditions	V_{CCIO} Level								Unit
		1.5 V		1.8 V		2.5 V		3.3 V		
		Min	Max	Min	Max	Min	Max	Min	Max	
Low sustaining current	$V_{IN} > V_{IL}$ (maximum)			30		50		70		μA
High sustaining current	$V_{IN} < V_{IH}$ (minimum)			-30		-50		-70		μA
Low overdrive current	$0 \text{ V} < V_{IN} < V_{CCIO}$				200		300		500	μA
High overdrive current	$0 \text{ V} < V_{IN} < V_{CCIO}$				-200		-300		-500	μA

Table 4–16. Cyclone Device Capacitance *Note (11)*

Symbol	Parameter	Typical	Unit
C_{IO}	Input capacitance for user I/O pin	4.0	pF
C_{LVDS}	Input capacitance for dual-purpose LVDS/user I/O pin	4.7	pF
C_{VREF}	Input capacitance for dual-purpose V_{REF} /user I/O pin.	12.0	pF
C_{DPCLK}	Input capacitance for dual-purpose $DPCLK$ /user I/O pin.	4.4	pF
C_{CLK}	Input capacitance for CLK pin.	4.7	pF

Notes to Tables 4–1 through 4–16:

- (1) See the *Operating Requirements for Altera Devices Data Sheet*.
- (2) Conditions beyond those listed in [Table 4–1](#) may cause permanent damage to a device. Additionally, device operation at the absolute maximum ratings for extended periods of time may have adverse effects on the device.
- (3) Minimum DC input is -0.5 V. During transitions, the inputs may undershoot to -0.5 V or overshoot to 4.6 V for input currents less than 100 mA and periods shorter than 20 ns.
- (4) Maximum V_{CC} rise time is 100 ms, and V_{CC} must rise monotonically.
- (5) All pins, including dedicated inputs, clock, I/O, and JTAG pins, may be driven before V_{CCINT} and V_{CCIO} are powered.
- (6) Typical values are for $T_A = 25^\circ$ C, $V_{CCINT} = 1.5$ V, and $V_{CCIO} = 1.5$ V, 1.8 V, 2.5 V, and 3.3 V.
- (7) This value is specified for normal device operation. The value may vary during power-up. This applies for all V_{CCIO} settings (3.3 , 2.5 , 1.8 , and 1.5 V).
- (8) Pin pull-up resistance values will lower if an external source drives the pin higher than V_{CCIO} .
- (9) Drive strength is programmable according to values in [Table 4–14](#).
- (10) The Cyclone LVDS interface requires a resistor network outside of the transmitter channels.
- (11) Capacitance is sample-tested only. Capacitance is measured using time-domain reflections (TDR). Measurement accuracy is within ± 0.5 pF.

Power Consumption

Designers can use the Altera web power calculator to estimate the device power.

Cyclone devices require a certain amount of power-up current to successfully power up because of the nature of the leading-edge process on which they are fabricated. Table 4–17 shows the maximum power-up current required to power up a Cyclone device.

Device	Maximum Power-Up Current Requirement	Unit
EP1C3	300	mA
EP1C4 (1)	400	mA
EP1C6 (2)	500	mA
EP1C12	900	mA
EP1C20	1,200	mA

Notes to Table 4–17:

- (1) The EP1C4 maximum power-up current is an estimated specification and may change.
- (2) The EP1C6 maximum power-up current is for all EP1C6 devices except for those with lot codes listed in the *Cyclone FPGA Family Errata Sheet*.

Designers should select power supplies and regulators that can supply this amount of current when designing with Cyclone devices. This specification is for commercial operating conditions. Measurements were performed with an isolated Cyclone device on the board. Decoupling capacitors were not used in this measurement. To factor in the current for decoupling capacitors, sum up the current for each capacitor using the following equation:

$$I = C (dV/dt)$$

The exact amount of current that will be consumed varies according to the process, temperature, and power ramp rate. If the power supply or regulator can supply more current than required, the Cyclone device may consume more current than the maximum current specified in Table 4–17. However, the device does not require any more current to successfully power up than what is listed in Table 4–17.

The duration of the I_{CCINT} power-up requirement depends on the V_{CCINT} voltage supply rise time. The power-up current consumption drops when the V_{CCINT} supply reaches approximately 0.75 V. For example, if the V_{CCINT} rise time has a linear rise of 15 ms, the current consumption spike will drop by 7.5 ms.

Typically, the user-mode current during device operation is lower than the power-up current in [Table 4-17](#). Altera recommends using the Cyclone Power Calculator, available on the Altera web site, to estimate the user-mode I_{CCINT} consumption and then select power supplies or regulators based on the higher value.

Timing Model

The DirectDrive technology and MultiTrack interconnect ensure predictable performance, accurate simulation, and accurate timing analysis across all Cyclone device densities and speed grades. This section describes and specifies the performance, internal, external, and PLL timing specifications.

All specifications are representative of worst-case supply voltage and junction temperature conditions.

Preliminary & Final Timing

Timing models can have either preliminary or final status. The Quartus II software issues an informational message during the design compilation if the timing models are preliminary. [Table 4-18](#) shows the status of the Cyclone device timing models.

Preliminary status means the timing model is subject to change. Initially, timing numbers are created using simulation results, process data, and other known parameters. These tests are used to make the preliminary numbers as close to the actual timing parameters as possible.

Final timing numbers are based on actual device operation and testing. These numbers reflect the actual performance of the device under worst-case voltage and junction temperature conditions.

Table 4-18. Cyclone Device Timing Model Status (Part 1 of 2)

Device	Preliminary	Final
EP1C3	✓	
EP1C4	✓	
EP1C6	✓	

Table 4–18. Cyclone Device Timing Model Status (Part 2 of 2)

Device	Preliminary	Final
EP1C12	✓	
EP1C20	✓	

Internal Timing Parameters

Internal timing parameters are specified on a speed grade basis independent of device density. Tables 4–19 through 4–22 describe the Cyclone device internal timing microparameters for LEs, IOEs, M4K memory structures, and MultiTrack interconnects.

Table 4–19. LE Internal Timing Microparameter Descriptions

Symbol	Parameter
t_{SU}	LE register setup time before clock
t_H	LE register hold time after clock
t_{CO}	LE register clock-to-output delay
t_{LUT}	LE combinatorial LUT delay for data-in to data-out
t_{CLR}	Minimum clear pulse width
t_{PRE}	Minimum preset pulse width
t_{CLKHL}	Minimum clock high or low time

Table 4–20. IOE Internal Timing Microparameter Descriptions

Symbol	Parameter
t_{SU}	IOE input and output register setup time before clock
t_H	IOE input and output register hold time after clock
t_{CO}	IOE input and output register clock-to-output delay
$t_{PIN2COMBOUT_R}$	Row input pin to IOE combinatorial output
$t_{PIN2COMBOUT_C}$	Column input pin to IOE combinatorial output
$t_{COMBIN2PIN_R}$	Row IOE data input to combinatorial output pin
$t_{COMBIN2PIN_C}$	Column IOE data input to combinatorial output pin
t_{CLR}	Minimum clear pulse width
t_{PRE}	Minimum preset pulse width
t_{CLKHL}	Minimum clock high or low time

Table 4–21. M4K Block Internal Timing Microparameter Descriptions

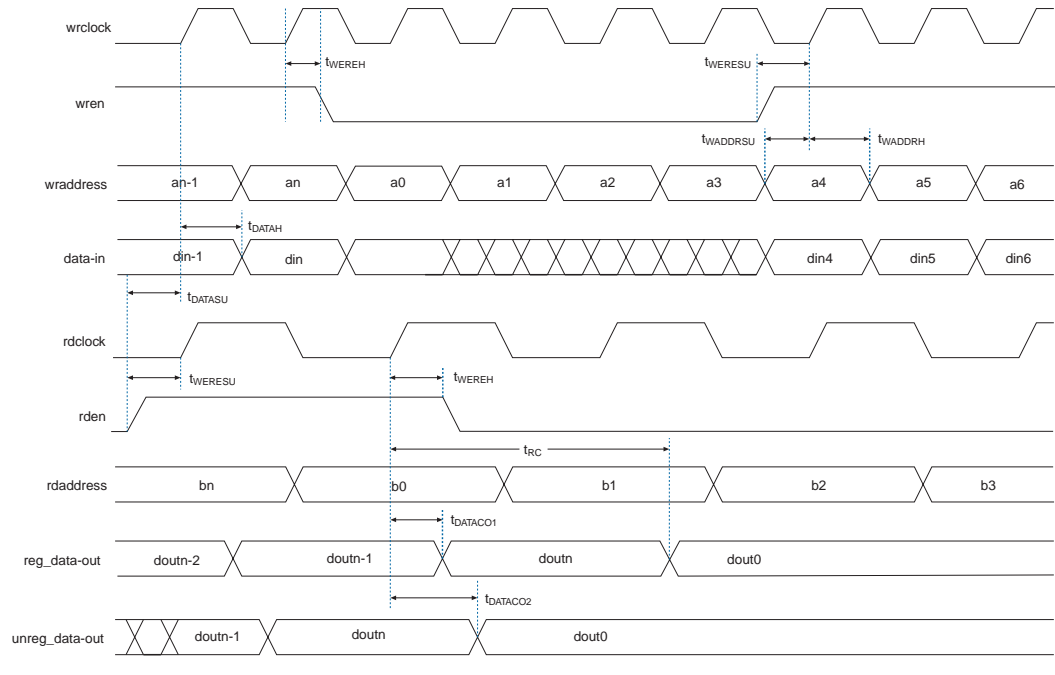
Symbol	Parameter
t_{M4KRRC}	Synchronous read cycle time
t_{M4KWC}	Synchronous write cycle time
$t_{M4KWRESU}$	Write or read enable setup time before clock
$t_{M4KWEREH}$	Write or read enable hold time after clock
$t_{M4KBESU}$	Byte enable setup time before clock
t_{M4KBEH}	Byte enable hold time after clock
$t_{M4KDATAASU}$	A port data setup time before clock
$t_{M4KDATAAH}$	A port data hold time after clock
$t_{M4KADDRASU}$	A port address setup time before clock
$t_{M4KADDRAH}$	A port address hold time after clock
$t_{M4KDATABSU}$	B port data setup time before clock
$t_{M4KDATA BH}$	B port data hold time after clock
$t_{M4KADDRBSU}$	B port address setup time before clock
$t_{M4KADDRBH}$	B port address hold time after clock
$t_{M4KDATA CO1}$	Clock-to-output delay when using output registers
$t_{M4KDATA CO2}$	Clock-to-output delay without output registers
$t_{M4KCLKHL}$	Minimum clock high or low time
t_{M4KCLR}	Minimum clear pulse width

Table 4–22. Routing Delay Internal Timing Microparameter Descriptions

Symbol	Parameter
t_{R4}	Delay for an R4 line with average loading; covers a distance of four LAB columns
t_{C4}	Delay for an C4 line with average loading; covers a distance of four LAB rows
t_{LOCAL}	Local interconnect delay

Figure 4–1 shows the memory waveforms for the M4K timing parameters shown in Table 4–21.

Figure 4–1. Dual-Port RAM Timing Microparameter Waveform



Internal timing parameters are specified on a speed grade basis independent of device density. Tables 4–23 through 4–26 show the internal timing microparameters for LEs, IOEs, TriMatrix memory structures, DSP blocks, and MultiTrack interconnects.

Table 4–23. LE Internal Timing Microparameters (Part 1 of 2)

Symbol	-6		-7		-8		Unit
	Min	Max	Min	Max	Min	Max	
t_{SU}	29		33		37		ps
t_H	12		13		15		ps
t_{CO}		173		198		224	ps
t_{LUT}		454		522		590	ps

Table 4–23. LE Internal Timing Microparameters (Part 2 of 2)

Symbol	-6		-7		-8		Unit
	Min	Max	Min	Max	Min	Max	
t_{CLR}	129		148		167		ps
t_{PRE}	129		148		167		ps
t_{CLKHL}	107		123		139		ps

Table 4–24. IOE Internal Timing Microparameters

Symbol	-6		-7		-8		Unit
	Min	Max	Min	Max	Min	Max	
t_{SU}	98		107		117		ps
t_H	65		71		78		ps
t_{CO}		161		177		193	ps
$t_{PIN2COMBOUT_R}$		1,107		1,217		1,328	ps
$t_{PIN2COMBOUT_C}$		1,112		1,223		1,334	ps
$t_{COMBIN2PIN_R}$		2,776		3,053		3,331	ps
$t_{COMBIN2PIN_C}$		2,764		3,040		3,316	ps
t_{CLR}	280		308		336		ps
t_{PRE}	280		308		336		ps
t_{CLKHL}	95		104		114		ps

Table 4–25. M4K Block Internal Timing Microparameters (Part 1 of 2)

Symbol	-6		-7		-8		Unit
	Min	Max	Min	Max	Min	Max	
t_{M4KRC}		4,379		5,035		5,691	ps
t_{M4KWC}		2,910		3,346		3,783	ps
$t_{M4KWRESU}$	72		82		93		ps
$t_{M4KWEREH}$	43		49		55		ps
$t_{M4KBESU}$	72		82		93		ps
t_{M4KBEH}	43		49		55		ps
$t_{M4KDATAASU}$	72		82		93		ps
$t_{M4KDATAAH}$	43		49		55		ps

Table 4–25. M4K Block Internal Timing Microparameters (Part 2 of 2)

Symbol	-6		-7		-8		Unit
	Min	Max	Min	Max	Min	Max	
$t_{M4KADDRASU}$	72		82		93		ps
$t_{M4KADDRAH}$	43		49		55		ps
$t_{M4KDATABSU}$	72		82		93		ps
$t_{M4KDATABH}$	43		49		55		ps
$t_{M4KADDRBSU}$	72		82		93		ps
$t_{M4KADDRBH}$	43		49		55		ps
$t_{M4KDATAO1}$		621		714		807	ps
$t_{M4KDATAO2}$		4,351		5,003		5,656	ps
$t_{M4KCLKHL}$	105		120		136		ps
t_{M4KCLR}	286		328		371		ps

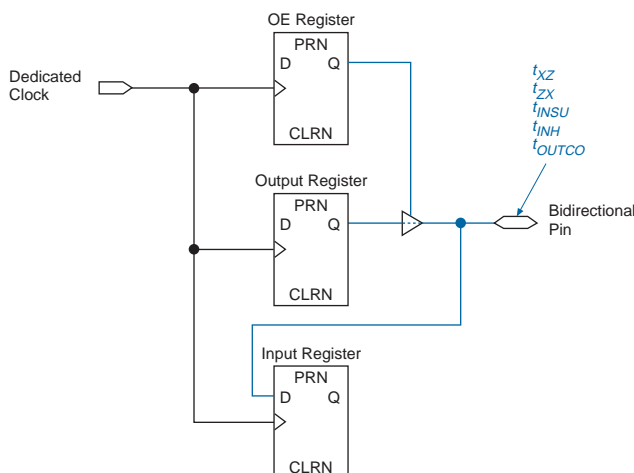
Table 4–26. Routing Delay Internal Timing Microparameters

Symbol	-6		-7		-8		Unit
	Min	Max	Min	Max	Min	Max	
t_{R4}		261		300		339	ps
t_{C4}		338		388		439	ps
t_{LOCAL}		244		281		318	ps

External Timing Parameters

External timing parameters are specified by device density and speed grade. [Figure 4–2](#) shows the timing model for bidirectional IOE pin timing. All registers are within the IOE.

Figure 4–2. External Timing in Cyclone Devices



All external I/O timing parameters shown are for 3.3-V LVTTTL I/O standard with the maximum current strength and fast slew rate. For external I/O timing using standards other than LVTTTL or for different current strengths, use the I/O standard input and output delay adders in [Tables 4–38 through 4–42](#).

[Table 4–27](#) shows the external I/O timing parameters when using global clock networks.

Symbol	Parameter	Conditions
t_{INSU}	Setup time for input or bidirectional pin using IOE input register with global clock fed by CLK pin	
t_{INH}	Hold time for input or bidirectional pin using IOE input register with global clock fed by CLK pin	
t_{OUTCO}	Clock-to-output delay output or bidirectional pin using IOE output register with global clock fed by CLK pin	$C_{LOAD} = 10 \text{ pF}$
t_{XZ}	Synchronous column IOE output enable register to output pin disable delay using global clock fed by CLK pin	$C_{LOAD} = 10 \text{ pF}$
t_{ZX}	Synchronous column IOE output enable register to output pin enable delay using global clock fed by CLK pin	$C_{LOAD} = 10 \text{ pF}$
$t_{INSUPLL}$	Setup time for input or bidirectional pin using IOE input register with global clock fed by Enhanced PLL with default phase setting	

Symbol	Parameter	Conditions
t_{INHPLL}	Hold time for input or bidirectional pin using IOE input register with global clock fed by enhanced PLL with default phase setting	
$t_{OUTCOPLL}$	Clock-to-output delay output or bidirectional pin using IOE output register with global clock enhanced PLL with default phase setting	$C_{LOAD} = 10\text{ pF}$
t_{XZPLL}	Synchronous column IOE output enable register to output pin disable delay using global clock fed by enhanced PLL with default phase setting	$C_{LOAD} = 10\text{ pF}$
t_{ZXPLL}	Synchronous column IOE output enable register to output pin enable delay using global clock fed by enhanced PLL with default phase setting	$C_{LOAD} = 10\text{ pF}$

Notes to Table 4–27:

- (1) These timing parameters are sample-tested only.
- (2) These timing parameters are for IOE pins using a 3.3-V LVTTTL, 24-mA setting. Designers should use the Quartus II software to verify the external timing for any pin.

Tables 4–28 through 4–29 show the external timing parameters on column and row pins for EP1C3 devices.

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{INSU}	2.496		2.715		2.935		ns
t_{INH}	0.000		0.000		0.000		ns
t_{OUTCO}	2.000	3.656	2.000	4.049	2.000	4.445	ns
t_{XZ}		5.283		5.840		6.398	ns
t_{ZX}		5.283		5.840		6.398	ns
$t_{INSUPLL}$	1.195		1.308		1.421		ns
t_{INHPLL}	0.000		0.000		0.000		ns
$t_{OUTCOPLL}$	0.500	1.900	0.500	2.094	0.500	2.291	ns
t_{XZPLL}		3.527		3.885		4.244	ns
t_{ZXPLL}		3.527		3.885		4.244	ns

Table 4–29. EP1C3 Row Pin Global Clock External I/O Timing Parameters

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{INSU}	2.574		2.806		3.041		ns
t_{INH}	0.000		0.000		0.000		ns
t_{OUTCO}	2.000	3.561	2.000	3.939	2.000	4.319	ns
t_{XZ}		5.147		5.684		6.223	ns
t_{ZX}		5.147		5.684		6.223	ns
$t_{INSUPLL}$	1.273		1.399		1.527		ns
t_{INHPLL}	0.000		0.000		0.000		ns
$t_{OUTCOPLL}$	0.500	1.805	0.500	1.984	0.500	2.165	ns
t_{XZPLL}		3.391		3.729		4.069	ns
t_{ZXPLL}		3.391		3.729		4.069	ns

Tables 4–30 through 4–31 show the external timing parameters on column and row pins for EP1C4 devices.

Table 4–30. EP1C4 Column Pin Global Clock External I/O Timing Parameters *Note (1)*

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{INSU}							ns
t_{INH}							ns
t_{OUTCO}							ns
t_{XZ}							ns
t_{ZX}							ns
$t_{INSUPLL}$							ns
t_{INHPLL}							ns
$t_{OUTCOPLL}$							ns
t_{XZPLL}							ns
t_{ZXPLL}							ns

Table 4–31. EP1C4 Row Pin Global Clock External I/O Timing Parameters (1)

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{INSU}							ns
t_{INH}							ns
t_{OUTCO}							ns
t_{XZ}							ns
t_{ZX}							ns
$t_{INSUPLL}$							ns
t_{INHPLL}							ns
$t_{OUTCOPLL}$							ns
t_{XZPLL}							ns
t_{ZXPLL}							ns

Note to Tables 4–30 and 4–31:

(1) Contact Altera Applications for EP1C4 device timing parameters.

Tables 4–32 through 4–33 show the external timing parameters on column and row pins for EP1C6 devices.

Table 4–32. EP1C6 Column Pin Global Clock External I/O Timing Parameters

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{INSU}	2.432		2.643		2.853		ns
t_{INH}	0.000		0.000		0.000		ns
t_{OUTCO}	2.000	3.720	2.000	4.121	2.000	4.527	ns
t_{XZ}		5.347		5.912		6.480	ns
t_{ZX}		5.347		5.912		6.480	ns
$t_{INSUPLL}$	1.188		1.301		1.414		ns
t_{INHPLL}	0.000		0.000		0.000		ns
$t_{OUTCOPLL}$	0.500	1.907	0.500	2.101	0.500	2.298	ns
t_{XZPLL}		3.534		3.892		4.251	ns
t_{ZXPLL}		3.534		3.892		4.251	ns

Table 4–33. EP1C6 Row Pin Global Clock External I/O Timing Parameters

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{NSU}	2.517		2.741		2.966		ns
t_{INH}	0.000		0.000		0.000		ns
t_{OUTCO}	2.000	3.618	2.000	4.004	2.000	4.394	ns
t_{XZ}		5.204		5.749		6.298	ns
t_{ZX}		5.204		5.749		6.298	ns
t_{INSUPLL}	1.273		1.399		1.527		ns
t_{INHPLL}	0.000		0.000		0.000		ns
t_{OUTCOPLL}	0.500	1.805	0.500	1.984	0.500	2.165	ns
t_{XZPLL}		3.391		3.729		4.069	ns
t_{ZXPLL}		3.391		3.729		4.069	ns

Tables 4–34 through 4–35 show the external timing parameters on column and row pins for EP1C12 devices.

Table 4–34. EP1C12 Column Pin Global Clock External I/O Timing Parameters

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{NSU}	2.187		2.363		2.535		ns
t_{INH}	0.000		0.000		0.000		ns
t_{OUTCO}	2.000	3.965	2.000	4.401	2.000	4.845	ns
t_{XZ}		5.592		6.192		6.798	ns
t_{ZX}		5.592		6.192		6.798	ns
t_{INSUPLL}	1.152		1.260		1.368		ns
t_{INHPLL}	0.000		0.000		0.000		ns
t_{OUTCOPLL}	0.500	1.943	0.500	2.142	0.500	2.344	ns
t_{XZPLL}		3.570		3.933		4.297	ns
t_{ZXPLL}		3.570		3.933		4.297	ns

Table 4–35. EP1C12 Row Pin Global Clock External I/O Timing Parameters

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{INSU}	2.308		2.502		2.694		ns
t_{INH}	0.000		0.000		0.000		ns
t_{OUTCO}	2.000	3.827	2.000	4.243	2.000	4.666	ns
t_{XZ}		5.413		5.988		6.570	ns
t_{ZX}		5.413		5.988		6.570	ns
$t_{INSUPLL}$	1.273		1.399		1.527		ns
t_{INHPLL}	0.000		0.000		0.000		ns
$t_{OUTCOPLL}$	0.500	1.805	0.500	1.984	0.500	2.165	ns
t_{XZPLL}		3.391		3.729		4.069	ns
t_{ZXPLL}		3.391		3.729		4.069	ns

Tables 4–36 through 4–37 show the external timing parameters on column and row pins for EP1C20 devices.

Table 4–36. EP1C20 Column Pin Global Clock External I/O Timing Parameters

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{INSU}	2.226		2.406		2.585		ns
t_{INH}	0.000		0.000		0.000		ns
t_{OUTCO}	2.000	3.926	2.000	4.358	2.000	4.795	ns
t_{XZ}		5.553		6.149		6.748	ns
t_{ZX}		5.553		6.149		6.748	ns
$t_{INSUPLL}$	1.138		1.244		1.349		ns
t_{INHPLL}	0.000		0.000		0.000		ns
$t_{OUTCOPLL}$	0.500	1.957	0.500	2.158	0.500	2.363	ns
t_{XZPLL}		3.584		3.949		4.316	ns
t_{ZXPLL}		3.584		3.949		4.316	ns

Table 4–37. EP1C20 Row Pin Global Clock External I/O Timing Parameters

Symbol	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
t_{INSU}	2.361		2.561		2.763		ns
t_{INH}	0.000		0.000		0.000		ns
t_{OUTCO}	2.000	3.774	2.000	4.184	2.000	4.597	ns
t_{XZ}		5.360		5.929		6.501	ns
t_{ZX}		5.360		5.929		6.501	ns
$t_{INSUPLL}$	1.273		1.399		1.527		ns
t_{INHPLL}	0.000		0.000		0.000		ns
$t_{OUTCOPLL}$	0.500	1.805	0.500	1.984	0.500	2.165	ns
t_{XZPLL}		3.391		3.729		4.069	ns
t_{ZXPLL}		3.391		3.729		4.069	ns

External I/O Delay Parameters

External I/O delay timing parameters for I/O standard input and output adders and programmable input and output delays are specified by speed grade independent of device density.

Tables 4–38 through 4–43 show the adder delays associated with column and row I/O pins for all packages. If an I/O standard is selected other than LVTTTL 24 mA with a fast slew rate, add the selected delay to the external t_{CO} and t_{SU} I/O parameters shown in Tables 4–23 through 4–26.

Table 4–38. Cyclone I/O Standard Column Pin Input Delay Adders (Part 1 of 2)

I/O Standard	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
LVC MOS		0		0		0	ps
3.3-V LVTTTL		0		0		0	ps
2.5-V LVTTTL		28		30		33	ps
1.8-V LVTTTL		214		235		256	ps
1.5-V LVTTTL		326		358		391	ps
SSTL-3 class I		–221		–244		–266	ps
SSTL-3 class II		–221		–244		–266	ps
SSTL-2 class I		–264		–291		–317	ps

Table 4–38. Cyclone I/O Standard Column Pin Input Delay Adders (Part 2 of 2)

I/O Standard	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
SSTL-2 class II		–264		–291		–317	ps
LVDS		–197		–217		–237	ps

Table 4–39. Cyclone I/O Standard Row Pin Input Delay Adders

I/O Standard	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
LVC MOS		0		0		0	ps
3.3-V LVTTTL		0		0		0	ps
2.5-V LVTTTL		28		30		33	ps
1.8-V LVTTTL		214		235		256	ps
1.5-V LVTTTL		326		358		391	ps
3.3-V PCI (1)		0		0		0	ps
SSTL-3 class I		–221		–244		–266	ps
SSTL-3 class II		–221		–244		–266	ps
SSTL-2 class I		–264		–291		–317	ps
SSTL-2 class II		–264		–291		–317	ps
LVDS		–197		–217		–237	ps

Table 4–40. Cyclone I/O Standard Output Delay Adders for Fast Slew Rate on Column Pins (Part 1 of 2)

Standard		-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
LVC MOS	2 mA		1,105		1,216		1,326	ps
	4 mA		601		661		721	ps
	8 mA		137		151		164	ps
	12 mA		0		0		0	ps
3.3-V LVTTTL	4 mA		1,105		1,216		1,326	ps
	8 mA		740		814		888	ps
	12 mA		130		143		156	ps
	16 mA		178		196		213	ps
	24 mA		0		0		0	ps

Table 4–40. Cyclone I/O Standard Output Delay Adders for Fast Slew Rate on Column Pins (Part 2 of 2)

Standard		-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
2.5-V LVTTTL	2 mA		1,504		1,654		1,804	ps
	8 mA		307		338		368	ps
	12 mA		338		372		405	ps
	16 mA		195		214		234	ps
1.8-V LVTTTL	2 mA		1,062		1,168		1,274	ps
	8 mA		812		893		974	ps
	12 mA		812		893		974	ps
1.5-V LVTTTL	2 mA		2,556		2,812		3,067	ps
	4 mA		1,613		1,774		1,935	ps
	8 mA		1,064		1,170		1,276	ps
SSTL-3 class I			616		678		739	ps
SSTL-3 class II			180		198		216	ps
SSTL-2 class I			528		581		633	ps
SSTL-2 class II			233		256		279	ps
LVDS			147		162		176	ps

Table 4–41. Cyclone I/O Standard Output Delay Adders for Fast Slew Rate on Row Pins (Part 1 of 2)

Standard		-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
LVCMOS	2 mA		1,105		1,216		1,326	ps
	4 mA		601		661		721	ps
	8 mA		137		151		164	ps
	12 mA		0		0		0	ps
3.3-V LVTTTL	4 mA		1,105		1,216		1,326	ps
	8 mA		740		814		888	ps
	12 mA		130		143		156	ps
	16 mA		178		196		213	ps
	24 mA		0		0		0	ps
2.5-V LVTTTL	2 mA		1,504		1,654		1,804	ps
	8 mA		307		338		368	ps
	12 mA		338		372		405	ps
	16 mA		195		214		234	ps

Table 4–41. Cyclone I/O Standard Output Delay Adders for Fast Slew Rate on Row Pins (Part 2 of 2)

Standard		-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
1.8-V LVTTTL	2 mA		2,556		2,812		3,067	ps
	8 mA		1,062		1,168		1,274	ps
	12 mA		812		893		974	ps
1.5-V LVTTTL	2 mA		2,556		2,812		3,067	ps
	4 mA		1,613		1,774		1,935	ps
	8 mA		1,064		1,170		1,276	ps
3.3-V PCI (1)			–8		–9		–10	ps
SSTL-3 class I			616		678		739	ps
SSTL-3 class II			180		198		216	ps
SSTL-2 class I			528		581		633	ps
SSTL-2 class II			233		256		279	ps
LVDS			147		162		176	ps

Table 4–42. Cyclone I/O Standard Output Delay Adders for Slow Slew Rate on Column Pins (Part 1 of 2)

I/O Standard		-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
LVCMOS	2 mA		2,288		2,517		2,745	ps
	4 mA		1,784		1,962		2,140	ps
	8 mA		1,320		1,452		1,583	ps
	12 mA		1,183		1,301		1,419	ps
3.3-V LVTTTL	4 mA		2,760		3,036		3,312	ps
	8 mA		2,395		2,634		2,874	ps
	12 mA		1,785		1,963		2,142	ps
	16 mA		1,833		2,016		2,199	ps
	24 mA		1,655		1,820		1,986	ps
2.5-V LVTTTL	2 mA		3,643		4,006		4,370	ps
	8 mA		2,446		2,690		2,934	ps
	12 mA		2,477		2,724		2,971	ps
	16 mA		2,334		2,566		2,800	ps
1.8-V LVTTTL	2 mA		6,606		7,267		7,927	ps
	8 mA		5,112		5,623		6,134	ps
	12 mA		4,862		5,348		5,834	ps

Table 4–42. Cyclone I/O Standard Output Delay Adders for Slow Slew Rate on Column Pins (Part 2 of 2)

I/O Standard		-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
1.5-V LVTTTL	2 mA		8,380		9,218		10,055	ps
	4 mA		7,437		8,180		8,923	ps
	8 mA		6,888		7,576		8,264	ps
SSTL-3 class I			1,799		1,979		2,158	ps
SSTL-3 class II			1,363		1,499		1,635	ps
SSTL-2 class I			2,115		2,326		2,537	ps
SSTL-2 class II			1,820		2,001		2,183	ps
LVDS			1,330		1,463		1,595	ps

Table 4–43. Cyclone I/O Standard Output Delay Adders for Slow Slew Rate on Row Pins (Part 1 of 2)

I/O Standard		-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
LVCMOS	2 mA		2,288		2,517		2,745	ps
	4 mA		1,784		1,962		2,140	ps
	8 mA		1,320		1,452		1,583	ps
	12 mA		1,183		1,301		1,419	ps
3.3-V LVTTTL	4 mA		2,760		3,036		3,312	ps
	8 mA		2,395		2,634		2,874	ps
	12 mA		1,785		1,963		2,142	ps
	16 mA		1,833		2,016		2,199	ps
	24 mA		1,655		1,820		1,986	ps
2.5-V LVTTTL	2 mA		3,643		4,006		4,370	ps
	8 mA		2,446		2,690		2,934	ps
	12 mA		2,477		2,724		2,971	ps
	16 mA		2,334		2,566		2,800	ps
1.8-V LVTTTL	2 mA		6,606		7,267		7,927	ps
	8 mA		5,112		5,623		6,134	ps
	12 mA		4,862		5,348		5,834	ps
1.5-V LVTTTL	2 mA		8,380		9,218		10,055	ps
	4 mA		7,437		8,180		8,923	ps
	8 mA		6,888		7,576		8,264	ps
3.3-V PCI			1,175		1,292		1,409	ps

Table 4–43. Cyclone I/O Standard Output Delay Adders for Slow Slew Rate on Row Pins (Part 2 of 2)

I/O Standard	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
	Min	Max	Min	Max	Min	Max	
SSTL-3 class I		1,799		1,979		2,158	ps
SSTL-3 class II		1,363		1,499		1,635	ps
SSTL-2 class I		2,115		2,326		2,537	ps
SSTL-2 class II		1,820		2,001		2,183	ps
LVDS		1,330		1,463		1,595	ps

Note to Tables 4–38 through 4–43:

- (1) EP1C3 devices do not support the PCI I/O standard.

Table 4–44 shows the adder delays for the IOE programmable delays. These delays are controlled with the Quartus II software options listed in the Parameter column.

Table 4–44. Cyclone IOE Programmable Delays on Column Pins

Parameter	Setting	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
Decrease input delay to internal cells	On		3,057		3,362		3,668	ps
	Small		2,212		2,433		2,654	ps
	Medium		2,639		2,902		3,166	ps
	Large		3,057		3,362		3,668	ps
Decrease input delay to input register	On		3,057		3,362		3,668	ps
Increase delay to output pin	On		552		607		662	ps

Table 4–45. Cyclone IOE Programmable Delays on Row Pins

Parameter	Setting	-6 Speed Grade		-7 Speed Grade		-8 Speed Grade		Unit
		Min	Max	Min	Max	Min	Max	
Decrease input delay to internal cells	On		3,057		3,362		3,668	ps
	Small		2,212		2,433		2,654	ps
	Medium		2,639		2,902		3,166	ps
	Large		3,057		3,362		3,668	ps
Decrease input delay to input register	On		3,057		3,362		3,668	ps
Increase delay to output pin	On		556		611		667	ps

Maximum Input & Output Clock Rates

Tables 4–46 and 4–47 show the maximum input clock rate for column and row pins in Cyclone devices.

Table 4–46. Cyclone Maximum Input Clock Rate for Column Pins

I/O Standard	-6 Speed Grade	-7 Speed Grade	-8 Speed Grade	Unit
LVTTTL	304	304	304	MHz
2.5 V	220	220	220	MHz
1.8 V	213	213	213	MHz
1.5 V	166	166	166	MHz
LVC MOS	304	304	304	MHz
SSTL-3 class I	100	100	100	MHz
SSTL-3 class II	100	100	100	MHz
SSTL-2 class I	134	134	134	MHz
SSTL-2 class II	134	134	134	MHz
LVDS	231	231	231	MHz

Table 4–47. Cyclone Maximum Input Clock Rate for Row Pins (Part 1 of 2)

I/O Standard	-6 Speed Grade	-7 Speed Grade	-8 Speed Grade	Unit
LVTTTL	304	304	304	MHz
2.5 V	220	220	220	MHz

Table 4–47. Cyclone Maximum Input Clock Rate for Row Pins (Part 2 of 2)

I/O Standard	-6 Speed Grade	-7 Speed Grade	-8 Speed Grade	Unit
1.8 V	213	213	213	MHz
1.5 V	166	166	166	MHz
LVC MOS	304	304	304	MHz
SSTL-3 class I	100	100	100	MHz
SSTL-3 class II	100	100	100	MHz
SSTL-2 class I	134	134	134	MHz
SSTL-2 class II	134	134	134	MHz
3.3-V PCI (1)	66	66	66	MHz
LVDS	231	231	231	MHz

Note to Tables 4–46 through 4–47:

- (1) EP1C3 devices do not support the PCI I/O standard. These parameters are only available on row I/O pins.

Tables 4–48 and 4–49 show the maximum output clock rate for column and row pins in Cyclone devices.

Table 4–48. Cyclone Maximum Output Clock Rate for Column Pins

I/O Standard	-6 Speed Grade	-7 Speed Grade	-8 Speed Grade	Unit
LVTTTL	304	304	304	MHz
2.5 V	220	220	220	MHz
1.8 V	213	213	213	MHz
1.5 V	166	166	166	MHz
LVC MOS	304	304	304	MHz
SSTL-3 class I	100	100	100	MHz
SSTL-3 class II	100	100	100	MHz
SSTL-2 class I	134	134	134	MHz
SSTL-2 class II	134	134	134	MHz
LVDS	231	231	231	MHz

Table 4–49. Cyclone Maximum Output Clock Rate for Row Pins

I/O Standard	-6 Speed Grade	-7 Speed Grade	-8 Speed Grade	Unit
LVTTTL	304	304	304	MHz
2.5 V	220	220	220	MHz
1.8 V	213	213	213	MHz
1.5 V	166	166	166	MHz
LVC MOS	304	304	304	MHz
SSTL-3 class I	100	100	100	MHz
SSTL-3 class II	100	100	100	MHz
SSTL-2 class I	134	134	134	MHz
SSTL-2 class II	134	134	134	MHz
3.3-V PCI (1)	66	66	66	MHz
LVDS	231	231	231	MHz

Note to Tables 4–48 through 4–49:

- (1) EP1C3 devices do not support the PCI I/O standard. These parameters are only available on row I/O pins.

Software

Cyclone devices are supported by the Altera Quartus[®] II design software, which provides a comprehensive environment for system-on-a-programmable-chip (SOPC) design. The Quartus[®] II software includes HDL and schematic design entry, compilation and logic synthesis, full simulation and advanced timing analysis, SignalTap II logic analysis, and device configuration. See the Design Software Selector Guide for more details on the Quartus[®] II software features.

The Quartus[®] II software supports the Windows 2000/NT/98, Sun Solaris, Linux Red Hat v7.1 and HP-UX operating systems. It also supports seamless integration with industry-leading EDA tools through the NativeLink[®] interface.

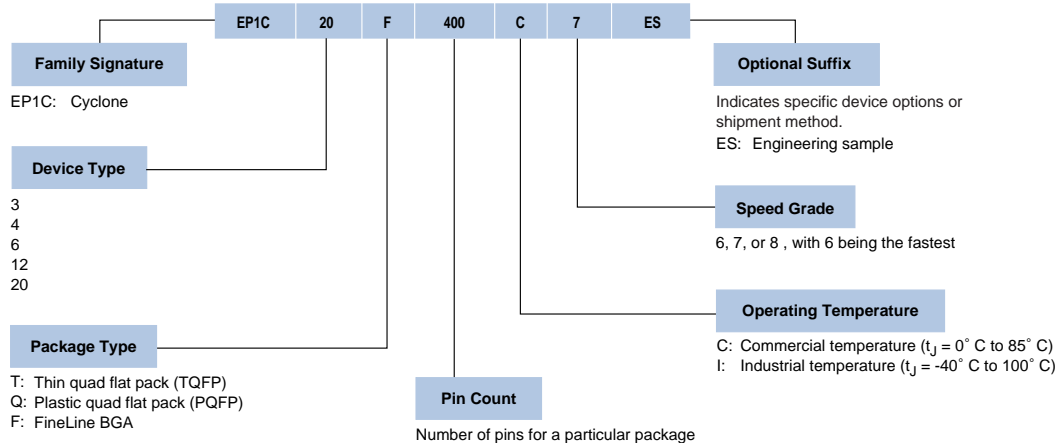
Device Pin-Outs

Device pin-outs for Cyclone devices are available on the Altera web site (www.altera.com) and in the *Cyclone FPGA Device Handbook*.

Ordering Information

Figure 5–1 describes the ordering codes for Cyclone devices. For more information on a specific package, refer to [Chapter 6, Package Information for Cyclone Devices](#).

Figure 5–1. Cyclone Device Packaging Ordering Information



This section provides information on the Cyclone phase-lock loops (PLLs). The PLLs assist designers in managing clocks internally and also have the ability to drive off chip to control system-level clock networks. This chapter contains detailed information on the features, the interconnections to the logic array and off chip, and the specifications for Cyclone PLLs.

This section contains the following:

- [Chapter 6. Using PLLs in Cyclone Devices](#)

Revision History

The table below shows the revision history for [Chapter 6](#).

Chapter(s)	Date / Version	Changes Made
6	May 2003 v1.0	Revised Table 6–1 with EP1C4. Updated Figure 6–8 and added information to Table 6–9 for f_{IN} and f_{OUT} .

Introduction

Cyclone™ FPGAs offer phase locked loops (PLLs) and a global clock network for clock management solutions. Cyclone PLLs offer clock multiplication and division, phase shifting, programmable duty cycle, and external clock outputs, allowing system-level clock management and skew control. The Altera® Quartus® II software enables Cyclone PLLs and their features without using any external devices. This application note explains how to design and enable Cyclone PLL features.

PLLs are commonly used to synchronize internal device clocks with an external clock, run internal clocks at higher frequencies than an external clock, minimize clock delay and clock skew, and reduce or adjust clock-to-out (T_{CO}) and set-up (T_{SU}) times.

Hardware Overview

Cyclone FPGAs contain up to two PLLs per device. [Table 6-1](#) shows which PLLs are available for each Cyclone FPGA.

Table 6-1. Cyclone FPGA PLL Availability

Device	PLL1 (1)	PLL2 (2)
EP1C3	✓	
EP1C4	✓	✓
EP1C6	✓	✓
EP1C12	✓	✓
EP1C20	✓	✓

Notes to Table 6-1:

- (1) Located on the center left side of the device.
- (2) Located on the center right side of the device.

Table 6–2 provides an overview of available Cyclone PLL features.

Table 6–2. Cyclone PLL Features	
Feature	Description
Clock multiplication and division	$M/(N \times \text{post-scale counter})$ (1)
Phase shift	Down to 156-pico second (ps) increments (2), (3)
Programmable duty cycle	✓
Number of internal clock outputs	Two per PLL
Number of external clock outputs (4)	One per PLL
Locked port can feed logic array	✓
PLL clock outputs can feed logic array	✓

Notes to Table 6–2:

- (1) M counter values range from 2 to 32. N and post-scale counter values range from 1 to 32.
- (2) The smallest phase shift is determined by the Voltage Control Oscillator (VCO) period divided by 8.
- (3) For degree increments, Cyclone FPGAs can shift output frequencies in increments of at least 45°. Smaller degree increments are possible depending on the multiplication/division ratio needed on the PLL clock output.
- (4) The EP1C3 device in the 100-pin thin quad flat pack (TQFP) package does not have support for a PLL LVDS input or an external clock output. The EP1C6 PLL2 in the 144-pin TQFP package does not support an external clock output.

Cyclone PLL Blocks

The main goal of a PLL is to synchronize the phase and frequency of an internal/external clock to an input reference clock. There are a number of components that comprise a PLL to achieve this phase alignment.

Cyclone PLLs align the rising edge of the reference input clock to a feedback clock using a phase-frequency detector (PFD). The falling edges are determined by the duty cycle specifications. The PFD produces an up or down signal that determines whether the VCO needs to operate at a higher or lower frequency. The PFD output is applied to the charge pump and loop filter, which produces a control voltage for setting the frequency of the VCO. If the PFD produces an up signal, then the VCO frequency increases, while a down signal causes the VCO frequency to decrease.

The PFD outputs these up and down signals to a charge pump. If the charge pump receives an up signal, current is driven into the loop filter. Conversely, if it receives a down signal, current is drawn from the loop filter. The loop filter converts these up and down signals to a voltage that

is used to bias the VCO. The loop filter also removes glitches from the charge pump and prevents voltage over-shoot, which minimizes the jitter on the VCO.

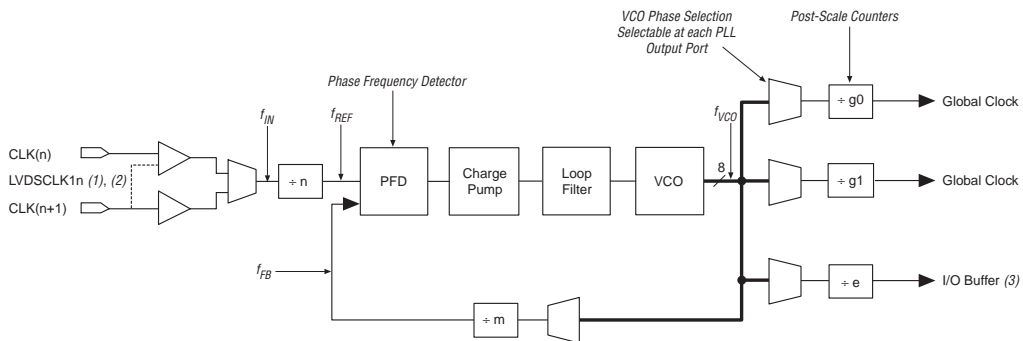
The voltage from the loop filter determines how fast the VCO operates. The VCO is implemented as a four-stage differential ring oscillator. A divide counter (M) is inserted in the feedback loop to increase the VCO frequency above the input reference frequency, making the VCO frequency (f_{VCO}) equal to M times the input reference clock (f_{REF}). The input reference clock (f_{REF}) to the PFD is equal to the input clock (f_{IN}) divided by the pre-scale counter (N). Therefore, the feedback clock (f_{FB}) that is applied to one input of the PFD is locked to the f_{REF} that is applied to the other input of the PFD.

The VCO output can feed up to three post-scale counters ($G0$, $G1$, and E). These post-scale counters allow a number of harmonically-related frequencies to be produced within the PLL.

Additionally, the PLL has internal delay elements to compensate for routing on the global clock networks and I/O buffers of the external clock output pins. These internal delays are fixed and not accessible to the user.

Figure 6–1 shows a block diagram of the major components of a Cyclone PLL.

Figure 6–1. Cyclone PLL



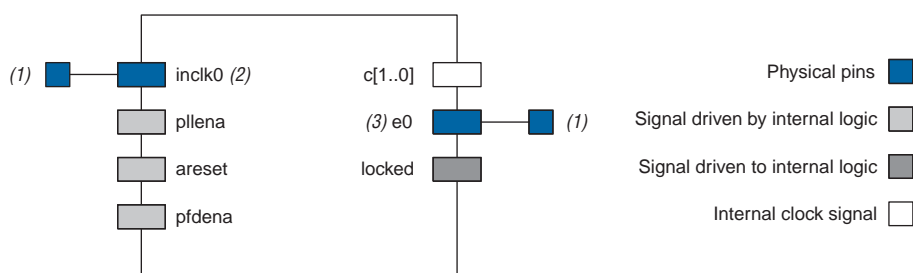
Notes to Figure 6–1:

- (1) The EP1C3 device in the 100-pin TQFP package does not have support for a PLL LVDS input.
- (2) If you are using the LVDS standard, then both CLK pins of that PLL are used. LVDS input is supported via the secondary function of the dedicated CLK pins. For PLL1, the CLK0 pin's secondary function is LVDSCLK1P and the CLK1 pin's secondary function is LVDSCLK1N. For PLL2, the CLK2 pin's secondary function is LVDSCLK2P and the CLK3 pin's secondary function is LVDSCLK2N.
- (3) The EP1C3 device in the 100-pin TQFP package, and the EP1C6 PLL2 in the 144-pin TQFP package do not support an external clock output.

Software Overview

Cyclone PLLs are enabled in the Quartus II software by using the `altp11` megafunction. Figure 6–2 shows the available ports (as they are named in the Quartus II `altp11` megafunction) of Cyclone PLLs and their sources and destinations. It is important to note that the `c[1..0]` and `e0` clock output ports from `altp11` are driven by the post-scale counters G0, G1, and E (not necessarily in that order). The G0 and G1 counters feed the internal global clock network on the `c0` and `c1` PLL outputs, and the E counter feeds the PLL external clock output pin on the `e0` PLL output.

Figure 6–2. Cyclone PLL Signals



Notes to Figure 6–2:

- (1) You can assign these signals to either a single-ended I/O standard or LVDS.
- (2) `inclk0` must be driven by the dedicated clock input pin(s).
- (3) `e0` drives the dual-purpose `PLL[2..1]_OUT` pins.

Table 6–3 and 6–4 describe the Cyclone PLL input and output ports.

Port	Description	Source	Destination
inclk0	Clock input to PLL.	Dedicated clock input pin (1)	±n counter
pllenna (2)	pllenna is an active-high signal that acts as a combined enable and reset signal for the PLL. You can use it for enabling or disabling one or two PLLs. When this signal is driven low, the PLL clock output ports are driven to GND and the PLL loses lock. Once this signal is driven high again, the lock process begins and the PLL re-synchronizes to its input reference clock. You can drive the pllenna port from internal logic or any general-purpose I/O pin.	Logic array (3)	PLL control signal
areset	areset is an active-high signal that resets all PLL counters to their initial values. When this signal is driven high, the PLL resets its counters, clears the PLL outputs, and loses lock. Once this signal is driven low again, the lock process begins and the PLL re-synchronizes to its input reference clock. You can drive the areset port from internal logic or any general-purpose I/O pin.	Logic array (3)	PLL control signal
pfdena	pfdena is an active-high signal that enables or disables the up/down output signals from the PFD. When pfdena is driven low, the PFD is disabled, while the VCO continues to operate. The PLL clock outputs continue to toggle regardless of the input clock, but can experience some long-term drift. Because the output clock frequency does not change for some time, you can use the pfdena port as a shutdown or cleanup function when a reliable input clock is no longer available. You can drive the pfdena port from internal logic or any general-purpose I/O pin.	Logic array (3)	PFD

Notes to Table 6–3:

- (1) The inclk0 port to the PLL must be driven by the dedicated clock input pin(s).
- (2) There is no dedicated pllenna pin for all PLLs, allowing you to choose either one pllenna pin for both PLLs or each PLL can have its own pllenna pin.
- (3) Logic array source means that you can drive the port from internal logic or any general-purpose I/O pin.

Table 6–4. PLL Output Signals

Port	Description	Source	Destination
c[1..0]	PLL clock outputs driving the internal global clock network.	PLL post-scale counter G0 or G1	Global clock network (1)
e0 (2)	PLL clock output driving the single-ended or LVDS external clock output pin(s).	PLL post-scale counter E	PLL[2..1]_OUT pin(s) (3)
locked	Gives the status of the PLL lock. When the PLL is locked, this port drives logic high. When the PLL is out of lock, this port drives logic low. The locked port can pulse high and low during the PLL lock process.	PLL lock detect	Logic array (4)

Notes to Table 6–4:

- (1) C[1..0] can also drive to any general-purpose I/O pin through the global clock network.
- (2) The EP1C3 device in the 100-pin TQFP package, and the EP1C6 PLL2 in the 144-pin TQFP package do not have support for the external clock output PLL[2..1]_OUT.
- (3) The PLL[2..1]_OUT pins are dual-purpose pins. If these pins are not required, they are available for use as general-purpose I/O pins.
- (4) Logic array destination means that you can drive the port to internal logic or any general-purpose I/O pin.

In the Quartus II software, you define which internal clock output from the PLL (c0 or c1) should be compensated. This PLL clock output is phase-aligned with respect to the PLL input clock. For example, if c0 is specified as the compensation clock in normal mode, the compensation is based on the c0 routing on the global clock network.

Pins & Clock Network Connections

You must drive Cyclone PLLs by the dedicated clock input pins CLK[3..0]. Inverted clocks and internally generated clocks cannot drive the PLL. Table 6–5 shows which dedicated clock pin drives which PLL input clock port.



A single clock input pin cannot drive both PLLs, but a single clock input pin can feed both registers in the logic array, as well as the PLL `inclk` port.

Clock Input Pins (1)	PLL1	PLL2 (2)
CLK0	✓	
CLK1	✓	
CLK2		✓
CLK3		✓

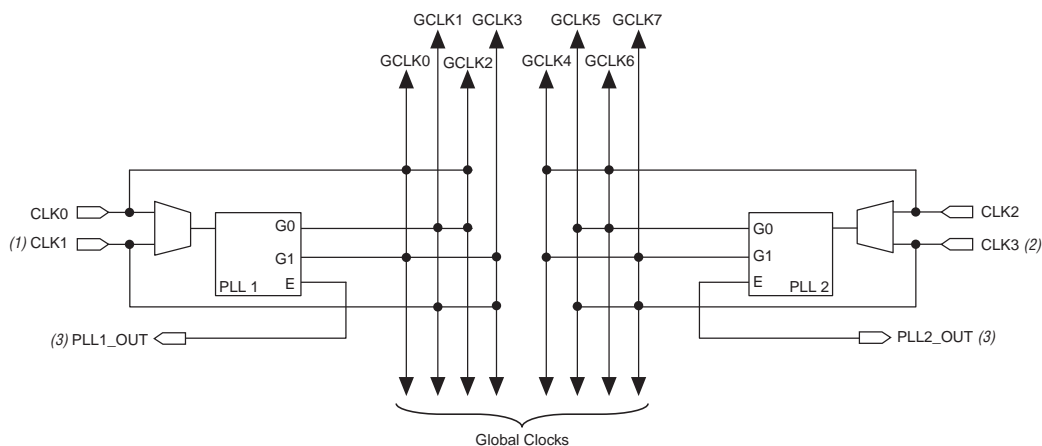
Notes to Table 6–5:

- (1) If you are using the LVDS standard, then both `CLK` pins driving that PLL are used.
- (2) The EP1C3 device only supports PLL1.

The `c[1..0]` and `e0` clock output ports from `altpll` are driven by the PLL post-scale counters G0, G1, and E (not necessarily in that order). The G0 and G1 counters feed the internal global clock network on the `c0` and `c1` PLL outputs, and the E counter feeds the PLL external clock output pin on the `e0` PLL output. Table 6–6 shows which global clock network can be driven by which PLL post-scale counter output.

PLL	Counter Output	GCLK0	GCLK1	GCLK2	GCLK3	GCLK4	GCLK5	GCLK6	GCLK7
PLL 1	G0		✓	✓					
	G1	✓			✓				
PLL2	G0						✓	✓	
	G1					✓			✓

Figure 6–3 summarizes Table 6–5 and 6–6 by showing the PLL input and output clock connections.

Figure 6–3. Cyclone PLL Clock Connections**Notes to Figure 6–3:**

- (1) PLL1 supports one single-ended or LVDS input via the CLK0 and CLK1 pins.
- (2) PLL2 supports one single-ended or LVDS input via the CLK2 and CLK3 pins.
- (3) PLL1_OUT and PLL2_OUT support single-ended or LVDS outputs. If the external clock output is not required, these pins are available as general-purpose I/O pins.

You can invert the clock outputs of the PLL at the logic array block (LAB) and at the input/output element (IOE) level.

Hardware Features

Cyclone PLLs have a number of advanced features available, including clock multiplication and division, phase shifting, programmable duty cycles, external clock outputs, and control signals.

Clock Multiplication & Division

Cyclone PLLs provide clock synthesis for PLL output ports using $M/(N \times \text{post-scale})$ scaling factors. There is one pre-scale divider (N) and one multiply counter (M) per PLL. M counter values range from 2 to 32. N and post-scale counter values range from 1 to 32. The input clock (f_{IN}) is divided by a pre-scale counter (N) to produce the input reference clock (f_{REF}) to the PFD. f_{REF} is then multiplied by the M feedback factor. The control loop drives the VCO frequency to match $f_{IN} \times (M/N)$. See the following equations:

$$f_{REF} = f_{IN} / N$$

$$f_{VCO} = f_{REF} \times M = f_{IN} \times (M/N)$$

Each output port has a unique post-scale counter to divide down the high-frequency VCO. There are three post-scale counters (G0, G1, and E) that range from 1 to 32. See the following equations:

$$f_{c0} = f_{VCO}/G0 = f_{IN} \times (M/(N \times G0))$$

$$f_{c1} = f_{VCO}/G1 = f_{IN} \times (M/(N \times G1))$$

$$f_E = f_{VCO}/E = f_{IN} \times (M/(N \times E))$$



c0 and c1 can use either post-scale counter, G0 or G1.

For multiple PLL outputs with different frequencies, the VCO is set to the least common multiple of the output frequencies that meets the VCO frequency specifications. Then, the post-scale counters scale down the output frequency for each PLL clock output port. For example, if clock output frequencies required from one PLL are 33 and 66 MHz, the VCO is set to 330 MHz (the least common multiple in the VCO's range).

Phase Shifting

Cyclone PLLs have advanced clock shift capability to provide programmable phase shifting. You can enter the desired phase shift in the `altpll` MegaWizard® Plug-In Manager and the Quartus II software automatically sets and displays the closest phase shift achievable. You can enter the phase shift in degrees, or units of time, for each PLL clock output port. This feature is supported on all three PLL post-scale counters, G0, G1, and E and is supported for all available clock feedback modes.

Phase shifting is performed with respect to the PLL clock output that is compensated. For example, you have a 100 MHz input clock and request a $\times 1$ multiplication with a $+90^\circ$ phase shift on c0 and a $\times 1$ multiplication with a $+45^\circ$ phase shift on c1. If you choose to compensate for the c0 clock output, the PLL uses a zero phase-shifted c0 clock as a reference point to produce the $+90^\circ$ phase shift on c0. Since c0 is the compensated clock, it is phase-shifted $+90^\circ$ from the input clock. The c1 clock also uses the zero phase-shifted c0 reference to produce the $+45^\circ$ phase shift on c1.

For fine phase adjustment, each PLL clock output counter can choose a different phase of the VCO from up to eight phase taps. In addition, each clock output counter can use a unique initial count setting to achieve individual coarse phase shift selection, in steps of one VCO period. The Quartus II software can use this clock output counter, along with an initial setting on the post-scale counter, to achieve a phase shift range for the entire period of the output clock. You can phase shift the PLL clock output up to $\pm 180^\circ$. The Quartus II software automatically sets the phase taps and counter settings according to the phase shift requested.

The resolution of the fine phase adjustment is dependent on the input frequency and the multiplication/division factors (i.e., it is a function of the VCO period), with the finest step being equal to an eighth ($\times 0.125$) of the VCO period. The minimum phase shift is $1/(8 \times f_{VCO})$ or $N/(8 \times M \times f_{IN})$. In Cyclone FPGAs, the VCO ranges from 300 to 800 MHz. Therefore, phase shifting can be performed with a resolution range of $1/(8 \times 800 \text{ MHz})$ to $1/(8 \times 300 \text{ MHz})$, which is 156 to 417 ps in time units.

Because there are eight VCO phase taps, the maximum step size is 45° . Smaller steps are possible, depending on the multiplication and division ratio necessary on the output clock port. The equation to determine the precision of the phase shifting in degrees is 45° divided by the post-scale counter value. For example, if you have an input clock of 125 MHz with $\times 1$, the post-scale counter G0 is 3. Therefore, the smallest phase shift step is ($45^\circ/3 = 15^\circ$) and possible phase-shift values would be multiples of 15° .

This type of phase shift provides the highest precision since it is the least sensitive to process, voltage and temperature variation.

Programmable Duty Cycle


The programmable duty cycle feature allows you to set the duty cycle of the PLL clock outputs. The duty cycle is the ratio of the clock output high/low time to the total clock cycle time, which is expressed as a percentage of high time. This feature is supported on all three PLL post-scale counters (G0, G1, and E).

The duty cycle is set by using a low- and high-time count setting for the post-scale counters. The Quartus II software uses the input frequency and target multiply/divide ratio to select the post-scale counter. The precision of the duty cycle is determined by the post-scale counter value chosen on a PLL clock output and is defined as 50% divided by the post-scale counter value. For example, if the post-scale counter value is 3, the allowed duty cycle precision would be 50% divided by 3 equaling 16.67%. Because the `altpll` megafunction does not accept non-integer values for the duty cycle values, the allowed duty cycles are 17, 33, 50, and 67%.

Due to hard limitations, you cannot achieve a duty cycle of 84% because you cannot achieve the closest value to 100% for a given counter value. However, you can achieve a duty cycle of 84% by choosing a 17% duty cycle and inverting the PLL clock output. For example, if the G0 counter is 10, increments of 5% are possible for duty cycle choices between 5 and 90%.

External Clock Output

Each PLL supports one single-ended or LVDS external clock output for general-purpose external clocks, or for source-synchronous transmitters. The output of the E counter drives the PLL external clock output ($\ominus 0$), which can only feed to the PLL[2..1]_OUT pins and not to internal logic. You can use PLL[2..1]_OUT in all three clock feedback modes.

 The EP1C3 device in the 100-pin package, and the EP1C6 PLL2 in the 144-pin package, do not have support for an external clock output.

The PLL[2..1]_OUT pins are dual-purpose pins, meaning if the pins are not required by the PLL, they are available for use as general-purpose I/O pins. The I/O standards supported by the PLL[2..1]_OUT pins are listed in [Table 6-7](#).

I/O Standard	Inclk	PLL[2..1]_OUT (1)
LVTTTL	✓	✓
LVC MOS	✓	✓
2.5-V	✓	✓
1.8-V	✓	✓
1.5-V	✓	✓
3.3-V PCI	✓	✓
LVDS (2)	✓	✓
SSTL-2 Class I	✓	✓
SSTL-2 Class II	✓	✓
SSTL-3 Class I	✓	✓
SSTL-3 Class II	✓	✓
Differential SSTL-2 Class II		✓

Notes to Table 6-7:

- (1) The EP1C3 device in the 100-pin TQFP package and the EP1C6 PLL2 in the 144-pin TQFP package do not support an external clock output.
- (2) The EP1C3 device in the 100-pin TQFP package does not support an LVDS input.

Since the `pllena` and `locked` signal can be driven by or driven to general-purpose I/O pins, respectively, they support all Cyclone I/O standards.

The Cyclone external clock output pins (`PLL[2..1]_OUT`) do not have a separate V_{CC} and GND bank internal to the device. The `PLL[2..1]_OUT` pins share a V_{CCIO} bank with neighboring I/O pins. Only the I/O pins in the same bank have an effect on the `PLL[2..1]_OUT` pins. Therefore, to minimize jitter on the `PLL[2..1]_OUT` pins, I/O pins directly adjacent to these pins should be either inputs or they should not be used. For more information about board design guidelines, see [“Jitter Considerations” on page 6–19](#).

Control Signals

There are four available control signals, `pllena`, `areset`, `pfdena`, and `locked`, in Cyclone PLLs that provide added PLL management.

pllena

The PLL enable signal, `pllena`, enables or disables the PLL. When `pllena` is low, the PLL clock output ports are driven to logic low and the PLL loses lock. When `pllena` goes high again, the PLL relocks and resynchronizes to the input clock. Therefore, `pllena` is an active-high signal. In Cyclone FPGAs, you can feed the `pllena` port from internal logic or any general-purpose I/O pin because there is no dedicated `pllena` pin. This feature offers added flexibility, since each PLL can have its own `pllena` control circuitry, or both PLLs can share the same `pllena` circuitry. The `pllena` signal is optional, and when it is not enabled in the software, the port is internally tied to V_{CC} .

areset

The PLL `areset` signal is the reset or resynchronization input for each PLL. When driven high, the PLL counters reset, clearing the PLL output and causing the PLL to lose lock. The VCO resets back to its nominal setting. When `areset` is again driven low, the PLL resynchronizes to its input clock as the PLL re-locks. If the target VCO frequency is below this nominal frequency, the PLL clock output frequency begins at a higher value than desired during the lock process. `areset` is an active-high signal. Cyclone FPGAs can drive this PLL input signal from internal logic or any general-purpose I/O pin. The `areset` signal is optional, and when it is not enabled in the software, the port is internally tied to GND.

pfdena

The `pfdena` signal controls the PFD output in the PLL with a programmable gate. If you disable the PFD by driving `areset` low, the VCO operates at its last set control voltage and frequency value with some long-term drift to a lower frequency. The VCO frequency can drift up to +/- 5% over 25 us. Even though the PLL clock outputs continue to

toggle regardless of the input clock, the PLL could lose lock. The system continues running when the PLL goes out of lock, or if the input clock is disabled. Because the last locked output frequency does not change for some time, you can use the `pfdena` port as a shutdown or cleanup function when a reliable input clock is no longer available. By maintaining this frequency, the system has time to store its current settings before shutting down. If the `pfdena` signal goes high again, the PLL relocks and resynchronizes to the input clock. Therefore, the `pfdena` pin is an active-high signal. You can drive the `pfdena` input signal by any general-purpose I/O pin, or from internal logic. This signal is optional, and when it is not enabled in the software, the port is internally tied to VCC.

locked

When the `locked` output is at a logic-high level, this level indicates a stable PLL clock output in phase with the PLL reference input clock. Without any additional circuitry, the `locked` port may toggle as the PLL begins tracking the reference clock. The `locked` port of the PLL can feed any general-purpose I/O pin and/or internal logic. This `locked` signal is optional, but is useful in monitoring the PLL lock process.

Clock Feedback Modes

Cyclone PLLs support three feedback modes: normal, zero delay buffer, and no compensation. Unlike other Altera device families, Cyclone PLLs do not have support for external feedback mode. All three supported clock feedback modes allow for multiplication/division, phase shifting, and programmable duty cycle. The following sections give a brief description of each mode.



The phase relationship shown in [Figure 6-4](#) through [6-6](#) are for the default phase shift setting of 0°. Changing the phase-shift setting will change the relationships.

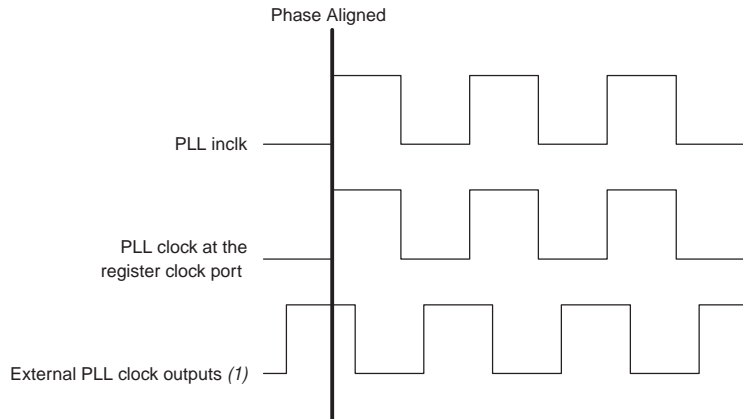
Normal Mode

In normal mode, the PLL phase aligns the input reference clock with the clock signal at the ports of the registers in the logic array or the IOE to compensate for the internal global clock network delay. In the `altpll` MegaWizard Plug-In Manager, you can define which internal clock output from the PLL (`c0` or `c1`) should be compensated.

If the external clock output (`PLL[2..1]_OUT`) is used in this mode, there will be a phase shift with respect to the clock input pin. Similarly, if you use the internal PLL clock outputs to drive general-purpose I/O pins, there will be a phase shift with respect to the clock input pin.

Figure 6–4 shows an example waveform of the PLL clocks' phase relationship in normal mode.

Figure 6–4. Phase Relationship Between PLL Clocks in Normal Mode

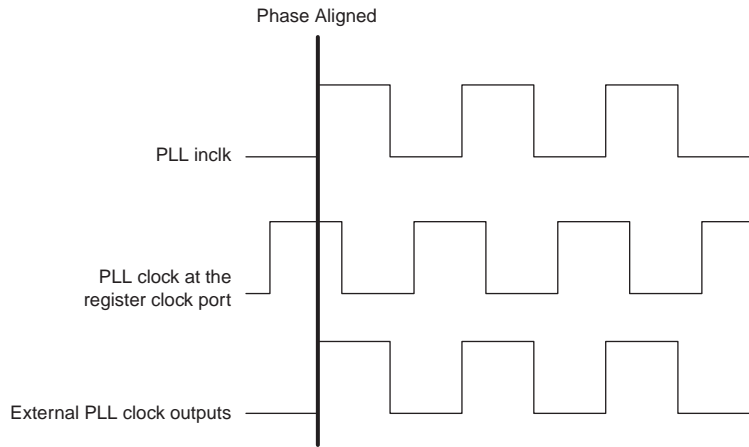


Note to Figure 6–4:

(1) The external clock output can lead or lag the PLL clock signals.

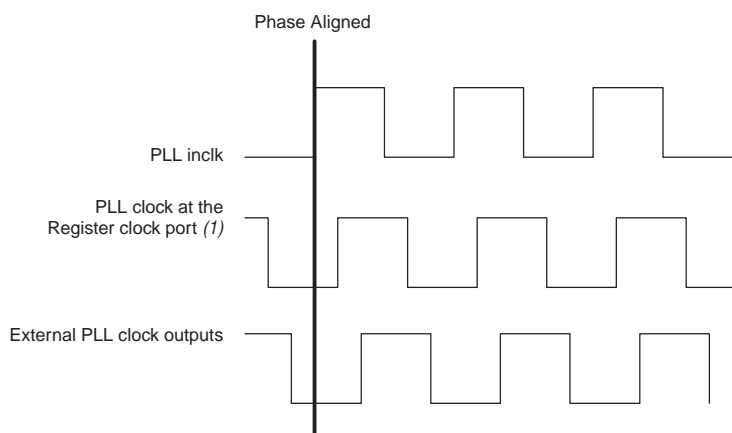
Zero Delay Buffer Mode

The clock signal on the PLL external clock output pin (`PLL[2..1]_OUT`) is phase-aligned with the PLL input clock for zero delay. If you use the `c[1..0]` ports to drive internal clock ports, there will be a phase shift with respect to the input clock pin. Figure 6–5 shows an example waveform of the PLL clocks' phase relationship in zero delay buffer mode.

Figure 6–5. Phase Relationship Between PLL Clocks in Zero Delay Buffer Mode

No Compensation

In this mode, the PLL does not compensate for any clock networks, which leads to better jitter performance because the clock feedback into the PFD does not pass through as much circuitry. Both the PLL internal and external clock outputs are phase shifted with respect to the PLL clock input. [Figure 6–6](#) shows an example waveform of the PLL clocks' phase relationship in no compensation mode.

Figure 6–6. Phase Relationship Between PLL Clocks in No Compensation Mode**Note to Figure 6–6:**

(1) Internal clocks fed by the PLL are in phase alignment with each other.

Pins

Table 6–8 describes the Cyclone PLL-related physical pins and their functionality.

Table 6–8. Cyclone PLL Pins (Part 1 of 2)

Pin Name	Description
CLK0	Single-ended or LVDS p-pin that can drive the <code>inclk0</code> port of PLL1.
CLK1 (1)	Single-ended or LVDS n-pin that can drive the <code>inclk0</code> port of PLL1.
CLK2	Single-ended or LVDS p-pin that can drive the <code>inclk0</code> port of PLL2.
CLK3 (1)	Single-ended or LVDS n-pin that can drive the <code>inclk0</code> port of PLL2.
PLL1_OUTp (2) PLL1_OUTn (2)	Single-ended or LVDS pins driven by the <code>e0</code> port from PLL1. If not used by the PLL, these are available as general-purpose I/O pins.
PLL2_OUTp (2) PLL2_OUTn (2)	Single-ended or LVDS pins driven by the <code>e0</code> port from PLL2. If not used by the PLL, these are available as general-purpose I/O pins.
VCCA_PLL1 (3)	Analog power for PLL1. Even if the PLL is not used, you must connect this pin to 1.5 V.
GNDA_PLL1 (4)	Analog ground for PLL1. You can connect this pin to the GND plane on the board.
VCCA_PLL2 (3)	Analog power for PLL2. Even if the PLL is not used, you must connect this pin to 1.5 V.

Table 6–8. Cyclone PLL Pins (Part 2 of 2)

Pin Name	Description
GND _A _PLL2 (4)	Analog ground for PLL2. You can connect this pin to the GND plane on the board.
GND _G _PLL1 (5)	Guard ring ground for PLL1. You can connect this pin to the GND plane on the board.
GND _G _PLL2 (5)	Guard ring ground for PLL2. You can connect this pin to the GND plane on the board.

Notes to Table 6–8:

- (1) The EP1C3 device in the 100-pin TQFP package does not have dedicated clock pins CLK1 and CLK3.
- (2) The EP1C3 device in the 100-pin TQFP package, and the EP1C6 PLL2 in the 144-pin TQFP package do not support an external clock output.
- (3) Refer to “Board Layout” on page 6–17 for filtering and other recommendations.
- (4) The EP1C3 device in the 100-pin TQFP package, and the EP1C6 PLL2 in the 144-pin TQFP package do not have a separate GND_A_PLL pin. They are internally tied to GND.
- (5) The Guard ring power (V_{CCG}_PLL) is tied internally to V_{CCINT}.

Board Layout

Cyclone PLLs contain analog components that are embedded in a digital device. These analog components have separate power and ground pins to provide immunity against noise generated by the digital components. These separate VCC and GND pins are used to isolate circuitry and improve noise resistance.

V_{CCA} & GND_A

Each PLL has separate VCC and GND pairs for their analog circuitry. The analog circuit power and ground pin for each PLL is called V_{CCA}_PLL# and GND_A_PLL# (# represents the PLL number). Even if the PLL is not used, the V_{CCA} power must be connected to a 1.5-V supply. The power connected to V_{CCA} must be isolated from the power to the rest of the Cyclone FPGA, or any other digital device on the board. The following sections describe three different methods for isolating V_{CCA}.

Separate V_{CCA} Power Plane

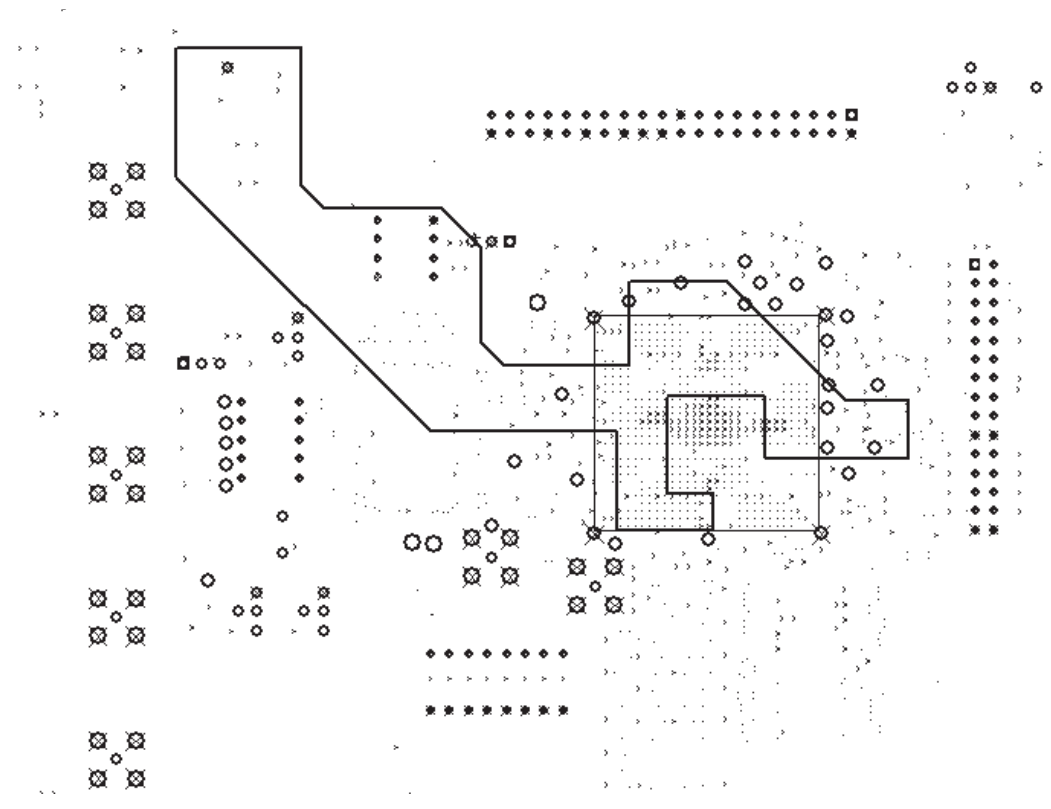
The designer of a mixed-signal system would have already partitioned the system into analog and digital sections, each with its own power planes on the board. In this case, you can connect V_{CCA} to the analog 1.5-V power plane.

Partitioned V_{CCA} Island within V_{CCINT} Plane

Most systems using Altera devices are fully digital, so there is not a separate analog power plane readily available on the board. Adding new planes to the board may be expensive. Therefore, you can create islands

for V_{CCA_PLL} . The dielectric boundary that creates the island is approximately 25 mils thick. Figure 6-7 shows a partitioned plane within V_{CCINT} for V_{CCA} .

Figure 6-7. V_{CCINT} Plane Partitioned for V_{CCA} Island



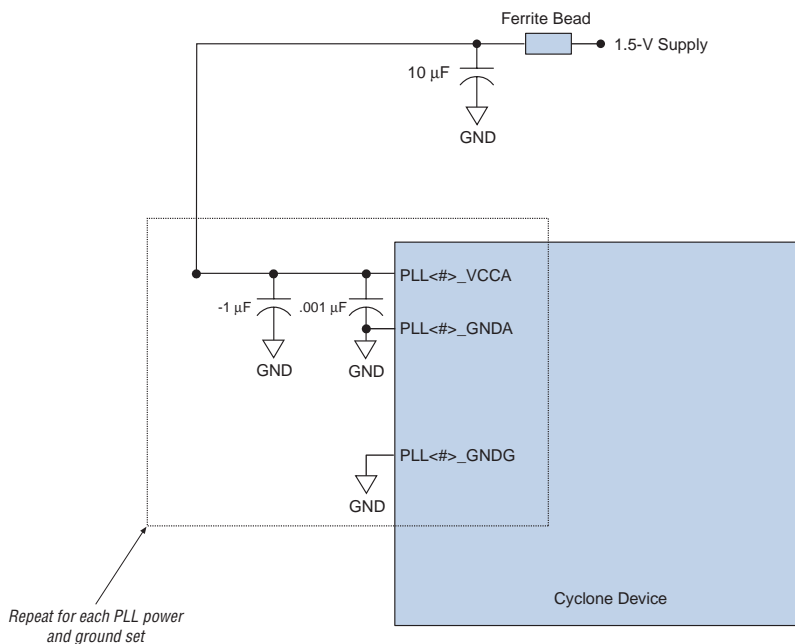
Thick V_{CCA} Traces

Due to board restraints, it may not be possible to partition a V_{CCA} island. Instead, run a thick trace from the power supply to each of the V_{CCA} pins. The traces should be at least 20 mils thick.

In all cases, each V_{CCA} pin must be filtered with a decoupling circuit shown in Figure 6-8. You must place a ferrite bead and a 10- μF tantalum parallel capacitor where the power enters the board. Choose a ferrite bead that exhibits high impedance at frequencies of 50 MHz or higher. Each V_{CCA} pin must be decoupled with a 0.1- μF and a 0.001- μF parallel combination of ceramic capacitors, along with a series 1- Ω resistor,

located as close as possible to the Cyclone FPGA. You can connect the GND pins directly to the same GND plane as the digital GND of the device.

Figure 6–8. PLL Power Schematic for Cyclone PLLs



For more information about board design guidelines, see *Application Note 75: High-Speed Board Design*.

Jitter Considerations

If the input clocks have any low-frequency jitter (below the PLL bandwidth), the PLL attempts to track it, which increases the jitter seen at the PLL clock output. To minimize this effect, avoid placing noisy signals in the same V_{CCIO} bank as those that power the PLL clock input buffer. This is only important if the PLL input clock is assigned to 3.3-V or 2.5-V LVTTTL or LVCMOS I/O standards. With these I/O standards, V_{CCIO}

powers the input clock buffer. Therefore, any noise on this V_{CCIO} supply can affect jitter performance. For all other I/O standards the input buffers are powered by V_{CCINT} .

Because Cyclone external clock output pins ($PLL[2..1]_{OUT}$) do not have a separate V_{CC} and GND bank, you should avoid placing noisy output signals directly next to these pins. Therefore, Altera recommends that $PLL[2..1]_{OUT}$ neighboring I/O pins should be either inputs pins or not used at all. If noisy outputs are placed next to the $PLL[2..1]_{OUT}$ pins, they could inject noise through ground bounce or V_{CC} sag and mutual pin inductance, which would result in worse jitter performance on the $PLL[2..1]_{OUT}$ pins.

Additionally, you should take into consideration the number of simultaneously switching outputs within the same V_{CCIO} bank as the $PLL[2..1]_{OUT}$ pins. Altera recommends that you switch as few outputs simultaneously in the same direction as possible in these V_{CCIO} banks. Also, if you have switching outputs in the same V_{CCIO} bank as the $PLL[2..1]_{OUT}$ pins, Altera recommends that you use the low current strength and/or slow slew rate options on those output pins as they will help to improve the jitter performance.

Specifications

Table 6–9 describes the Cyclone FPGA PLL specifications.

Symbol	Parameter	Min	Max	Unit
f_{IN} (-6 speed grade)	Input frequency	15.00	200	MHz
f_{IN} (-7 speed grade)	Input frequency	15.00	181	MHz
f_{IN} (-8 speed grade)	Input frequency	15.00	166	MHz
f_{IN} DUTY	Input clock duty cycle	40.00	60	%
t_{IN} JITTER	Input clock jitter (peak-to-peak)		± 200	ps
f_{OUT} (-6 speed grade)	PLL output frequency	9.38	312	MHz
f_{OUT} (-7 speed grade)	PLL output frequency	9.38	283	MHz
f_{OUT} (-8 speed grade)	PLL output frequency	9.38	260	MHz
t_{OUT} DUTY	Duty cycle for external clock output (when set to 50%)	45.00	55	%
t_{JITTER} (2)	PLL external clock output jitter (peak-to-peak)		TBD	ps
t_{LOCK}	Time required to lock from end of device configuration	10.00	100	μs

Table 6–9. Cyclone PLL Specifications *Note (1) (Part 2 of 2)*

Symbol	Parameter	Min	Max	Unit
f_{VCO}	PLL internal VCO operating range	300.00	800	MHz
M (3)	Counter values	2	32	integer
N, G0, G1, E	Counter values	1	32	integer

Notes to Table 6–9:

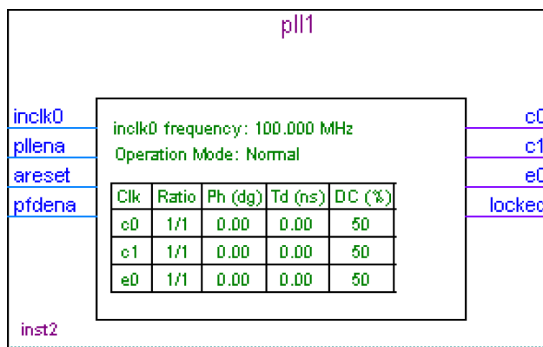
- (1) These numbers are preliminary and pending silicon characterization.
- (2) The t_{JITTER} specification for the PLL [2 . . 1] _OUT pins are dependent on the I/O pins in its V_{CCIO} bank, how many of them are switching outputs, how much they toggle, and whether or not they use programmable current strength or slow slew rate.
- (3) M can only range from 2 - 32 because the maximum PLL input frequency is 200 MHz and the minimum VCO frequency is 300 MHz. Since $f_{VCO} = f_{IN} \times (M / N)$ there can never be a situation when $M = 1$ since that would violate the minimum VCO frequency specification.

Software Support

Support for Cyclone PLLs is available in the Quartus II software by using the `altpll` megafunction. The following section describes how the `altpll` megafunction enables the various Cyclone PLL features and options. This section includes the megafunction symbol, the input and output ports, a description of the MegaWizard Plug-In Manager options, and example MegaWizard screen shots.

Quartus II altpll Megafunction

Figure 6–9 shows the `altpll` megafunction symbol in the Quartus II software.

Figure 6–9. altpll Megafunction Symbol Targeted for Cyclone FPGAs



Refer to Quartus II Help for the `altpll` megafunction AHDL functional prototypes (applicable to Verilog HDL), VHDL component declaration, and parameter descriptions.

altpll Input Ports

Table 6–10 shows the input ports of the `altpll` megafunction and describes their function.

Port Name	Required	Description
<code>inclk0</code> (1)	Yes	The input clock port that drives the PLL.
<code>pllena</code> (2)	No	<code>pllena</code> is an active-high signal, which acts as a combined enable and reset signal for the PLL. You can use it for enabling or disabling one or both PLLs. When this signal is driven low, the PLL clock output ports are driven to GND and the PLL loses lock. Once this signal is driven high again, the lock process begins and the PLL re-synchronizes to its input reference clock. The <code>pllena</code> port can be driven from internal logic or any general-purpose I/O pin.
<code>areset</code> (2)	No	<code>areset</code> is an active-high signal, which resets all PLL counters to their initial values. When this signal is driven high, the PLL resets its counters, clears the PLL outputs, and loses lock. Once this signal is driven low again, the lock process begins and the PLL re-synchronizes to its input reference clock. You can drive the <code>areset</code> port from internal logic or any general-purpose I/O pin.
<code>pfdena</code> (2)	No	<code>pfdena</code> is an active-high signal, which enables or disables the up/down output signals from the PFD. When <code>pfdena</code> is driven low, the PFD is disabled, while the VCO continues to operate. PLL clock outputs continue to toggle regardless of the input clock, but can experience some long-term drift. Because the output clock frequency does not change for some time, you can use the <code>pfdena</code> port as a shutdown or cleanup function when a reliable input clock is no longer available. You can drive the <code>pfdena</code> port from internal logic or any general-purpose I/O pin.

Notes to Table 6–10:

- (1) The `inclk0` port to the PLL must be driven by the dedicated clock input pin(s).
- (2) See “Control Signals” on page 6–12 for further details.

altpll Output Ports

Table 6-11 shows the output ports of the altpll megafunction and describes their function.

Port Name	Required	Description
c[1..0] (1)	No	Clock output of the PLL that drives the internal global clock network.
e0 (1)	No	Clock output that feeds the external clock output pins, PLL[2..1]_OUT.
locked (2)	No	Gives the status of the PLL lock. When the PLL is locked, this port drives logic high. When the PLL is out of lock, this port drives logic low. The locked port can pulse high and low during the PLL lock process.

Notes to Table 6-11:

- (1) Either the internal or external clock output of the PLL must be selected.
- (2) See “Control Signals” on page 6-12 for further details.

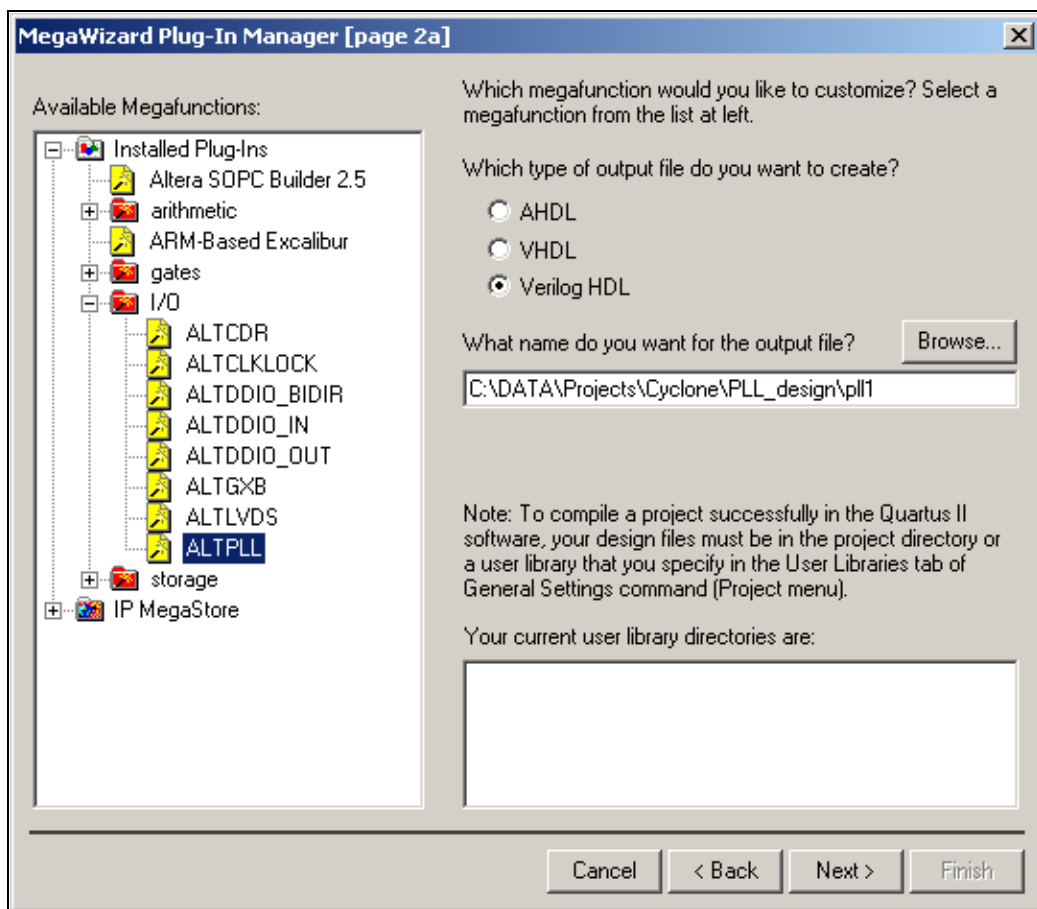
MegaWizard Customization

You can use the MegaWizard Plug-In Manager to set the altpll megafunction options for each PLL instance in your design.



If you instantiate the altpll megafunction without using the MegaWizard Plug-In Manager, search for “altpll” in the Quartus II Help for a list of the altpll parameters.

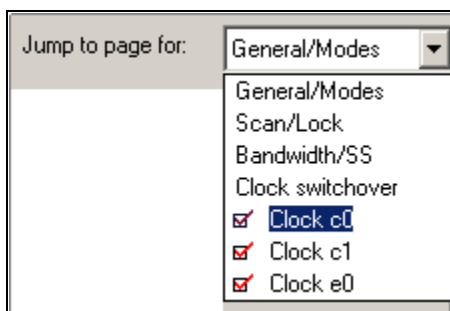
In the MegaWizard Plug-In Manager, select the altpll megafunction in the I/O directory from the **Available Megafunctions** dialog box (see Figure 6-10). The altclklock megafunction is also available from the Quartus II software for backward compatibility, but instantiates the new altpll megafunction when targeting Cyclone FPGAs.

Figure 6–10. *altpll* Megafunction Selection in the MegaWizard Plug-In Manager

The `altpll` MegaWizard Plug-In Manager has separate pages that apply to Cyclone PLLs. The MegaWizard will gray-out options that are unavailable in Cyclone PLLs. During compilation, the Quartus II Compiler verifies the `altpll` parameters selected against the available PLLs, and any PLL or input clock location assignments.

At the top right-hand corner of each page of the `altpll` MegaWizard Plug-In Manager, there is a **jump to page** drop-down list (see [Figure 6–11](#)). This drop-down list allows you to jump to any particular `altpll` MegaWizard page and set those options.

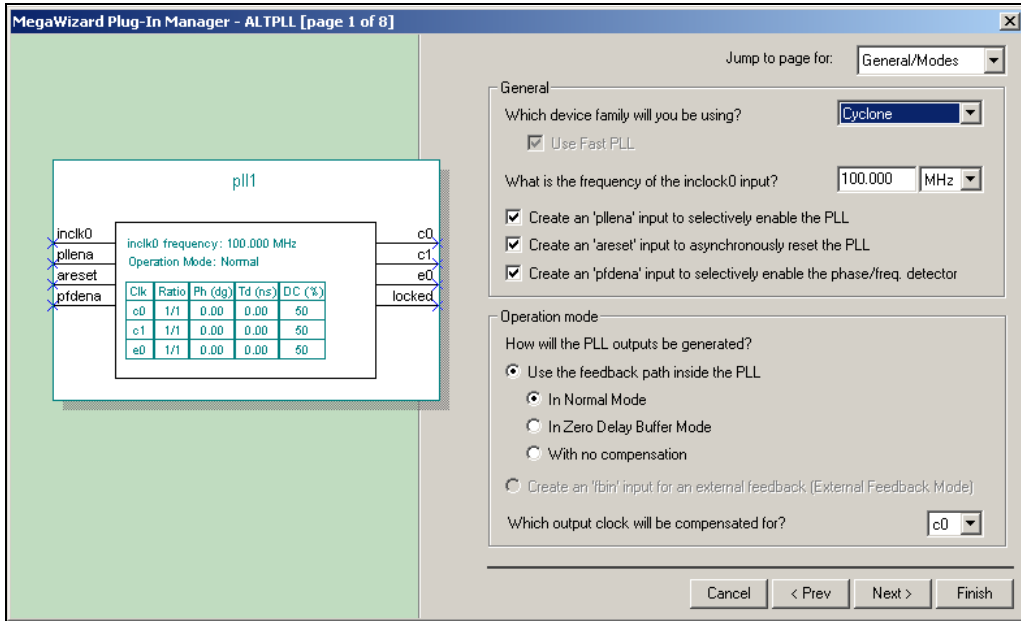
Figure 6–11. Jump to Page Drop-Down List in the altpll MegaWizard Plug-In



MegaWizard Page Description

This section describes the options available on the altpll MegaWizard pages. Each of the MegaWizard pages are shown. Tables 6–12 through 6–14 describe the features or settings on that page that apply to Cyclone PLLs. Use these tables, along with the hardware descriptions of the PLL features, to determine appropriate settings for your PLL instance.

You can use the **General/Modes** (Page 1) of the altpll MegaWizard Plug-In Manager for selecting the target device family, clock input frequency, general control signal selection, and clock feedback operation mode (see Figure 6–12 and Table 6–12).

Figure 6–12. *altpll MegaWizard Plug-In Manager (Page 1)*Table 6–12. *altpll MegaWizard Plug-In Options Page 1 (Part 1 of 2)*

Function	Description
Which device family will you be using?	This application note explains all <code>altpll</code> options that apply when Cyclone is the target device family selected.
What is the frequency of the <code>inclock0</code> input	The frequency for the PLL input clock, <code>inclock0</code> .
Create an <code>pllena</code> input to selectively enable the PLL	Creates a <code>pllena</code> port for this PLL instance. See Table 6–10 for <code>pllena</code> port description.
Create an <code>areset</code> input to asynchronously reset the PLL	Creates a <code>areset</code> port for this PLL instance. See Table 6–10 for <code>areset</code> port description.
Create an <code>pfdena</code> input to selectively enable the PFD	Creates a <code>pfdena</code> port for this PLL instance. See Table 6–10 for <code>pfdena</code> port description.

Table 6–12. altpll MegaWizard Plug-In Options Page 1 (Part 2 of 2)

Function	Description
Use the feedback path inside the PLL	<p>This option sets the <code>OPERATION_MODE</code> parameter to either normal, zero delay buffer, or no compensation mode.</p> <p>In normal mode, the PLL feedback path comes from a global clock network, which minimizes the clock delay to registers for that specific PLL clock output. You can specify which PLL output is compensated for by using the <code>COMPENSATE_CLOCK</code> parameter.</p> <p>In zero delay buffer mode, the PLL feedback path is confined to the dedicated PLL external output pin. The clock signal driven off-chip on the <code>PLL_OUT</code> pin is phase aligned with the PLL clock input for a minimized delay between clock input and external clock output. If the PLL is also used to drive the internal clock network, a corresponding phase shift of that clock network results.</p> <p>In no compensation mode, the PLL feedback path is confined to the PLL loop; it does not come from the global clock network or an external source. There is no clock network compensation, but this mode minimizes jitter on clocks. This mode may lead to positive hold times on IOE registers; you can use manual phase shifting to compensate for positive hold times.</p> <p>For more information, see “Clock Feedback Modes” on page 6–13.</p>
Which output clock will be compensated?	Indicates which output port of the PLL is compensated. For normal mode, you can select <code>c0</code> or <code>c1</code> .

You can use **Scan/Lock** (Page 2) for selecting the locked output port (see Figure 6–13 and Table 6–13).

Figure 6–13. *altpll MegaWizard Plug-In Manager (Page 2)*

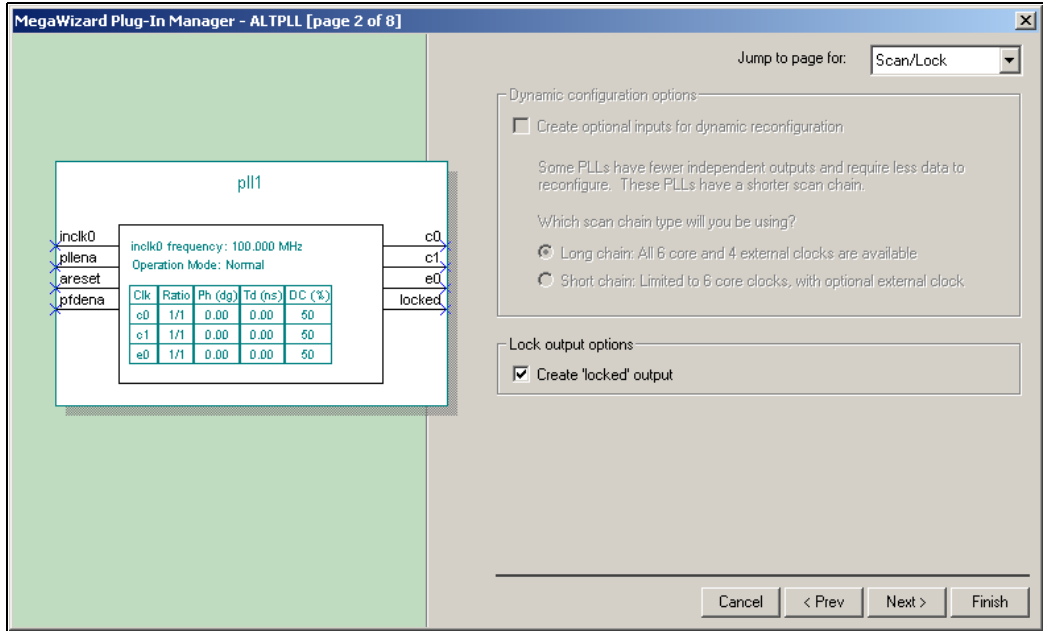


Table 6–13. altpll MegaWizard Plug-In Options Page 2

Function	Description
Create "locked" output	Creates a locked output port to indicate PLL lock. See <code>locked</code> port description in Table 6–11.

The options on the next two pages of the MegaWizard Plug-In Manager, (Pages 3 to 4, titled **Bandwidth/SS** and **Clock Switchover**) are not supported in Cyclone FPGAs.

Figure 6–14. altpll MegaWizard Plug-In Manager Pages 5 of 8

MegaWizard Plug-In Manager - ALTPLL [page 5 of 8]

c0 - Core Output Clock Jump to page for: Clock c0

Use this clock

clock multiplication factor: 2

clock division factor: 1

clock phase shift: 0.00 deg

clock time shift (nsec): 0.00

clock duty cycle (%): 50.00

Able to implement the requested PLL

Requested settings	Actual settings
2	2
1	1
0.00	0.00
0.00	0.00
50.00	50.00

pll1

inclk0
pllana
areset
pfdena

inclk0 frequency: 100.000 MHz
Operation Mode: Normal

Clk	Ratio	Ph (dg)	Td (ns)	DC (%)
c0	2/1	0.00	0.00	50
c1	1/1	0.00	0.00	50
e0	1/1	0.00	0.00	50

c0
c1
e0
locked

Cancel < Prev Next > Finish

The last 3 pages of the MegaWizard Plug-In Manager (Pages 5 to 7) allow you to set the multiplication/division factors, phase shift, and duty cycle for each PLL output port (see [Figure 6–14](#) and [Table 6–14](#)).

Each page represents the settings for one PLL clock output port. [Table 6–14](#) describes the options for Pages 5 to 8.

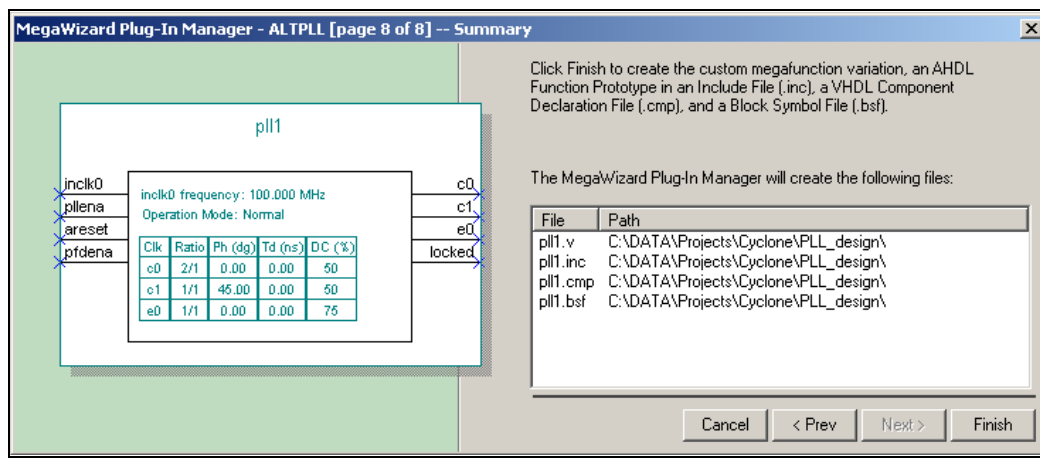
Function	Description
Clock multiplication factor (ratio)	Specifies the clock multiplication for this PLL output. The multiplication factor cannot be greater than 32.
Clock division factor (ratio)	Specifies the clock division for this PLL output.
Clock phase shift (Ph)	<p>Sets the programmable phase shift for the clock output with respect to the PLL clock output that is compensated. The equation to determine the precision of the phase shifting in degrees is (45° divided by the post-scale counter value). Therefore, the maximum step size is 45°, and smaller steps are possible, depending on the multiplication/division ratio necessary on the clock output port. For example, if you have an input clock of 125 MHz with $\times 1$, the post-scale counter G0 is 3. Therefore, the smallest phase shift step is 15°, and additional phase shifting is in 15° increments.</p> <p>The up/down buttons cycle through the possible phase shift settings with the default M and post-scale dividers that the MegaWizard Plug-In Manager has chosen for your target frequency and multiplication/division ratio. It is possible to get other granularities of phase shifts if you manually enter a number into the phase shift field. For example, you can override the MegaWizard-chosen values and manually enter 7.5°. The MegaWizard Plug-In Manager verifies this is possible by using $M = 6$ and $G0 = 6$. The MegaWizard Plug-In Manager tries to achieve the closest phase shift possible. For example, if you enter 10°, the MegaWizard Plug-In Manager verifies that 9° is possible by using $M = 5$ and $G0 = 5$.</p> <p>For more information, see “Phase Shifting” on page 6–9.</p>
Clock duty cycle (DC)	<p>Specifies the clock duty cycle of the PLL clock output.</p> <p>The equation to determine the precision of the duty cycle is (50% divided by the post-scale counter value). For example, if post-scale counter G0 is 3, the allowed duty cycles are 50% divided by 3, equaling 16.67%. Because the <code>altpll</code> megafunction does not accept non-integer values for the duty cycle values, the allowed duty cycles are 17, 33, 50, and 67%. Due to hard limitations, a duty cycle of 84% cannot be achieved because the closest value to 100% cannot be achieved for a given counter value. However, you can achieve a duty cycle of 84% by choosing a 17% duty cycle and inverting the PLL clock output. Use the up/down buttons to cycle through all possible settings.</p> <p>For more information, see “Programmable Duty Cycle” on page 6–10.</p>

Page 8 is the summary page and tells you what files the MegaWizard Plug-In Manager will create (see [Figure 6–15](#)).



You can click **Finish** at anytime while in the MegaWizard Plug-In Manager to update the files.

Figure 6–15. altpll MegaWizard Plug-In Manager Page 8



Compilation Report

During compilation, an information message displays whether the requested multiplication/division factors, and/or phase shift, and/or duty cycle were achieved. If you enter an invalid multiplication/division ratio, compilation fails, and the Quartus II software displays an error message. If you enter an invalid phase shift or duty cycle value, the compilation proceeds, and you will receive an information message displaying the best alternative values chosen by the Quartus II software.

The **Resource Section** of the compilation report provides two PLL reports: the **PLL Summary** and the **PLL Usage** reports. The **PLL Summary** provides information on each PLL's parameters (see [Figure 6–16](#)). The **PLL Summary** is column-based in the report file, where each column represents a different PLL instance. [Table 6–15](#) lists and explains the parameters shown in the **PLL Summary** report. PLL properties not listed in [Table 6–15](#) do not apply to Cyclone PLLs.

Figure 6–16. PLL Summary Report

PLL Summary		
	PLL Property	pll1_inst[altpll_component]pll
1	PLL type	-
2	Scan chain	None
3	PLL mode	Normal
4	Feedback source	-
5	Compensate clock	clock0
6	Switchover on loss of clock	-
7	Switchover on gated lock	-
8	Switchover counter	-
9	Primary clock	-
10	Input frequency 0	100.0 MHz
11	Input frequency 1	-
12	Nominal VCO frequency	400.0 MHz
13	Freq min lock	74.99 MHz
14	Freq max lock	200.0 MHz
15	Hold conf done	Off
16	M value	4
17	N value	1
18	M counter delay	-
19	N counter delay	-
20	M2 value	-
21	N2 value	-
22	SS counter	-
23	Downspread	-
24	Spread frequency	-
25	Charge pump current	-
26	Loop filter resistance	-
27	Loop filter capacitance	-
28	Freq zero	-
29	Bandwidth	-
30	Freq pole	-
31	enable0 counter	-
32	enable1 counter	-
33	Real time reconfigurable	-
34	Bit stream for reprogramming	-

Table 6–15. PLL Summary in Compilation Report File (Part 1 of 2)

PLL Property	Description
PLL mode	Clock feedback mode
Compensate clock	Indicates which PLL clock output (<code>clock0</code> , <code>clock1</code> , or <code>extclock0</code>) port is compensated
Input frequency 0	Clock input frequency for <code>inclk0</code>

Table 6–15. PLL Summary in Compilation Report File (Part 2 of 2)

PLL Property	Description
Nominal VCO frequency	Shows the VCO frequency; $f_{VCO} = f_{IN} \times M/N$
Freq min lock	Shows the minimum PLL input clock frequency for which the current combination of M/N still provides a valid VCO lock
Freq max lock	Shows the maximum PLL input clock frequency for which the current combination of M/N still provides a valid VCO lock
M value	M counter value
N value	N counter value

The **PLL Usage** report shows the breakdown information for each PLL clock output (see [Figure 6–17](#)). This report is categorized by PLL clock output ports, such that each row represents a different PLL clock output used in your design. [Table 6–16](#) lists and explains the parameters shown in the **PLL Usage** report file in a row format. PLL parameters not listed in [Table 6–16](#) do not apply to Cyclone PLLs.

Figure 6–17. PLL Usage Report

PLL Usage													
Name	Output Clock	Mult	Div	Output Frequency	Phase Shift	D	Duty Cycle	Counter	C	Counter Value	High / Low	Initial	VCO Tap
pll1:instaltpll_atpll_component_clk0	clock0	2	1	200.0 MHz	0 (0 ps)	0.	50/50	G1	-	2	1/1 Even	1	0
pll1:instaltpll_atpll_component_clk1	clock1	1	1	100.0 MHz	45 (1250 ps)	0.	50/50	G0	-	4	2/2 Even	1	4
pll1:instaltpll_atpll_component_extclk0	extclock0	1	1	100.0 MHz	0 (0 ps)	0.	75/25	E0	-	4	3/1 Even	1	0

Timing Analysis

[Table 6–16](#) shows the usage in the compilation report file.

Table 6–16. PLL Usage in Compilation Report File (Part 1 of 2)

PLL Parameter	Description
Name	Indicates the PLL instance name and clock output reported.
Output Clock	Indicates the PLL clock output (<code>clock0</code> , <code>clock1</code> , or <code>extclock0</code>) for which the parameter information in this row applies. This is the clock port specified in the MegaWizard Plug-In Manager (<code>c0</code> , <code>c1</code> , <code>e0</code>).
Mult	Overall multiplication ratio.
Div	Overall division ratio.
Output Frequency	Output frequency for this output clock.
Phase Shift	Achieved phase shift in degrees and units of time (can differ from user-entered value).

Table 6–16. PLL Usage in Compilation Report File (Part 2 of 2)

PLL Parameter	Description
Duty Cycle	Duty cycle for this clock output.
Counter	Post-scale counter used for this clock output, which counter (G0, G1, E0) feeds the clock output.
Counter Value	Value of post-scale counter.
High/Low	High- and low-time counts that make up the counter value. The ratio of high- and low-counts is directly proportional to the duty cycle.
Initial	Initial value for this post-scale counter (achieves the coarse granularity for phase shifting). Specifies the initial number of VCO cycles before starting the counter.
VCO Tap	VCO tap ranges from 0 to 7 (achieves fine granularity for phase shift in units of 1/8 of the VCO period).

The register-to-register timing for each PLL clock output that drives the logic array is reported with slack. The timing analysis section of the report file provides slack information in a clock requirement line for each PLL clock output.

You can derive f_{MAX} numbers from the slack reporting. The microparameters t_{CO} , t_{SU} , and the path delay are given for a `List Path` command on the Actual Maximum P2P timing in the Slack Report window. You can add and invert these to find the f_{MAX} for that path. See the following equation:

$$f_{MAX} = 1 / (<register\ to\ register\ delay> - <clock\ skew\ delay> + <micro\ setup\ delay> + <micro\ clock\ to\ output\ delay>)$$

During timing analysis for Cyclone designs using PLLs, the project clock settings override the PLL input clock frequency and duty cycle settings. It is important to note the following:

- A warning during compilation reports that the project clock settings override the PLL clock settings.
- The project clock setting overrides the PLL clock settings for timing-driven compilation. When you compile a design with timing-driven compilation turned on, you are overconstraining the design so that the fitter can give you a better f_{MAX} performance. For example, if the PLL is set to output a 150 MHz clock, you can set a project clock setting for 170 MHz so that the fitter tries to achieve a design performance of 170 MHz.

- The Compiler checks the lock frequency range of the PLL. If the frequency specified in the project clock settings is outside the lock frequency range, the PLL clock settings will not be overridden.
- Overriding the PLL clock settings only changes the timing requirements; it does not change the overall multiplication/division and phase delay on each clock output of the PLL. The MegaWizard Plug-In Manager does not use the project clock settings to determine the `altpll` parameters.
- Performing a timing analysis without recompiling your design does not change the programming files. You must recompile your design to update the programming files.
- A Default Required f_{MAX} setting does not override the PLL clock settings. Only individual clock settings will override the PLL clock settings.

This capability is useful when you have configured a Cyclone device and want to see if your timing requirements are met when you feed the PLL a different input clock than what is specified for the PLL parameters. Therefore, this feature allows you to overwrite the PLL input clock frequency settings for timing analysis, meaning you do not have to re-synthesize or re-fit your design. The following procedure allows you to override the PLL input frequency setting and re-generate timing analysis.

1. Choose **Timing Settings** (Project menu).
2. Click on the **Clock Settings** tab.
3. Under **Specify circuit frequency as**, select **Settings for individual clock signals**.
4. Click **New**.
5. In the **New Clock Settings** dialog box, type a <name> for the new clock settings in the **Clock settings** box.
6. If you want to specify timing requirements for an absolute clock, follow these steps:
 - a. Under **Relationship to other clock settings**, select **Independent of other clock settings**.
 - b. In the **Required fMAX** box, type the required frequency (f_{MAX}) of the clock signal and select a time unit from the list.

- c. In the **Duty Cycle** list, specify the required duty cycle for the clock.



Cyclone PLLs accept input clocks with 40 to 60% duty cycle.

- d. If you want to include external delays to and from device pins in the f_{MAX} calculations, turn on **Include external delays to and from device pins in fMAX calculations**.
 - e. Click **OK**.
7. Click **OK** to close the Timing Settings window.
 8. Open the **Assignment Organizer** dialog box (Tools menu).
 9. Click on the **By Node** tab.
 10. Under *Mode*, select **Edit specific entity & node settings for**.
 11. If necessary, copy a specific PLL input clock pin name to the **Name** box using the **Node Finder** dialog box.
 12. Under **Assignment Categories**, click the + icon next to **Timing**.
 13. Click on **Click here to add a new assignment**.
 14. Under **Assignment**, select **Clock Settings** in the **Name** list, and select the <name> of the clock settings you created in step 5.
 15. Under **Stored in assignments for**, select **This instance only**, **This instance in all occurrences of its parent entity**, or **Other**.
 16. Click **Add**.
 17. Click **OK** or **Apply**.
 18. Select **Start Timing Analysis** (Processing Menu).

Simulation

The `altpll` megafunction supports behavioral and timing simulation in both the Quartus II software and supported third-party simulation tools. You can simulate all digital aspects of the PLL, but none of the analog aspects. Simulation supports all control signals and clock outputs.

Table 6–17 explains the simulation support for `altpll`.

Feature	Simulation Support
<code>pllena</code>	The <code>pllena</code> signal is modeled. When this signal is driven low, the PLL loses lock and the PLL clock outputs are driven to logic low.
<code>areset</code>	The <code>areset</code> signal is modeled. When this signal is driven high, the PLL loses lock and the PLL clock outputs are driven to logic low. Frequency over-shoot on the PLL clock outputs is not modeled.
<code>pfdena</code>	The <code>pfdena</code> control signal is modeled. When this signal is driven low, the PLL's locked output is undefined and the PLL clock outputs continue to toggle at their last set frequency. The finite frequency long-term drift of the VCO is not modeled.
<code>locked</code>	The <code>locked</code> signal is modeled for a high-bandwidth condition only. The PLL locks or relocks within 2 to 10 cycles during simulation, and does not necessarily reflect the real lock time.
Frequency input change	If the input frequency of the PLL is changed in simulation, the model checks that $f_{IN} \times (M/N)$ is within the VCO frequency range and loses lock if outside the VCO operating range.
Jitter	Jitter is not modeled in simulation.

You can use the `altpll` behavioral model to simulate the Cyclone PLLs. The Cyclone behavioral model instantiation must follow the same guidelines and restrictions as the design entry. The `altpll` behavioral and timing models do not simulate jitter, lock time, or VCO drift.

The behavioral models for `altpll` reside in the `\quartus\eda\sim_lib` directory. `ALTERA_MF.VHD` contains the VHDL behavioral models and can be used for Cyclone designs that instantiate `altpll`. `ALTERA_MF.v` contains the Verilog HDL behavioral models. The behavioral model does not perform parameter error checking, and you must specify only valid values.



You must set the resolution of the simulator to units of pico seconds (ps) to simulate the model successfully. A larger resolution rounds off the calculations, providing incorrect results.

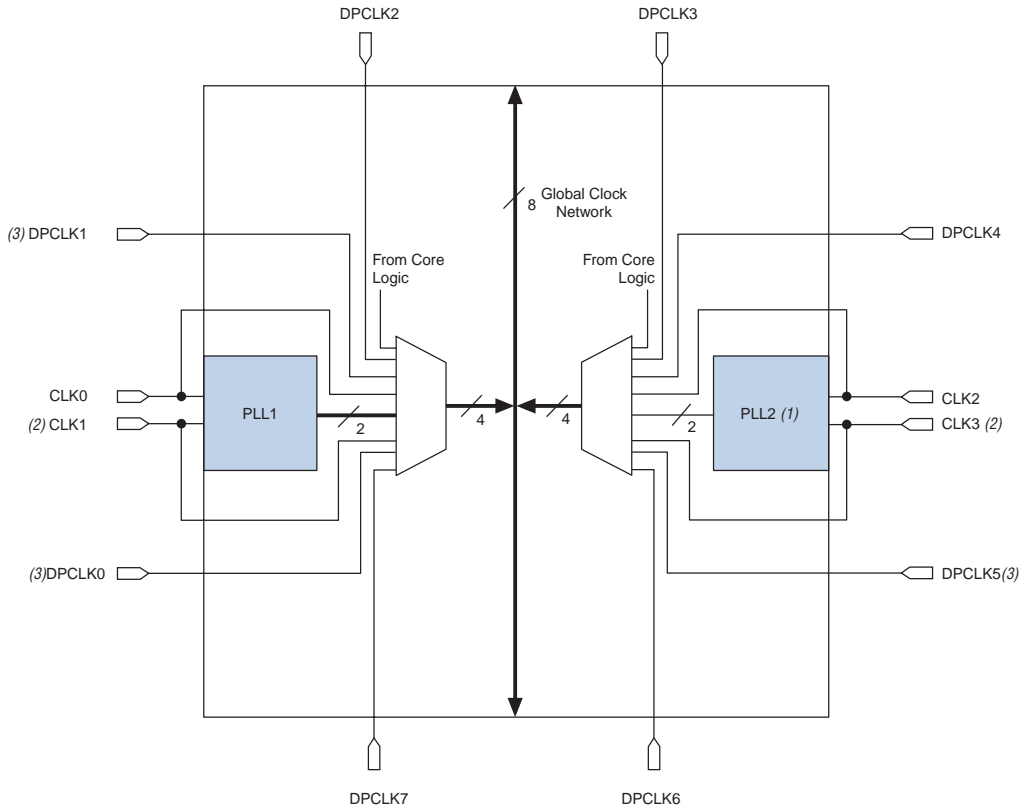
Global Clock Network

Cyclone FPGAs have eight global clock networks. The four dedicated clock input pins ($CLK[3..0]$), eight dual-purpose clock pins ($DPCLK[7..0]$), and PLL clock outputs can drive the global clock networks. In addition, internal logic for internally-generated global clocks and asynchronous clears, clock enables, or other control signals with large fanout can drive the global clock networks.

The eight global clock lines that comprise the global clock network drive throughout the entire device. You can use the global clock network as clock sources for all device resources, including IOEs, logic elements (LEs), and memory blocks. You can also use global clock resources for control signals, such as clock enables and synchronous or asynchronous clears fed from external pins.

Figure 6–18 shows the global clock network resources.

Figure 6–18. Global Clock Generation



Notes to Figure 6–18:

- (1) The EP1C3 device contains PLL1 only.
- (2) The EP1C3 device in the 100-pin TQFP package does not have dedicated clock pins CLK1 and CLK3.
- (3) The EP1C3 device in the 100-pin TQFP package has five DPCLK pins (DPCLK2, DPCLK3, DPCLK4, DPCLK6, and DPCLK7). For more information, see ["Dual-Purpose Clock I/O Pins"](#) on page 6–40.

Dedicated Clock Input Pins

Cyclone FPGAs have up to four dedicated clock input pins (CLK [3 . . 0]), two on the left and right side of the device. You can use the CLK [3 . . 0] pins to drive the PLLs, or directly drive them onto the global clock network. Table 6–18 shows which clock pins drive which global clock network.

Clock Input Pin	GCLK0	GCLK1	GCLK2	GCLK3	GCLK4	GCLK5	GCLK6	GCLK7
CLK0	✓		✓					
CLK1 (1)		✓		✓				
CLK2					✓		✓	
CLK3 (1)						✓		✓

Note to Table 6–18:

(1) The EP1C3 device in the 100-pin TQFP package does not have dedicated clock pins CLK1 and CLK3.

Dual-Purpose Clock I/O Pins

Cyclone FPGAs can have up to eight dual-purpose clock pins, DPCLK [7 . . 0] (two on each side of the device). These dual-purpose pins can connect to the global clock network. You can use the DPCLK [7 . . 0] pins for high fanout control signals, such as asynchronous clears, presets, clock enables, or protocol control signals (e.g., TRDY and IRDY for PCI, or DQS signals for external memory interfaces). These pins are also available as general-purpose I/O pins, meaning they can be inputs, outputs, or bidirectional pins. Table 6–19 shows which dual-purpose clock pins drive which global clock network in Cyclone FPGAs.

Dual-Purpose Clock Pin	GCLK0	GCLK1	GCLK2	GCLK3	GCLK4	GCLK5	GCLK6	GCLK7
DPCLK0(1)				✓				
DPCLK1(1)			✓					
DPCLK2	✓							
DPCLK3					✓			
DPCLK4							✓	

Table 6–19. Dual-Purpose Clock I/O Connections to the Global Clock Network (Part 2 of 2)

Dual-Purpose Clock Pin	GCLK0	GCLK1	GCLK2	GCLK3	GCLK4	GCLK5	GCLK6	GCLK7
DPCLK5 (1)								✓
DPCLK6						✓		
DPCLK7		✓						

Note to Table 6–19:

(1) The EP1C3 device in the 100-pin TQFP package does not have the DPCLK0, DPCLK1, or DPCLK5 pins

Combined Sources

Table 6–20 shows which combined sources drive which global clock network.

Table 6–20. Global Clock Network Sources (Part 1 of 2)

Source		GCLK0	GCLK1	GCLK2	GCLK3	GCLK4	GCLK5	GCLK6	GCLK7
PLL Counter Outputs	PLL1 G0		✓	✓					
	PLL1 G1	✓			✓				
	PLL2 G0 (1)						✓	✓	
	PLL2 G1 (1)					✓			✓
Dedicated Clock Input Pins	CLK0	✓		✓					
	CLK1 (2)		✓		✓				
	CLK2					✓		✓	
	CLK3 (2)						✓		✓

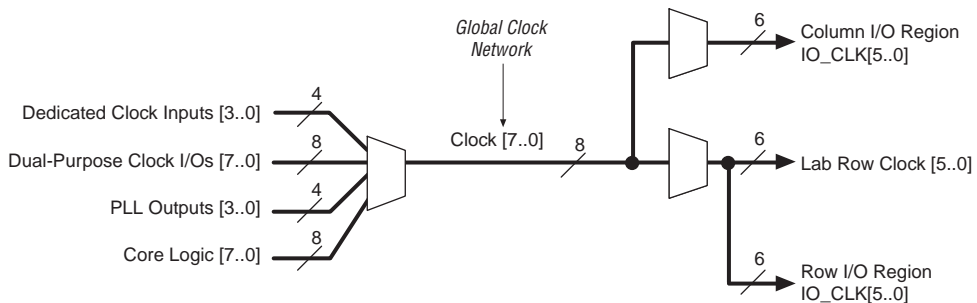
Table 6–20. Global Clock Network Sources (Part 2 of 2)

Source		GCLK0	GCLK1	GCLK2	GCLK3	GCLK4	GCLK5	GCLK6	GCLK7
Dual-Purpose Clock Pins	DPCLK0				✓				
	DPCLK1 (3)			✓					
	DPCLK2	✓							
	DPCLK3					✓			
	DPCLK4							✓	
	DPCLK5								✓
	DPCLK6						✓		
	DPCLK7		✓						

Notes to Table 6–20:

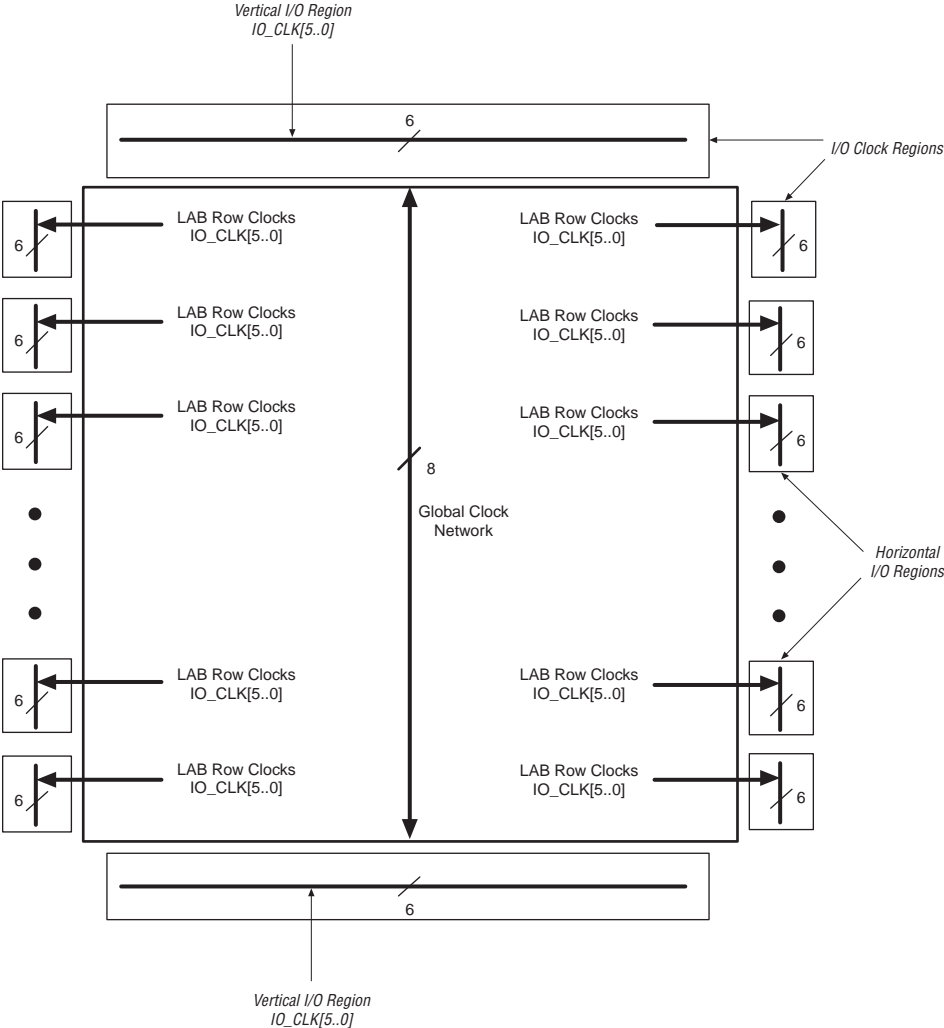
- (1) The EP1C3 device only has PLL1.
- (2) The EP1C3 device in the 100-pin TQFP package does not have dedicated clock pins CLK1 and CLK3.
- (3) The EP1C3 device does not have DPCLK1.

In the Cyclone FPGA, there are eight distinct dedicated global clock networks. Multiplexers are used with these clocks to form six-bit buses to drive LAB row clocks, column IOE clocks, or row IOE clocks (see [Figure 6–19](#)). Another multiplexer is used at the LAB level to select two of the six row clocks to feed the LE registers within the LAB.

Figure 6–19. Global Clock Network Multiplexers

IOE clocks have horizontal (row) and vertical (column) block regions that are clocked by six I/O clock signals chosen from the eight global clock resources. [Figure 6–20](#) shows the I/O clock regions.

Figure 6–20. I/O Clock Regions



Conclusion

Cyclone PLLs provide significant features such as $M/(N \times \text{post-scale})$ multiplication/division, phase shift, and programmable duty cycle for your cost-sensitive clock synthesis applications. The reduction in clock delay, and the elimination of clock skew within the device, improves design speed. Cyclone PLL features simplify board design by running the internal logic of the device at a faster rate than the input clock frequency.

This section provides information on the M4K embedded memory blocks internal to Cyclone devices.

It contains the following:

- [Chapter 7. On-Chip Memory Implementations Using Cyclone Memory Blocks](#)

Revision History

The table below shows the revision history for [Chapter 7](#).

Chapter(s)	Date / Version	Changes Made
7	May 2003 v1.0	Updated Table 7–2 with EP1C4.

Introduction

Cyclone™ devices feature embedded memory blocks that can be easily configured to support a wide range of system requirements. These M4K memory blocks present a very flexible and fast memory solution that you can use to provide excellent memory bandwidth and density for a host of cost-sensitive applications.

You can use M4K memory blocks in various memory modes, including single-port, simple dual-port, true dual-port (also known as bidirectional dual-port), shift-register, ROM, and first-in first-out (FIFO) mode. M4K memory blocks also include advanced features such as support for byte-enable operation, parity-bit-based error correction, and mixed-port widths. This application note describes these modes and other characteristics of the M4K memory blocks.

M4K Memory Features

Table 7–1 summarizes the features supported by the M4K memory block.

<i>Table 7–1. Summary of M4K Memory Features (Part 1 of 2)</i>	
Performance	200 MHz
Total RAM bits (including parity bits)	4,608
Configurations	4K × 1 2K × 2 1K × 4 512 × 8 512 × 9 256 × 16 256 × 18 128 × 32 128 × 36 (1)
Parity bits	✓
Byte enable	✓
Single-port memory	✓
Simple dual-port memory	✓
True dual-port memory	✓
Embedded shift register	✓
ROM	✓

FIFO buffer	✓
Simple dual-port mixed width support	✓
True dual-port mixed width support	✓
Memory initialization (.mif)	✓
Mixed-clock mode	✓
Power-up condition	Outputs cleared
Register clears	Input and output registers (2)
Same-port read-during-write	New data available at positive clock edge
Mixed-port read-during-write	Outputs set to unknown or old data

Notes to Table 7–1:

- (1) The Altera® Quartus® II software will automatically cascade or concatenate multiple M4K memory blocks to provide deeper or wider memory functions.
- (2) Asserting the clear port of the `rd_en` and byte-enable registers drives the output of these registers high.

Table 7–2 shows the memory capacity for M4K memory blocks in each Cyclone device.

Device	Columns	Blocks	Total RAM Bits
EP1C3	1	13	59,904
EP1C4	1	17	78,336
EP1C6	1	20	92,160
EP1C12	2	52	239,616
EP1C20	2	64	294,912

Parity Bit Support

M4K memory blocks support an optional parity bit for each data byte. Of the 4,608 bits of storage space available in an M4K block, 512 are available for use as parity-bit storage. The parity bit, along with logic implemented in logic elements (LEs), can facilitate parity-checking methods of error detection to ensure data integrity. You can also use parity-size data words to store user-specified control bits or as extra data bits to provide support for 9-bit, 18-bit, or 36-bit wide memories.

Byte-Enable Support

Byte-enable signals can be used to mask the input data so that only specific bytes in memory are overwritten. The unwritten bytes retain the data value that was last written to them. The write-enable signal (*wren*) is used in conjunction with byte-enable signals (*byteena*) to control the M4K block's write operations. The default value for the *byteena* signal is high (enabled), in which case no bytes are masked and writing is controlled only by the *wren* signals.

Asserting the clear port of the byte-enable register drives the byte-enable signal to its default high level.

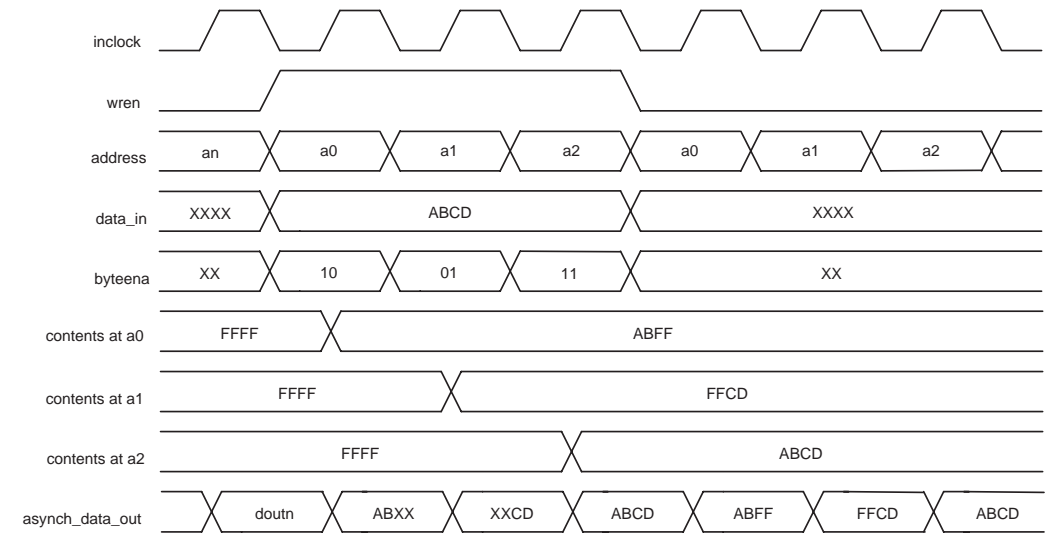
M4K blocks support byte write operations when the write port has a data width of 16, 18, 32, or 36 bits. Table 7-3 summarizes how *byteena* controls which bits are masked.

byteena	datain × 18	datain × 36
[0] = 1	[8..0]	[8..0]
[1] = 1	[17..9]	[17..9]
[2] = 1	–	[26..18]
[3] = 1	–	[35..27]

Notes to Table 7-3:

- (1) Any combination of byte-enable signals is possible.
- (2) Byte enables can be used in the same manner with 8-bit words, i.e., in × 16 and × 32 modes.

Figure 7-1 shows how both the *wren* and the *byteena* signals control the write operations of the RAM.

Figure 7-1. Byte-Enable Operation Functional Waveform

Power-up Conditions & Memory Initialization

Upon power-up, M4K memory is in an idle state. The outputs always power-up to zero, regardless of whether the output registers are used or bypassed. Even if a memory initialization file is used to pre-load the contents of the RAM block, the outputs will still power-up cleared. For example, if address 0 is pre-initialized to FF, the M4K blocks power-up with the output at 00.

Using M4K Memory

M4K memory blocks include input registers that synchronize write operations and output registers to pipeline designs and improve system performance. All M4K memory blocks are fully synchronous, meaning that all inputs are registered, but outputs can be either registered or combinatorial. M4K memory can emulate asynchronous memory.



For more information, see *Application Note 210: Converting Memory from Asynchronous to Synchronous for Stratix Designs*.

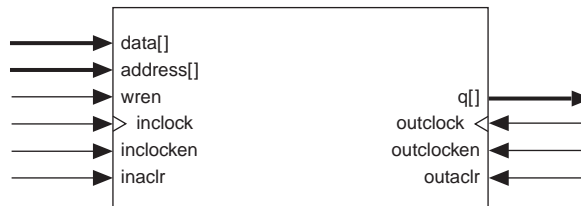
M4K memory blocks can operate in various modes, including:

- Single-port
- Simple dual-port
- True dual-port (bidirectional dual-port)
- Shift-register
- ROM
- FIFO

Implementing Single-Port Mode

Single-port mode supports non-simultaneous read and write operations. [Figure 7-2](#) shows the single-port memory configuration for M4K blocks.

Figure 7-2. Single-Port Memory *Note (1)*



Note to [Figure 7-2](#):

- (1) Two single-port memory blocks can be implemented in a single M4K block.

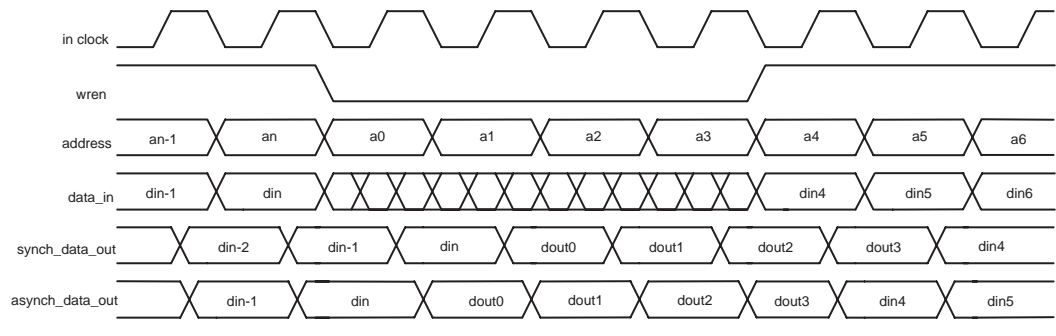
M4K memory blocks can also be divided in half and used for two independent single-port RAM blocks. The Quartus II software automatically uses this method of single-port memory packing when running low on memory resources. When deliberately assigning two single-port memories to one M4K block, first ensure that each of the two independent RAM blocks is equal to or less than half the size of the M4K block.

In the single-port RAM configuration, the outputs can only be in read-during-write mode, which means that during the write operation, data written to the RAM flows through to the RAM outputs. When the output registers are bypassed, the new data is available on the rising edge of the same clock cycle on which it was written.



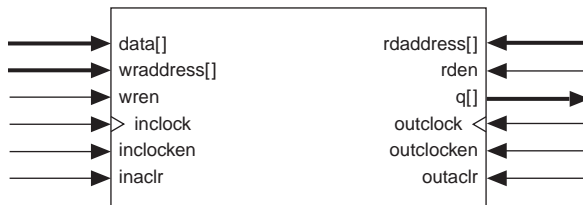
For more information about read-during-write mode, see [“Read-during-Write Operation at the Same Address”](#) on page 7-20.

[Figure 7-3](#) shows timing waveforms for read and write operations in single-port mode.

Figure 7-3. Single-Port Timing Waveforms

Implementing Simple Dual-Port Mode

Simple dual-port memory supports simultaneous read and write operations. [Figure 7-4](#) shows the simple dual-port memory configuration for M4K blocks.

Figure 7-4. Simple Dual-Port Memory *Note (1)***Note to Figure 7-4:**

- (1) Simple dual-port RAM supports read/write clock mode in addition to the input/output clock mode shown.

M4K memory supports mixed-width configurations, allowing different read and write port widths. This capability is useful for many applications, including implementing serializer-deserializers (SERDES)

as well as interfacing with buses of differing widths. Table 7–4 shows the mixed-width configurations supported by the M4K blocks in Cyclone devices..

Table 7–4. M4K Block Mixed-Width Configurations (Simple Dual-Port Mode)

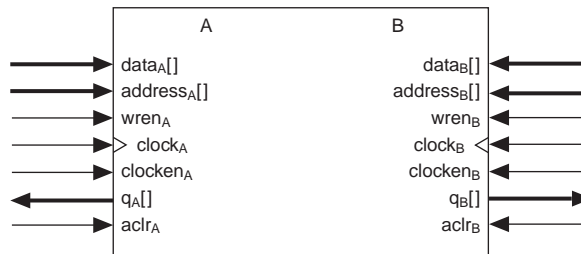
Read Port	Write Port								
	4K × 1	2K × 2	1K × 4	512 × 8	256 × 16	128 × 32	512 × 9	256 × 18	128 × 36
4K × 1	✓	✓	✓	✓	✓	✓			
2K × 2	✓	✓	✓	✓	✓	✓			
1K × 4	✓	✓	✓	✓	✓	✓			
512 × 8	✓	✓	✓	✓	✓	✓			
256 × 16	✓	✓	✓	✓	✓	✓			
128 × 32	✓	✓	✓	✓	✓	✓			
512 × 9							✓	✓	✓
256 × 18							✓	✓	✓
128 × 36							✓	✓	✓

In simple dual-port mode, M4K blocks have one write-enable and one read-enable signal. On the M4K block, asserting the clear port of the `rden` register drives `rden` high, which allows the read operation to occur. When the read-enable signal is deactivated, the current data is retained at the output ports. If the read-enable signal is activated during a write operation with the same address location selected, the simple dual-port RAM output is either unknown or can be set to output the old data stored at the memory address.



For more information, see [“Read-during-Write Operation at the Same Address”](#) on page 7–20.

Figure 7–5 shows timing waveforms for read and write operations in simple dual-port mode.

Figure 7-6. True Dual-Port Memory *Note (1)***Note to Figure 7-6:**

- (1) True dual-port memory supports input/output clock mode in addition to the independent clock mode shown.

The widest bit configuration of a single M4K block in true dual-port mode is 256×16 -bit (or 256×18 -bit with parity). The 128×32 -bit (128×36 -bit with parity) configuration of the M4K block is unavailable because the number of output drivers is equivalent to the maximum bit width of the M4K block. Because true dual-port RAM has outputs on two ports, the maximum width of the true dual-port RAM equals half of the total number of output drivers. However, multiple M4K blocks can be concatenated to support wider memory configurations. Table 7-5 lists the possible M4K RAM block configurations.

Table 7-5. M4K Block Mixed-Port Width Configurations (True Dual-Port Mode)

Port A	Port B						
	4K × 1	2K × 2	1K × 4	512 × 8	256 × 16	512 × 9	256 × 18
4K × 1	✓	✓	✓	✓	✓		
2K × 2	✓	✓	✓	✓	✓		
1K × 4	✓	✓	✓	✓	✓		
512 × 8	✓	✓	✓	✓	✓		
256 × 16	✓	✓	✓	✓	✓		
512 × 9						✓	✓
256 × 18						✓	✓

In true dual-port mode, the RAM outputs can only be configured for read-during-write mode. This means that during write operation, data being written to the A or B port of the RAM flows through to the A or B outputs, respectively. When the output registers are bypassed, the new data is available on the rising edge of the same clock cycle it was written on.



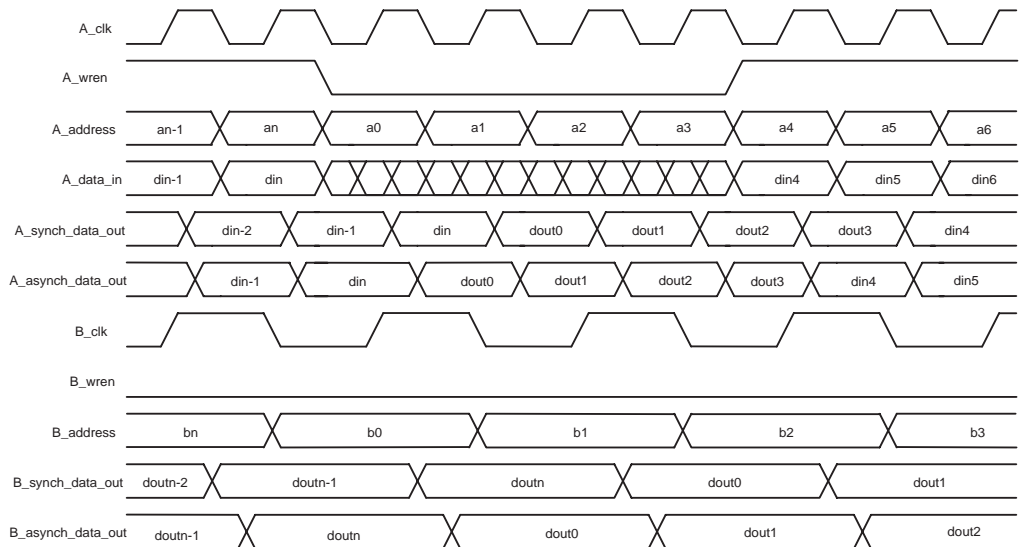
For sample waveforms and other information on mixed-port read-during-write mode, see [“Read-during-Write Operation at the Same Address”](#) on page 7–20.

Potential write conflicts must be resolved external to the RAM because simultaneously writing to the same address location at both ports results in unknown data storage at that location. For a valid write operation to the same address of the RAM block, the rising edge of the write clock for port A must occur following the minimum write cycle time interval after the rising edge of the write clock for port B. Since data is written into the M4K blocks at the falling edge of the write clock, the rising edge of the write clock for port A should occur following half of the minimum write cycle time interval after the falling edge of the write clock for port B. If this timing is not met, the data stored in that particular address will be invalid.



See [Section I, Cyclone FPGA Family Data Sheet](#) for more information about the minimum synchronous write cycle time.

[Figure 7–7](#) shows true dual-port timing waveforms for a write operation at port A and a read operation at port B.

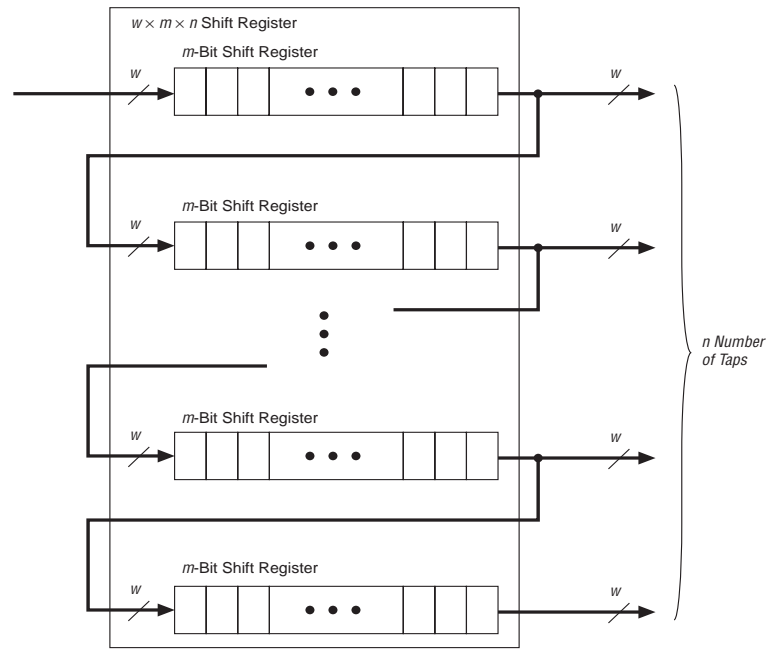
Figure 7-7. True Dual-Port Timing Waveforms

Implementing Shift-Register Mode

Embedded memory configurations can implement shift-register blocks for digital signal processing (DSP) applications, such as finite impulse response (FIR) filters, pseudo-random number generators, multi-channel filtering, and auto-correlation and cross-correlation functions. These and other DSP applications require local data storage, traditionally implemented with standard flip-flops that can quickly consume many logic cells for large shift registers. A more efficient alternative is to use embedded memory as a shift-register block, which saves logic cell and routing resources and provides a more efficient implementation.

The size of a $(w \times m \times n)$ shift register is determined by the input data width (w), the length of the taps (m), and the number of taps (n). The size of a $(w \times m \times n)$ shift register must be less than or equal to the 4,608 bits. In addition, the size of $(w \times n)$ must be less than or equal to 36 bits. If a larger shift register is required, memory blocks can be cascaded together.

Data is written into each address location at the falling edge of the clock and read from the address at the rising edge of the clock. The shift-register mode logic automatically controls the positive and negative edge clocking to shift the data in one clock cycle. [Figure 7-8](#) shows the M4K memory block in shift-register mode.

Figure 7-8. M4K Shift-Register Memory Configuration

Implementing ROM Mode

M4K blocks can also be configured as ROM. ROM can be initialized in an M4K block by using a memory initialization file (.mif). Because all M4K memory configurations must have synchronous inputs, the address lines of the ROM are registered. ROM outputs can be registered or combinatorial. The read operation of the ROM is identical to the read operation of the single-port RAM configuration.

Implementing FIFO Buffers

FIFO buffer outputs are always combinatorial. Simultaneous read and write operations from an empty FIFO buffer are not supported.

Clock Modes

Depending on the M4K memory mode, independent, input/output, read/write, and/or single-port clock modes are available. [Table 7-6](#) shows the clock modes supported by the M4K memory modes.

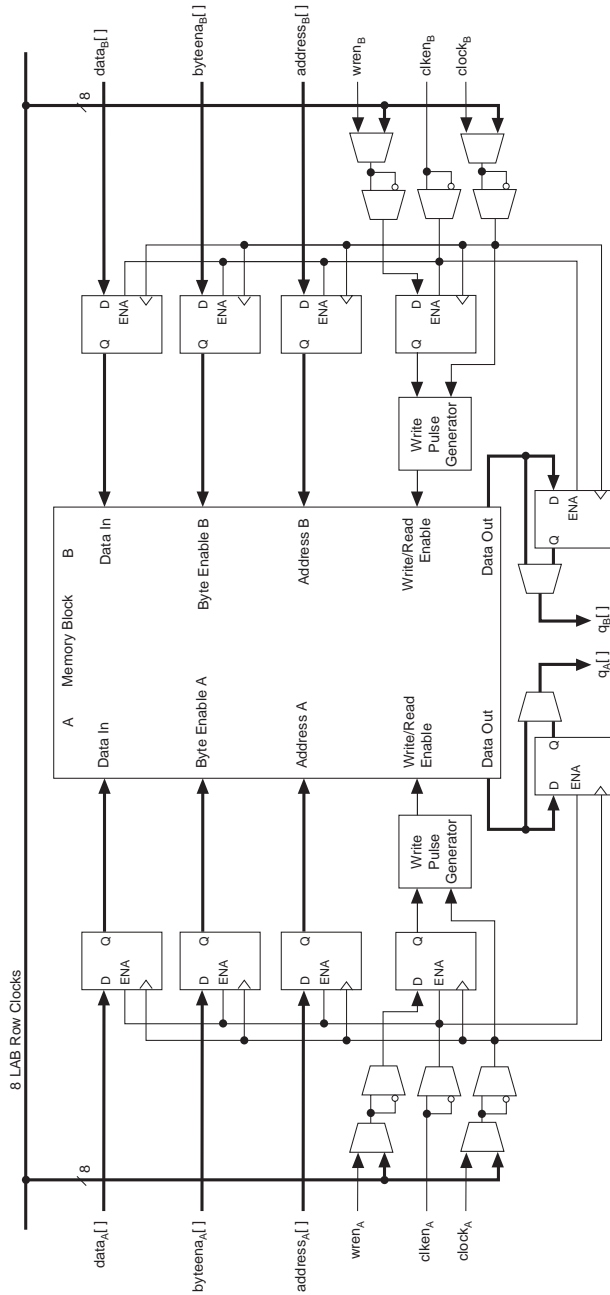
Table 7-6. M4K Memory Clock Modes

Clocking Mode	True-Dual Port Mode	Simple Dual-Port Mode	Single-Port Mode
Independent	✓		
Input/output	✓	✓	
Read/write		✓	
Single-port			✓

Independent Clock Mode

M4K memory blocks can implement independent clock mode for true dual-port memory. In this mode, a separate clock is available for each port (A and B). Clock A controls all registers on the port A side, while clock B controls all registers on the port B side. Each port also supports independent clock-enable signals and asynchronous clear signals for port A and B registers. [Figure 7-9](#) shows an M4K memory block in independent clock mode.

Figure 7-9. Independent Clock Mode



Input/Output Clock Mode

M4K memory blocks can implement input/output clock mode for true and simple dual-port memory. On each of the two ports, A and B, one clock controls all registers for inputs (data input, `wren`, and `address`) into the memory block. The other clock controls the block's data output registers. Each memory block port also supports independent clock enables and asynchronous clear signals for input and output registers. [Figures 7-10](#) and [7-11](#) show the memory block in input/output clock mode for true and simple dual-port modes, respectively.

Figure 7-10. Input/Output Clock Mode in True Dual-Port Mode

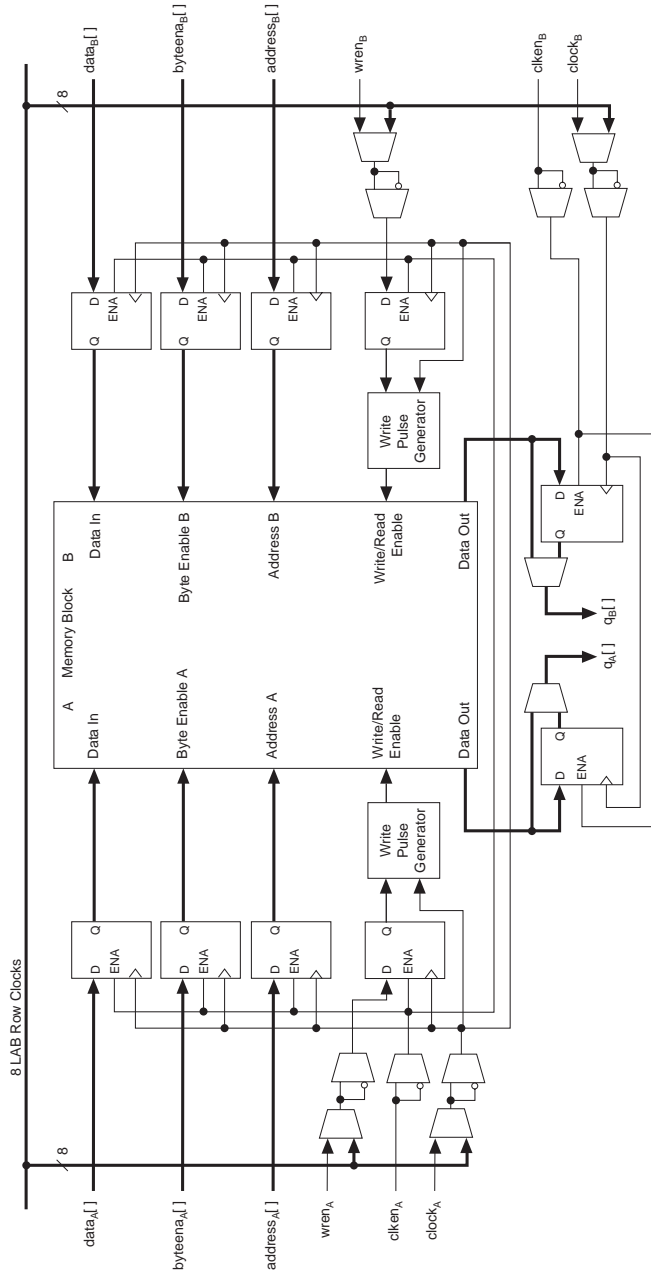
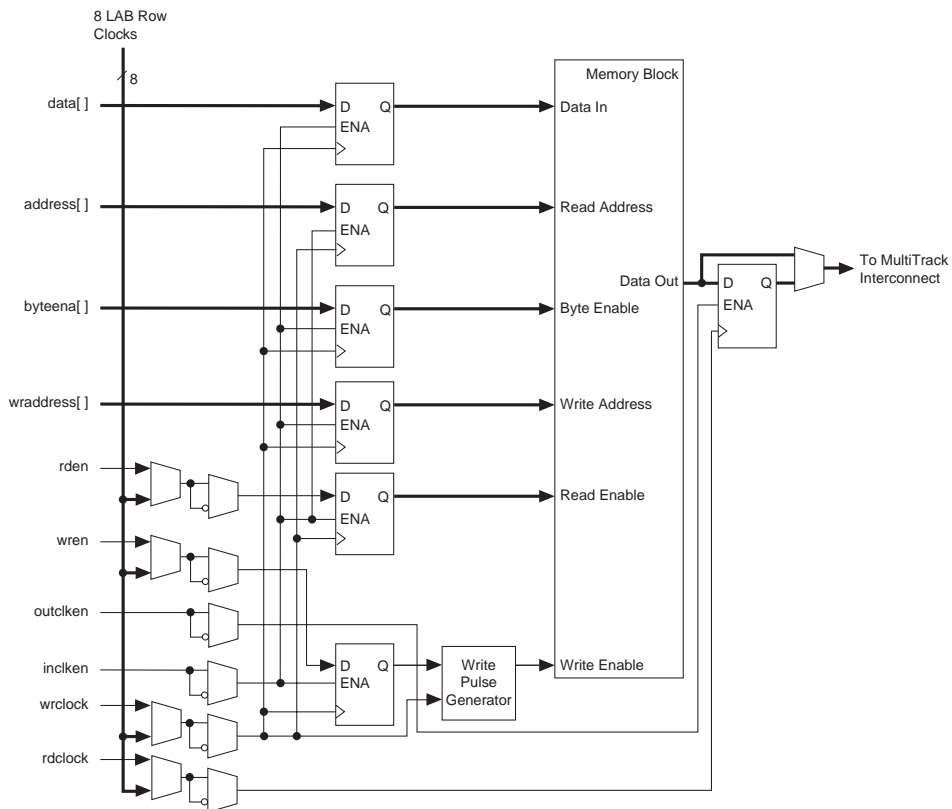


Figure 7-11. Input/Output Clock Mode in Simple Dual-Port Mode *Note (1)*

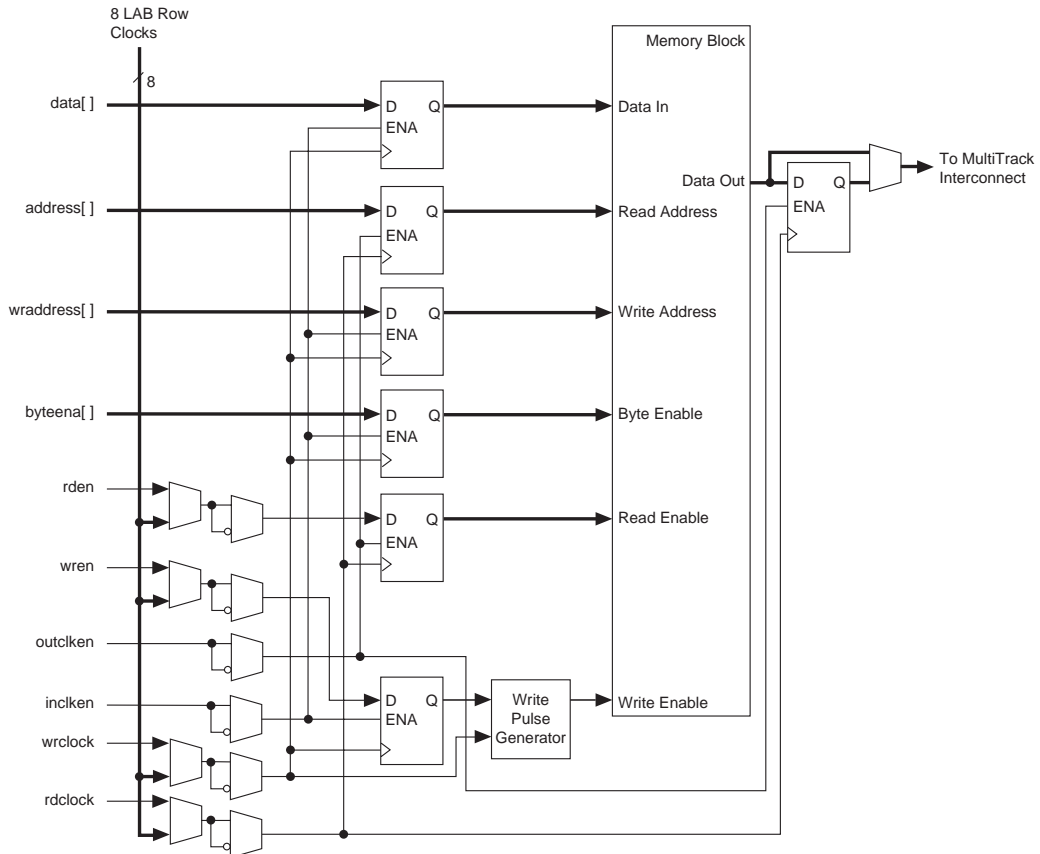


Note to Figure 7-11:

(1) For more information on the MultiTrack™ interconnect, see [Section I, Cyclone FPGA Family Data Sheet](#).

Read/Write Clock Mode

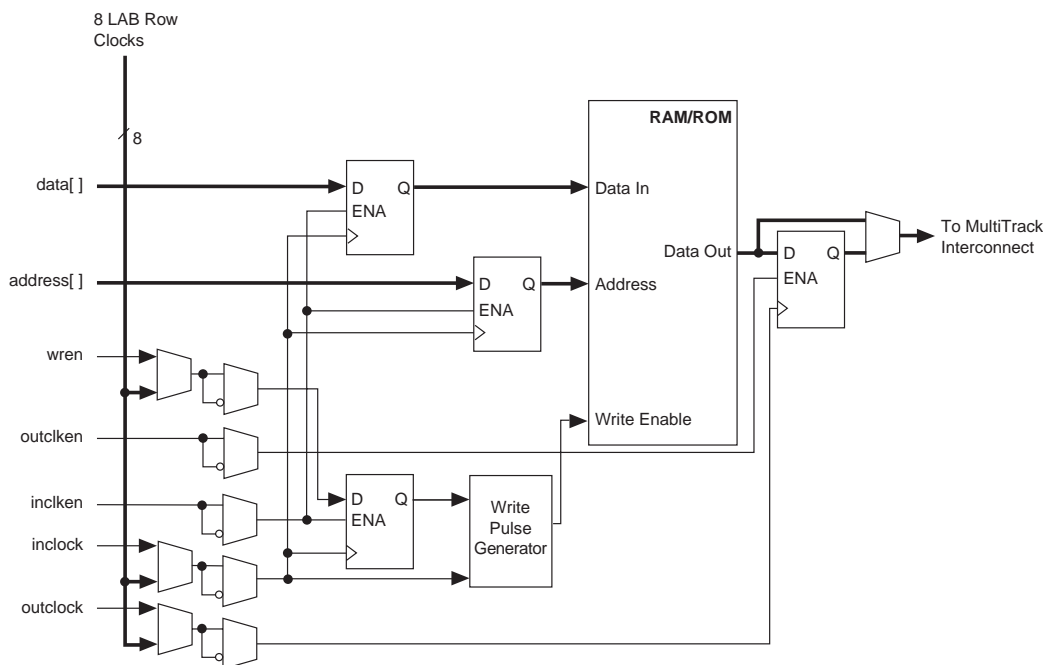
M4K memory blocks can implement read/write clock mode for simple dual-port memory. This mode can use up to two clocks. The write clock controls the block's data inputs, *waddress*, and *wren*. The read clock controls the data output, *rdaddress*, and *rden*. The memory blocks support independent clock enables for each clock and asynchronous clear signals for the read- and write-side registers. [Figure 7-12](#) shows a memory block in read/write clock mode.

Figure 7-12. Read/Write Clock Mode in Simple Dual-Port Mode *Note (1)***Note to Figure 7-12:**

(1) For more information on the MultiTrack interconnect, see [Section I, Cyclone FPGA Family Data Sheet](#).

Single-Port Mode

The M4K memory blocks can implement single-port clock mode when simultaneous read and write operations are not required (see [Figure 7-13](#)). A single block in a memory block can support up to two single-port mode RAM blocks in M4K blocks.

Figure 7-13. Single-Port Mode *Note (1)*

Note to Figure 13:

(1) For more information on the MultiTrack interconnect, see [Section I, Cyclone FPGA Family Data Sheet](#).

Synchronous & Pseudo-Asynchronous Modes

The M4K memory architecture implements synchronous, pipelined RAM by registering both the input and output signals to the RAM block. All M4K memory inputs are registered, providing synchronous write cycles. In synchronous operation, an M4K block generates its own self-timed strobe write enable (*wren*) signal derived from the global or regional clock. In contrast, a circuit using asynchronous RAM must generate the RAM *wren* signal while ensuring its data and address signals meet setup and hold time specifications relative to the *wren* signal. The output registers can be bypassed.

In an asynchronous memory, neither the input nor the output is registered. While Cyclone devices do not support asynchronous memory, they do support a pseudo-asynchronous read operation where the output data is available during the same clock cycle as when the read address is driven into it. Pseudo-asynchronous reading is possible in the simple and

true dual-port modes of the M4K blocks by clocking the read enable and read address registers on the negative clock edge and bypassing the output registers.

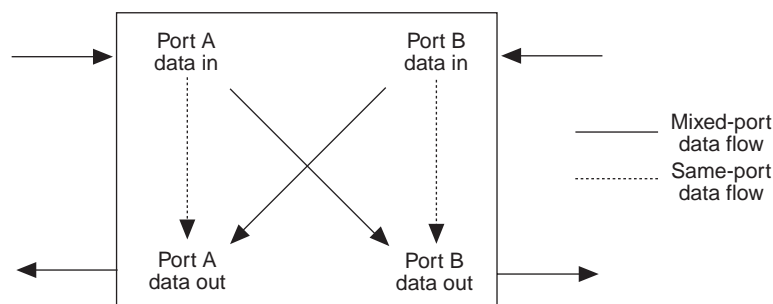


For more information, see *AN 210: Converting Memory from Asynchronous to Synchronous for Stratix Designs*.

Read-during-Write Operation at the Same Address

The following two sections describe the functionality of the various M4K memory configurations when reading from an address during a write operation at that same address. There are two types of read-during-write operations: same-port and mixed-port. [Figure 7-14](#) illustrates the difference in data flow between same-port and mixed-port read-during-write.

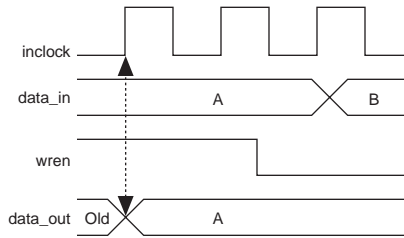
Figure 7-14. Read-during-Write Data Flow



Same-Port Read-during-Write Mode

For read-during-write operation of a single-port RAM or the same port of a true dual-port RAM, the new data is available on the rising edge of the same clock cycle it was written on. See [Figure 7-15](#) for a sample functional waveform.

When using byte-enable signals in true dual-port RAM mode, the outputs for the masked bytes on the same port are unknown. (See [Figure 7-1](#).) The non-masked bytes are read out as shown in [Figure 7-15](#).

Figure 7–15. Same-Port Read-during-Write Functionality *Note (1)*

Note to Figure 7–15:

(1) Outputs are not registered.

Mixed-Port Read-during-Write Mode

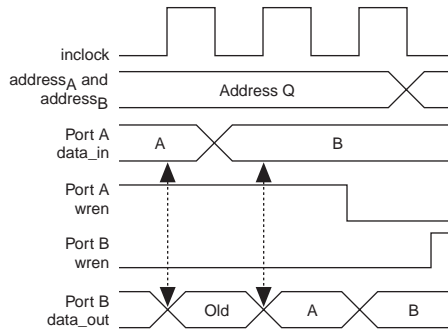
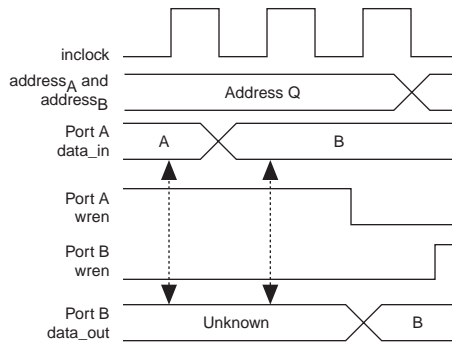
This mode is used when a RAM in simple or true dual-port mode has one port reading and the other port writing to the same address location with the same clock. You can configure the M4K memory block to operate in this mode and modify the parameter shown below using the MegaWizard® Plug-In Manager included with the Quartus II software.

The READ_DURING_WRITE_MODE_MIXED_PORTS parameter for M4K memory blocks determines whether or not to output the old data at the address. Setting this parameter to OLD_DATA outputs the old data at that address. Setting this parameter to DONT_CARE outputs an unknown value. During the instantiation of an ALTSYNCRAM or LPM_RAM_DP+ storage megafunction using the Quartus II software, the MegaWizard plug-in manager asks “How should the q output behave when reading a memory location that is being written from the other port?” Clicking “I don’t care” assigns the DONT_CARE value to the parameter, and clicking “Old memory contents appear” assigns the OLD_DATA value to the parameter.



Altera recommends using the MegaWizard Plug-In Manager to create these memory megafunctions rather than directly creating instances. Once a storage megafunction is created using the MegaWizard Plug-In Manager, use the MegaWizard Plug-In Manager to make any necessary changes.

See [Figures 7–16](#) and [7–17](#) for sample functional waveforms showing mixed-port read-during-write mode operation. These figures assume that the outputs are not registered.

Figure 7-16. Mixed-Port Read-during-Write: OLD_DATA**Figure 7-17. Mixed-Port Read-during-Write: DONT_CARE**

When two different clocks are used in dual-port RAM, the read-during-write behavior depends on the relationship of the clocks. The writing of the new contents starts at the falling edge of the write clock. Therefore, if the read clock's rising edge occurs before the falling edge of the write clock, the old data is read out. If the read clock's rising edge occurs between the falling edge of the write clock and half the minimum write cycle time interval, the output is unknown data.



For the minimum synchronous-write-cycle time see [Section I, Cyclone FPGA Family Data Sheet](#).

Conclusion

M4K memory blocks are a flexible memory solution available in Cyclone devices that provide advanced features such as byte-enable capability, parity bit storage capability, and shift-register mode, as well as mixed-port width support and true dual-port mode. This flexibility makes these embedded memory blocks well suited for a wide range of applications including ATM cell packet processing, header/cell storage, channelized functions, and program memory for processors.

This section provides information on the Cyclone FPGA I/O capabilities. It also includes information on selecting I/O standards for Cyclone devices in the Quartus II software.

This section contains the following chapters:

- Chapter 8. Using Selectable I/O Standards in Cyclone Devices
- Chapter 9. Implementing LVDS in Cyclone Devices

Revision History

The table below shows the revision history for Chapter 8 and 9.

Chapter(s)	Date / Version	Changes Made
8	May 2003 v1.0	Added Figure 8–5 and section titled “Differential SSTL-2 - EIA/JEDEC Standard JESD8-9A”. Added last row to Table 8–1 for Differential SSTL - 2.
9	May 2003 v1.0	Revised Table 9–1 with EP1C4.

Introduction

The proliferation of I/O standards and the need for improved I/O performance have made it critical that low-cost devices have flexible I/O capabilities. Selectable I/O capabilities such as SSTL-2, SSTL-3, and LVDS compatibility allow Cyclone™ devices to connect to other devices on the same printed circuit board (PCB) that may require different operating and I/O voltages. With these aspects of implementation easily manipulated using the Altera® Quartus® II software, the Cyclone device family enables system designers to use low-cost FPGAs while keeping pace with increasing design complexity.

This application note is a guide to understanding the input/output capabilities of the Cyclone devices, including:

- Supported I/O Standards
- Cyclone I/O Banks
- Programmable Current Drive Strength
- Hot Socketing
- I/O Termination
- Pad Placement & DC Guidelines
- Quartus II Software Support

“[Quartus II Software Support](#)” on page 8–17 describes how to use the Quartus II software to specify device and pin options and assign pins to implement the above features of Cyclone devices.

Supported I/O Standards

Cyclone devices support the I/O standards shown in [Table 8-1](#).



See [Section I, Cyclone FPGA Family Data Sheet](#) for more details on the I/O Standards discussed in this section.

I/O Standard	Type	Input Voltage Level (V)	Output Voltage Level (V)	Input V_{REF} (V)	Output V_{CCIO} (V)	Termination V_{TT} (V)
3.3-V LVTTTL/LVCMOS	Single-ended	3.3/2.5	3.3	N/A	3.3	N/A
2.5-V LVTTTL/LVCMOS	Single-ended	3.3/2.5	2.5	N/A	2.5	N/A
1.8-V LVTTTL/LVCMOS	Single-ended	3.3/2.5/1.8	1.8	N/A	1.8	N/A
1.5-V LVCMOS	Single-ended	3.3/2.5/1.8/1.5	1.5	N/A	1.5	N/A
PCI	Single-ended	3.3	3.3	N/A	3.3	N/A
SSTL-3 Class I and II	Voltage-referenced	-0.3 to 3.9	3.3	1.5	3.3	1.5
SSTL-2 Class I and II	Voltage-referenced	-0.3 to 3.0	2.5	1.25	2.5	1.25
LVDS Compatibility	Differential	0 to 2.4	VOD = 0.25 to 0.55	N/A	2.5	N/A
Differential SSTL - 2	Differential	N/A (3)	2.5	1.25	2.5	1.25

Notes to [Table 8-1](#):

- (1) The EP1C3 device in the 100-pin thin quad flat pack (TQFP) package does not have support for a PLL LVDS input or an external clock output.
- (2) Cyclone devices have dual-purpose differential inputs. Outputs are balanced SSTL outputs requiring an external resistor divider.
- (3) This I/O standard is only available on output clock pins (PLL_OUT pins).

3.3-V LVTTTL (EIA/JEDEC Standard JESD8-B)

The 3.3-V LVTTTL I/O standard is a general-purpose, single-ended standard used for 3.3-V applications. The LVTTTL standard defines the DC interface parameters for digital circuits operating from a 3.0-V/3.3-V power supply and driving or being driven by LVTTTL-compatible devices.

The LVTTTL input standard specifies a wider input voltage range of $-0.3\text{ V} \leq V_I \leq 3.9\text{ V}$. Altera recommends an input voltage range of $-0.5\text{ V} \leq V_I \leq 4.1\text{ V}$. The LVTTTL standard does not require input reference voltages or board terminations. Cyclone devices support both input and output levels for 3.3-V LVTTTL.

3.3-V LVCMOS (EIA/JEDEC Standard JESD8-B)

The 3.3-V LVCMOS I/O standard is a general-purpose, single-ended standard used for 3.3-V applications. The LVCMOS standard defines the DC interface parameters for digital circuits operating from a 3.0-V or 3.3-V power supply and driving or being driven by LVCMOS-compatible devices.

The LVCMOS standard specifies the same input voltage requirements as LVTTTL ($-0.3\text{ V} \leq V_I \leq 3.9\text{ V}$). The output buffer drives to the rail to meet the minimum high-level output voltage requirements. The 3.3-V I/O Standard does not require input reference voltages or board terminations. Cyclone devices support both input and output levels specified by the 3.3-V LVCMOS I/O standard.

2.5-V LVTTTL Normal & Wide Voltage Ranges (EIA/JEDEC Standard EIA/JESD8-5)

The 2.5-V I/O standard is used for 2.5-V LVTTTL applications. This standard defines the DC interface parameters for high-speed, low-voltage, non-terminated digital circuits driving or being driven by other 2.5-V devices. The input and output voltage requirements are:

- The 2.5-V normal and wide range input standards specify an input voltage range of $-0.3\text{ V} \leq V_I \leq 3.0\text{ V}$.
- The normal range minimum high-level output voltage requirement (V_{OH}) is 2.1-V.
- The wide range minimum high-level output voltage requirement (V_{OH}) is $V_{CCIO} - 0.2\text{ V}$.

The 2.5-V standard does not require input reference voltages or board terminations. Cyclone devices support input and output levels for both 2.5-V LVTTTL ranges.

2.5-V LVCMOS Normal & Wide Voltage Ranges (EIA/JEDEC Standard EIA/JESD8-5)

The 2.5-V I/O standard is used for 2.5-V LVCMOS applications. This standard defines the DC interface parameters for high-speed, low-voltage, non-terminated digital circuits driving or being driven by other 2.5-V parts. The input and output voltage ranges are:

- The 2.5-V normal and wide range input standards specify an input voltage range of $-0.3\text{-V} \leq V_I \leq 3.0\text{-V}$.
- The normal range minimum V_{OH} requirement is 2.1-V.
- The wide range minimum V_{OH} requirement is $V_{CCIO} - 0.2\text{ V}$.

The 2.5-V standard does not require input reference voltages or board terminations. Cyclone devices support input and output levels for both 2.5-V LVCMOS ranges.

1.8-V LVTTTL Normal & Wide Voltage Ranges (EIA/JEDEC Standard EIA/JESD8-7)

The 1.8-V I/O standard is used for 1.8-V LVTTTL applications. This standard defines the DC interface parameters for high-speed, low-voltage, non-terminated digital circuits driving or being driven by other 1.8-V parts. The input and output voltage ranges are:

- The 1.8-V normal and wide range input standards specify an input voltage range of $-0.3\text{ V} \leq V_I \leq 2.25\text{ V}$.
- The normal range minimum V_{OH} requirement is $V_{CCIO} - 0.45\text{ V}$.
- The wide range minimum V_{OH} requirement is $V_{CCIO} - 0.2\text{ V}$.

The 1.8-V standard does not require input reference voltages or board terminations. Cyclone devices support input and output levels for both normal and wide 1.8-V LVTTTL ranges.

1.8-V LVCMOS Normal & Wide Voltage Ranges (EIA/JEDEC Standard EIA/JESD8-7)

The 1.8-V I/O standard is used for 1.8-V LVCMOS applications. This standard defines the DC interface parameters for high-speed, low-voltage, non-terminated digital circuits driving or being driven by other 1.8-V devices. The input and output voltage ranges are:

- The 1.8-V normal and wide range input standards specify an input voltage range of $-0.3\text{ V} \leq V_I \leq 2.25\text{ V}$.
- The normal range minimum V_{OH} requirement is $V_{CCIO} - 0.45\text{ V}$.
- The wide range minimum V_{OH} requirement is $V_{CCIO} - 0.2\text{ V}$.

The 1.8-V standard does not require input reference voltages or board terminations. Cyclone devices support input and output levels for both normal and wide 1.8V LVCMOS ranges.

1.5-V LVCMOS Normal & Wide Voltage Ranges (EIA/JEDEC Standard JESD8-11)

The 1.5-V I/O standard is used for 1.5-V applications. This standard defines the DC interface parameters for high-speed, low-voltage, non-terminated digital circuits driving or being driven by other 1.5-V devices. The input and output voltage ranges are:

- The 1.5-V normal and wide range input standards specify an input voltage range of $-0.3\text{ V} \leq V_I \leq 1.9\text{-V}$.
- The normal range minimum V_{OH} requirement is 1.05-V.
- The wide range minimum V_{OH} requirement is $V_{CCIO} - 0.2\text{-V}$.

The 1.5-V standard does not require input reference voltages or board terminations. Cyclone devices support input and output levels for both normal and wide 1.5-V LVCMOS ranges.

3.3-V (PCI Special Interest Group (SIG) PCI Local Bus Specification Revision 2.2)

The PCI local bus specification is used for applications that interface to the PCI local bus, which provides a processor-independent data path between highly integrated peripheral controller components, peripheral add-in boards, and processor/memory systems. The conventional PCI specification revision 2.2 defines the PCI hardware environment including the protocol, electrical, mechanical, and configuration specifications for the PCI devices and expansion boards. This standard requires 3.3-V V_{CCIO} . The 3.3-V PCI standard does not require input reference voltages or board terminations.

Although PCI is not supported on the smallest member of the Cyclone device family, the EP1C3, all other Cyclone devices are fully compliant with the 3.3-V PCI Local Bus Specification Revision 2.2 and meet 32-bit/66-MHz operating frequency and timing requirements. The devices support PCI input and output levels on I/O banks 1 and 3 only. See “Cyclone I/O Banks” for more details.

SSTL-3 Class I & II (EIA/JEDEC Standard JESD8-8)

The SSTL-3 I/O standard is a 3.3-V memory bus standard used for applications such as high-speed SDRAM interfaces. This standard defines the input and output specifications for devices that operate in the

SSTL-3 logic switching range of 0.0 to 3.3 V. The SSTL-3 standard specifies an input voltage range of $-0.3 \text{ V} \leq V_I \leq V_{CCIO} + 0.3 \text{ V}$. SSTL-3 requires a 1.5-V V_{REF} and a 1.5-V V_{TT} to which the series and termination resistors are connected (see Figures 8-1 and 8-2). In typical applications, both the termination voltage and reference voltage track the output supply voltage.

Figure 8-1. SSTL-3 Class I Termination

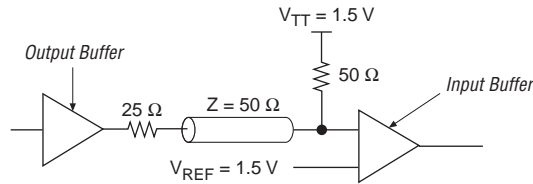
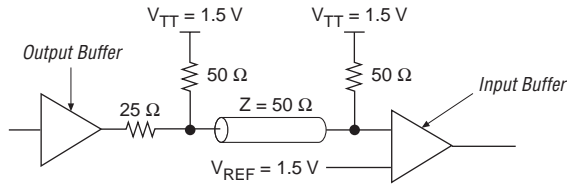


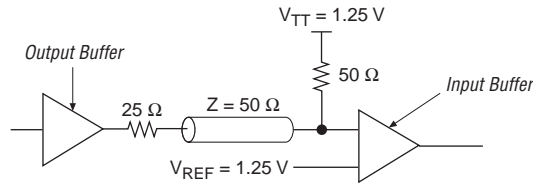
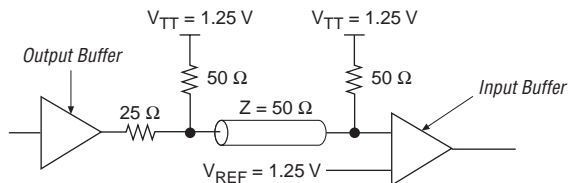
Figure 8-2. SSTL-3 Class II Termination



Cyclone devices support both input and output SSTL-3 Class I & II levels.

SSTL-2 Class I & II (EIA/JEDEC Standard JESD8-9A)

The SSTL-2 I/O standard is a 2.5-V memory bus standard used for applications such as high-speed double data rate (DDR) SDRAM interfaces. This standard defines the input and output specifications for devices that operate in the SSTL-2 logic switching range of 0.0-V to 2.5-V. This standard improves operation in conditions where a bus must be isolated from large stubs. The SSTL-2 standard specifies an input voltage range of $-0.3 \text{ V} \leq V_I \leq V_{CCIO} + 0.3 \text{ V}$. SSTL-2 requires a V_{REF} value of 1.25 V and a V_{TT} value of 1.25 V connected to the series and termination resistors (see Figures 8-3 and 8-4).

Figure 8–3. SSTL-2 Class I Termination**Figure 8–4. SSTL-2 Class II Termination**

Cyclone devices support both input and output SSTL-2 Class I & II levels.

LVDS (ANSI/TIA/EIA Standard ANSI/TIA/EIA-644)

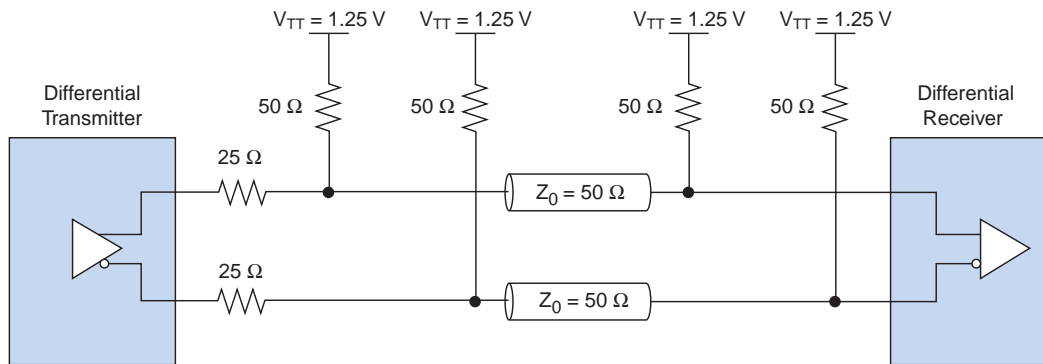
The LVDS I/O standard is a differential high-speed, low-voltage swing, low-power, general-purpose I/O interface standard. This standard is used in applications requiring high-bandwidth data transfer, backplane drivers, and clock distribution. The ANSI/TIA/EIA-644 standard specifies LVDS transmitters and receivers capable of operating at recommended maximum data signaling rates of 655 Mbps. Devices can operate at slower speeds if needed however, and there is a theoretical maximum of 1.923 Gbps. Due to the low-voltage swing of the LVDS I/O standard, the electromagnetic interference (EMI) effects are much smaller than CMOS, TTL, and PECL. This low EMI makes LVDS ideal for applications with low EMI requirements or noise immunity requirements. The LVDS standard specifies a differential output voltage range of $250 \text{ mV} \leq V_{OD} \leq 550 \text{ mV}$.

The Cyclone device family meets the ANSI/TIA/EIA-644 standard and is LVDS-compatible but, unlike previous products with LVDS support, Cyclone does not have dedicated SERDES or LVDS drivers. While external resistors are required for LVDS output support, Cyclone does have direct LVDS-compatible input support throughout the chip. This flexible approach to LVDS support allows LVDS compatibility on every bank of the Cyclone chip at speeds up to 311Mbps. (Contact Altera Applications for the latest LVDS specification).

Differential SSTL-2 - EIA/JEDEC Standard JESD8-9A

The differential SSTL-2 I/O standard is a 2.5-V standard used for applications such as high-speed DDR SDRAM clock interfaces. This standard supports differential signals in systems using the SSTL-2 standard and supplements the SSTL-2 standard for differential clocks. The differential SSTL-2 standard specifies an input voltage range of $-0.3\text{ V} \leq V_I \leq V_{CCIO} + 0.3\text{ V}$. The differential SSTL-2 standard does not require an input reference voltage differential. See [Figure 8-5](#) for details on differential SSTL-2 termination. Cyclone devices support output clock levels for differential SSTL-2 class II operation.

Figure 8-5. SSTL-2 Class II Differential Termination

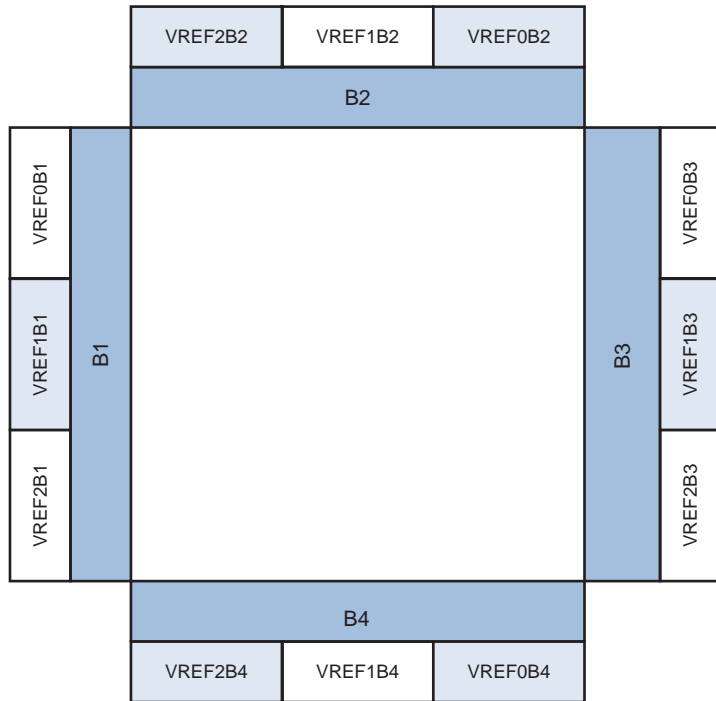


See [Section I, Cyclone FPGA Family Data Sheet](#) for more details on the I/O Standards discussed in this section.

Cyclone I/O Banks

The I/O pins on Cyclone devices are grouped together into I/O banks and each bank has a separate power bus. This permits designers to select the preferred I/O standard for a given bank enabling tremendous flexibility in the Cyclone device's I/O support.

Each Cyclone device supports four I/O banks regardless of density. Similarly, each device I/O pin is associated with one of these specific, numbered I/O banks. To accommodate voltage-referenced I/O standards, each Cyclone I/O bank has a common V_{REF} bus and each bank supports 3 V_{REF} pins (see [Figure 8-6](#)). In the event these pins are not used as V_{REF} pins, they may be used as regular I/O pins.

Figure 8–6. Cyclone Power Bank & V_{REF} Arrangement

Additionally, each Cyclone I/O bank has its own V_{CCIO} pins. Any single I/O bank must have only one V_{CCIO} setting from among 1.5-V, 1.8-V, 2.5-V or 3.3-V. Although there can only be one V_{CCIO} voltage, Cyclone devices permit additional input signaling capabilities as shown in [Table 8–2](#).

Table 8–2. Acceptable Input Levels for LVTTTL/LVCMOS

Bank V_{CCIO}	Acceptable Input Levels			
	3.3-V	2.5-V	1.8-V	1.5-V
3.3-V	✓	✓		
2.5-V	✓	✓		
1.8-V	✓	✓	✓	
1.5-V	✓	✓	✓	✓



For more information on acceptable input levels, see [Chapter 11, Using Cyclone Devices in Multiple-Voltage Systems](#).

Any number of supported single-ended or differential standards can be simultaneously supported in a single I/O bank as long as they use compatible V_{CCIO} levels for input and output pins. For example, an I/O bank with a 2.5-V V_{CCIO} setting can support 2.5-V LVTTTL inputs and outputs, 2.5-V LVDS-compatible inputs and outputs, and 3.3-V LVCMOS inputs only.

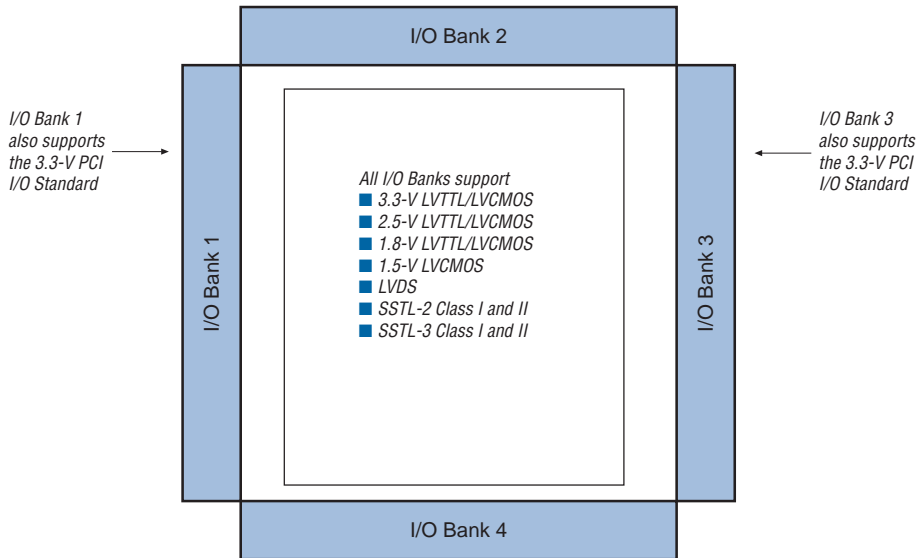
Voltage-referenced standards can be supported in an I/O bank using any number of single-ended or differential standards as long as they use the same V_{REF} and a compatible V_{CCIO} value. For example, if you choose to implement both SSTL-3 and SSTL-2 in your Cyclone device, I/O pins using these standards—because they require different V_{REF} values—must be in different banks from each other. However, SSTL-3 and 3.3-V LVCMOS could be supported in the same bank with the V_{CCIO} set to 3.3-V and the V_{REF} set to 1.5-V.



See [“Pad Placement & DC Guidelines” on page 8–13](#) for more information.

All four I/O banks support all of the I/O standards with the exception of PCI, which is only supported on banks 1 and 3 (see [Figure 8–7](#)).

Figure 8–7. I/O Standards Supported in Cyclone Devices Notes (1), (2)



Notes to Figure 8–7

- (1) PCI is not supported on the EP1C3 device.
- (2) The EP1C3 device in the 100-pin thin quad flat pack (TQFP) package does not have support for a PLL LVDS-compatible input or an external clock output.

Programmable Current Drive Strength

The Cyclone device I/O standards support various output current drive settings as shown in [Table 8–3](#). These programmable drive-strength settings are a valuable tool in helping decrease the effects of simultaneously switching outputs (SSO) in conjunction with reducing system noise. The supported settings ensure that the device driver meets the specifications for I_{OH} and I_{OL} of the corresponding I/O standard.

These drive-strength settings are programmable on a per-pin basis (for output and bidirectional pins only) using the Quartus II software. To modify the current strength of a particular pin, see [“Programmable Drive Strength Settings”](#).

Table 8–3. Programmable Drive Strength

I/O Standard	I_{OH}/I_{OL} Current Strength Setting
3.3-V LVTTTL	24, 16, 12, 8, 4 mA
3.3-V LVCMOS	12, 8, 4, 2 mA
2.5-V LVTTTL/LVCMOS	16, 12, 8, 2 mA
1.8-V LVTTTL/LVCMOS	12, 8, 2 mA
1.5-V LVCMOS	8, 4, 2 mA
SSTL-3 class I and II	Minimum strength
SSTL-2 class I and II	Minimum strength

Hot Socketing

Cyclone devices support any power-up or power-down sequence (V_{CCIO} and V_{CCINT}) to facilitate hot socketing. You can drive signals into the device before or during power-up or power-down without damaging the device. Cyclone devices will not drive out until the device is configured and has attained proper operating conditions.

You can power up or power down the V_{CCIO} and V_{CCINT} pins in any sequence. The power supply ramp rates can range from 100 ns to 100 ms and I/O pins can be driven by active signals with rise/fall times of 2ns to 40ns. Additionally, during power-up, the I/O pin capacitance is less than 15 pF and the clock pin capacitance is less than 20pF.

- The hot socketing DC specification is $|I_{IOPIN}| < 300 \mu\text{A}$.
- The hot socketing AC specification is $|I_{IOPIN}| < 8 \text{ mA}$ for 10 ns or less.

I/O Termination

The majority of the Cyclone I/O standards are single-ended, non-voltage-referenced I/O standards and, as such, the following I/O standards do not specify a recommended termination scheme:

- 3.3-V LVTTTL / LVCMOS
- 2.5-V LVTTTL / LVCMOS
- 1.8-V LVTTTL / LVCMOS
- 1.5-V LVCMOS
- 3.3-V PCI

The Cyclone device family does not feature on-chip I/O termination resistors.

Voltage-Referenced I/O Standard Termination

Voltage-referenced I/O standards require both an input reference voltage, V_{REF} , and a termination voltage, V_{TT} . The reference voltage of the receiving device tracks the termination voltage of the transmitting device.



For more information on termination for voltage-referenced I/O standards, see “Supported I/O Standards” on page 8–2.

Differential I/O Standard Termination

Differential I/O standards typically require a termination resistor between the two signals at the receiver. The termination resistor must match the differential load impedance of the bus.

LVDS is the only differential I/O standard supported by Cyclone devices. For information on LVDS termination, contact Altera Applications.

Pad Placement & DC Guidelines

This section provides pad placement guidelines for the programmable I/O standards supported by Cyclone devices and includes essential information for designing systems using the devices’ selectable I/O capabilities. This section also discusses the DC limitations and guidelines.

Differential Pad Placement Guidelines

In order to maintain an acceptable noise level on the V_{CCIO} supply, there are restrictions on placement of single-ended I/O pads in relation to differential pads. Use the following guidelines for placing single-ended pads with respect to differential pads in Cyclone devices.

- Single-ended inputs may only be placed four or more pads away from a differential pad.
- Single-ended outputs and bidirectional pads may only be placed five or more pads away from a differential pad.



The Quartus II software generates an error message for illegally placed pads.

V_{REF} Pad Placement Guidelines

In order to maintain an acceptable noise level on the V_{CCIO} supply and to prevent output switching noise from shifting the V_{REF} rail, there are restrictions on the placement of single-ended voltage referenced I/Os with respect to V_{REF} pads and V_{CCIO}/GND pairs. Please use the following guidelines for placing single-ended pads in Cyclone devices.

Input Pads

Each V_{REF} pad supports a maximum of 40 input pads with up to 20 on each side of the V_{REF} pad. This is irrespective of $VCCIO/GND$ pairs.

Output Pads

When a voltage referenced input or bidirectional pad does not exist in a bank, there is no limit to the number of output pads that can be implemented in that bank. When a voltage referenced input exists, each $VCCIO/GND$ pair supports 9 outputs for Fineline BGA® packages or 4 outputs for quad flat pack (QFP) packages. Any output pads must be placed greater than 2 pads away from your V_{REF} pad to maintain acceptable noise levels.

Bidirectional Pads

Bidirectional pads must satisfy input and output guidelines simultaneously. If the bidirectional pads are all controlled by the same OE and there are no other outputs or voltage referenced inputs in the bank, then there is no case where there is a voltage referenced input active at the same time as an output. Therefore, the output limitation does not apply. However, since the bidirectional pads are linked to the same OE, the bidirectional pads will all act as inputs at the same time. Therefore, the input limitation of 40 input pads (20 on each side of your V_{REF} pad) will apply.

If the bidirectional pads are all controlled by different output enables (OE) and there are no other outputs or voltage referenced inputs in the bank, then there may be a case where one group of bidirectional pads is acting as inputs while another group is acting as outputs. In such cases, apply the formulas shown in [Table 8-4](#).

Package Type	Formula
FineLine BGA	(Total number of bidirectional pads) - (Total number of pads from the smallest group of pads controlled by an OE) ≤ 9 (per $VCCIO/GND$ pair)
QFP	(Total number of bidirectional pads) - (Total number of pads from the smallest group of pads controlled by an OE) ≤ 4 (per $VCCIO/GND$ pair).

Consider an FineLine BGA package with 4 bidirectional pads controlled by OE1, 4 bidirectional pads controlled by OE2, and 2 bidirectional pads controlled by OE3. If OE1 and OE2 are active and OE3 is inactive, there are 10 bidirectional pads, but it is safely allowable because there would be 8 or fewer outputs per VCCIO/GND pair.

When at least one additional voltage referenced input and no other outputs exist in the same V_{REF} bank, the bidirectional pad limitation applies in addition to the input and output limitations. See the following equation.

$$(Total\ number\ of\ bidirectional\ pads) + (Total\ number\ of\ input\ pads) \leq 40$$

(20 on each side of your V_{REF} pad)



The bidirectional pad limitation applies to both Fineline BGA packages and QFP packages.

After applying the equation above, apply one of the equations in [Table 8-5](#), depending on package type.


Table 8-5. Bidirectional Pad Limitation Formulas (Where V_{REF} Inputs Exist)	
Package Type	Formula
FineLine BGA	(Total number of bidirectional pads) ≤ 9 (per VCCIO/GND pair)
QFP	(Total number of bidirectional pads) ≤ 4 (per VCCIO/GND pair)

When at least one additional output exists but no voltage referenced inputs exist, apply the appropriate formula from [Table 8-6](#).

Table 8-6. Bidirectional Pad Limitation Formulas (Where V_{REF} Outputs Exist)	
Package Type	Formula
FineLine BGA	(Total number of bidirectional pads) + (Total number of additional output pads) - (Total number of pads from the smallest group of pads controlled by an OE) ≤ 9 (per VCCIO/GND pair)
QFP	(Total number of bidirectional pads) + (Total number of additional output pads) - (Total number of pads from the smallest group of pads controlled by an OE) = 4 (per VCCIO/GND pair)

When additional voltage referenced inputs and other outputs exist in the same V_{REF} bank, then the bidirectional pad limitation must again simultaneously adhere to the input and output limitations. As such, the following rules apply:

Total number of bidirectional pads + Total number of input pads \leq 40 (20 on each side of your V_{REF} pad).

 The bidirectional pad limitation applies to both Fineline BGA packages and QFP packages.

After applying the equation above apply one of the equations in [Table 8–7](#), depending on package type.

Package Type	Formula
FineLine BGA	(Total number of bidirectional pads) + (Total number of output pads) \leq 9 (per V_{CCIO}/GND pair)
QFP	Total number of bidirectional pads + Total number of output pads \leq 4 (per V_{CCIO}/GND pair)

Each I/O bank can only be set to a single V_{CCIO} voltage level and a single V_{REF} voltage level at a given time. Pins of different I/O standards can share the bank if they have compatible V_{CCIO} values (see [Table 8–2](#) for more details).

In all cases listed above, the Quartus II software generates an error message for illegally placed pads.

DC Guidelines

There is a current limit of 320 mA per 10 consecutive output pins, as shown by the following equation:

$$\sum_{pin}^{pin + 9} I_{pin} < 320 \text{ mA}$$

[Table 8–8](#) shows the current allowed per pin by select I/O standards as measured under the standard's defined loading conditions. PCI, LVTTTL, LVCMOS, and other supported I/O standards not shown in the table do

not have standardized loading conditions. As such, the current allowed per pin in a series-loaded condition for these standards is considered negligible.

Pin I/O Standard	I Pin (mA)	
	3.3-V V_{CCIO}	2.5-V V_{CCIO}
SSTL-3 Class I	8	N/A
SSTL-3 Class II	16	N/A
SSTL-2 Class I	N/A	8.1
SSTL-2 Class II	N/A	16.4
LVDS	N/A	

Quartus II Software Support

Use the Quartus II software to specify which programmable I/O standards to use for Cyclone devices. This section describes Quartus II implementation, placement, and assignment guidelines, including:

- Compiler settings
- Device & pin options
- Assigning pins
- Programmable drive strength settings
- I/O banks in the floorplan view
- Auto placement & verification

Compiler Settings

The Compiler Settings dialog box (Processing menu) includes options allowing you to set a default I/O standard, optimize for I/O placement, assign I/O pins, and numerous other I/O-related options. The most pertinent user features are described in detail below.

Device & Pin Options

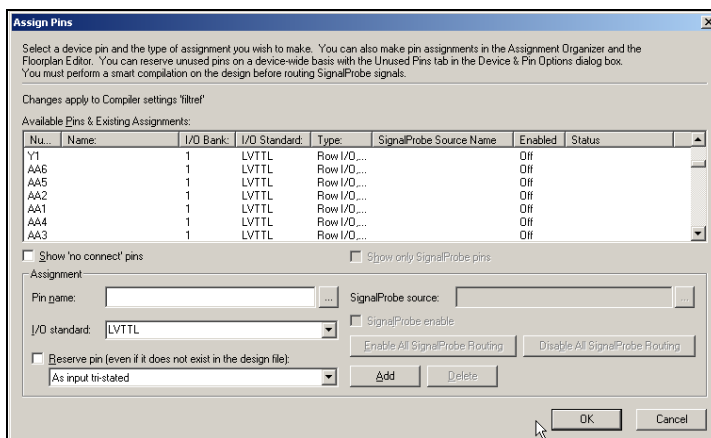
To access Device & Pin Options, choose **Compiler Settings** (Processing menu), then choose the **Chips and Devices** tab. There are numerous categories in the Device & Pin Options dialog box, including General, Configuration, Programming Files, Unused Pins, Dual-Purpose Pins, and Voltage. Similarly, each of these categories contains settings vital to the device operation such as the default I/O standard applied to the chip (Voltage tab), how to reserve all unused pins (Unused Pins tab), and whether or not the device should enable a device-wide reset (General tab).

Assigning Pins

Assuming a specific device has been chosen in the available devices list in the Compiler Settings dialog box, clicking **Assign Pins** provides the device's pin settings and pin assignments (see [Figure 8–8](#)). You can view, add, remove and update pin settings under the Available Pins & Existing Assignments section within this window. The information for each pin includes:

- Number
- Name
- I/O bank
- I/O standard
- Type (e.g., row or column I/O and differential or control)
- SignalProbe Source Name
- Enabled (i.e., whether SignalProbe routing is enabled or disabled status)

Figure 8–8. Assign Pins



While assigned and unassigned pins are displayed in the Assign Pins dialog box, note that this listing does not include dedicated pins. Consult the device pin-out table for a completing listing of pins including dedicated pins.

When you assign an I/O standard that requires a reference voltage to an I/O pin, the Quartus II software automatically assigns VREF pins. Refer to Quartus II Help for instructions on how to use an I/O standard for a pin.

Programmable Drive Strength Settings

To specify programmable drive strength settings, perform the following steps:

1. Choose **Assignment Organizer** (Tools menu).
2. Choose the **Edit specific entity & node settings for:** setting, then select the output or bidirectional pin for which you will specify the current strength.
3. Select **Options for Individual Nodes Only** in the Assignment Categories dialog box.
4. Select **Click here to add a new assignment**.
5. In the **Assignment** dialog box, set the **Name** field to **Current Strength** then enter the desired value in the **Setting** field.
6. Click **Add**.
7. Click **Apply** then **OK**.

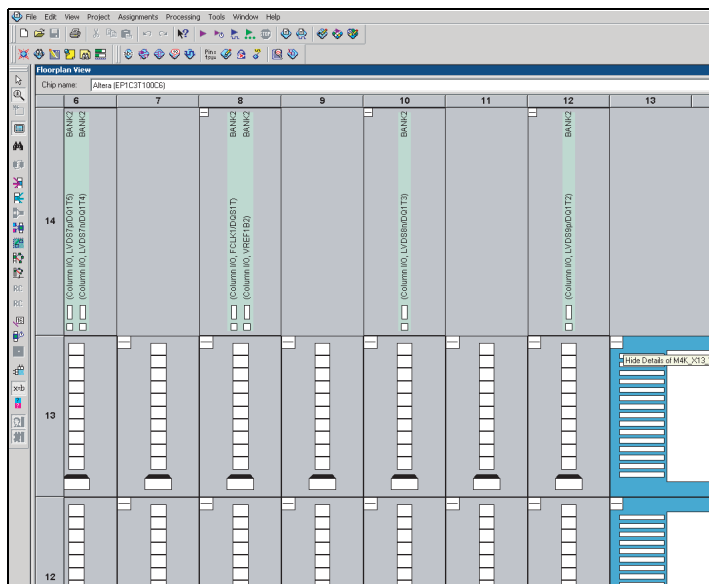
Note that the Quartus II software displays the entire range of drive strength choices. While the Quartus II software does not prohibit you from specifying any of these for your I/O pin, not every setting is supported by every I/O standard. Please refer to [Table 8-3](#) for supported combinations.

I/O Banks in the Floorplan View

View the arrangement of the device I/O banks by choosing **Interior Cells** (View menu) with the Floorplan View displayed (see [Figure 8-9](#)). Pins that belong to the same I/O bank must use the same V_{CCIO} voltage. You can assign multiple I/O standards to the I/O pins in any given I/O bank as long as the V_{CCIO} voltage of the desired I/O standards is the same.

A given bank can have up to three V_{REF} signals, and each signal can support one voltage-referenced I/O standard. Each device I/O pin belongs to a specific, numbered I/O bank. By default, the **Show I/O Banks** option is enabled, allowing the I/O banks to be displayed as color coded (See [Figure 8-9](#)).

Figure 8–9. Floorplan View Window



Auto Placement & Verification of Selectable I/O Standards

The Quartus II software automatically verifies the placement for all I/O and VREF pins and performs the following actions:

- Automatically places I/O pins of different V_{REF} standards without pin assignments in separate I/O banks and enables the VREF pins of these I/O banks.
- Verifies that voltage-referenced I/O pins requiring different V_{REF} levels are not placed in the same bank.
- Reports an error message if the current limit is exceeded for a Cyclone power bank (See “DC Guidelines”).
- Automatically assigns VREF pins and I/O pins such that the current requirements are met and I/O standards are placed properly.

Conclusion

Cyclone device I/O capabilities enable system designers to keep pace with increasing design complexity utilizing a low-cost FPGA device family. Support for I/O standards including SSTL and LVDS compatibility allow Cyclone devices to fit into a wide variety of applications. The Quartus II software makes it easy to use these I/O standards in Cyclone device designs. After design compilation, the software also provides clear, visual representations of pads and pins and

the selected I/O standards. Taking advantage of the support of these I/O standards in Cyclone devices will allow you to lower your design costs without compromising design flexibility or complexity.

More Information

For more information on Cyclone devices refer to the following resources:

- [Section I, Cyclone FPGA Family Data Sheet](#)
- [Chapter 11, Using Cyclone Devices in Multiple-Voltage Systems](#)
- [Application Note 75: High-Speed Board Layout Guidelines](#)

References

For more information on the I/O standards referred to in this document, see the following sources:

- Stub Series Terminated Logic for 2.5-V (SSTL-2), JESD8-9A, Electronic Industries Association, December 2000.
- 1.5-V +/- 0.1-V (Normal Range) and 0.9-V - 1.6-V (Wide Range) Power Supply Voltage and Interface Standard for Non-terminated Digital Integrated Circuits, JESD8-11, Electronic Industries Association, October 2000.
- 1.8-V +/- 0.15-V (Normal Range) and 1.2-V - 1.95-V (Wide Range) Power Supply Voltage and Interface Standard for Non-terminated Digital Integrated Circuits, JESD8-7, Electronic Industries Association, February 1997.
- 2.5-V +/- 0.2-V (Normal Range) and 1.8-V to 2.7-V (Wide Range) Power Supply Voltage and Interface Standard for Non-terminated Digital Integrated Circuits, JESD8-5, Electronic Industries Association, October 1995.
- Interface Standard for Nominal 3-V/ 3.3-V Supply Digital Integrated Circuits, JESD8-B, Electronic Industries Association, September 1999.
- PCI Local Bus Specification, Revision 2.2, PCI Special Interest Group, December 1998.
- Electrical Characteristics of Low Voltage Differential Signaling (LVDS) Interface Circuits, ANSI/TIA/EIA-644, American National Standards Institute/Telecommunications Industry/Electronic Industries Association, October 1995.

Introduction

From high-speed backplane applications to high-end switch boxes, LVDS is the technology of choice. LVDS is a low-voltage differential signaling standard, allowing higher noise immunity than single-ended I/O technologies. Its low-voltage swing allows for high-speed data transfers, low power consumption, and less electromagnetic interference (EMI). LVDS I/O signaling is a data interface standard defined in the TIA/EIA-644 and IEEE Std. 1596.3 specifications.

Altera® Cyclone™ devices allow you to transmit and receive data through LVDS signals at a data rate up to 311 megabits per second (Mbps). For the LVDS transmitter and receiver, the Cyclone device's input and output pins support serialization and deserialization through internal logic.

This application note describes how to use Cyclone I/O pins for LVDS signaling and contains the following topics:

- Cyclone LVDS I/O Banks
- Cyclone LVDS I/O Interface
- Cyclone Receiver & Transmitter Termination
- Implementing Cyclone LVDS I/O Pins in the Quartus II Software
- Design Guidelines

Cyclone LVDS I/O Banks

Cyclone devices offer four I/O banks, as shown in [Figure 9-1](#). A subset of pins in each of the four I/O banks (on both rows and columns) support the LVDS interface. Cyclone pin tables list the pins that support the LVDS I/O interface. The EP1C3 device in the 100-pin thin quad flat pack (TQFP) package does not support the LVDS I/O interface.

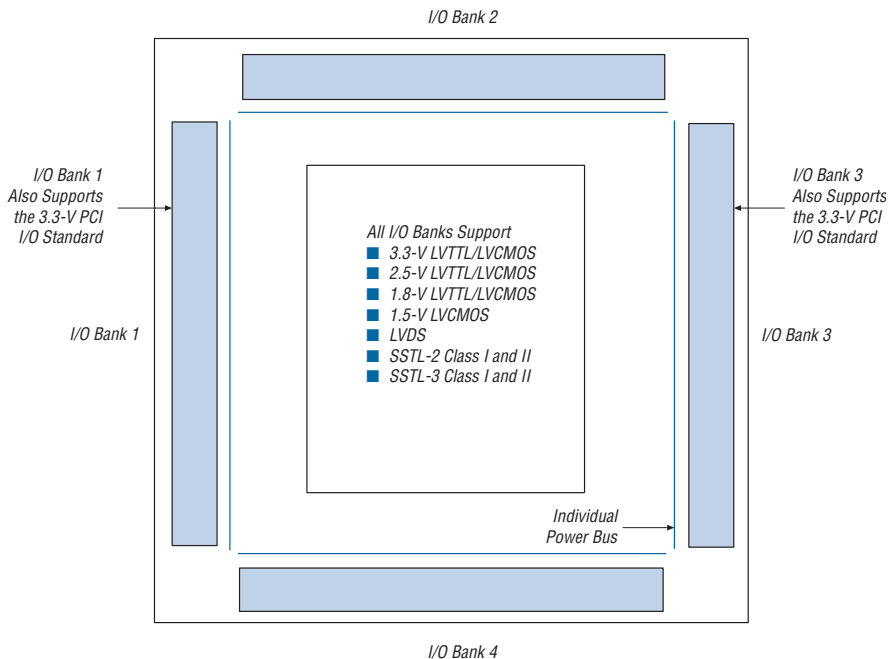
Figure 9–1. Cyclone I/O Banks

Table 9–1 shows the total number of supported LVDS channels in each Cyclone device. You can use each channel as a receiver or transmitter.

Cyclone devices support different modes (ranging from $\times 1$ to $\times 10$) of operation with a maximum internal clock frequency of 311 MHz and a maximum data rate of 311 Mbps.

Table 9–1. Number of LVDS Channels Per Cyclone Device

Device	Pin Count	Total Number of LVDS Channels
EP1C3	144	34
EP1C4	324	103
	400	129
EP1C6	144	29
	240	72
	256	72
EP1C12	240	66
	256	72
	324	103
EP1C20	324	95
	400	129



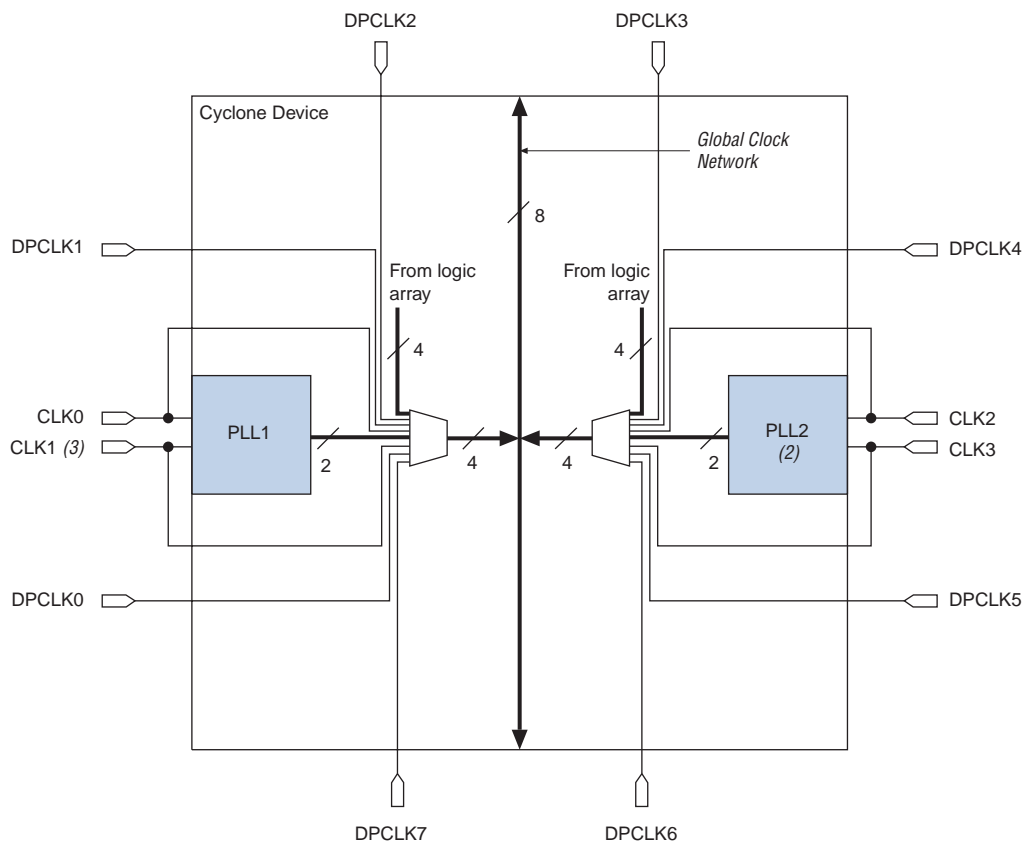
For more information on I/O standards supported by Cyclone devices, see [Chapter 8, Using Selectable I/O Standards in Cyclone Devices](#).

Cyclone LVDS I/O Interface

You can use the I/O pins and internal logic to implement an LVDS receiver and transmitter in Cyclone devices. Cyclone devices do not contain dedicated serialization or deserialization circuitry; therefore, shift registers, internal global phase-locked loops (PLLs), and I/O cells are used to perform serial-to-parallel conversions on incoming data and parallel-to-serial conversion on outgoing data.

Clock Domains

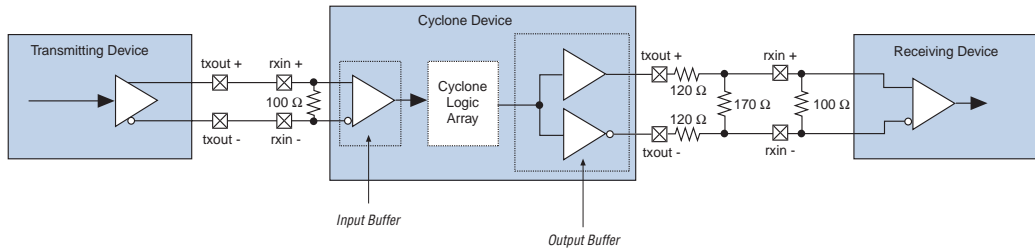
Cyclone devices provide a global clock network and two PLLs (the EP1C3 device only contains one PLL). The global clock network consists of eight global clock lines that drive through the entire device (see [Figure 9–2](#)). There are four dedicated clock pins that feed the PLL inputs (two dedicated clocks for each PLL). PLL pins can also act as LVDS input pins. Cyclone PLLs provide general-purpose clocking with clock multiplication and phase shifting as well as external outputs for LVDS differential I/O support.

Figure 9–2. Cyclone Global Clock Network *Note (1)***Notes to Figure 9–2:**

- (1) The EP1C3 device in the 100-pin TQFP package has five DPCLK pins (DPCLK2, DPCLK3, DPCLK4, DPCLK6, and DPCLK7).
- (2) EP1C3 devices only contain one PLL (PLL1).
- (3) EP1C3 devices in the 100-pin TQFP package do not support differential clock inputs or outputs.

LVDS Receiver & Transmitter

Figure 9–3 shows a simple point-to-point LVDS application where the source of the data is a LVDS transmitter. These LVDS signals are typically transmitted over a pair of printed circuit board (PCB) traces, but a combination of a PCB trace, connectors, and cables is a common application setup.

Figure 9–3. Typical LVDS Application

The Cyclone LVDS I/O pins meet the IEEE 1596 LVDS specification. [Figures 9–4](#) and [9–5](#) show the signaling levels for LVDS receiver inputs and transmitter outputs.

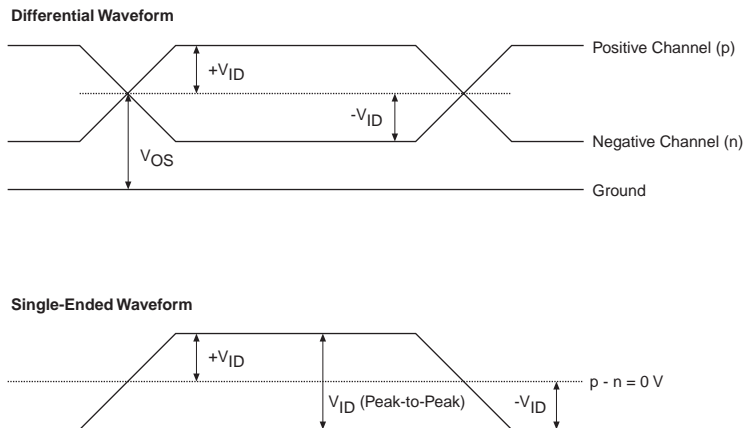
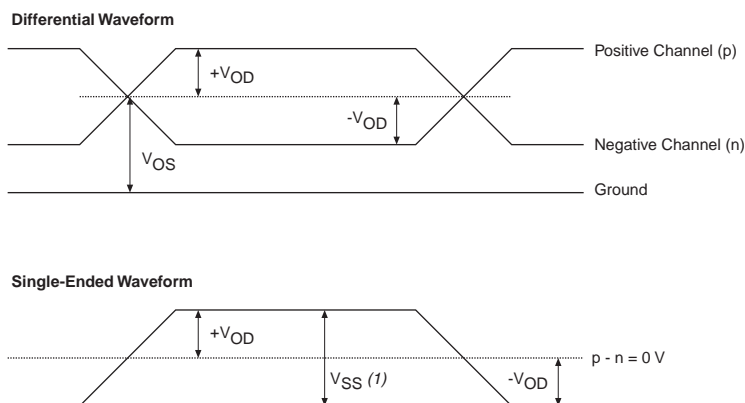
Figure 9–4. Receiver Input Waveform for the Differential I/O Standard

Figure 9–5. Transmitter Output Waveform for Differential I/O Standard

Note to Figure 9–5:

(1) V_{SS} : steady-state differential output voltage.

Table 9–2 lists the LVDS I/O specifications.

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{CCINT}	Supply Voltage		1.425	1.5	1.575	V
V_{CCIO}	I/O Supply Voltage		2.375	2.5	2.625	V
V_{OD}	Differential Output Voltage	$R_L = 100\ \Omega$	250		550	mV
ΔV_{OD}	Change in V_{OD} between H and L	$R_L = 100\ \Omega$			50	mV
V_{OS}	Output Offset Voltage	$R_L = 100\ \Omega$	1.125	1.25	1.375	V
ΔV_{OS}	Change in V_{OS} between H and L	$R_L = 100\ \Omega$			50	mV
V_{TH}	Differential Input Threshold	$V_{CM} = 1.2\text{ V}$	–100		100	mV
V_{IN}	Receiver input voltage range		0		2.4	V
R_L	Receiver Differential Input Resistor		90	100	110	W

LVDS Timing in Cyclone Devices

Since LVDS enables data transmission at very high speed, LVDS timing analysis is different than other I/O standards. You must understand how to analyze timing for the LVDS signal, which is based on skew between the data and the clock signal.

You should also consider board skew, cable skew, and clock jitter in your calculation. This section briefly explains the LVDS timing parameter in Cyclone devices.

Table 9-3 defines the parameters of the timing diagram shown in Figure 9-6.

Parameter	Definition	Description
SW	Sampling Window	Period of time input data must be stable so it can be successfully sampled by the receiver.
TCCS	Channel-to-Channel Skew	Difference between the fastest and slowest data output transitions, which include clock-to-output (t_{CO}) and clock skew of the transmitter.
RSKM	Receiver Input Skew Margin	Total margin left after accounting for SW and TCCS.

Figure 9-6. LVDS Timing Diagram

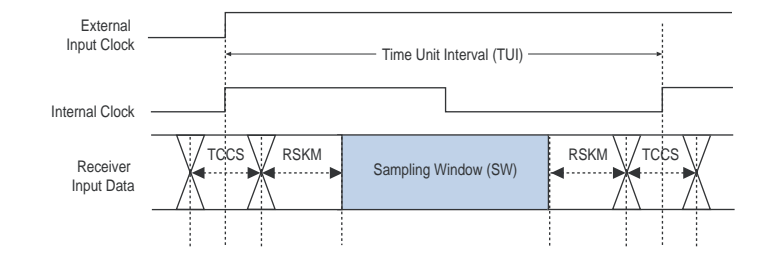
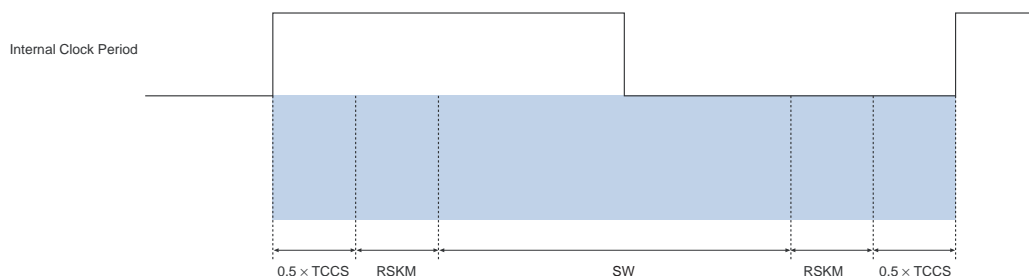


Figure 9-7 shows the LVDS timing budget.

Figure 9–7. Cyclone LVDS Timing Budget *Note (1)***Note to Figure 9–7:**

(1) The equation for the LVDS timing budget is: $\text{Period} = 0.5 \times \text{TCCS} + \text{RSKM} + \text{SW} + \text{RSKM} + 0.5 \times \text{TCCS}$.

Table 9–4 shows the preliminary timing budget for Cyclone devices at 311 Mbps.

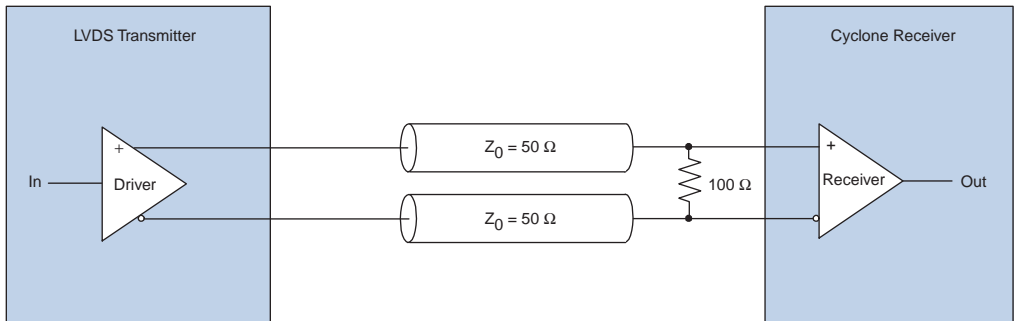
Parameter	Time (ns)
Period	3.22
SW	1.20
TCCS	1.02
RSKM	0.50



This application note will be updated with actual silicon data after device characterization is complete.

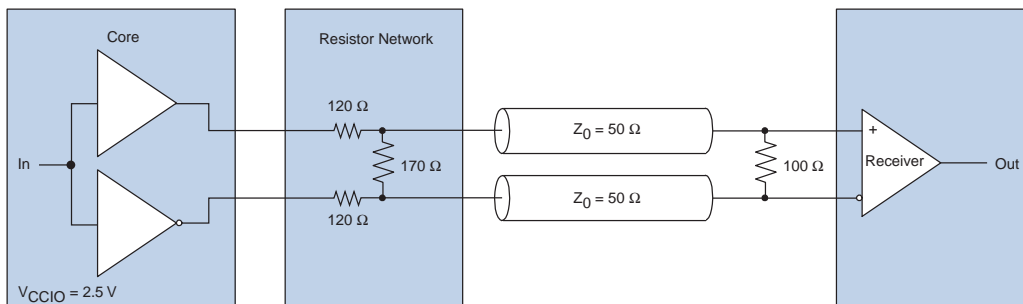
Cyclone Receiver & Transmitter Termination

Receiving LVDS signals on Cyclone I/O pins is straightforward, and can be done by assigning LVDS to desired pins in the Quartus II software. A 100-Ω parallel terminator is required at the receiver input pin, as shown in Figure 9–8.

Figure 9–8. Termination Scheme on Cyclone LVDS Receiver

For PCB layout guidelines, refer to *Application Note 224: High-Speed Board Layout Guidelines*.

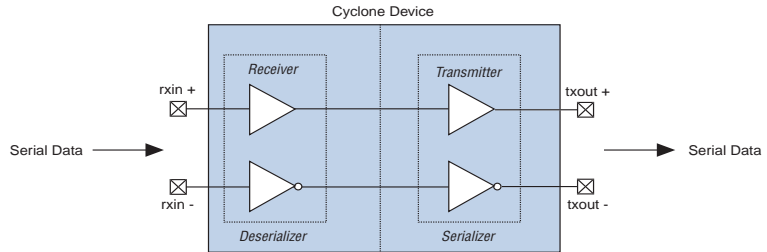
Cyclone LVDS transmitter signals are generated using a resistor network, as shown in [Figure 9–9](#) (with $R_S = 120\ \Omega$ and $R_{DIV} = 170\ \Omega$). The resistor network attenuates the driver outputs to levels similar to the LVDS signaling, which is recognized by LVDS receivers with minimal effect on 50- Ω trace impedance.

Figure 9–9. Termination Scheme on Cyclone LVDS Transmitter

Implementing Cyclone LVDS I/O Pins in the Quartus II Software

For differential signaling, the receiver must deserialize the incoming data and send it to the internal logic as a parallel signal. Accordingly, the transmitter must serialize the parallel data coming from the internal logic to send it off-chip (see [Figure 9–10](#)).

Figure 9–10. Deserialization & Serialization at Receiver & Transmitter



Although Cyclone devices do not incorporate a dedicated serializer/deserializer (SERDES), you can incorporate these functions in your design using the Quartus II software.

[Table 9–5](#) shows the three different reference design examples discussed in this application note.



Reference design examples for EP1C20, EP1C12, EP1C6, and EP1C4 devices have two PLLs per device, whereas EP1C3 devices in the 144-pin TQFP package have only one. Reference design files are listed under the title of this application note on the Altera web site at www.altera.com.

Table 9–5. Reference Designs

PLL Mode	Input Clock Frequency (MHz)
x2	155.50
x4	77.75
x8	38.88

Transmitting Serial Data on Cyclone LVDS Outputs

The LVDS transmitter reference design allows the data and clock frequency to be simultaneously transmitted. [Figure 9–11](#) shows the circuit schematic of a reference design for serialization of an 8-bit parallel bus implemented in EP1C20, EP1C12, EP1C6, and EP1C4 devices.

Figure 9–12 shows the $\times 8$ mode serialization circuitry implementation in EP1C3 devices. You can modify reference designs for desired serialization.

Figure 9–11. Reference Design Schematic for $\times 8$ Mode Serializer Implemented for EP1C20, EP1C12 & EP1C6 Devices

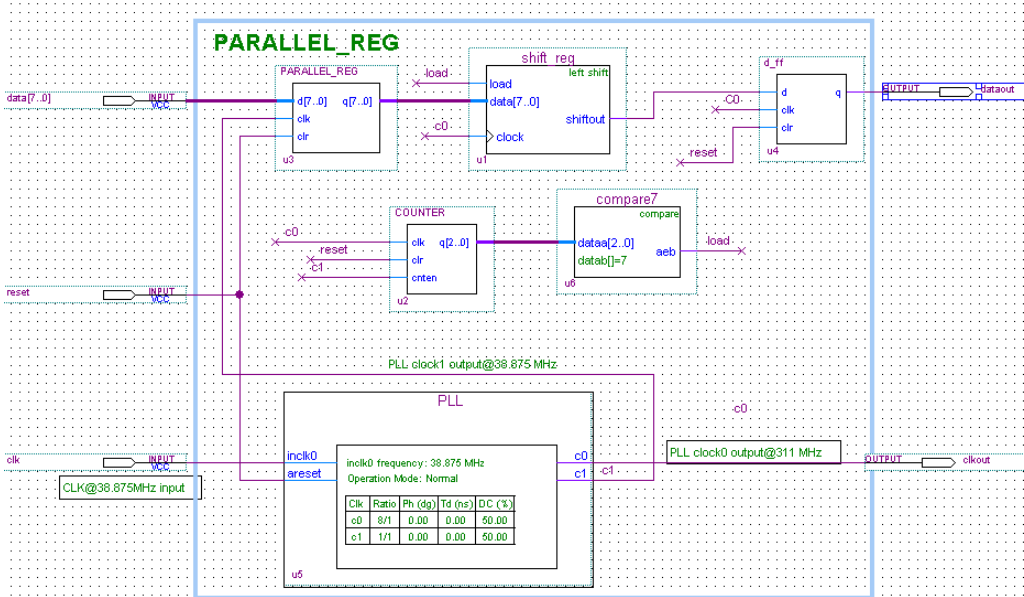
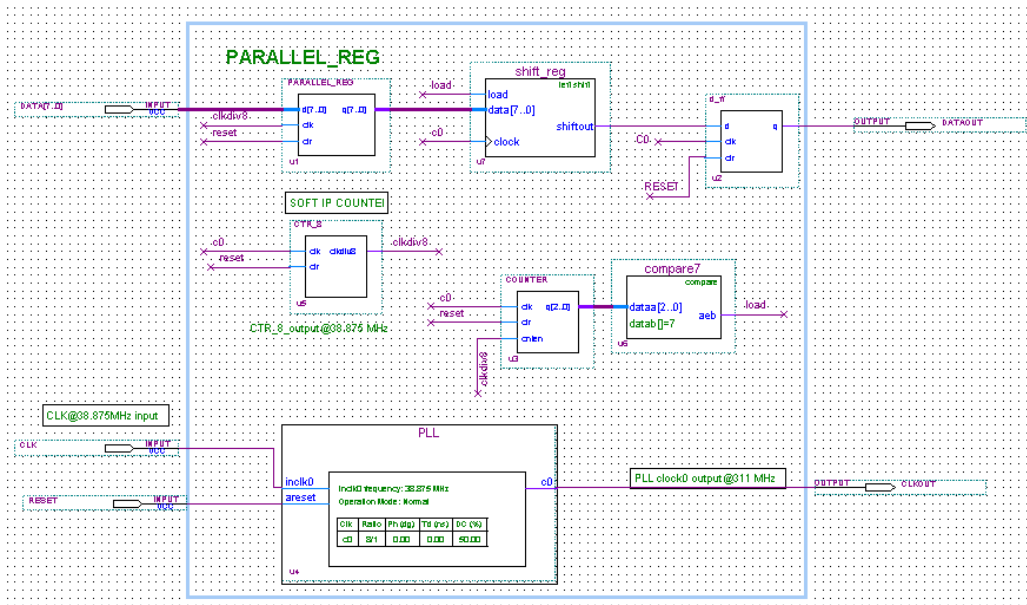


Figure 9–12. Reference Design Schematic for $\times 8$ Mode Serializer Implemented for EP1C3 Devices (144-Pin TQFP Package)



In Figures 9–11 and 9–12, the D-type flipflops (D_FF) are used to register the parallel data, and a Cyclone PLL is used to multiply the core logic clock frequency. Cyclone PLLs provide clock synthesis for PLL output ports using $M/(N \times \text{post-scalar})$ scaling factors. A shift register is used to convert the parallel-to-serial data stream, and a counter and a comparator are used to determine the byte boundary.

Transmitter Circuit

The input and output signals and their function in the sample transmitter design are listed in [Tables 9–6](#) and [9–7](#).

Table 9–6. LVDS Input Pins (LVDS_TX)	
Pin	Description
data[7..0]	8 bits of parallel inputs.
clk	PLL input clock. If ×8 mode is used, the input clock frequency is 38.88 MHz; for ×4 mode, the input frequency is 77.75 MHz; and for ×2 mode, the input frequency is 155.5 MHz.
reset	Active-high reset signal. This pin is driven high at the beginning of operation.

Table 9–7. LVDS Output Pins (LVDS_TX)	
Pin	Description
dataout	The data rate is 311 Mbps.
clkout	You can choose whether to have a fast clock as the clock out (311 MHz), or a slow clock as the clock out (38.88 MHz for ×8 mode, 77.75 MHz for ×4 mode, or 155.5 MHz for ×2 mode). The frequency is dependent on the input clock frequency required on the receiver of the transmitted data. The clock out frequency in this reference design is 311 MHz. Modify the design if another output clock frequency is desired.

[Table 9–8](#) lists the modules used in the circuit and their corresponding functions or purpose.

Table 9–8. Transmitter Circuit Modules (Part 1 of 2)	
Module	Description
PARALLEL_REG	Consists of eight registers, each is connected to one bit of data input. The slow clock from the PLL is used to register the data.
PLL	Input of the PLL is the input <code>clk</code> signal. In the ×8 mode design, the frequency is 38.88 MHz. Therefore, the PLL outputs are <code>c0</code> at 311 MHz and <code>c1</code> at 38.88 MHz. If needed, you can use the PLL locked signal.
SHIFT_REG	This parallel-in-serial-out <code>SHIFT_REG</code> acts as a serializer. The PLL output <code>c0</code> clocks <code>SHIFT_REG</code> at 311 MHz. Consequently, the serial output of the shift register can be transmitted at 311 Mbps. The best location for the shift register is the logic array block (LAB) adjacent to the <code>dataout</code> pin.

Module	Description
COUNTER	The counter is enabled after the first rising edge of the slow clock <code>c1</code> . The counter and comparator are used to determine the byte boundary.
COMPARE7	COMPARE7 is a comparator. When the input of COMPARE7 is <code>d'7</code> , it will drive out high. The output of COMPARE7 is the load signal of the parallel-in-serial-out shift register.
D_FF	To register the data before driving off chip, use the register in the input/output element (IOE) of the output pin.
CTR_8	This counter is used in EP1C3 devices only. Since EP1C3 devices have only one PLL, this counter is used as a divider to produce the slow clock <code>c1</code> .

Capturing Serial Data on Cyclone LVDS Inputs

Cyclone devices do not incorporate a dedicated deserializer to capture the serial stream data and clock. However, you can design a deserializer using the Quartus II software. [Figure 9–13](#) shows a reference design for a deserializer circuit implemented in EP1C20, EP1C12, EP1C6, and EP1C4 devices. [Figure 9–14](#) shows the $\times 8$ mode deserializer circuitry implemented in EP1C3 devices.

Figure 9–13. Reference Design Schematic for Receiver Deserializer Implemented in EP1C20, EP1C12, EP1C6 & EP1C4 Devices

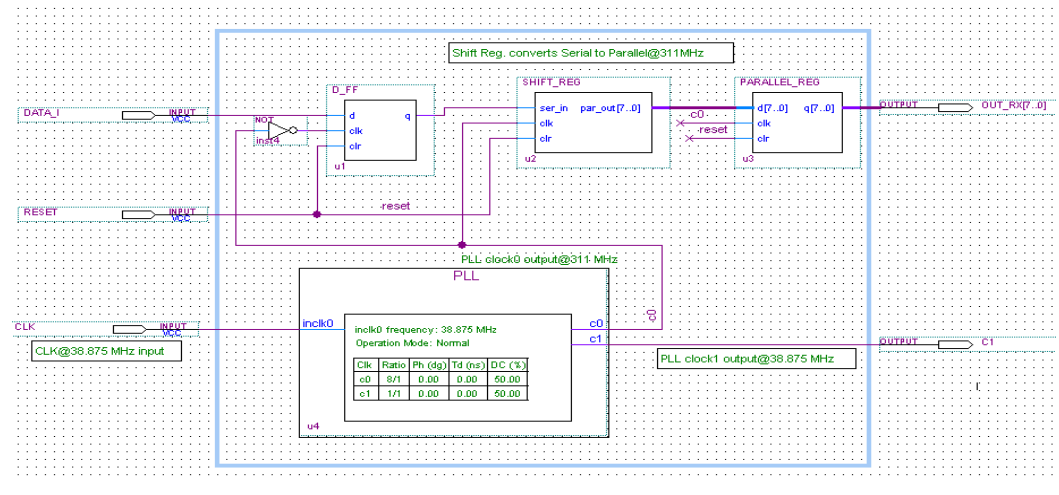
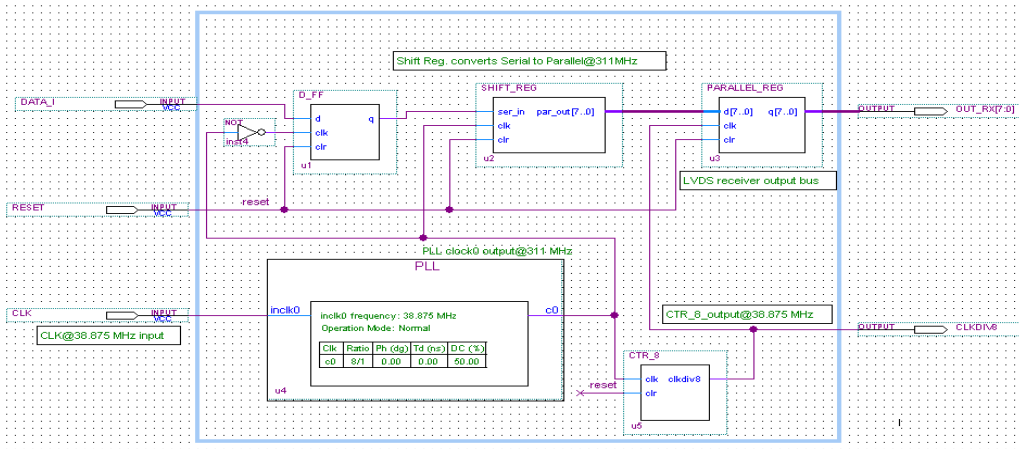


Figure 9–14. Reference Design Schematic for Receiver Deserializer Implemented in EP1C3 Devices



Receiver Circuit

The input and output signals and their function in a sample receiver design are listed in [Tables 9–9](#) and [9–10](#).

Pin	Description
data_i	Incoming serial stream of data.
clk	PLL input clock. If $\times 8$ mode is used, the input clock frequency is 38.88 MHz; for $\times 4$ mode, the input frequency is 77.75 MHz; and for $\times 2$ mode, the input frequency is 155.5 MHz.
reset	Active-high reset signal. This pin is driven high at the beginning of operation.

Pin	Description
out_rx[7..0]	Output bus (8 bits in $\times 8$ mode).
c1/clkdiv8	Slower PLL output clock which goes to internal logic. If $\times 8$ mode is used, the input clock frequency is 38.88 MHz; for $\times 4$ mode, the input frequency is 77.75 MHz; and for $\times 2$ mode, the input frequency is 155.5 MHz.

Table 9–11 lists the modules used in the circuit and their corresponding functions or purpose.

Module	Description
D_FF	Captures the incoming serial stream data. PLL output c0 (311 MHz) is inverted to sample the LVDS receiver data in the middle of the data eye. The register is placed in the IOE of the data_i pin.
PLL	Input of the PLL is the input clk signal. PLL output c0 (311 MHz) clocks SHIFT_REG and the inverted c0 clocks D_FF. PLL output c1 (38.88 MHz) provides the clock for PARALLEL_REG.
SHIFT_REG	Serial-in-parallel-out shift register. Consists of eight D_FF modules. Converts the serial data from 311 Mbps to eight bits of parallel data clocked at 38.88 MHz. The best location for the shift register is the LAB adjacent to the data_i pin.
PARALLEL_REG	Consists of eight registers, each is connected to one bit of data input. The slow clock from the PLL (c1) is used to clock the parallel register.
CTR_8	This counter is used in only EP1C3 devices. Since EP1C3 devices have only one PLL, this counter is used as a divider to produce the slow clock.

Design Guidelines

To implement LVDS in Cyclone devices, adhere to the following design guidelines in the Quartus II software.

- Route LVDS CLKOUT to pins through regular user LVDS pins. This routing provides better TCCS margin.
- To meet the t_{SU} and t_{CO} timing requirement between serial and parallel registers, use the I/O registers of the input and output pins.
- f_{MAX} is limited by the delay between the IOE and the next logic element (LE) register. To achieve an f_{MAX} of 311 MHz, the delay between the IOE and the next LE register at the receiver and transmitter side must not be more than 3.215 ns.
- The best location to implement the shift registers is within the LAB adjacent to the input or output pin.
- LVDS data and clock should be aligned at the output pin. If these signals are not aligned, use a phase shift to align them.



The Cyclone LVDS reference design did not need this delay since the delay between LVDS clock and data at the pin was negligible.

Differential Pad Placement Guidelines

To maintain an acceptable noise level on the V_{CCIO} supply, there are restrictions on placement of single-ended I/O pins in relation to differential pads. Refer to the guidelines in [Chapter 8, Using Selectable I/O Standards in Cyclone Devices](#) for placing single-ended pads with respect to differential pads in Cyclone devices.

Board Design Considerations

This section explains how to get the optimal performance from the Cyclone I/O block and ensure first-time success in implementing a functional design with optimal signal quality. The critical issues of controlled impedance of traces and connectors, differential routing, and termination techniques must all be considered to get the best performance from the integrated circuit (IC). Use this application note together with [Section I, Cyclone FPGA Family Data Sheet](#).

The Cyclone device generates signals that travel over the media at frequencies as high as 311 Mbps. Use the following general guidelines:

- Base board designs on controlled differential impedance. Calculate and compare all parameters such as trace width, trace thickness, and the distance between two differential traces.
- Maintain equal distance between traces in LVDS pairs, as much as possible. Routing the pair of traces close to each other will maximize the common-mode rejection ratio (CMRR)
- Longer traces have more inductance and capacitance. These traces should be as short as possible to limit signal integrity issues.
- Place termination resistors as close to receiver input pins as possible.
- Use surface mount components.
- Avoid 90° or 45° corners.
- Use high-performance connectors.
- Design backplane and card traces so that trace impedance matches the connector's and/or the termination's impedance.
- Keep equal number of vias for both signal traces.

- Create equal trace lengths to avoid skew between signals. Unequal trace lengths result in misplaced crossing points and decrease system margins as the TCCS value increases.
- Limit vias because they cause discontinuities.
- Use the common bypass capacitor values such as 0.001 μF , 0.01 μF , and 0.1 μF to decouple the high-speed PLL power and ground planes.
- Keep switching TTL signals away from differential signals to avoid possible noise coupling.
- Do not route TTL clock signals to areas under or above the differential signals.
- Analyze system-level signals.

Conclusion

Cyclone LVDS I/O capabilities enable you to keep pace with increasing design complexity while offering the lowest-cost FPGA on the market. Support for I/O standards including LVDS allows Cyclone devices to fit into a wide variety of applications. Taking advantage of these I/O standards and Cyclone pricing allows you to lower your design costs while remaining on the cutting edge of technology.

This section provides documentation on design considerations when utilizing Cyclone devices. In addition to these design considerations, refer to the Intellectual Property section of the Altera web site for a complete offering of IP cores for Cyclone devices.

This section contains the following chapters:

- Chapter 10. Implementing Double Data Rate I/O Signaling in Cyclone Devices
- Chapter 11. Using Cyclone Devices in Multiple-Voltage Systems
- Chapter 12. Designing with 1.5-V Devices

Revision History

The table below shows the revision history for Chapter 10 and 11.

Chapter(s)	Date / Version	Changes Made
10	May 2003 v1.0	Updated text under Figure 10–3.
11	May 2003 v1.0	Initial release.
12	May 2003 v1.0	Initial handbook release.

Introduction

Double data rate (DDR) transmission is used in many applications where fast data transmission is needed, such as memory access and first-in first-out (FIFO) memory structures. DDR uses both edges of a clock to transmit data, which facilitates data transmission at twice the rate of a single data rate (SDR) architecture using the same clock speed. This method also reduces the number of I/O pins required to transmit data.

This application note shows implementations of a double data rate I/O interface using Cyclone™ devices. Cyclone devices support DDR input, DDR output, and bidirectional DDR signaling.

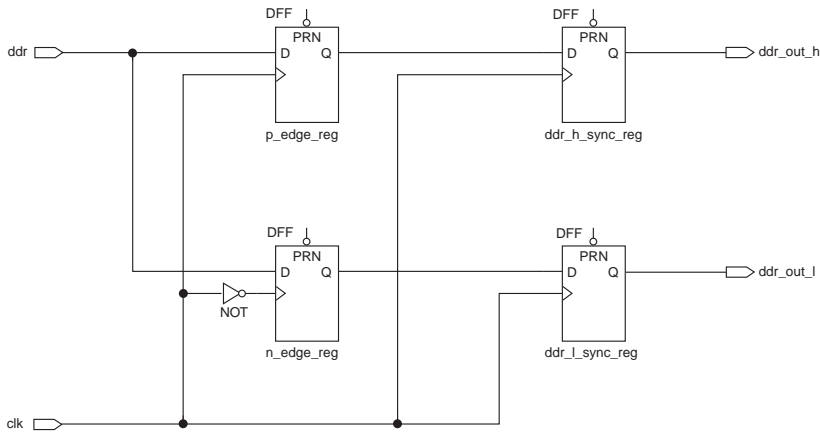


For more information on using Cyclone devices in applications with DDR SDRAM and FCRAM memory devices, see “[DDR Memory Support](#)” on page 10–4.

Double Data Rate Input

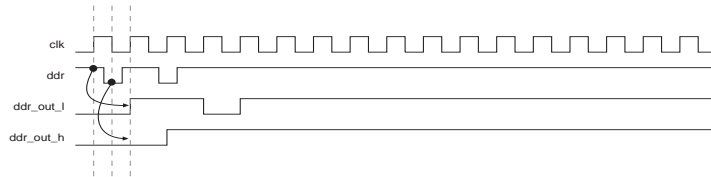
The DDR input implementation shown in [Figure 10–1](#) uses four internal logic element (LE) registers located in the logic array block (LAB) adjacent to the DDR input pin. The DDR data is fed to the first two of four registers. One register captures the DDR data present during the rising edge of the clock. The second register captures the DDR data present during the falling edge of the clock.

Figure 10–1. Double Data Rate Input Implementation



The third and fourth registers synchronize the two data streams to the rising edge of the clock. [Figure 10-2](#) shows examples of functional waveforms from a double data rate input implementation.

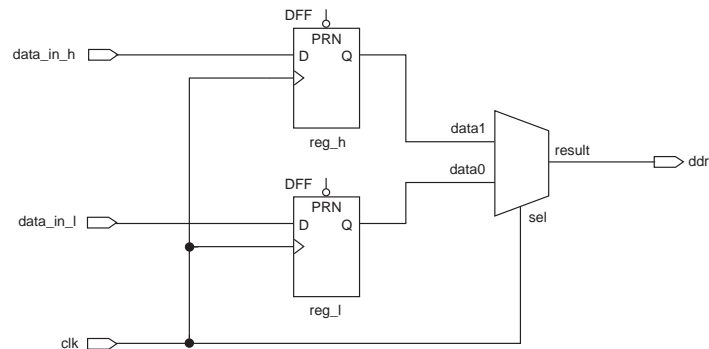
Figure 10-2. Double Data Rate Input Functional Waveforms



Double Data Rate Output

[Figure 10-3](#) shows a schematic representation of double data rate output implemented in a Cyclone device. The DDR output logic is implemented using LEs in the LAB adjacent to the output pin. Two registers are used to synchronize two serial data streams. The registered outputs are then multiplexed by the common clock to drive the DDR output pin at two times the data rate.

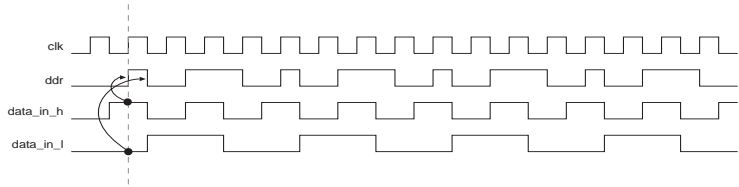
Figure 10-3. Double Data Rate Output Implementation



While the clock signal is logic-high, the output from `reg_h` is driven onto the DDR output pin. While the clock signal is logic-low, the output from `reg_l` is driven onto the DDR output pin. The DDR output pin can be any available user I/O pin.

[Figure 10-4](#) shows examples of functional waveforms from a double data rate output implementation.

Figure 10–4. Double Data Rate Output Waveforms



Bidirectional Double Data Rate

Figure 10–5 shows a bidirectional DDR interface, constructed using the DDR input and DDR output examples described in the previous two sections. As with the DDR input and DDR output examples, the bidirectional DDR pin can be any available user I/O pin, and the registers used to implement DDR bidirectional logic are LEs in the LAB adjacent to that pin. The tri-state buffer (TRI) controls when the device drives data onto the bidirectional DDR pin.

Figure 10–5. Bidirectional Double Data Rate Implementation

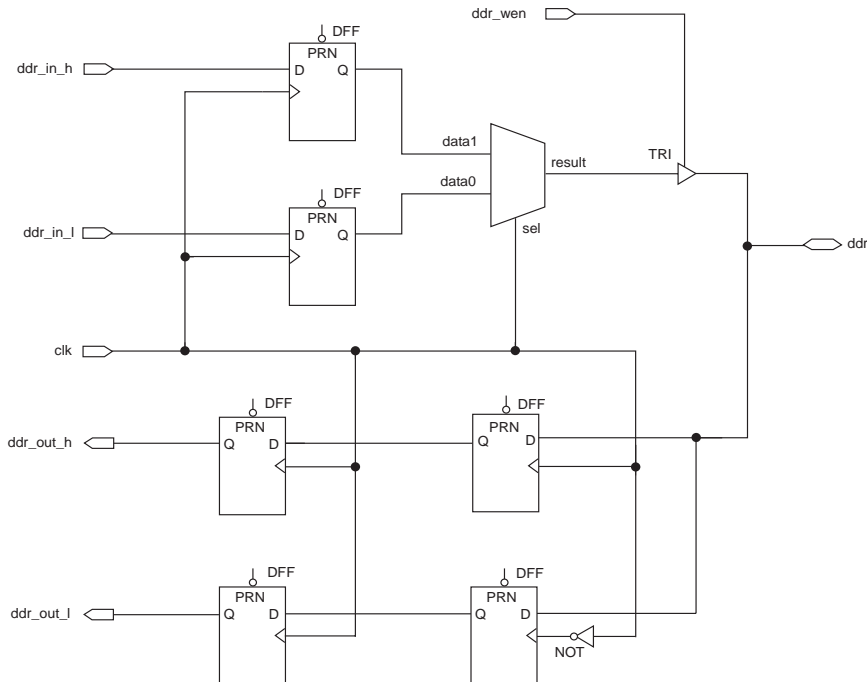
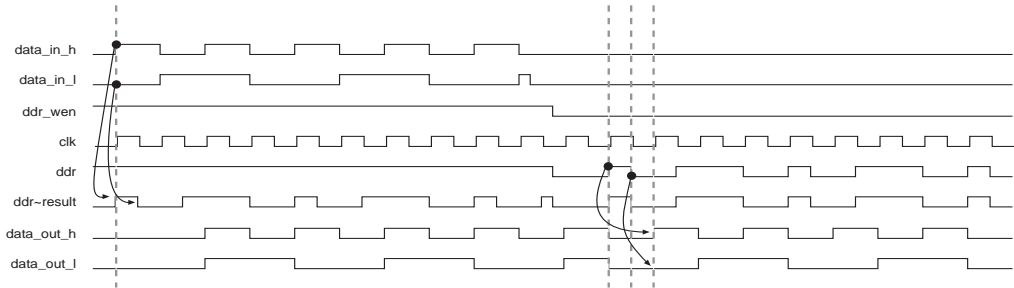


Figure 10–6 shows example waveforms from a bidirectional double data rate implementation.

Figure 10–6. Double Data Rate Bidirectional Waveforms



DDR Memory Support

The Cyclone device family supports both DDR SDRAM and FCRAM memory interfaces up to 133 MHz.



For more information on extended DDR memory support in Cyclone devices, see [Section I, Cyclone FPGA Family Data Sheet](#).

Conclusion

Utilizing both the rising and falling edges of a clock signal, double data rate transmission is a popular strategy for increasing the speed of data transmission while reducing the required number of I/O pins. Cyclone devices can be used to implement this strategy for use in applications such as FIFO structures, SDRAM/FCRAM interfaces, as well as other time-sensitive memory access and data-transmission situations.

Introduction

To meet the demand for higher system speed in data communications, semiconductor vendors use increasingly advanced processing technologies requiring lower operating voltages. As a result, printed circuit boards (PCBs) often incorporate devices conforming to one of several voltage level I/O standards, such as 3.3-V, 2.5-V, 1.8-V and 1.5-V. A mixture of components with various voltage level I/O standards on a single PCB is inevitable.

In order to accommodate this mixture of devices on a single PCB, a device that can act as a bridge or interface between these devices is needed. The Cyclone™ device family's MultiVolt™ I/O operation capability meets the increasing demand for compatibility with devices of different voltages. MultiVolt I/O operation separates the power supply voltage from the output voltage, enabling Cyclone devices to interoperate with other devices using different voltage levels on the same PCB.

In addition to MultiVolt I/O operation, this application note discusses several other features that allow you to use Cyclone devices in multiple-voltage systems without damaging the device or the system, including:

- Hot-Socketing—add and remove Cyclone devices to and from a powered-up system without affecting the device or system operation
- Power-Up Sequence flexibility—Cyclone devices can accommodate any possible power-up sequence
- Power-On Reset—Cyclone devices maintain a reset state until voltage is within operating range

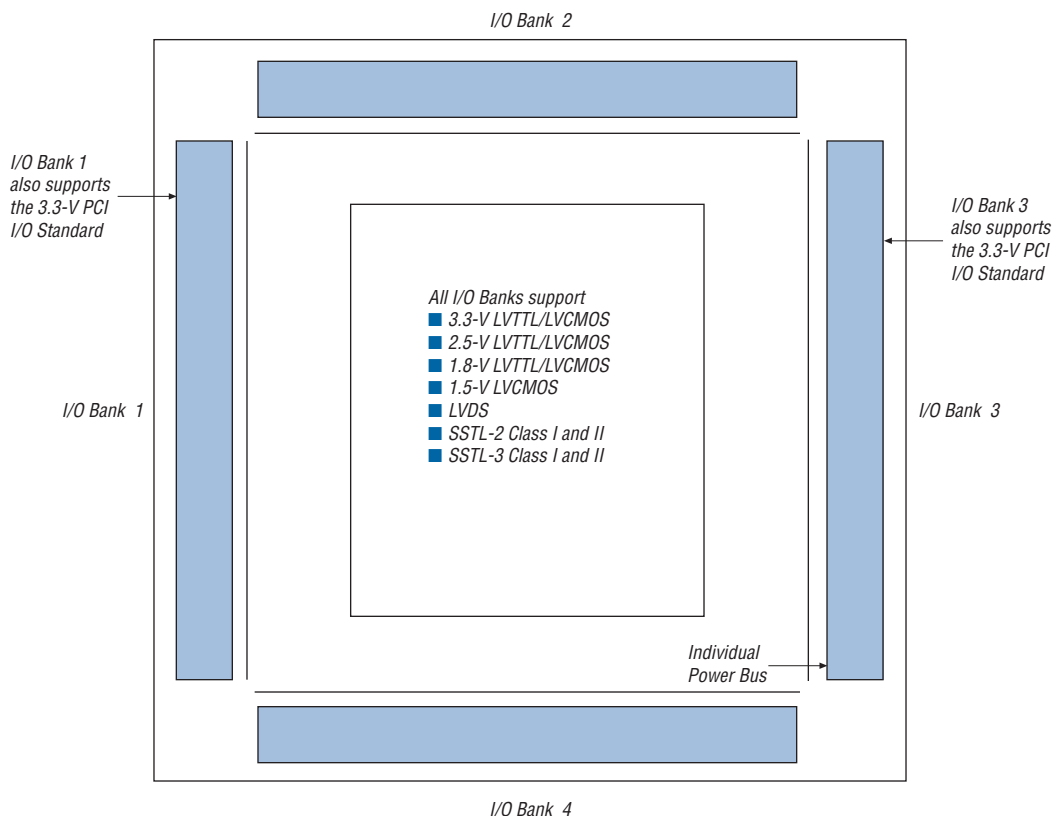
I/O Standards

The I/O buffer of a Cyclone device is programmable and supports a wide range of I/O voltage standards. Each I/O bank in a Cyclone device can be programmed to comply with a different I/O standard. All I/O banks can be configured with the following I/O standards:

- 3.3-V LVTTTL/LVCMOS
- 2.5-V LVTTTL/LVCMOS
- 1.8-V LVTTTL/LVCMOS
- 1.5-V LVCMOS
- LVDS
- SSTL-2 Class I and II
- SSTL-3 Class I and II

I/O banks 1 and 3 also include 3.3-V PCI I/O standard interface capability. See Figure 11–1.

Figure 11–1. I/O Standards Supported by Cyclone Devices Notes (1), (2), (3)



Notes to Figure 11–1

- (1) Figure 1 is a top view of the silicon die.
- (2) Figure 1 is a graphical representation only. Refer to the pin list and the Quartus® II software for exact pin locations.
- (3) The EP1C3 device in the 100-pin thin quad flat pack (TQFP) package does not have support for a PLL LVDS input or an external clock output.

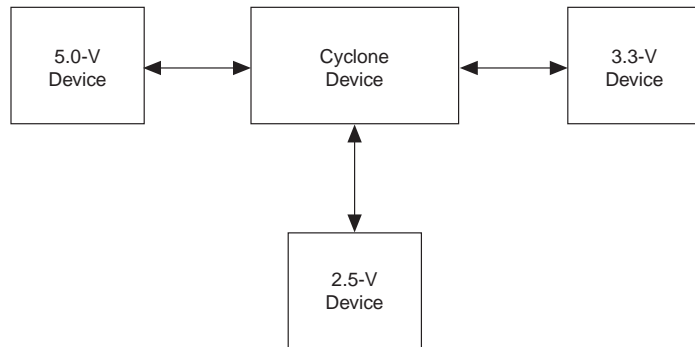
MultiVolt I/O Operation

Cyclone devices include MultiVolt I/O operation capability, allowing the core and I/O blocks of the device to be powered-up with separate supply voltages. The VCCINT pins supply power to the device core and the VCCIO pins supply power the device's I/O buffers.



Supply all device V_{CCIO} pins that have MultiVolt I/O capability at the same voltage level (e.g., 3.3-V, 2.5-V, 1.8-V, or 1.5-V). See [Figure 11-2](#).

Figure 11-2. Implementing a Multiple-Voltage System with a Cyclone Device

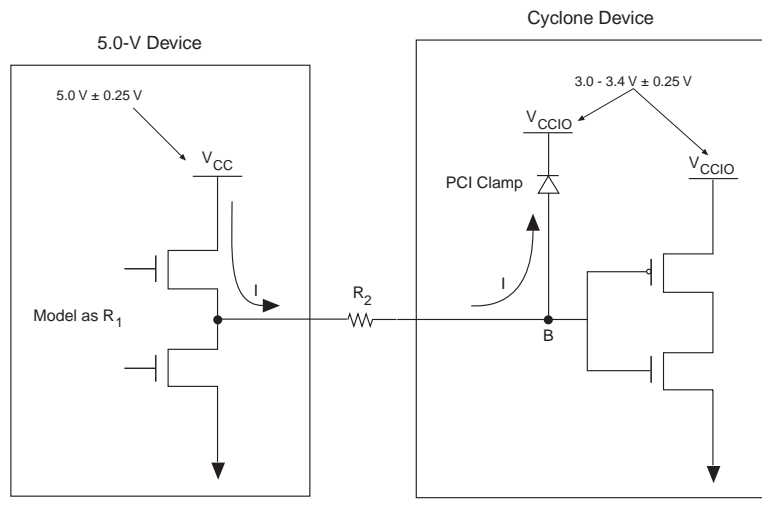


5.0-V Device Compatibility

A Cyclone device may not correctly interoperate with a 5.0-V device if the output of the Cyclone device is connected directly to the input of the 5.0-V device. If V_{OUT} of the Cyclone device is greater than V_{CCIO} , the PMOS pull-up transistor still conducts if the pin is driving high, preventing an external pull-up resistor from pulling the signal to 5.0-V.

A Cyclone device can drive a 5.0-V LVTTTL device by connecting the V_{CCIO} pins of the Cyclone device to 3.3 V. This is because the output high voltage (V_{OH}) of a 3.3-V interface meets the minimum high-level voltage of 2.4-V of a 5.0-V LVTTTL device. (A Cyclone device cannot drive a 5.0-V LVCMOS device.)

Because the Cyclone devices are 3.3-V, 32-bit, 66 MHz PCI compliant the input circuitry accepts a maximum high-level input voltage (V_{IH}) of 4.1-V. To drive a Cyclone device with a 5.0-V device, you must connect a resistor (R_2) between the Cyclone device and the 5.0-V device. See [Figure 11-3](#).

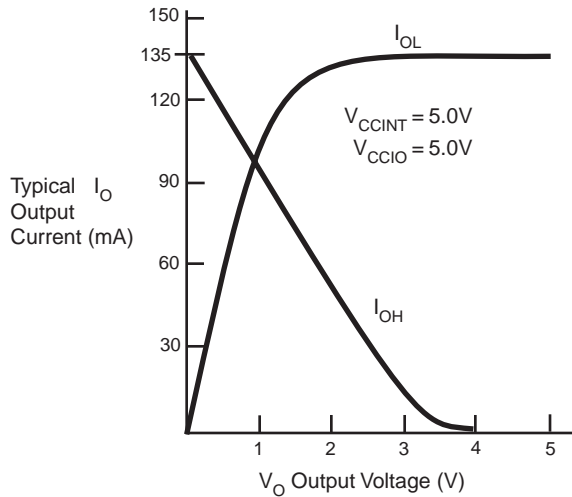
Figure 11–3. Driving a Cyclone Device with a 5.0-Volt Device

If V_{CCIO} is between 3.0-V and 3.6-V and the PCI clamping diode is enabled, the voltage at point B in [Figure 11–3](#) is 4.3-V or less. To limit large current draw from the 5.0-V device, R_2 should be small enough for a fast signal rise time and large enough so that it does not violate the high-level output current (I_{OH}) specifications of the devices driving the trace. The PCI clamping diode in the Cyclone device can support 25mA of current.

To compute the required value of R_2 , first calculate the model of the pull-up transistors on the 5.0-V device. This output resistor (R_1) can be modeled by dividing the 5.0-V device supply voltage (V_{CC}) by the I_{OH} :

$$R_1 = V_{CC}/I_{OH}$$

[Figure 11–4](#) shows an example of typical output drive characteristics of a 5.0-V device.

Figure 11–4. Output Drive Characteristics of a 5.0-V Device

As shown above, $R_1 = 5.0\text{-V}/135\text{ mA}$.



The values usually shown in data sheets reflect typical operating conditions. Subtract 20% from the data sheet value for guard band. This subtraction applied to the above example gives R_1 a value of $30\ \Omega$.

R_2 should be selected to not violate the driving device's I_{OH} specification. For example, if the above device has a maximum I_{OH} of 8 mA, given the PCI clamping diode, $V_{IN} = V_{CCI0} + 0.7\text{-V} = 3.7\text{-V}$. Given that the maximum supply load of a 5.0-V device (V_{CC}) will be 5.25-V, the value of R_2 can be calculated as follows:

$$R_2 = \frac{(5.25\text{V} - 3.7\text{ V}) - (8\text{ mA} \times 30\ \Omega)}{8\text{ mA}} = 164\ \Omega$$

This analysis assumes worst-case conditions. If your system will not see a wide variation in voltage-supply levels, you can adjust these calculations accordingly.



Because 5.0-V device tolerance in Cyclone devices requires use of the PCI clamp, and this clamp is activated during configuration, 5.0-V signals may not be driven into the device until it is configured.

Hot-Socketing

Hot-socketing, also known as hot-swapping, refers to inserting or removing a board or device into or out of a system board while system power is on. For a system to support hot-socketing, plug-in or removal of the subsystem or device must not damage the system or interrupt system operation.

All devices in the Cyclone family are designed to support hot-socketing without special design requirements. The following features have been implemented in Cyclone devices to facilitate hot-socketing:

- Devices can be driven before power-up with no damage to the device.
- I/O pins remain tri-stated during power-up.
- Signal pins do not drive the V_{CCIO} or V_{CCINT} power supplies.



Because 5.0-V tolerance in Cyclone devices require the use of the PCI clamping diode, and the clamping diode is only available after configuration has finished, be careful not to connect 5.0-V signals to the device.

Devices Can Be Driven before Power-Up

The device I/O pins, dedicated input pins, and dedicated clock pins of Cyclone devices can be driven before or during power-up without damaging the devices.

I/O Pins Remain Tri-Stated during Power-Up

A device that does not support hot-socketing may interrupt system operation or cause contention by driving out before or during power-up. For Cyclone devices, I/O pins are tri-stated before and during power-up and configuration, and will not drive out.

Signal Pins Do Not Drive the V_{CCIO} or V_{CCINT} Power Supplies

A device that does not support hot-socketing will short power supplies together when powered-up through its signal pins. This irregular power-up can damage both the driving and driven devices and can disrupt card power-up.

In Cyclone devices, there is no current path from I/O pins, dedicated input pins, or dedicated clock pins to the V_{CCIO} or V_{CCINT} pins before or during power-up. A Cyclone device may be inserted into (or removed from) a powered-up system board without damaging or interfering with system-board operation. When hot-socketing, Cyclone devices have a minimal effect on the signal integrity of the backplane.



The maximum DC current when hot-socketing Cyclone devices is less than 300 μA , whereas the maximum AC current during hot-socketing is less than 8 mA for a period of 10ns or less.

During hot-socketing, the signal pins of a device may be connected and driven by the active system before the power supply can provide current to the device V_{CC} and ground planes. Known as latch-up, this condition can cause parasitic diodes to turn on within the device, causing the device to consume a large amount of current, and possibly causing electrical damage. This operation can also cause parasitic diodes to turn on inside of the driven device. Cyclone devices are immune to latch-up when hot-socketing.

Power-Up Sequence

Because Cyclone devices can be used in a multi-voltage environment, they are designed to tolerate any possible power-up sequence. Either V_{CCINT} or V_{CCIO} can initially supply power to the device, and 3.3-V, 2.5-V, 1.8-V, or 1.5-V input signals can drive the devices without special precautions before V_{CCINT} or V_{CCIO} is applied. Cyclone devices can operate with a V_{CCIO} voltage level that is higher than the V_{CCINT} level. You can also change the V_{CCIO} supply voltage while the board is powered-up. However, you must ensure that the V_{CCINT} and V_{CCIO} power supplies stay within the correct device operating conditions.

When V_{CCIO} and V_{CCINT} are supplied from different power sources to a Cyclone device, a delay between V_{CCIO} and V_{CCINT} may occur. Normal operation does not occur until both power supplies are in their recommended operating range. When V_{CCINT} is powered-up, the IEEE Std. 1149.1 Joint Test Action Group (JTAG) circuitry is active. If TMS and TCK are connected to V_{CCIO} and V_{CCIO} is not powered-up, the JTAG signals are left floating. Thus, any transition on TCK can cause the state machine to transition to an unknown JTAG state, leading to incorrect operation when V_{CCIO} is finally powered-up. To disable the JTAG state during the power-up sequence, TCK should be pulled low to ensure that an inadvertent rising edge does not occur on TCK.

Power-On Reset

When designing a circuit, it is important to consider system state at power-up. Cyclone devices maintain a reset state during power-up. When power is applied to a Cyclone device, a power-on-reset event occurs if V_{CC} reaches the recommended operating range within a certain period of time (specified as a maximum V_{CC} rise time). A POR event does not occur if these conditions are not met because slower rise times can cause incorrect device initialization and functional failure.



If V_{CCINT} does not remain in the specified operating range, operation is not assured until V_{CCINT} re-enters the range.

Conclusion

PCBs often contain a mix of 5.0-V, 3.3-V, 2.5-V, 1.8-V, and 1.5-V devices. The Cyclone device family's MultiVolt I/O operation capability allows you to incorporate newer-generation devices with devices of varying voltage levels. This capability also enables the device core to run at its core voltage, V_{CCINT} , while maintaining I/O pin compatibility with other logic levels. Altera has taken further steps to make system design easier by designing devices that allow V_{CCINT} and V_{CCIO} to power-up in any sequence and by incorporating support for hot-socketing.

Introduction

The Cyclone™ FPGA family provides the best solution for high-volume, cost-sensitive applications. Similar to Stratix™ devices, Cyclone devices are fabricated on a leading-edge 1.5-V, 0.13- μm , all-layer copper SRAM process.

Using a 1.5-V operating voltage provides the following advantages:

- Lower power consumption compared to 2.5-V or 3.3-V devices.
- Lower operating temperature.
- Less need for fans and other temperature-control elements.

Since many existing designs are based on 5.0-V, 3.3-V and 2.5-V power supplies, a voltage regulator may be required to lower the voltage supply level to 1.5-V. This application note provides guidelines for designing with Cyclone devices in mixed-voltage and single-voltage systems and provides examples using voltage regulators. This application note also includes information on:

- Power Sequencing & Hot Socketing
- Using MultiVolt I/O Pins
- Voltage Regulators
- 1.5-V Regulator Application Examples
- Board Layout
- Power Sequencing & Hot Socketing

Power Sequencing & Hot Socketing

Because 1.5-V Cyclone FPGAs can be used in a mixed-voltage environment, they have been designed specifically to tolerate any possible power-up sequence. Therefore, the V_{CCIO} and V_{CCINT} power supplies may be powered in any order.

You can drive signals into Cyclone FPGAs before and during power up without damaging the device. In addition, Cyclone FPGAs do not drive out during power up since they are tri-stated during power up. Once the device reaches operating conditions and is configured, Cyclone FPGAs operate as specified by the user.



See the *Cyclone Field Programmable Gate Array Family Data Sheet* for more information.

Using MultiVolt I/O Pins

Cyclone FPGAs require a 1.5-V V_{CCINT} and a 3.3-V, 2.5-V, 1.8-V, or 1.5-V I/O supply voltage level (V_{CCIO}). All pins, including dedicated inputs, clock, I/O, and JTAG pins, are 3.3-V tolerant before and after V_{CCINT} and V_{CCIO} are powered.

When V_{CCIO} is connected to 1.5-V, the output is compatible with 1.5-V logic levels. The output pins can be made 1.8-V, 2.5-V, or 3.3-V compatible by using open-drain outputs pulled up with external resistors. You can use external resistors to pull open-drain outputs up with a 1.8-V, 2.5-V, or 3.3-V V_{CCIO} . Table 12-1 summarizes Cyclone MultiVolt I/O support.

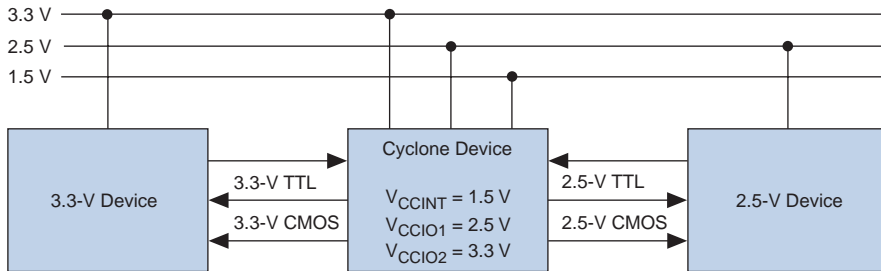
Table 12-1. Cyclone MultiVolt I/O Support *Note (1)*

V_{CCIO} (V)	Input Signal					Output Signal				
	1.5-V	1.8-V	2.5-V	3.3-V	5.0-V	1.5-V	1.8-V	2.5-V	3.3-V	5.0-V
1.5-V	✓	✓	✓ (2)	✓ (2)		✓				
1.8-V		✓	✓	✓		✓ (3)	✓			
2.5-V			✓	✓		✓ (5)	✓ (5)	✓		
3.3-V			✓ (4)	✓	✓ (6)	✓ (7)	✓ (7)	✓ (7)	✓	✓ (8)

Notes to Table 12-1:

- (1) The PCI clamping diode must be disabled to drive an input with voltages higher than V_{CCIO} .
- (2) When $V_{CCIO} = 1.5\text{-V}$ and a 2.5-V or 3.3-V input signal feeds an input pin, higher pin leakage current is expected.
- (3) When $V_{CCIO} = 1.8\text{-V}$, a Cyclone device can drive a 1.5-V device with 1.8-V tolerant inputs.
- (4) When $V_{CCIO} = 3.3\text{-V}$ and a 2.5-V input signal feeds an input pin, the V_{CCIO} supply current will be slightly larger than expected.
- (5) When $V_{CCIO} = 2.5\text{-V}$, a Cyclone device can drive a 1.5-V or 1.8-V device with 2.5-V tolerant inputs.
- (6) Cyclone devices can be 5.0-V tolerant with the use of an external resistor and the internal PCI clamp diode.
- (7) When $V_{CCIO} = 3.3\text{-V}$, a Cyclone device can drive a 1.5-V, 1.8-V, or 2.5-V device with 3.3-V tolerant inputs.
- (8) When $V_{CCIO} = 3.3\text{-V}$, a Cyclone device can drive a device with 5.0-V LVTTTL inputs but not 5.0-V LVCMOS inputs.

Figure 12-1 shows how Cyclone FPGAs interface with 3.3-V and 2.5-V devices while operating with a 1.5-V V_{CCINT} to increase performance and save power.

Figure 12–1. Cyclone FPGAs Interface with 3.3-V & 2.5-V Devices

Voltage Regulators

This section explains how to generate a 1.5-V supply from another system supply. Supplying power to the 1.5-V logic array and/or I/O pins requires a 5.0-V- or 3.3-V-to-1.5-V voltage regulator. A linear regulator is ideal for low-power applications because it minimizes device count and has acceptable efficiency for most applications. A switching voltage regulator provides optimal efficiency. Switching regulators are ideal for high-power applications because of their high efficiency.

This section will help you decide which regulator to use in your system, and how to implement the regulator in your design. There are several companies that provide voltage regulators for low-voltage devices, such as Linear Technology Corporation, Maxim Integrated Products, Intersil Corporation (Elantec), and National Semiconductor Corporation.

Table 12–2 shows the terminology and specifications commonly encountered with voltage regulators. Symbols are shown in parentheses. If the symbols are different for linear and switching regulators, the linear regulator symbol is listed first.

Table 12–2. Voltage Regulator Specifications & Terminology (Part 1 of 2)

Specification/Terminology	Description
Input voltage range (V_{IN}, V_{CC})	Minimum and maximum input voltages define the input voltage range, which is determined by the regulator process voltage capabilities.
Line regulation (line regulation, V_{OUT})	Line regulation is the variation of the output voltage (V_{OUT}) with changes in the input voltage (V_{IN}). Error amplifier gain, pass transistor gain, and output impedance all influence line regulation. Higher gain results in better regulation. Board layout and regulator pin-outs are also important because stray resistance can introduce errors.

Table 12–2. Voltage Regulator Specifications & Terminology (Part 2 of 2)

Specification/Terminology	Description
Load regulation (load regulation, V_{OUT})	Load regulation is a variation in the output voltage caused by changes in the input supply current. Linear Technology regulators are designed to minimize load regulation, which is affected by error amplifier gain, pass transistor gain, and output impedance.
Output voltage selection	Output voltage selection is adjustable by resistor voltage divider networks, connected to the error amplifier input, that control the output voltage. There are multiple output regulators that create 5.0-, 3.3-, 2.5-, 1.8- and 1.5-V supplies.
Quiescent current	Quiescent current is the supply current during no-load or quiescent state. This current is sometimes used as a general term for a supply current used by the regulator.
Dropout voltage	Dropout voltage is the difference between the input and output voltages when the input is low enough to cause the output to drop out of regulation. The dropout voltage should be as low as possible for better efficiency.
Current limiting	Voltage regulators are designed to limit the amount of output current in the event of a failing load. A short in the load causes the output current and voltage to decrease. This event cuts power dissipation in the regulator during a short circuit.
Thermal overload protection	This feature limits power dissipation if the regulator overheats. When a specified temperature is reached, the regulator turns off the output drive transistors, allowing the regulator to cool. Normal operation resumes once the regulator reaches a normal operating temperature.
Reverse current protection	If the input power supply fails, large output capacitors can cause a substantial reverse current to flow backward through the regulator, potentially causing damage. To prevent damage, protection diodes in the regulator create a path for the current to flow from V_{OUT} to V_{IN} .
Stability	The dominant pole placed by the output capacitor influences stability. Voltage regulator vendors can assist you in output capacitor selection for regulator designs that differ from what is offered.
Minimum load requirements	A minimum load from the voltage divider network is required for good regulation, which also serves as the ground for the regulator's current path.
Efficiency	Efficiency is the division of the output power by the input power. Each regulator model has a specific efficiency value. The higher the efficiency value, the better the regulator.

Linear Voltage Regulators

Linear voltage regulators generate a regulated output from a larger input voltage using current pass elements in a linear mode. There are two types of linear regulators available: one using a series pass element and another using a shunt element (e.g., a zener diode). Altera recommends using series linear regulators because shunt regulators are less efficient.

Series linear regulators use a series pass element (i.e., a bipolar transistor or MOSFET) controlled by a feedback error amplifier (see Figure 12–2) to regulate the output voltage by comparing the output to a reference voltage. The error amplifier drives the transistor further on or off continuously to control the flow of current needed to sustain a steady voltage level across the load.

Figure 12–2. Series Linear Regulator

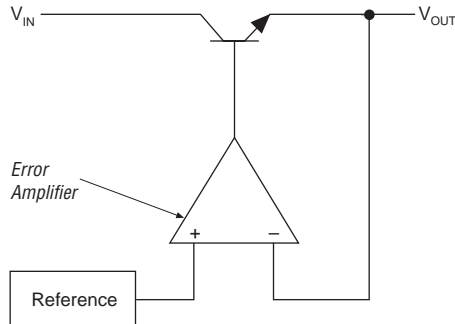


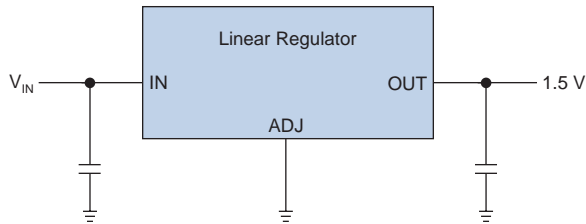
Table 12–3 shows the advantages and disadvantages of linear regulators compared to switching regulators.

Advantages	Disadvantages
<ul style="list-style-type: none"> Requires few supporting components Low cost Requires less board space Quick transient response Better noise and drift characteristics No electromagnetic interference (EMI) radiation from the switching components Tighter regulation 	<ul style="list-style-type: none"> Less efficient (typically 60%) Higher power dissipation Larger heat sink requirements

You can minimize the difference between the input and output voltages to improve the efficiency of linear regulators. The dropout voltage is the minimum allowable difference between the regulator’s input and output voltage.

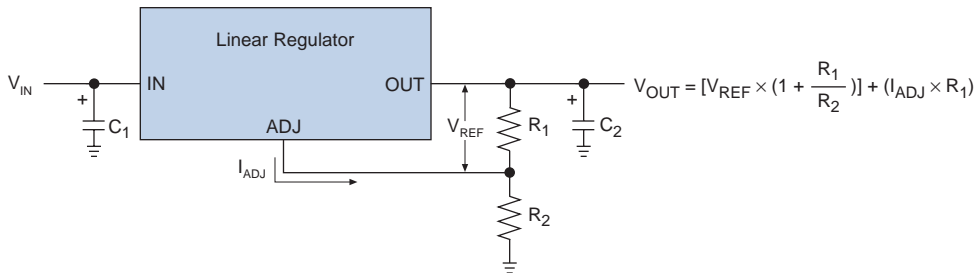
Linear regulators are available with fixed, variable, single, or multiple outputs. Multiple-output regulators can generate multiple outputs (e.g., 1.5- and 3.3-V outputs). If the board only has a 5.0-V power voltage supply, you should use multiple-output regulators. The logic array requires a 1.5-V power supply, and a 3.3-V power supply is required to interface with 3.3- and 5.0-V devices. However, fixed-output regulators have fewer supporting components, reducing board space and cost. Figure 12-3 shows an example of a three-terminal, fixed-output linear regulator.

Figure 12-3. Three-Terminal, Fixed-Output Linear Regulator



Adjustable-output regulators contain a voltage divider network that controls the regulator's output. Figure 12-4 shows how you can also use a three-terminal linear regulator in an adjustable-output configuration.

Figure 12-4. Adjustable-Output Linear Regulator



Switching Voltage Regulators

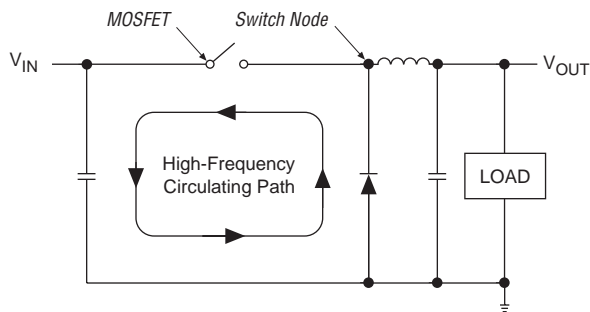
Step-down switching regulators can provide 3.3-V-to-1.5-V conversion with up to 95% efficiencies. This high efficiency comes from minimizing quiescent current, using a low-resistance power MOSFET switch, and, in higher-current applications, using a synchronous switch to reduce diode losses.

Switching regulators supply power by pulsing the output voltage and current to the load. Table 12-4 shows the advantages and disadvantages of switching regulators compared to linear regulators. For more information on switching regulators, see *Application Note 35: Step Down Switching Regulators* from Linear Technology.

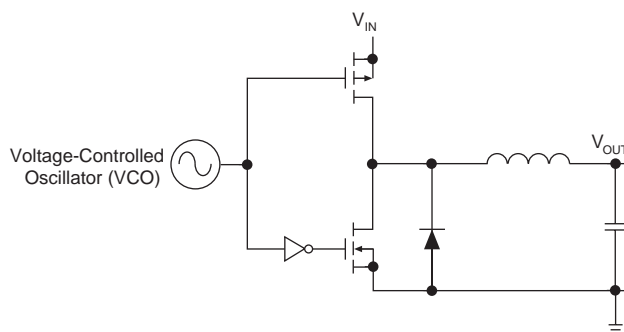
Advantages	Disadvantages
Highly efficient (typically >80%) Reduced power dissipation Smaller heat sink requirements Wider input voltage range High power density	Generates EMI Complex to design Requires 15 or more supporting components Higher cost Requires more board space

There are two types of switching regulators, asynchronous and synchronous. Asynchronous switching regulators have one field effect transistor (FET) and a diode to provide the current path while the FET is off (see Figure 12-5).

Figure 12-5. Asynchronous Switching Regulator



Synchronous switching regulators have a voltage- or current-controlled oscillator that controls the on and off time of the two MOSFET devices that supply the current to the circuit (see Figure 12-6).

Figure 12–6. Voltage-Controlled Synchronous Switching Regulator

Maximum Output Current

Select an external MOSFET switching transistor (optional) based on the maximum output current that it can supply. Use a MOSFET with a low on-resistance and a voltage rating high enough to avoid avalanche breakdown. For gate-drive voltages less than 9-V, use a logic-level MOSFET. A logic-level MOSFET is only required for topologies with a controller IC and an external MOSFET.

Selecting Voltage Regulators

Your design requirements determine which voltage regulator you need. The key to selecting a voltage regulator is understanding the regulator parameters and how they relate to the design.

The following checklist can help you select the proper regulator for your design:

- Do you require a 3.3-V, 2.5-V, and 1.5-V output (V_{OUT})?
- What precision is required on the regulated 1.5-V supplies (line and load regulation)?
- What supply voltages (V_{IN} or V_{CC}) are available on the board?
- What voltage variance (input voltage range) is expected on V_{IN} or V_{CC} ?
- What is the maximum I_{CC} (I_{OUT}) required by your Altera® device?
- What is the maximum current surge ($I_{OUT(MAX)}$) that the regulator will need to supply instantaneously?

Choose a Regulator Type

If required, select either a linear, asynchronous switching, or synchronous switching regulator based on your output current, regulator efficiency, cost, and board-space requirements. DC-to-DC converters have output current capabilities from 1 to 8 A. You can use a controller with an external MOSFET rated for higher current for higher-output-current applications.

Calculate the Maximum Input Current

Use the following equation to estimate the maximum input current based on the output power requirements at the maximum input voltage:

$$I_{IN,DC(MAX)} = \frac{V_{OUT} \times I_{OUT(MAX)}}{\eta \times V_{IN(MAX)}}$$

Where η is nominal efficiency: typically 90% for switching regulators, 60% for linear 2.5-V-to-1.5-V conversion, 45% for linear 3.3-V-to-1.5-V conversion, and 30% for linear 5.0-V-to-1.5-V conversion.

Once you identify the design requirements, select the voltage regulator that is best for your design. Tables 12-5 and 12-6 list a few Linear Technology and Elantec regulators available at the time this document was published. There may be more regulators to choose from depending on your design specification. Contact a regulator manufacturer for availability.

Table 12-5. Linear Technology 1.5-V Output Voltage Regulators

Voltage Regulator	Regulator Type	Total Number of Components	V _{IN} (V)	I _{OUT} (A)	Special Features
LT1573	Linear	10	2.5 or 3.3 (1)	6	–
LT1083	Linear	5	5.0	7.5	–
LT1084	Linear	5	5.0	5	–
LT1085	Linear	5	5.0	3	Inexpensive solution
LTC1649	Switching	22	3.3	15	Selectable output
LTC1775	Switching	17	5.0	5	–

Note to Table 12-5:

(1) A 3.3-V V_{IN} requires a 3.3-V supply to the regulator's input and 2.5-V supply to bias the transistors.

Table 12–6. Elantec 1.5-V Output Voltage Regulators

Voltage Regulator	Regulator Type	Total Number of Components	V _{IN} (V)	I _{OUT} (A)	Special Features
EL7551C	Switching	11	5.0	1	–
EL7564CM	Switching	13	5.0	4	–
EL7556BC	Switching	21	5.0	6	–
EL7562CM	Switching	17	3.3 or 5.5	2	–
EL7563CM	Switching	19	3.3	4	–

Voltage Divider Network

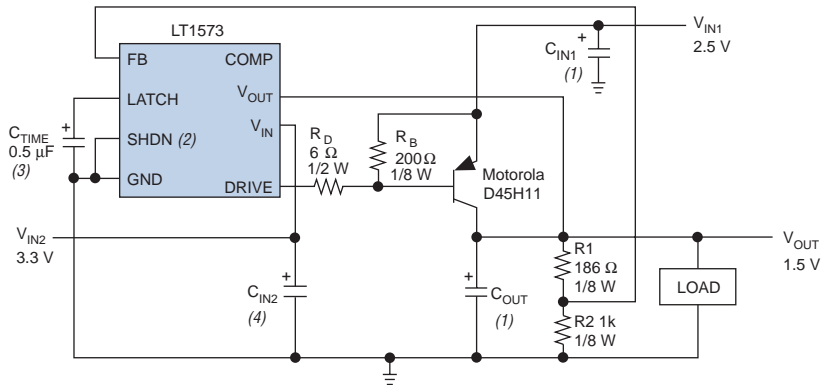
Design a voltage divider network if you are using an adjustable output regulator. Follow the controller or converter IC's instructions to adjust the output voltage.

1.5-V Regulator Circuits

This section contains the circuit diagrams for the voltage regulators discussed in this application note. You can use the voltage regulators in this section to generate a 1.5-V power supply. Refer to the voltage regulator data sheet to find detailed specifications. If you require further information that is not shown in the data sheet, contact the regulator's vendor.

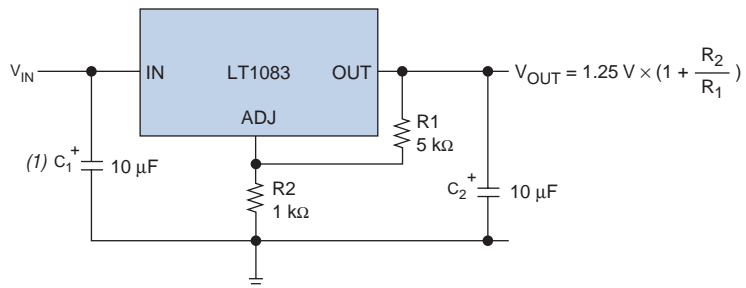
Figures 12–7 through 12–12 show the circuit diagrams of Linear Technology voltage regulators listed in Table 12–5.

The LT1573 linear voltage regulator converts 2.5-V to 1.5-V with an output current of 6A (see Figure 12–7).

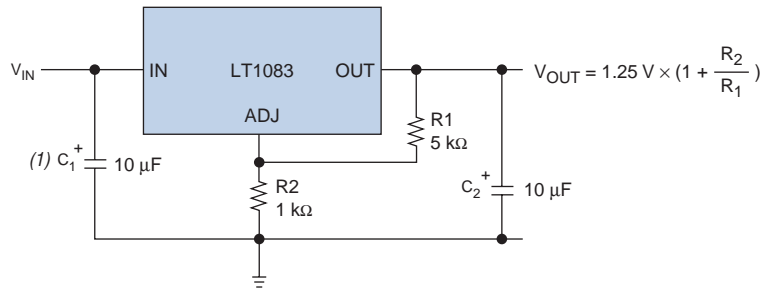
Figure 12-7. LT1573: 2.5-V-to-1.5-V/6.0-A Linear Voltage Regulator**Notes to Figure 12-7:**

- (1) C_{IN1} and C_{OUT} are AVX 100- μ F/10-V surface-mount tantalum capacitors.
- (2) Use SHDN (active high) to shut down the regulator.
- (3) C_{TIME} is a 0.5- μ F capacitor for 100-ms time out at room temperature.
- (4) C_{IN2} is an AVX 15- μ F/10-V surface-mount tantalum capacitor.

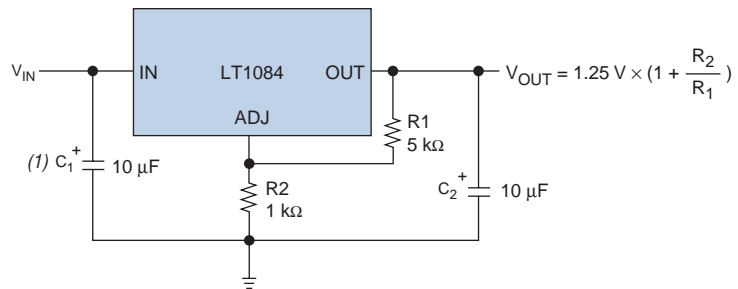
Use adjustable 5.0- to 1.5-V regulators (shown in Figures 12-8 through 12-10) for 3.0- to 7.5-A low-cost, low-device-count, board-space-efficient solutions.

Figure 12-8. LT1083: 5.0-V-to-1.5-V/7.5-A Linear Voltage Regulator**Note to Figure 12-8:**

- (1) This capacitor is necessary to maintain the voltage level at the input regulator. There could be a voltage drop at the input if the voltage supply is too far away.

Figure 12–9. LT1084: 5.0-V-to-1.5-V/5.0-A Linear Voltage Regulator**Note to Figure 12–9:**

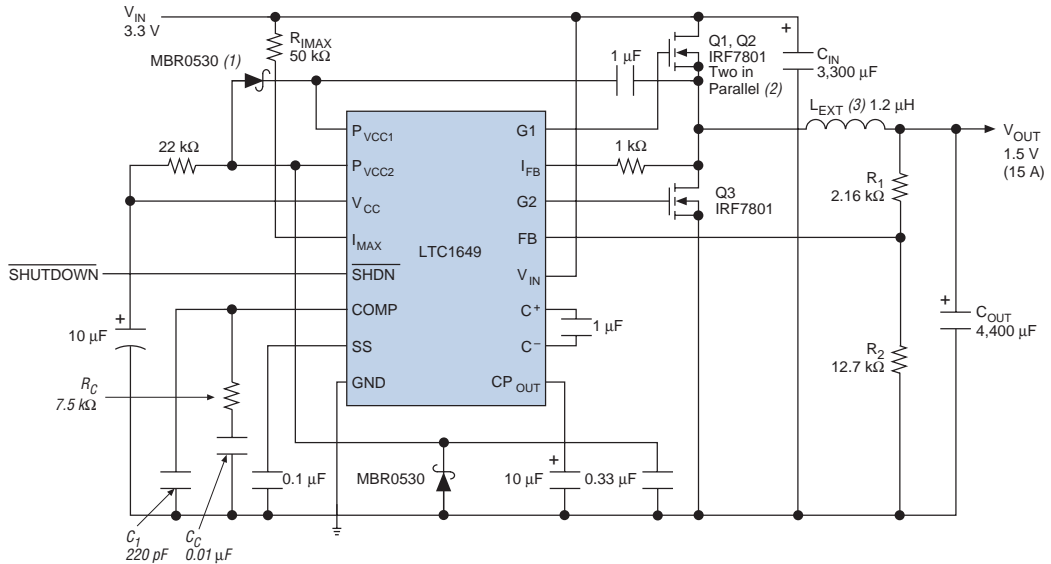
- (1) This capacitor is necessary to maintain the voltage level at the input regulator. There could be a voltage drop at the input if the voltage supply is too far away.

Figure 12–10. LT1085: 5.0-V-to-1.5-V/3-A Linear Voltage Regulator**Note to Figure 12–10:**

- (1) This capacitor is necessary to maintain the voltage level at the input regulator. There could be a voltage drop at the input if the voltage supply is too far away.

Figure 12–11 shows a high-efficiency switching regulator circuit diagram. A selectable resistor network controls the output voltage. The resistor values in Figure 12–11 are selected for 1.5-V output operation.

Figure 12–11. LT1649: 3.3-V-to-1.5-V/15-A Asynchronous Switching Regulator



Notes to Figure 12–11:

- (1) MBR0530 is a Motorola device.
- (2) IRF7801 is a International Rectifier device.
- (3) Refer to the Panasonic 12TS-1R2HL device.

Figures 12-13 through 12-17 show the circuit diagrams of Elantec voltage regulators listed in Table 12-6.

Figures 12-13 through 12-15 show the switching regulator that converts 5.0-V to 1.5-V with different output current.

Figure 12-13. EL7551C: 5.0-V-to-1.5-V/1-A Synchronous Switching Regulator

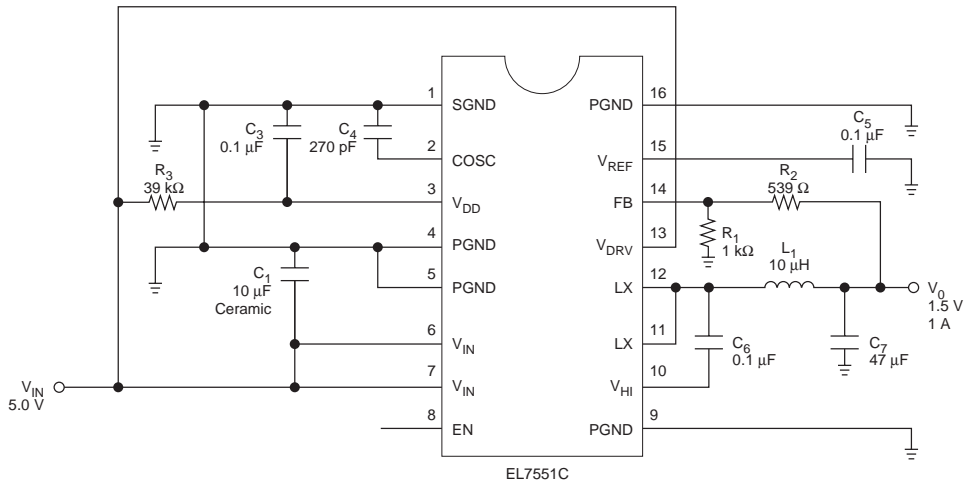


Figure 12–14. EL7564CM: 5.0-V-to-1.5-V/4-A Synchronous Switching Regulator

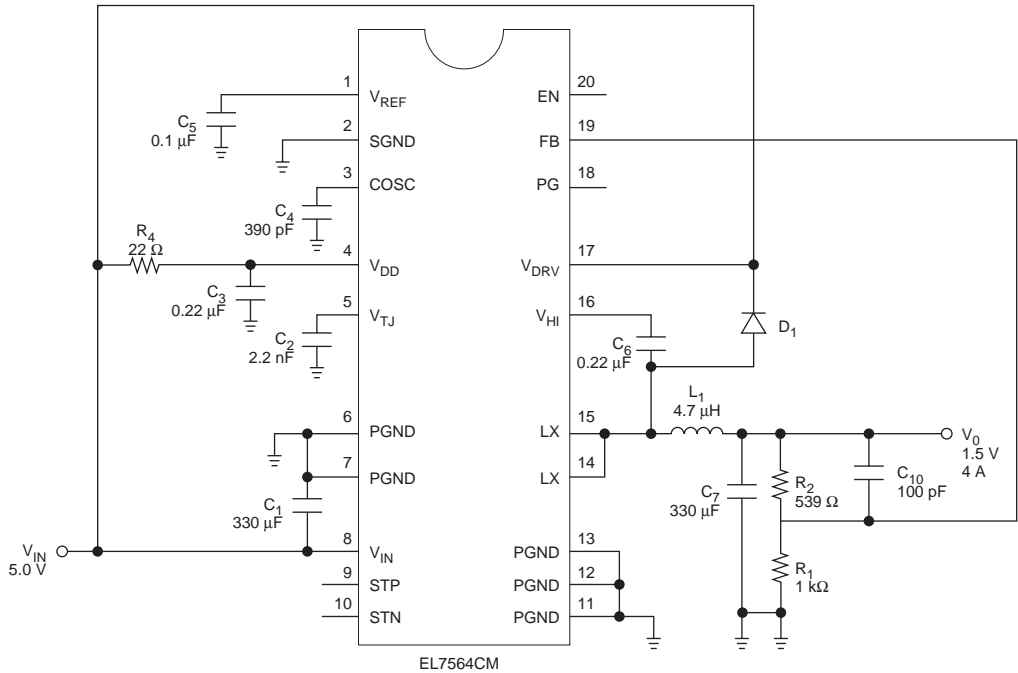
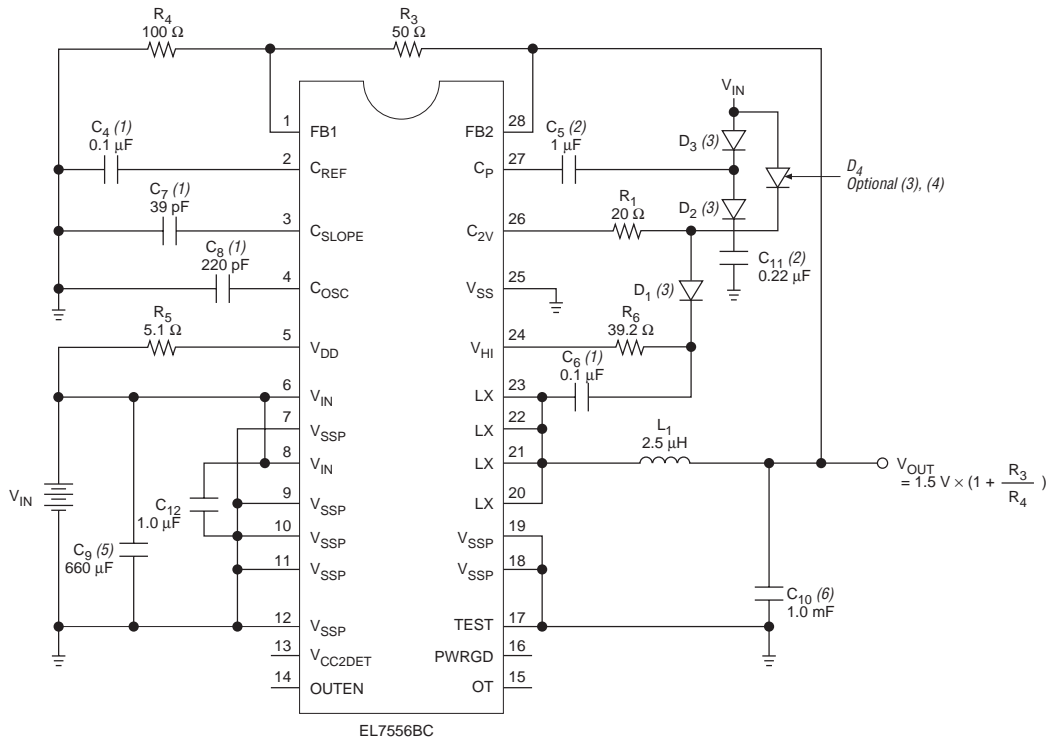


Figure 12–15. EL7556BC: 5.0-V-to-1.5-V/6-A Synchronous Switching Regulator



Notes to Figures 12–13 – 12–15:

- (1) These capacitors are ceramic capacitors.
- (2) These capacitors are ceramic or tantalum capacitor.
- (3) These are BAT54S fast diodes.
- (4) D4 is only required for EL7556ACM.
- (5) This is a Sprague 293D337X96R3 2X330μF capacitor.
- (6) This is a Sprague 293D337X96R3 3X330μF capacitor.

Figures 12-16 and 12-17 show the switching regulator that converts 3.3 V to 1.5 V with different output currents.

Figure 12-16. EL7562CM: 3.3-V to 1.5-V/2-A Synchronous Switching Regulator

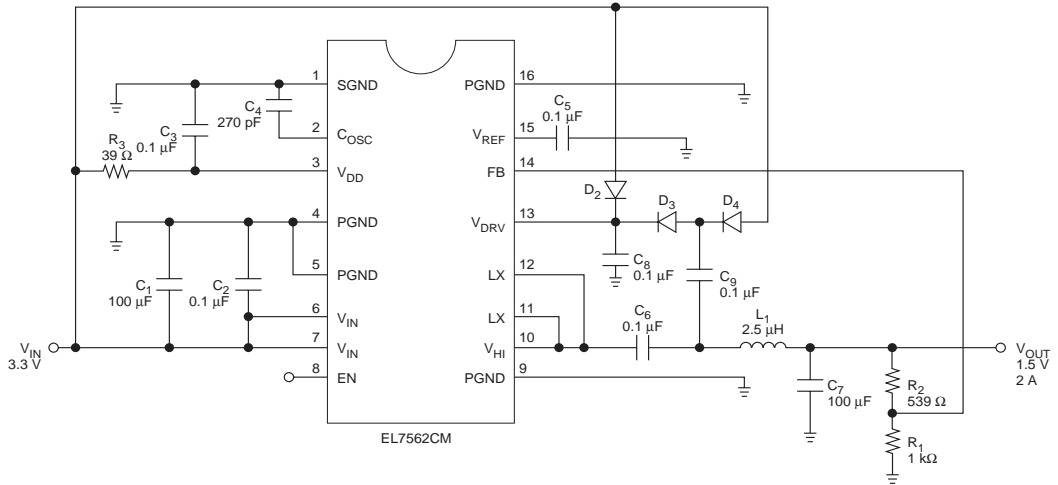
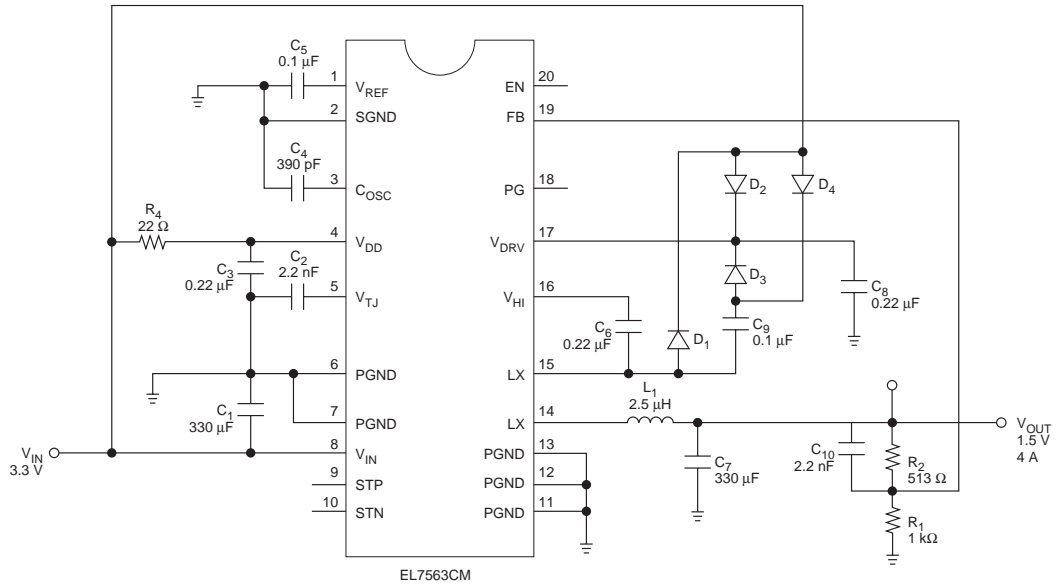


Figure 12-17. EL7563CM: 3.3-V to 1.5-V/4-A Synchronous Switching Regulator



1.5-V Regulator Application Examples

The following sections show the process used to select a voltage regulator for three sample designs. The regulator selection is based on the amount of power that the Cyclone device consumes. There are 14 variables to consider when selecting a voltage regulator. The following variables apply to Cyclone device power consumption:

- f_{MAX}
- Output and bidirectional pins
- Average toggle rate for I/O pins (to_{gIO})
- Average toggle rate for logic elements (LEs) (to_{gLC})
- User-mode I_{CC} consumption
- Maximum power-up I_{CCINT} requirement
- Utilization
- V_{CCIO} supply level
- V_{CCINT} supply level

The following variables apply to the voltage regulator:

- Output voltage precision requirement
- Supply voltage on the board
- Voltage supply output current
- Variance of board supply
- Efficiency

Different designs have different power consumptions based on the variables listed. Once you calculate the Cyclone device's power consumption, you must consider how much current the Cyclone device needs. You can use the Cyclone power calculator (available at www.altera.com) or the PowerGauge™ tool in the Quartus II software to determine the current needs. Also check the maximum power-up current requirement listed in the Power Consumption section of the Cyclone FPGA Family Data Sheet because the power-up current requirement may exceed the user-mode current consumption for a specific design.

Once you determine the minimum current the Cyclone device requires, you must select a voltage regulator that can generate the desired output current with the voltage and current supply that is available on the board using the variables listed in this section. An example is shown to illustrate the voltage regulator selection process.

Synchronous Switching Regulator Example

This example shows a worst-case scenario for power consumption where the design uses all the LEs and RAM. Table 12–7 shows the design requirements for 1.5-V design using a Cyclone EP1C12 FPGA.

Design Requirement	Value
Output voltage precision requirement	±5%
Supply voltages available on the board	3.3 V
Voltage supply output current available for this section ($I_{IN, DC(MAX)}$)	2 A
Variance of board supply (V_{IN})	±5%
f_{MAX}	150 MHz
Average t_{ogIO}	12.5%
Average t_{ogLC}	12.5%
Utilization	100%
Output and bidirectional pins	125
V_{CCIO} supply level	3.3 V
V_{CCINT} supply level	1.5 V
Efficiency	≥90%

Table 12–8 uses the checklist on page 12–8 to help select the appropriate voltage regulator.

Output voltage requirements	$V_{OUT} = 1.5 \text{ V}$
Supply voltages	V_{IN} OR $V_{CC} = 3.3 \text{ V}$
Supply variance from Linear Technology data sheet	Supply variance = ±5%
Estimated I_{CCINT} Use Cyclone Power Calculator	$I_{CCINT} = 620 \text{ mA}$
Estimated I_{CCIO} if regulator powers V_{CCIO} Use Cyclone Power Calculator (not applicable in this example because $V_{CCIO} = 3.3 \text{ V}$)	$I_{CCIO} = \text{N/A}$
Total user-mode current consumption $I_{CC} = I_{CCINT} + I_{CCIO}$	$I_{CC} = 620 \text{ mA}$

Table 12–8. Voltage Regulator Selection Process for EP1C12F324C Design (Part 2 of 2)

EP1C12 maximum power-up current requirement See Power Consumption section of the Cyclone FPGA Family Data Sheet for other densities	$I_{PUC(MAX)} = 900 \text{ mA}$
Maximum output current required Compare I_{CC} with $I_{PUC(MAX)}$	$I_{OUT(MAX)} = 900 \text{ mA}$
Voltage regulator selection See <i>Linear Technology LTC 1649 data sheet</i> See <i>Intersil (Elantec) EL7562C data sheet</i>	LTC1649 $I_{OUT(MAX)} = 15 \text{ A}$ EL7562C $I_{OUT(MAX)} = 2 \text{ A}$
LTC1649	
Nominal efficiency (η)	Nominal efficiency (η) = > 90%
Line and load regulation Line regulation + load regulation = $(0.17 \text{ mV} + 7 \text{ mV}) / 1.5 \text{ V} \times 100\%$	Line and Load Regulation = $0.478\% < 5\%$
Minimum input voltage ($V_{IN(MIN)}$) $(V_{IN(MIN)}) = V_{IN}(1 - \Delta V_{IN}) = 3.3\text{V}(1 - 0.05)$	$(V_{IN(MIN)}) = 3.135 \text{ V}$
Maximum input current $I_{IN, DC(MAX)} = (V_{OUT} \times I_{OUT(MAX)}) / (\eta \times V_{IN(MIN)})$	$I_{IN, DC(MAX)} = 478 \text{ mA} < 2 \text{ A}$
EL7562C	
Nominal efficiency (η)	Nominal efficiency (η) = > 95%
Line and load regulation Line regulation + load regulation = $(0.17 \text{ mV} + 7 \text{ mV}) / 1.5 \text{ V} \times 100\%$	Line and Load Regulation = $0.5\% < 5\%$
Minimum input voltage ($V_{IN(MIN)}$) $(V_{IN(MIN)}) = V_{IN}(1 - \Delta V_{IN}) = 3.3\text{V}(1 - 0.05)$	$(V_{IN(MIN)}) = 3.135 \text{ V}$
Maximum input current $I_{IN, DC(MAX)} = (V_{OUT} \times I_{OUT(MAX)}) / (\eta \times V_{IN(MIN)})$	$I_{IN, DC(MAX)} = 453 \text{ mA} < 2 \text{ A}$

Board Layout

Laying out a printed circuit board (PCB) properly is extremely important in high-frequency ($\geq 100 \text{ kHz}$) switching regulator designs. A poor PCB layout results in increased EMI and ground bounce, which affects the reliability of the voltage regulator by obscuring important voltage and current feedback signals. Altera recommends using Gerber files — pre-designed layout files— supplied by the regulator vendor for your board layout.

If you cannot use the supplied layout files, contact the voltage regulator vendor for help on re-designing the board to fit your design requirements while maintaining the proper functionality.

Altera recommends that you use separate layers for signals, the ground plane, and voltage supply planes. You can support separate layers by using multi-layer PCBs, assuming you are using two signal layers.

Figure 12–18 shows how to use regulators to generate 1.5-V and 2.5-V power supplies if the system needs two power supply systems. One regulator is used for each power supply.

Figure 12–18. Two Regulator Solution for Systems that Require 5.0-V, 2.5-V & 1.5-V Supply Levels

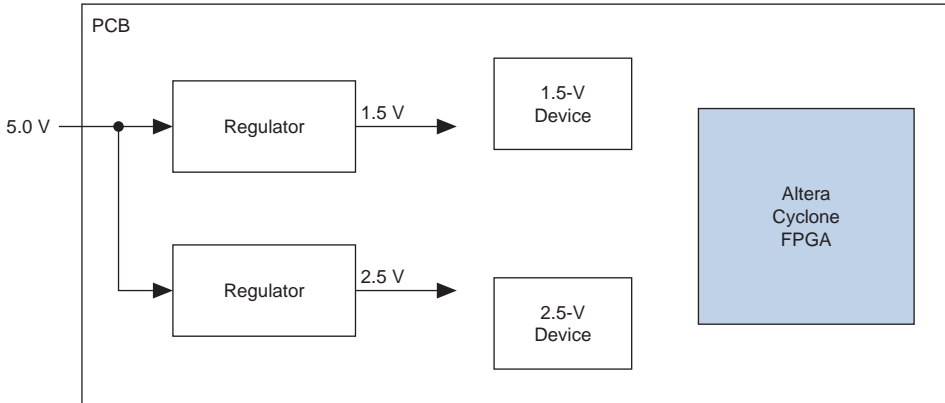
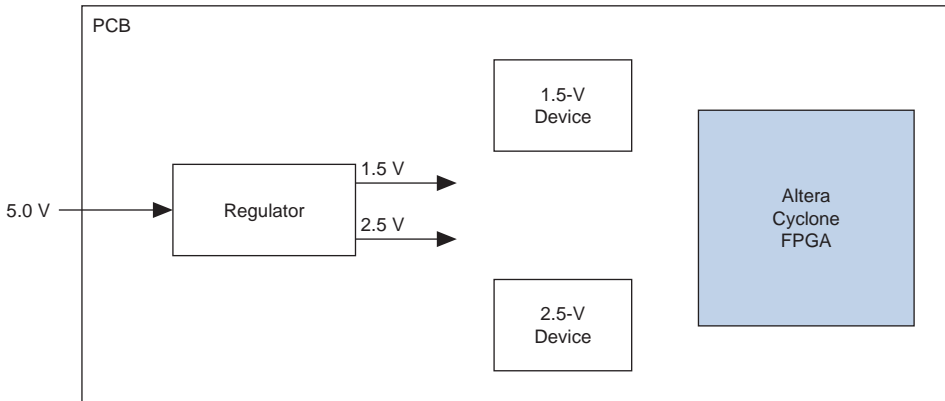


Figure 12–19 shows how to use a single regulator to generate two different power supplies (1.5-V and 2.5-V). The use of a single regulator to generate 1.5-V and 2.5-V supplies from the 5.0-V power supply can minimize the board size and thus save cost.

Figure 12–19. Single Regulator Solution for Systems that Require 5.0-V, 2.5-V & 1.5-V Supply Levels



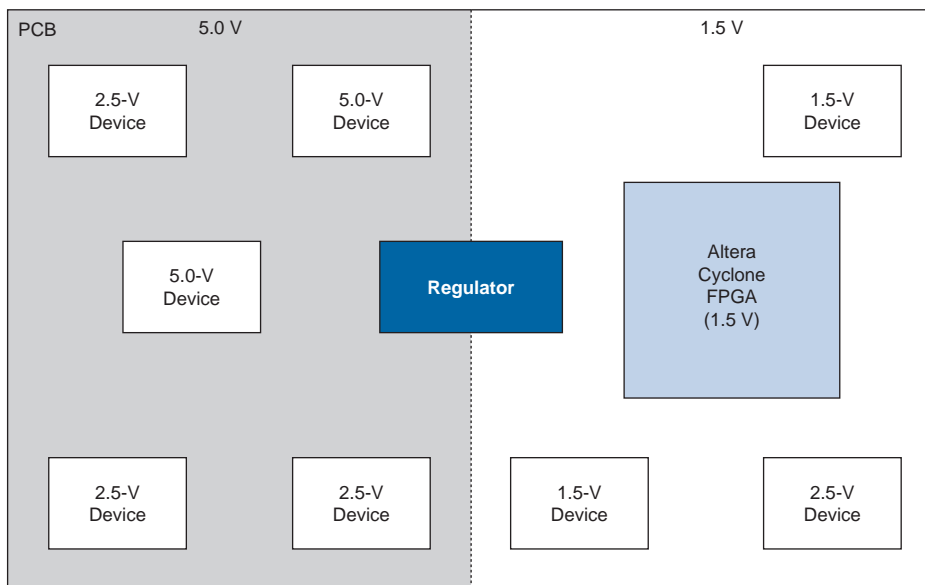
Split-Plane Method

The split-plane design method reduces the number of planes required by placing two power supply planes in one plane (see Figure 12–20). For example, the layout for this method can be structured as follows:

- One 2.5-V plane, covering the entire board
- One plane split between 5.0-V and 1.5-V

This technique assumes that the majority of devices are 2.5-V. To support MultiVolt I/O, Altera devices must have access to 1.5-V and 2.5-V planes.

Figure 12–20. Split Board Layout for 2.5-V Systems With 5.0-V & 1.5-V Devices



Conclusion

With the proliferation of multiple voltage levels in systems, it is important to design a voltage system that can support a low-power device like Cyclone devices. Designers must consider key elements of the PCB, such as power supplies, regulators, power consumption, and board layout when successfully designing a system that incorporates the low-voltage Cyclone family of devices.

References

Linear Technology Corporation. *Application Note 35 (Step-Down Switching Regulators)*. Milpitas: Linear Technology Corporation, 1989.

Linear Technology Corporation. *LT1573 Data Sheet (Low Dropout Regulator Driver)*. Milpitas: Linear Technology Corporation, 1997.

Linear Technology Corporation. *LT1083/LT1084/LT1085 Data Sheet (7.5 A, 5 A, 3 A Low Dropout Positive Adjustable Regulators)*. Milpitas: Linear Technology Corporation, 1994.

Linear Technology Corporation. *LTC1649 Data Sheet (3.3V Input High Power Step-Down Switching Regulator Controller)*. Milpitas: Linear Technology Corporation, 1998.

Linear Technology Corporation. *LTC1775 Data Sheet (High Power No Rsense Current Mode Synchronous Step-Down Switching Regulator)*. Milpitas: Linear Technology Corporation, 1999.

Intersil Corporation. *EL7551C Data Sheet (Monolithic 1 Amp DC:DC Step-Down Regulator)*. Milpitas: Intersil Corporation, 2002.

Intersil Corporation. *EL7564C Data Sheet (Monolithic 4 Amp DC:DC Step-Down Regulator)*. Milpitas: Intersil Corporation, 2002.

Intersil Corporation. *EL7556BC Data Sheet (Integrated Adjustable 6 Amp Synchronous Switcher)*. Milpitas: Intersil Corporation, 2001.

Intersil Corporation. *EL7562C Data Sheet (Monolithic 2 Amp DC:DC Step-Down Regulator)*. Milpitas: Intersil Corporation, 2002.

Intersil Corporation. *EL7563C Data Sheet (Monolithic 4 Amp DC:DC Step-Down Regulator)*. Milpitas: Intersil Corporation, 2002.

This section provides information for all of the supported configuration schemes for Cyclone devices. The last chapter provides information on EPCS1 and EPCS4 serial configuration devices.

This section contains the following chapters:

- [Chapter 13. Configuring Cyclone FPGAs](#)
- [Chapter 14. Serial Configuration Devices \(EPCS1 & EPCS4\) Data Sheet](#)

Revision History

The table below shows the revision history for [Chapter 13](#) and [14](#).

Chapter(s)	Date / Version	Changes Made
13	May 2003 v1.0	Updates to existing figures and notes. Added Figure 13–2 and Figure 13–3 . Added information for EP1C4 and removed EPC1441.
14	May 2003 v1.0	Initial release.

Introduction

You can configure Cyclone™ FPGAs using one of several configuration schemes, including the new active serial (AS) configuration scheme. This new scheme is used with the new, low cost serial configuration devices. Passive serial (PS) and Joint Test Action Group (JTAG)-based configuration schemes are also supported by Cyclone FPGAs. Additionally, Cyclone FPGAs can receive a compressed configuration bit stream and decompress this data in real-time, reducing storage requirements and configuration time.

This application note provides details on each of the three supported Cyclone configuration schemes.

Device Configuration Overview

Cyclone FPGAs use SRAM cells to store configuration data. Since SRAM memory is volatile, configuration data must be downloaded to Cyclone FPGAs each time the device powers up. You can download configuration data to Cyclone FPGAs using the AS, PS, or JTAG interfaces. See [Table 13-1](#).

<i>Table 13-1. Cyclone FPGA Configuration Schemes</i>	
Configuration Scheme	Description
Active serial (AS) configuration	Configuration using: <ul style="list-style-type: none"> ● Serial configuration devices (EPCS1 or EPCS4)
Passive serial (PS) configuration	Configuration using: <ul style="list-style-type: none"> ● Enhanced configuration devices (EPC4, EPC8, and EPC16) ● EPC2, EPC1 configuration devices ● Intelligent host (microprocessor) ● Download cable
JTAG-based configuration	Configuration via JTAG pins using: <ul style="list-style-type: none"> ● Download cable ● Intelligent host (microprocessor) ● Jam™ Standard Test and Programming Language (STAPL)

You can select a Cyclone FPGA configuration scheme by driving its MSEL1 and MSEL0 pins either high (1) or low (0), as shown in Table 13–2.

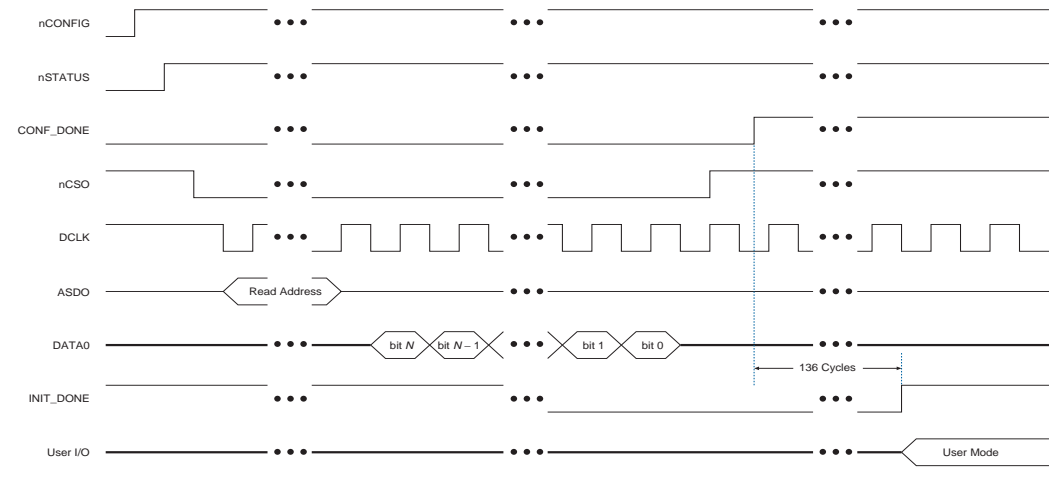
MSEL1	MSEL0	Configuration Scheme
0	0	AS
0	1	PS
0	(1)	JTAG-based (2), (3)

Notes to Table 13–2:

- (1) You can set MSEL0 either high or low.
- (2) Do not leave MSEL pins floating. Connect them to a low- or high-logic level.
- (3) JTAG-based configuration takes precedence over other schemes (i.e., ignores MSEL pin settings).

After configuration, Cyclone FPGAs will initialize registers and I/O pins, then enter user mode and function as per the user design. Figure 13–1 shows an AS configuration waveform.

Figure 13–1. AS Configuration Waveform



You can configure Cyclone FPGAs using the 3.3-V, 2.5-V, 1.8-V, or 1.5-V LVTTTL I/O standard on configuration and JTAG input pins. These devices do not feature a VCCSEL pin; therefore, you should connect the VCCIO pins of the I/O banks containing configuration or JTAG pins according to the I/O standard specifications.

Table 13–3 summarizes the approximate uncompressed configuration file size for each Cyclone FPGA. To calculate the amount of storage space required for multi-device configurations, add the file size of each device together.

Device	SRAM Object File Size (Mbits)
EP1C3	0.628
EP1C4	0.925
EP1C6	1.167
EP1C12	2.324
EP1C20	3.559

Note to Table 13–3:

(1) These values are preliminary.

You should only use the numbers in Table 13–3 to estimate the SRAM Object File (.sof) size before design compilation. The exact file size can vary because different Altera® Quartus® II software versions can add a slightly different number of padding bits during programming. However, for any specific version of the Quartus II software, any design targeted for the same device has the same uncompressed configuration file size. If compression is used, the file size can vary after each compilation.

Data Compression

Cyclone FPGAs are the first FPGAs to support decompression of configuration data. This feature allows you to store compressed configuration data in configuration devices or other memory, and transmit this compressed bit stream to Cyclone FPGAs. During configuration, the Cyclone FPGA decompresses the bit stream in real time and programs its SRAM cells.

Cyclone FPGAs support compression in the AS and PS configuration schemes. Compression is not supported for JTAG-based configuration.



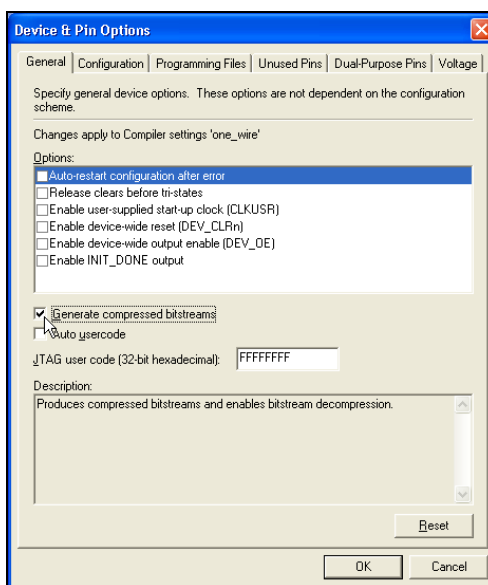
Preliminary data indicates that compression reduces configuration bit stream size by 35 to 60%.

When you enable compression, the Quartus II software generates configuration files with compressed configuration data. This compression reduces the storage requirements in the configuration device or flash, and decreases the time needed to transmit the bit stream to the Cyclone FPGA.

There are two methods to enable compression for Cyclone bitstreams: before design compilation (in Compiler Settings menu) & after design compilation (in Convert Programming Files window).

To enable compression in the project's compiler settings, select "Device" under the "Assignments" menu to bring up the settings window. After selecting your Cyclone device open the "Device & Pin Options" window, and in the "General" settings tab enable the check box for "Generate compressed bitstreams" (as shown in [Figure 13–2](#)).

Figure 13–2. Enabling compression for Cyclone bitstreams in Compiler Settings

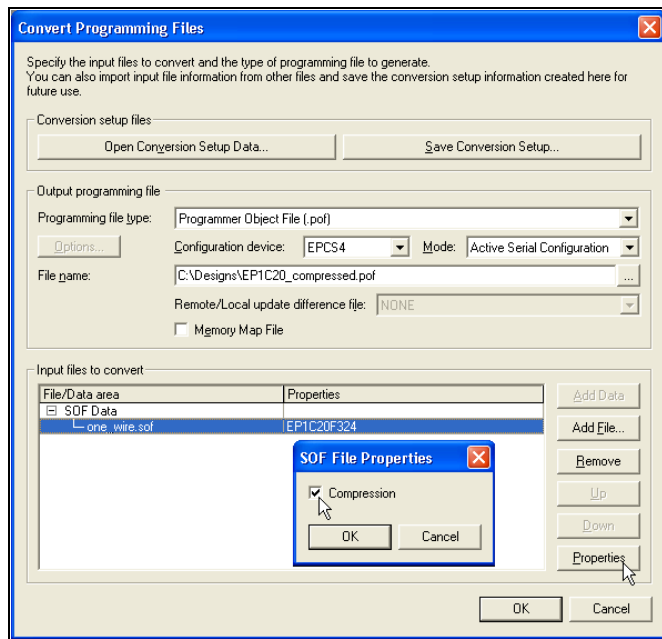


Compression can also be enabled when creating programming files from the "Convert Programming Files". See [Figure 13–3](#).

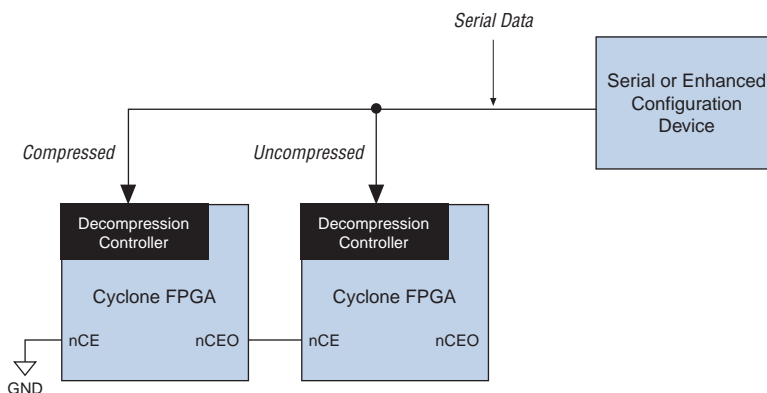
1. Open "File -> Convert Programming Files".
2. Select the Programming File type (POF, SRAM HEXOUT, RBF, or TTF).
3. For POF output files, select a configuration device.
4. Select "Add File" and add Cyclone SOF file.

5. Select the name of file you added to the "SOF Data" area and click on "Properties".
6. Enable the "Compression" checkbox.

Figure 13–3. Enabling compression for Cyclone bitstreams in Convert Programming Files



When multiple Cyclone devices are cascaded, the compression feature can be selectively enabled for each device in the chain. Figure 13–4 depicts a chain of two Cyclone FPGAs. The first Cyclone FPGA has compression enabled and therefore receives a compressed bit stream from the configuration device. The second Cyclone FPGA has the compression feature disabled and receives uncompressed data.

Figure 13–4. Compressed & Uncompressed Configuration Data in the Same Programming File *Note (1)***Note to Figure 13–4:**

- (1) The first device in the chain should be set up in AS configuration mode ($MSEL[1..0] = "00"$). The remaining devices in the chain must be set up in PS configuration mode ($MSEL[1..0] = "01"$).

You can generate programming files for this setup from the Convert Programming Files window (File menu) in the Quartus II software.

The decompression feature supported by Cyclone FPGAs is separate from the decompression feature in enhanced configuration devices (EPC16, EPC8, and EPC4). The data compression feature in the enhanced configuration devices allows them to store compressed data and decompress the bit stream before transmitting to the target devices. When using Cyclone FPGAs with enhanced configuration devices, Altera recommends using compression on one of the devices, not both (preferably the Cyclone FPGA since transmitting compressed data reduces configuration time).

Configuration Schemes

This section describes the various configuration schemes you can use to configure Cyclone FPGAs. Descriptions include an overview of the protocol, pin connections, and timing information. The schemes discussed are:

- AS configuration (serial configuration devices)
- PS configuration
- JTAG-based configuration

Active Serial Configuration (Serial Configuration Devices)

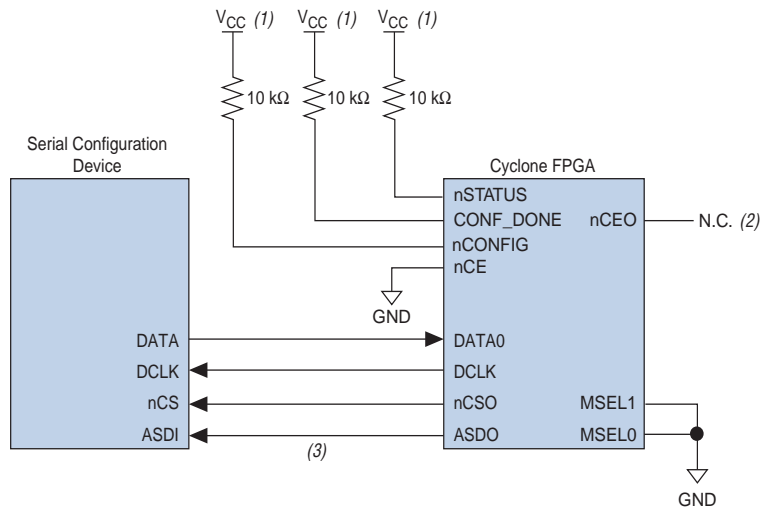
In the AS configuration scheme, Cyclone FPGAs are configured using the new serial configuration devices. These configuration devices are low cost devices with non-volatile memory that feature a simple four-pin interface and a small form factor. These features make serial configuration devices an ideal solution for configuring the low-cost Cyclone FPGAs.



For more information on serial configuration devices, see [Chapter 14, Serial Configuration Devices \(EPCS1 & EPCS4\) Data Sheet](#).

Serial configuration devices provide a serial interface to access configuration data. During device configuration, Cyclone FPGAs read configuration data via the serial interface, decompress data if necessary, and program their SRAM cells. This scheme is referred to as an AS configuration scheme because the FPGA controls the configuration interface. This scheme is in contrast to the PS configuration scheme where the configuration device controls the interface.

Serial configuration devices have a four-pin interface: serial clock input (DCLK), serial data output (DATA), AS data input (ASDI), and an active-low chip select ($\bar{n}CS$). This four-pin interface connects to Cyclone FPGA pins, as shown in [Figure 13–5](#).

Figure 13–5. AS Configuration of a Single Cyclone FPGA**Notes to Figure 13–5:**

- (1) Power up the ByteBlaster II Vcc with a 3.3-V supply.
- (2) The nCEO pin is left unconnected.
- (3) Cyclone FPGAs use the ASDO to ASDI path to control the configuration device.

Connecting the MSEL[1..0] pins to 00 selects the AS configuration scheme. The Cyclone chip enable signal, nCE, must also be connected to ground for successful configuration.

During system power up, both the Cyclone FPGA and serial configuration device enter a power-on reset (POR) period. As soon as the Cyclone FPGA enters POR, it drives nSTATUS low to indicate it is busy and drives CONF_DONE low to indicate that it has not been configured. After POR, which typically lasts 100 ms, the Cyclone FPGA releases nSTATUS and enters configuration mode when this signal is pulled high by the external 10-kΩ resistor.

The serial clock (DCLK) generated by the Cyclone FPGA controls the entire configuration cycle (see Figure 13–1 on page 13–2) and this clock line provides the timing for the serial interface. Cyclone FPGAs use an internal oscillator to generate DCLK. Typical DCLK frequency during AS configuration is 15 MHz.

The serial configuration device latches input/control signals on the rising edge of DCLK and drives out configuration data on the falling edge. Cyclone FPGAs drive out control signals on the falling edge of DCLK and latch configuration data on the rising edge of DCLK.

In configuration mode, the Cyclone FPGA enables the serial configuration device by driving the `nCS0` output pin low that is connected to the chip select (`nCS`) pin of the configuration device. The Cyclone FPGA's serial clock (`DCLK`) and serial data output (`ASDO`) pins are used to read configuration data. The configuration device provides data on its serial data output (`DATA`) pin that is connected to the `DATA0` input on Cyclone FPGAs.

After all configuration bits are received by the Cyclone FPGA, it releases the open-drain `CONF_DONE` pin allowing the external 10-k Ω resistor to pull this signal to a high level. Initialization begins only after the `CONF_DONE` line reaches a high level. Initialization completes within 136 clock cycles and the device enters user mode.

You can select the clock used for initialization by using the **User Supplied Start-Up Clock** option in the Quartus II software. The Quartus II software uses the 10-MHz internal oscillator by default to initialize the Cyclone FPGA. When you enable the **User Supplied Start-Up Clock** option, the software uses the `CLKUSR` pin as the initialization clock.

If an error occurs during configuration, the Cyclone FPGA asserts the `nSTATUS` signal low indicating a data frame error, and the `CONF_DONE` signal will stay low. With the **Auto-Restart Configuration on Frame Error** option enabled in the Quartus II software, the Cyclone FPGA resets the configuration device by pulsing `nCS0`, releases `nSTATUS` after a reset time-out period (about 30 micro-seconds), and retries configuration. After successful configuration, the `CONF_DONE` signal is tri-stated by the target device and then pulled high by the pull-up resistor.

All AS configuration pins, `DATA0`, `DCLK`, `nCS0`, and `ASDO`, have weak internal pull-up resistors. These pull-up resistors are always active.

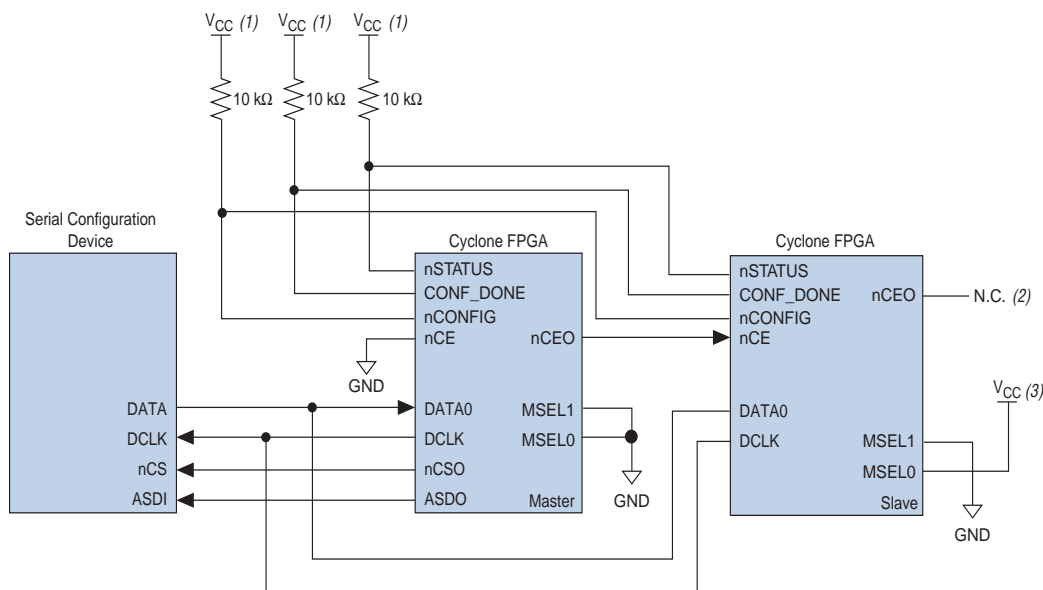
Configuring Multiple Devices (Cascading)

You can configure multiple Cyclone FPGAs using a single serial configuration device. You can cascade multiple Cyclone FPGAs using the chip-enable (`nCE`) and chip-enable-out (`nCEO`) pins. The first device in the chain must have its `nCE` pin connected to ground. You must connect its `nCEO` chip-enable-out pin to the chip-enable (`nCE`) pin of the next device in the chain. When the first device captures all of its configuration data from the bit stream, it drives the `nCEO` pin low enabling the next device in the chain. You must leave the `nCEO` pin of the last device unconnected.

This first Cyclone FPGA in the chain is the configuration master and controls configuration of the entire chain. You must connect its `MSEL` pins to select the AS configuration scheme. The remaining Cyclone FPGAs are

configuration slaves and you must connect their MSEL pins to select the PS configuration scheme. Figure 13–6 shows the pin connections for this setup.

Figure 13–6. Configuring Multiple Devices Using a Serial Configuration Device (AS)



Notes to Figure 13–6:

- (1) Power up the ByteBlaster II V_{CC} with a 3.3-V supply.
- (2) The nCEO pin is left unconnected.
- (3) Connect MSEL0 to the V_{CC} supply voltage of the I/O Bank it resides in.

As shown in Figure 13–6, the nSTATUS and CONF_DONE pins on all target FPGAs are connected together with external pull-up resistors. These pins are open-drain bidirectional pins on the FPGAs. When the first device asserts nCEO (after receiving all of its configuration data), it releases its CONF_DONE pin. But the subsequent devices in the chain keep this shared CONF_DONE line low until they have received their configuration data. When all target FPGAs in the chain have received their configuration data and have released CONF_DONE, the pull-up resistor drives a high level on this line and all devices simultaneously enter initialization mode. If an error occurs at any point during configuration, the nSTATUS line is driven by the failing FPGA. If you enable the **Auto Restart Configuration on Frame Error** option, reconfiguration of the entire chain begins.

Furthermore, while you can cascade Cyclone FPGAs, serial configuration devices cannot be cascaded or chained together. If the configuration bit stream size exceeds the capacity of a serial configuration device, you must select a larger configuration device and/or enable the compression feature. While configuring multiple devices, the size of the bit stream is the sum of the individual devices' configuration bit streams.

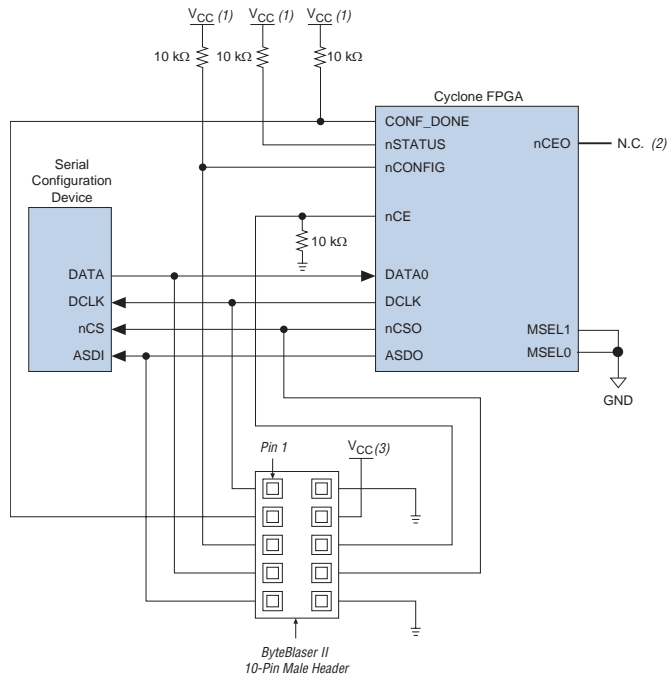
Programming Serial Configuration Devices

Serial configuration devices are non-volatile, flash-memory-based devices. You can program these devices in-system using the ByteBlaster™ II download cable. Alternatively, you can program them using the Altera Programming Unit (APU) or supported third-party programmers.

You can perform in-system programming of serial configuration devices via the AS programming interface. During in-system programming, the download cable disables FPGA access to the AS interface by driving the chip-enable `nCE` pin high. Cyclone FPGAs are also held in reset by a low level on `nCONFIG`. After programming is complete, the download cable releases `nCE` and `nCONFIG`, allowing the pull-down and pull-up resistor to drive `GND` and `VCC`, respectively. [Figure 13-7](#) shows the download cable connections to the serial configuration device.



For more information on the ByteBlaster II cable, see the *ByteBlaster II Download Cable Data Sheet*.

Figure 13–7. In-System Programming of Serial Configuration Devices**Notes to Figure 13–7:**

- (1) Connect these pull-up resistors to 3.3-V supply.
- (2) The nCEO pin is left unconnected.
- (3) Power up the ByteBlaster II Vcc with a 3.3-V supply.

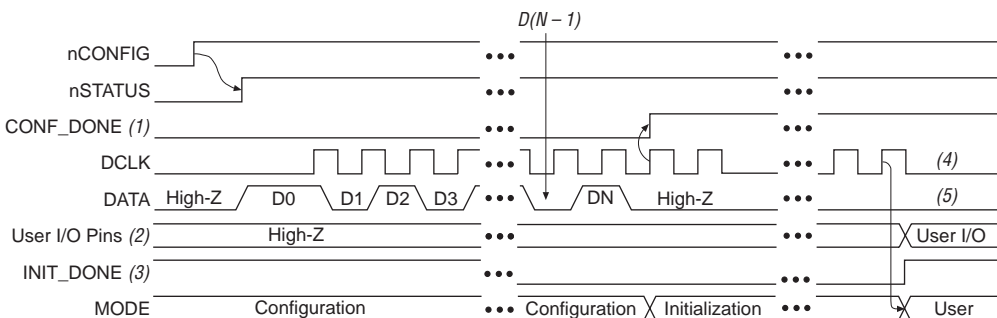
You can program serial configuration devices by using the Quartus II software with the APU and the appropriate configuration device programming adapter. All serial configuration devices are offered in an eight-pin small outline integrated circuit (SOIC) package and can be programmed using the PLMSEPC-8 adapter.

In production environments, Serial Configuration devices can be programmed using multiple methods. Altera programming hardware (APU) or other third-party programming hardware can be used to program blank Serial Configuration devices before they are mounted onto PCBs. Alternatively, you can use an on-board microprocessor to program the Serial Configuration device in-system using C-based software drivers provided by Altera. For more information on these and other new methods, please refer to the Cyclone Literature web page.

Passive Serial Configuration

Cyclone FPGAs also feature the PS configuration scheme supported by all Altera FPGAs. In the PS scheme, an external host (configuration device, embedded processor, or host PC) controls configuration. Configuration data is clocked into the target Cyclone FPGAs via the DATA0 pin at each rising edge of DCLK. The configuration waveforms for this scheme are shown in Figure 13–8.

Figure 13–8. PS Configuration Cycle Waveform



Notes to Figure 13–8:

- (1) During initial power up and configuration, CONF_DONE is low. After configuration, CONF_DONE goes high to indicate successful configuration. If the device is reconfigured, CONF_DONE goes low after nCONFIG is driven low.
- (2) User I/O pins are tri-stated during configuration. Cyclone FPGAs also have a weak pull-up resistor on I/O pins during configuration. After initialization, the user I/O pins perform the function assigned in the user's design.
- (3) When used, the optional INIT_DONE signal is high when nCONFIG is low before configuration and during the first 136 clock cycles of configuration.
- (4) In user mode, DCLK should be driven high or low when using the PS configuration scheme. When using the AS configuration scheme, DCLK is a Cyclone output pin and should not be driven externally.
- (5) In user mode, DATA0 should be driven high or low.

PS Configuration using Configuration Device

In the PS configuration device scheme, nCONFIG is usually tied to V_{CC} (when using EPC16, EPC8, EPC4, or EPC2 devices, you can connect nCONFIG to nINIT_CONF). Upon device power-up, the target Cyclone FPGA senses the low-to-high transition on nCONFIG and initiates configuration. The target device then drives the open-drain CONF_DONE pin low, which in-turn drives the configuration device's nCS pin low. When exiting POR, both the target and configuration device release the open-drain nSTATUS pin (typically Cyclone POR lasts 100 ms).

Before configuration begins, the configuration device goes through a POR delay of up to 100 ms (maximum) to allow the power supply to stabilize. You must power the Cyclone FPGA before or during the POR

time of the enhanced configuration device. During POR, the configuration device drives its OE pin low. This low signal delays configuration because the OE pin is connected to the target device's nSTATUS pin. When the target and configuration devices complete POR, they both release the nSTATUS to OE line, which is then pulled high by a pull-up resistor.

When configuring multiple devices, configuration does not begin until all devices release their OE or nSTATUS pins. When all devices are ready, the configuration device clocks out DATA and DCLK to the target devices using an internal oscillator.

After successful configuration, the Cyclone FPGA starts initialization using the 10-MHz internal oscillator as the reference clock. The CONF_DONE pin is released by the target device and then pulled high by a pull-up resistor. When initialization is complete, the target Cyclone FPGA enters user mode.

If an error occurs during configuration, the target device drives its nSTATUS pin low, resetting itself internally and resetting the configuration device. If you turn on the **Auto-Restart Configuration on Frame Error** option, the device reconfigures automatically if an error occurs. To set this option, select **Compiler Settings** (Processing menu), and click on the **Chips & Devices** tab. Select **Device & Pin Options**, and click on the **Configuration** tab.

If the **Auto-Restart Configuration on Frame Error** option is turned off, the external system (configuration device or microprocessor) must monitor nSTATUS for errors and then pulse nCONFIG low to restart configuration. The external system can pulse nCONFIG if it is under system control rather than tied to V_{CC}. When configuration is complete, the target device releases CONF_DONE, which disables the configuration device by driving nCS high. The configuration device drives DCLK low before and after configuration.

In addition, if the configuration device sends all of its data and then detects that CONF_DONE has not gone high, it recognizes that the target device has not configured successfully. (For CONF_DONE to reach a high state, enhanced configuration devices wait for 64 DCLK cycles after the last configuration bit. EPC2 devices wait for 16 DCLK cycles.) In this case, the configuration device pulses its OE pin low for a few microseconds, driving the target device's nSTATUS pin low. If the **Auto-Restart Configuration on Frame Error** option is set in the Quartus II software, the target device resets and then releases its nSTATUS pin after a reset time-out period. When nSTATUS returns high, the configuration device reconfigures the target device.

You should not pull `CONF_DONE` low to delay initialization. Instead, use the Quartus II software's **User-Supplied Start-Up Clock** option to synchronize the initialization of multiple devices that are not in the same configuration chain. Devices in the same configuration chain initialize together since their `CONF_DONE` pins are tied together. For more information on this option, see "Device Options" on page 13-41.

`CONF_DONE` goes high during the first few clock cycles of initialization. Hence when using the `CLKUSR` feature you would not see the `CONF_DONE` signal high until you start clocking `CLKUSR`. However, the device does retain configuration data and waits for these initialization clocks to release `CONF_DONE` and go into user mode.


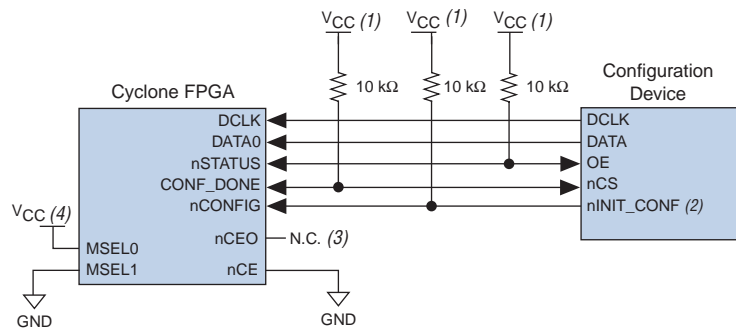
 When using internal pull-up resistors on configuration devices, power the supply voltage on the Cyclone FPGA I/O pins (V_{CCIO}) to 3.3-V. EPC2, EPC4, EPC8, and EPC16 devices support 3.3-V operation but not 2.5-V operation. Therefore, you must set the V_{CCIO} voltages for the banks where programming pins reside to 3.3 V.

Figure 13-9 shows how to configure one Cyclone FPGA with one configuration device.

Figure 13-9. Single Device Configuration Circuit



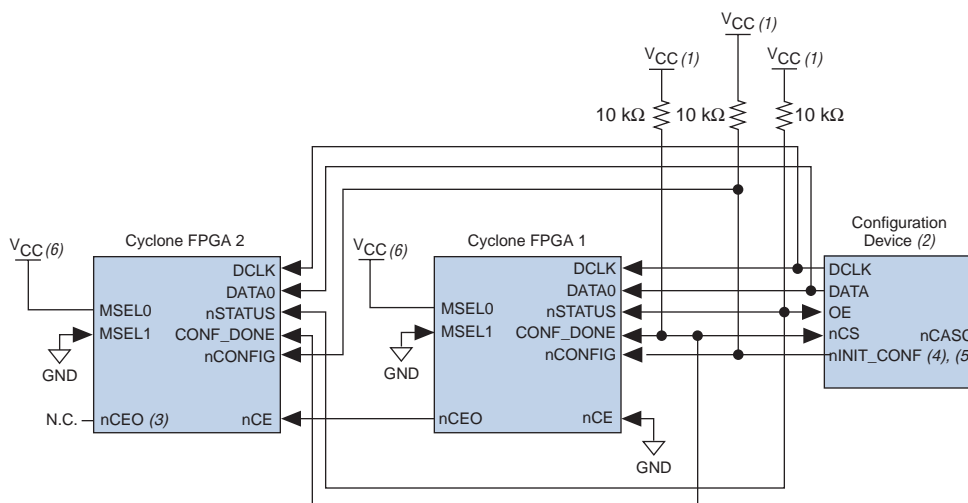
Notes to Figure 13-9:

- (1) The pull-up resistor should be connected to the same supply voltage as the configuration device. This pull-up resistor is 10 k Ω . The EPC16, EPC8, EPC4, and EPC2 devices' `OE` and `nCS` pins have internal, user-configurable pull-up resistors. If you use internal pull-up resistors, do not use external pull-up resistors on these pins.
- (2) The `nINIT_CONF` pin is available on EPC16, EPC8, EPC4, and EPC2 devices and has an internal pull-up resistor that is always active. If `nINIT_CONF` is not used, `nCONFIG` must be pulled to V_{CC} through a resistor.
- (3) The `nCEO` pin is left unconnected for the last device in the chain.
- (4) Connect `MSEL0` to the V_{CC} supply voltage of I/O Bank it resides in.

Configuring Multiple Cyclone FPGAs

You can use a single configuration device to configure multiple Cyclone FPGAs. In this setup, the `nCEO` pin of the first device is connected to the `nCE` pin of the second device in the chain. If there are additional devices, connect the `nCE` pin of the next device to the `nCEO` pin of the previous device. You should leave the `nCEO` pin on the last device in the chain unconnected. To configure properly, all of the target device `CONF_DONE` and `nSTATUS` pins must be tied together. Figure 13–10 shows an example of configuring multiple Cyclone FPGAs using a single configuration device.

Figure 13–10. Configuring Multiple Cyclone FPGAs with a Single Configuration Device



Notes to Figure 13–10:

- (1) The pull-up resistor should be connected to the same supply voltage as the configuration device. The EPC16, EPC8, EPC4, and EPC2 devices' `OE` and `nCS` pins have internal, user-configurable pull-up resistors. If you use internal pull-up resistors, do not use external pull-up resistors on these pins.
- (2) EPC16, EPC8, and EPC4 configuration devices cannot be cascaded.
- (3) The `nCEO` pin is left unconnected for the last device in the chain.
- (4) The `nINIT_CONF` pin is available on EPC16, EPC8, EPC4, and EPC2 devices. If `nINIT_CONF` is not used, `nCONFIG` must be pulled to `VCC` through a resistor.
- (5) The `nINIT_CONF` pin has an internal pull-up resistor that is always active in EPC16, EPC8, EPC4, and EPC2 devices. These devices do not need an external pull-up resistor on the `nINIT_CONF` pin.
- (6) Connect `MSEL0` to the `VCC` supply voltage of I/O Bank it resides in.

When performing multi-device PS configuration, you must generate the configuration device programming file (`.sof`) from each project. Then you must combine multiple `.sof` files using the Quartus II software through the **Convert Programming Files** dialog box.



For more information on how to create Programmer Object Files (.pof) for enhanced configuration devices, see *Application Note 218: Using Enhanced Configuration Devices*. For a description of the various configuration and programming files, see “[Device Configuration Files](#)” on page 13–47.

After the first Cyclone FPGA completes configuration during multi-device configuration, its `nCEO` pin activates the second device’s `nCE` pin, prompting the second device to begin configuration. Because all device `CONF_DONE` pins are tied together, all devices initialize and enter user mode at the same time.

In addition, all `nSTATUS` pins are tied together; therefore, if any device (including the configuration device) detects an error, configuration stops for the entire chain. Also, if the configuration device does not detect `CONF_DONE` going high at the end of configuration, it resets the chain by pulsing its `OE` pin low for a few microseconds. For `CONF_DONE` to reach a high state, enhanced configuration devices wait for 64 `DCLK` cycles after the last configuration bit. EPC2 devices wait for 16 `DCLK` cycles.

If the **Auto-Restart Configuration on Frame Error** option is turned on in the Quartus II software, the Cyclone FPGA releases its `nSTATUS` pins after a reset time-out period (about 30 micro-seconds). When the `nSTATUS` pins are released and pulled high, the configuration device reconfigures the chain. If the **Auto-Restart Configuration on Frame Error** option is not turned on, the devices drive `nSTATUS` low until they are reset with a low pulse on `nCONFIG`.

You can also cascade several EPC2 configuration devices to configure multiple Cyclone FPGAs. When all data from the first configuration device is sent, it drives `nCASC` low, which in turn drives `nCS` on the subsequent EPC2 device. Because a configuration device requires less than one clock cycle to activate a subsequent configuration device, the data stream is uninterrupted. You cannot cascade EPC16, EPC8, and EPC4 configuration devices.

Programming Configuration Devices

Enhanced configuration devices (EPC4, EPC8, and EPC16 devices) and EPC2 devices support in-system programming via JTAG. You can program these configuration devices using the Quartus II software and a download cable (e.g., ByteBlaster II, MasterBlaster™, or ByteBlasterMV™ cables).

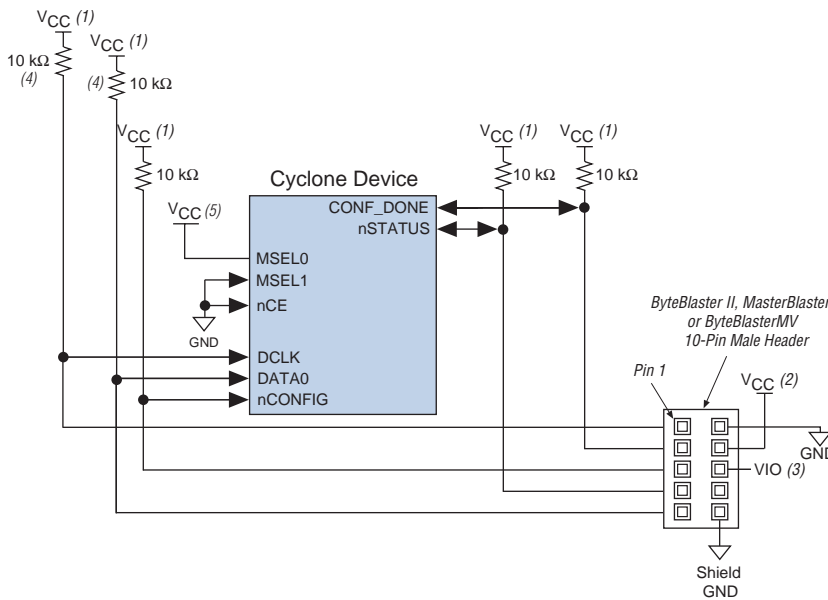
You can also program configuration devices using the Quartus II software, the APU, and the appropriate configuration device programming adapter. Table 13–4 shows which programming adapter to use with each configuration device.

Device	Package	Adapter
EPC16	88-pin Ultra FineLine BGA® 100-pin PQFP	PLMUEPC-88 PLMQEPC-100
EPC8	100-pin PQFP	PLMQEPC-100
EPC4	100-pin PQFP	PLMQEPC-100
EPC2	20-pin J-Lead 32-pin TQFP	PLMJ1213 PLMT1213
EPC1	8-pin DIP 20-pin J-Lead	PLMJ1213 PLMJ1213

PS Configuration Using a Download Cable

Using a download cable in PS configuration, an intelligent host (e.g., your PC) transfers data from a storage device (e.g., your hard drive) to the Cyclone FPGA through a ByteBlaster II, MasterBlaster, or ByteBlasterMV cable. To initiate configuration in this scheme, the download cable generates a low-to-high transition on the `nCONFIG` pin. The programming hardware then sends the configuration data one bit at a time on the device's `DATA0` pin. The data is clocked into the target device using `DCLK` until the `CONF_DONE` goes high.

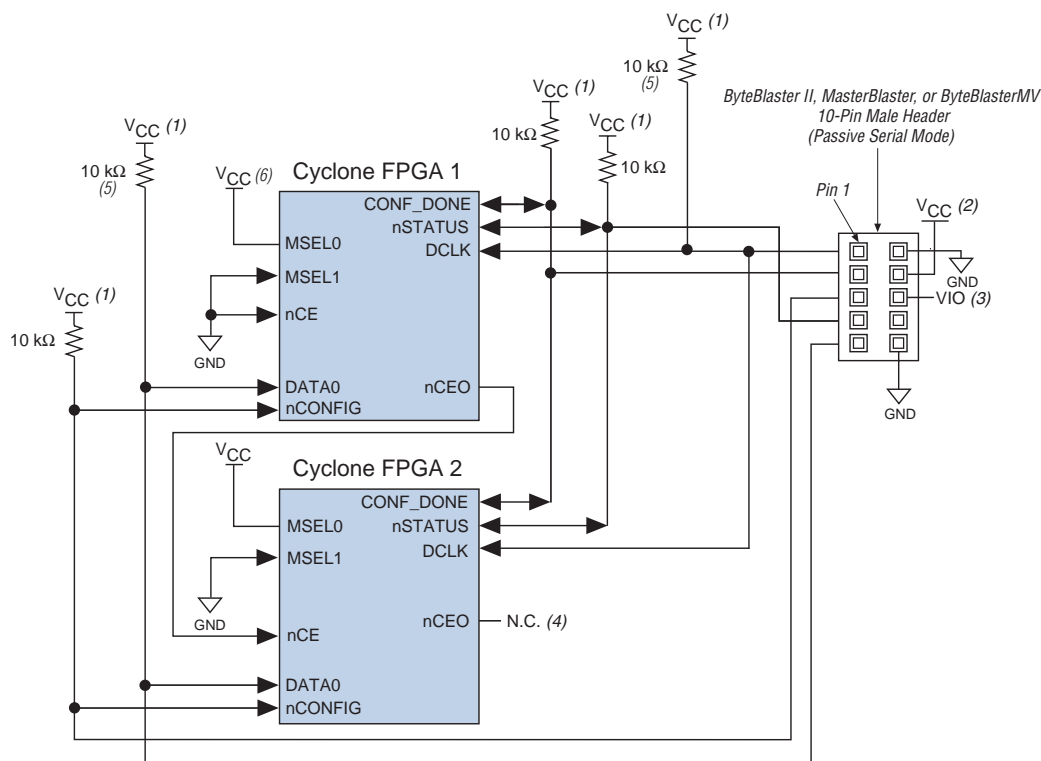
When using programming hardware for the Cyclone FPGA, turning on the **Auto-Restart Configuration on Frame Error** option does not affect the configuration cycle because the Quartus II software must restart configuration when an error occurs. Figure 13–11 shows the PS configuration setup for the Cyclone FPGA using a ByteBlaster II, MasterBlaster, or ByteBlasterMV cable.

Figure 13–11. PS Configuration Circuit with ByteBlaster II, MasterBlaster, or ByteBlasterMV Cable**Notes to Figure 13–11:**

- (1) You should connect the pull-up resistor to the same supply voltage as the MasterBlaster (V_{IO} pin) or ByteBlasterMV cable.
- (2) Power supply voltage: V_{CC} = 3.3-V for the ByteBlaster II, MasterBlaster, and ByteBlasterMV cable.
- (3) Pin 6 of the header is a V_{IO} reference voltage for the MasterBlaster output driver. V_{IO} should match the device's V_{CCIO}. This pin is a no-connect pin for the ByteBlasterMV header.
- (4) The pull-up resistors on DATA0 and DCLK are only needed if the download cable is the only configuration scheme used on your board. This is to ensure that DATA0 and DCLK are not left floating after configuration. For example, if you are also using a configuration device, the pull-up resistors on DATA0 and DCLK are not needed.
- (5) Connect MSEL0 to the V_{cc} supply voltage of I/O Bank it resides in.

You can use the download cable to configure multiple Cyclone FPGAs by connecting each device's nCEO pin to the subsequent device's nCE pin. All other configuration pins are connected to each device in the chain.

Because all CONF_DONE pins are tied together, all devices in the chain initialize and enter user mode at the same time. In addition, because the nSTATUS pins are tied together, the entire chain halts configuration if any device detects an error. In this situation, the Quartus II software must restart configuration; the **Auto-Restart Configuration on Frame Error** option does not affect the configuration cycle. Figure 13–12 shows how to configure multiple Cyclone FPGAs with a ByteBlaster II, MasterBlaster, or ByteBlasterMV cable.

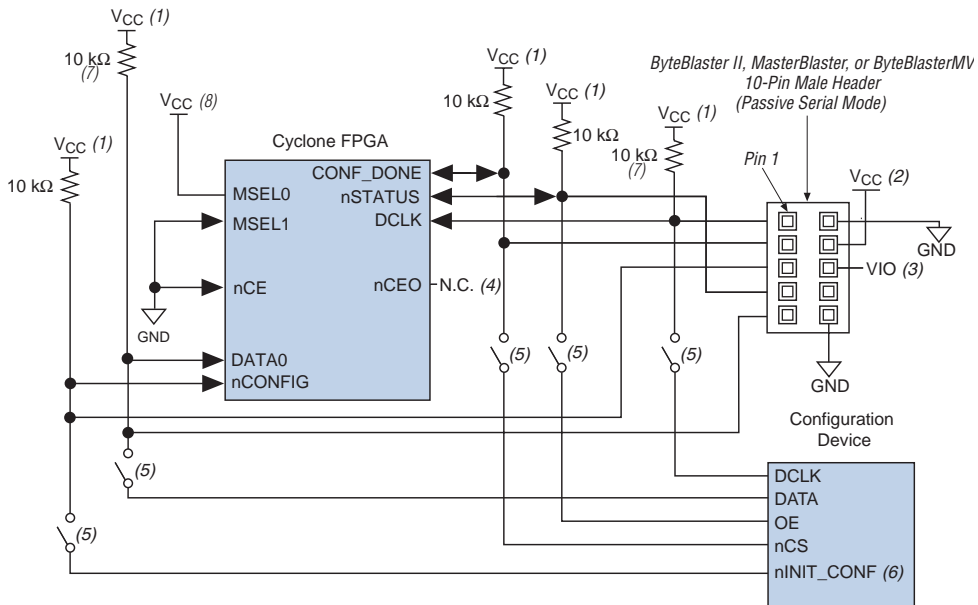
Figure 13–12. Multi-Device PS Configuration with a ByteBlaster II, MasterBlaster, or ByteBlasterMV Cable**Notes to Figure 13–12:**

- (1) You should connect the pull-up resistor to the same supply voltage as the MasterBlaster (V_{IO} pin) or ByteBlasterMV cable.
- (2) Power supply voltage: V_{CC} = 3.3-V for the ByteBlaster II, MasterBlaster, and ByteBlasterMV cable.
- (3) V_{IO} is a reference voltage for the MasterBlaster output driver. V_{IO} should match the device's V_{CCIO}. Refer to the *MasterBlaster Serial/USB Communications Cable Data Sheet* for this value.
- (4) The nCEO pin is left unconnected for the last device in the chain.
- (5) The pull-up resistors on DATA0 and DCLK are only needed if the download cable is the only configuration scheme used on your board. This is to ensure that DATA0 and DCLK are not left floating after configuration. For example, if you are also using a configuration device, the pull-up resistors on DATA0 and DCLK are not needed.
- (6) Connect MSEL0 to the V_{CC} supply voltage of I/O Bank it resides in.

If you are using a ByteBlaster II, MasterBlaster, or ByteBlasterMV cable to configure device(s) on a board that also is populated with configuration devices, you should electrically isolate the configuration devices from the target device(s) and cable. One way to isolate the configuration devices is to add logic, such as a multiplexer, that can select between the configuration devices and the cable. The multiplexer allows bidirectional transfers on the nSTATUS and CONF_DONE signals. Another option is to

add switches to the five common signals (CONF_DONE, nSTATUS, DCLK, nCONFIG, and DATA0) between the cable and the configuration devices. The last option is to remove the configuration devices from the board when configuring with the cable. Figure 13–13 shows a combination of a configuration device and a ByteBlaster II, MasterBlaster, or ByteBlasterMV cable to configure a Cyclone FPGA.

Figure 13–13. Configuring with a Combined PS & Configuration Device Scheme



Notes to Figure 13–13:

- (1) You should connect the pull-up resistor to the same supply voltage as the configuration device.
- (2) Power supply voltage: $V_{CC} = 3.3\text{-V}$ for the ByteBlaster II, MasterBlaster, and ByteBlasterMV cable.
- (3) Pin 6 of the header is a V_{IO} reference voltage for the MasterBlaster output driver. V_{IO} should match the target device's V_{CCIO} . This is a no-connect pin for the ByteBlasterMV header.
- (4) The nCEO pin is left unconnected.
- (5) You should not attempt configuration with a ByteBlaster II, MasterBlaster, or ByteBlasterMV cable while a configuration device is connected to a Cyclone FPGA. Instead, you should either remove the configuration device from its socket when using the download cable or place a switch on the five common signals between the download cable and the configuration device. Remove the ByteBlaster II, MasterBlaster, or ByteBlasterMV cable when configuring with a configuration device.
- (6) If nINIT_CONF is not used, nCONFIG must be pulled to V_{CC} either directly or through a resistor.
- (7) The pull-up resistors on DATA0 and DCLK are only needed if the download cable is the only configuration scheme used on your board. This is to ensure that DATA0 and DCLK are not left floating after configuration. For example, if you are also using a configuration device, the pull-up resistors on DATA0 and DCLK are not needed.
- (8) Connect MSEL0 to the V_{CC} supply voltage of I/O Bank it resides in.



For more information on how to use the ByteBlaster II, MasterBlaster, or ByteBlasterMV cables, see the following documents:

- *ByteBlaster II Parallel Port Download Cable Data Sheet*
- *MasterBlaster Serial/USB Communications Cable Data Sheet*
- *ByteBlasterMV Parallel Port Download Cable Data Sheet*

PS Configuration from a Microprocessor

In PS configuration with a microprocessor, a microprocessor transfers data from a storage device to the target Cyclone FPGA. To initiate configuration in this scheme, the microprocessor must generate a low-to-high transition on the `nCONFIG` pin and the target device must release `nSTATUS`. The microprocessor then places the configuration data one bit at a time on the `DATA0` pin of the Cyclone FPGA. The least significant bit (LSB) of each data byte must be presented first. Data is clocked continuously into the target device using `DCLK` until the `CONF_DONE` signal goes high.

The Cyclone FPGA starts initialization using the internal oscillator after all configuration data is transferred. The device's `CONF_DONE` pin goes high to show successful configuration and the start of initialization. Driving `DCLK` to the device after configuration does not affect device operation.

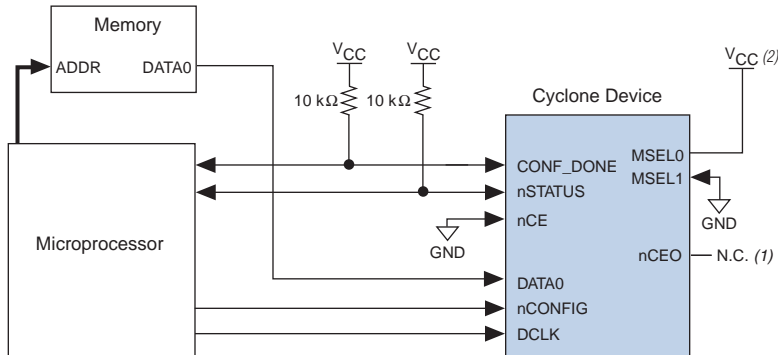
Since the PS configuration scheme is a synchronous scheme, the configuration clock speed must be below the specified maximum frequency to ensure successful configuration. Maximum `DCLK` frequency supported by Cyclone FPGAs is 100 MHz (See [Table 13-5 on page 13-24](#)). No maximum `DCLK` period (i.e., minimum `DCLK` frequency) exists. You can pause configuration by halting `DCLK` for an indefinite amount of time.

If the target device detects an error during configuration, it drives its `nSTATUS` pin low to alert the microprocessor. The microprocessor can then pulse `nCONFIG` low to restart the configuration process. Alternatively, if the **Auto-Restart Configuration on Frame Error** option is turned on in the Quartus II software, the target device releases `nSTATUS` after a reset time-out period. After `nSTATUS` is released, the microprocessor can reconfigure the target device without needing to pulse `nCONFIG` low.

The microprocessor can also monitor the `CONF_DONE` and `INIT_DONE` pins to ensure successful configuration and initialization. If the microprocessor sends all data but `CONF_DONE` and `INIT_DONE` has not gone high, it must reconfigure the target device. `CONF_DONE` should go

high within 1 ms, and `INIT_DONE` should go high within 15 ms. Figure 13–14 shows the circuit for PS configuration with a microprocessor.

Figure 13–14. PS Configuration Circuit with a Microprocessor



Note to Figure 13–14:

- (1) The `nCEO` pin is left unconnected.
- (2) Connect `MSEL0` to the `Vcc` supply voltage of I/O Bank it resides in.

Configuring Cyclone FPGAs with the MicroBlaster Software

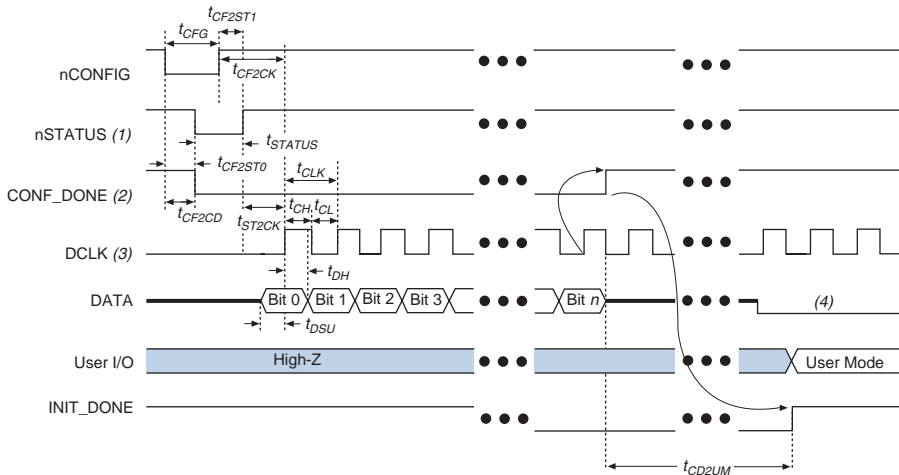
The MicroBlaster™ software driver allows you to configure Altera FPGAs, including Cyclone FPGAs, through the ByteBlaster II or ByteBlasterMV cable in PS mode. The MicroBlaster software driver supports a Raw Binary File (`.rbf`) programming input file and is targeted for embedded PS configuration. The source code is developed for the Windows NT operating system, although you can customize it to run on other operating systems. For more information on the MicroBlaster software driver, see the *Configuring the MicroBlaster Passive Serial Software Driver White Paper* and source files on the Altera web site at www.altera.com.

Passive Serial Timing

For successful configuration using the PS scheme, several timing parameters such as setup, hold, and maximum clock frequency must be satisfied. The enhanced configuration and EPC2 devices are designed to meet these interface timing specifications. If you use a microprocessor or another intelligent host to control the PS interface, ensure that you meet these timing requirements.

Figure 13–15 shows the PS timing waveform for Cyclone FPGAs.

Figure 13–15. PS Timing Waveform for Cyclone FPGAs



Notes to Figure 13–15:

- (1) Upon power-up, the Cyclone FPGA holds `nSTATUS` low for about 100 ms.
- (2) Upon power-up and before configuration, `CONF_DONE` is low.
- (3) In user mode, `DCLK` should be driven high or low when using the PS configuration scheme. When using the AS configuration scheme, `DCLK` is a Cyclone output pin and should not be driven externally.
- (4) `DATA` should not be left floating after configuration. It should be driven high or low, whichever is more convenient.

Table 13–5 contains the PS timing information for Cyclone FPGAs.

Symbol	Parameter	Min	Max	Units
t_{CF2CD}	<code>nCONFIG</code> low to <code>CONF_DONE</code> low		800	ns
t_{CF2ST0}	<code>nCONFIG</code> low to <code>nSTATUS</code> low		800	ns
t_{CF2ST1}	<code>nCONFIG</code> high to <code>nSTATUS</code> high		40 (4)	μ s
t_{CFG}	<code>nCONFIG</code> low pulse width (2)	40		μ s
t_{STATUS}	<code>nSTATUS</code> low pulse width	10	40 (4)	μ s
t_{CF2CK}	<code>nCONFIG</code> high to first rising edge on <code>DCLK</code>	40		μ s
t_{ST2CK}	<code>nSTATUS</code> high to first rising edge on <code>DCLK</code>	1		μ s
t_{DSU}	Data setup time before rising edge on <code>DCLK</code>	7		ns
t_{DH}	Data hold time after rising edge on <code>DCLK</code>	0		ns

Table 13–5. PS Timing Parameters for Cyclone Devices *Note (1) (Part 2 of 2)*

Symbol	Parameter	Min	Max	Units
t_{CH}	DCLK high time	4		ns
t_{CL}	DCLK low time	4		ns
t_{CLK}	DCLK period	10		ns
f_{MAX}	DCLK maximum frequency		100	MHz
t_{CD2UM}	CONF_DONE high to user mode (3)	6	20	μ s

Notes to Table 13–5:

- (1) This information is preliminary.
- (2) This value applies only if the internal oscillator is selected as the clock source for device initialization. If the clock source is CLKUSR, multiply the clock period by 270 to obtain this value. CLKUSR must be running during this period to reset the device.
- (3) The minimum and maximum numbers apply only if the internal oscillator is chosen as the clock source for device initialization. If the clock source is CLKUSR, multiply the clock period by 140 to obtain this value.
- (4) You can obtain this value if you do not delay configuration by extending the nSTATUS low-pulse width.

JTAG-Based Configuration

JTAG has developed a specification for boundary-scan testing. This boundary-scan test (BST) architecture offers the capability to efficiently test components on printed circuit boards (PCBs) with tight lead spacing. The BST architecture can test pin connections without using physical test probes and capture functional data while a device is operating normally. You can also use the JTAG circuitry to shift configuration data into Cyclone FPGAs. The Quartus II software automatically generates .sof files that can be used for JTAG configuration.



For more information on JTAG boundary-scan testing, see *Application Note 39: IEEE 1149.1 (JTAG) Boundary-Scan Testing in Altera Devices*.

A device operating in JTAG mode uses four required pins, TDI, TDO, TMS, and TCK. Cyclone FPGAs do not support the optional TRST pin. The three JTAG input pins, TCK, TDI, and TMS, have weak internal pull-up resistors. All user I/O pins are tri-stated during JTAG configuration.

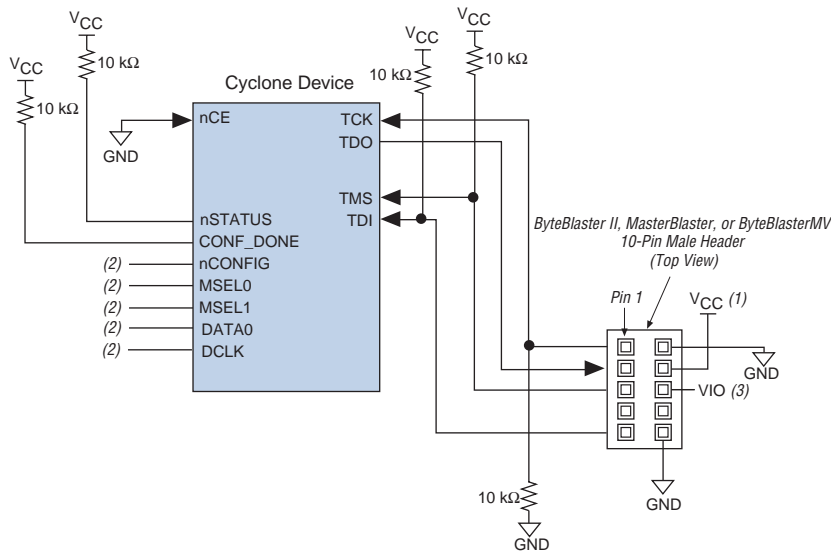
Cyclone is designed such that JTAG instructions have precedence over any device operating modes. So JTAG configuration can take place without waiting for other configuration to complete (e.g., configuration with serial or enhanced configuration devices). If you attempt JTAG configuration in Cyclone FPGAs during non-JTAG configuration, non-JTAG configuration will be terminated and JTAG configuration will be initiated.

Table 13–6 shows each JTAG pin’s function.

Pin	Description	Function
TDI	Test data input	Serial input pin for instructions as well as test and programming data. 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 on the rising edge of TCK. Therefore, TMS must be set up before the rising edge of TCK. TMS is evaluated on the rising edge of TCK.
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.

JTAG Configuration Using a Download Cable

During JTAG configuration, data is downloaded to the device on the board through a ByteBlaster II, ByteBlasterMV, or MasterBlaster download cable. Configuring devices through a cable is similar to programming devices in-system. See Figure 13–16 for pin connection information.

Figure 13–16. JTAG Configuration of Single Cyclone FPGA**Notes to Figure 13–16:**

- (1) You should connect the pull-up resistor to the same supply voltage as the download cable.
- (2) You should connect the nCONFIG, MSEL0, and MSEL1 pins to support a non-JTAG configuration scheme. If you only use JTAG configuration, connect nCONFIG to V_{CC}, and MSEL0 and MSEL1 to ground. Pull DATA0 and DCLK to high or low.
- (3) V_{IO} is a reference voltage for the MasterBlaster output driver. V_{IO} should match the device's V_{CCIO}. Refer to the *MasterBlaster Serial/USB Communications Cable Data Sheet* for this value.

To configure a single device in a JTAG chain, the programming software places all other devices in bypass mode. In bypass mode, devices pass programming data from the TDI pin to the TDO pin through a single bypass register without being affected internally. This scheme enables the programming software to program or verify the target device. Configuration data driven into the device appears on the TDO pin one clock cycle later.

Cyclone FPGAs have dedicated JTAG pins. Not only can you perform JTAG testing on Cyclone FPGAs before and after, but also during configuration. While other device families do not support JTAG testing during configuration, Cyclone FPGAs support the BYPASS, IDCODE, and SAMPLE instructions during configuration without interrupting configuration. All other JTAG instructions may only be issued by first interrupting configuration and reprogramming I/O pins using the CONFIG_IO instruction.

The `CONFIG_IO` instruction allows I/O buffers to be configured via the JTAG port, and when issued, interrupts configuration. This instruction allows you to perform board-level testing prior to configuring the Cyclone FPGA or waiting for a configuration device to complete configuration. Once configuration has been interrupted and JTAG testing is complete, the part must be reconfigured via JTAG (`PULSE_CONFIG` instruction) or by pulsing `nCONFIG` low.

The chip-wide reset and output enable pins on Cyclone FPGAs do not affect JTAG boundary-scan or programming operations. Toggling these pins does not affect JTAG operations (other than the usual boundary-scan operation).

When designing a board for JTAG configuration of Cyclone FPGAs, you should consider the regular configuration pins. [Table 13–7](#) shows how you should connect these pins during JTAG configuration.

Table 13–7. JTAG Termination of Unused Pins

Signal	Description
<code>nCE</code>	Drive all Cyclone devices in the chain low by connecting <code>nCE</code> to ground, pulling it down via a resistor, or driving it low by some control circuitry.
<code>nSTATUS</code>	Pulled to V_{CC} through a 10-k Ω resistor. When configuring multiple devices in the same JTAG chain, pull up each <code>nSTATUS</code> pin to V_{CC} individually. (1)
<code>CONF_DONE</code>	Pulled to V_{CC} through a 10-k Ω resistor. When configuring multiple devices in the same JTAG chain, pull up each <code>CONF_DONE</code> pin to V_{CC} individually. (1)
<code>nCONFIG</code>	Driven high by connecting to V_{CC} , pulling up through a resistor, or driving it high by some control circuitry.
<code>MSEL0</code> , <code>MSEL1</code>	Do not leave these pins floating. These pins support whichever non-JTAG configuration is used in production. If only JTAG configuration is used, you should tie these pins to ground.
<code>DCLK</code>	Do not leave these pins floating. Drive low or high, whichever is more convenient.
<code>DATA0</code>	Do not leave these pins floating. Drive low or high, whichever is more convenient.

Note to Table 13–7:

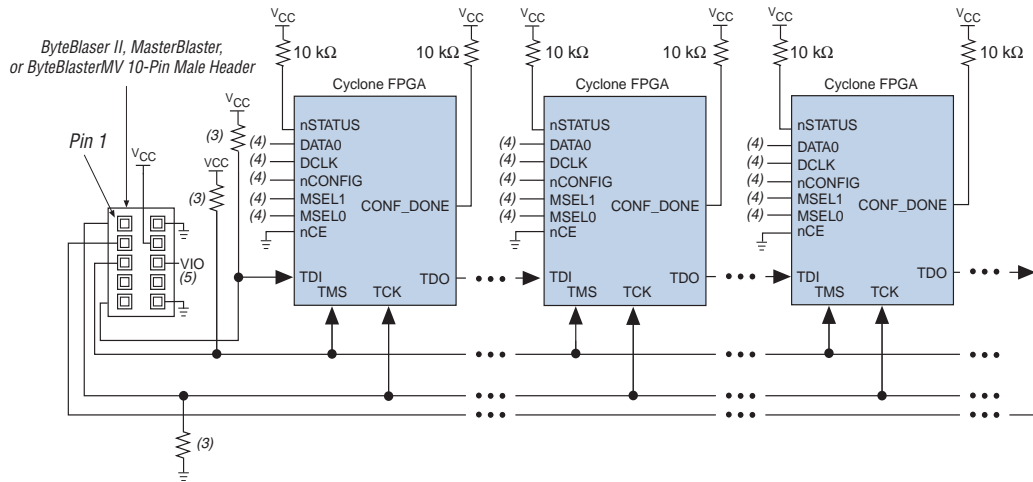
- (1) `nSTATUS` going low in the middle of JTAG configuration indicates that an error has occurred; `CONF_DONE` going high at the end of JTAG configuration indicates successful configuration.

JTAG Configuration of Multiple Devices

When programming a JTAG device chain, one JTAG-compatible header, such as the ByteBlaster II header, is connected to several devices. The number of devices in the JTAG chain is limited only by the drive capacity of the download cable. However, when four or more devices are connected in a JTAG chain, Altera recommends buffering the `TCK`, `TDI`, and `TMS` pins with an on-board buffer.

JTAG-chain device configuration is ideal when the system contains multiple devices, or when testing your system using JTAG BST circuitry. [Figure 13–17](#) shows multi-device JTAG configuration.

Figure 13–17. Multi-Device JTAG Configuration



Notes to [Figure 13–17](#):

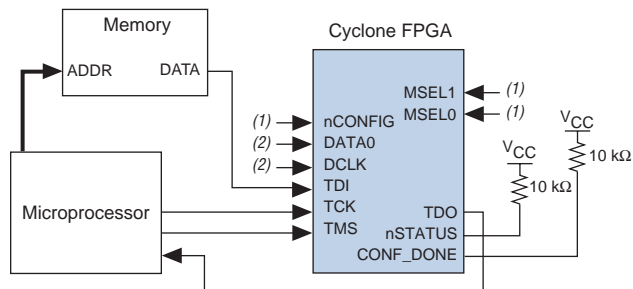
- (1) Cyclone, APEX™ II, APEX 20K, Mercury™, ACEX® 1K, and FLEX® 10K devices can be placed within the same JTAG chain for device programming and configuration.
- (2) For more information on all configuration pins connected in this mode, refer to [Table 13–6 on page 13–26](#).
- (3) These pull-up/pull-down resistors are 10 kΩ.
- (4) Connect the nCONFIG, MSEL0, and MSEL1 pins to support a non-JTAG configuration scheme. If only JTAG configuration is used, connect nCONFIG to V_{CC}, and MSEL0 and MSEL1 to ground. Pull DATA0 and DCLK to either high or low.
- (5) V_{IO} is a reference voltage for the MasterBlaster output driver. V_{IO} should match the device's V_{CCIO}. Refer to the *MasterBlaster Serial/USB Communications Cable Data Sheet* for this value.

The Quartus II software verifies successful JTAG configuration upon completion. The software checks the state of CONF_DONE through the JTAG port. If CONF_DONE is not high, the Quartus II software indicates that configuration has failed. If CONF_DONE is high, the software indicates that configuration was successful.



If V_{CCIO} is tied to 3.3-V, both the I/O pins and the JTAG TDO port drive at 3.3-V levels.

[Figure 13–18](#) shows the JTAG configuration of a Cyclone FPGA with a microprocessor.

Figure 13–18. JTAG Configuration of Cyclone FPGAs with a Microprocessor**Notes to Figure 13–18:**

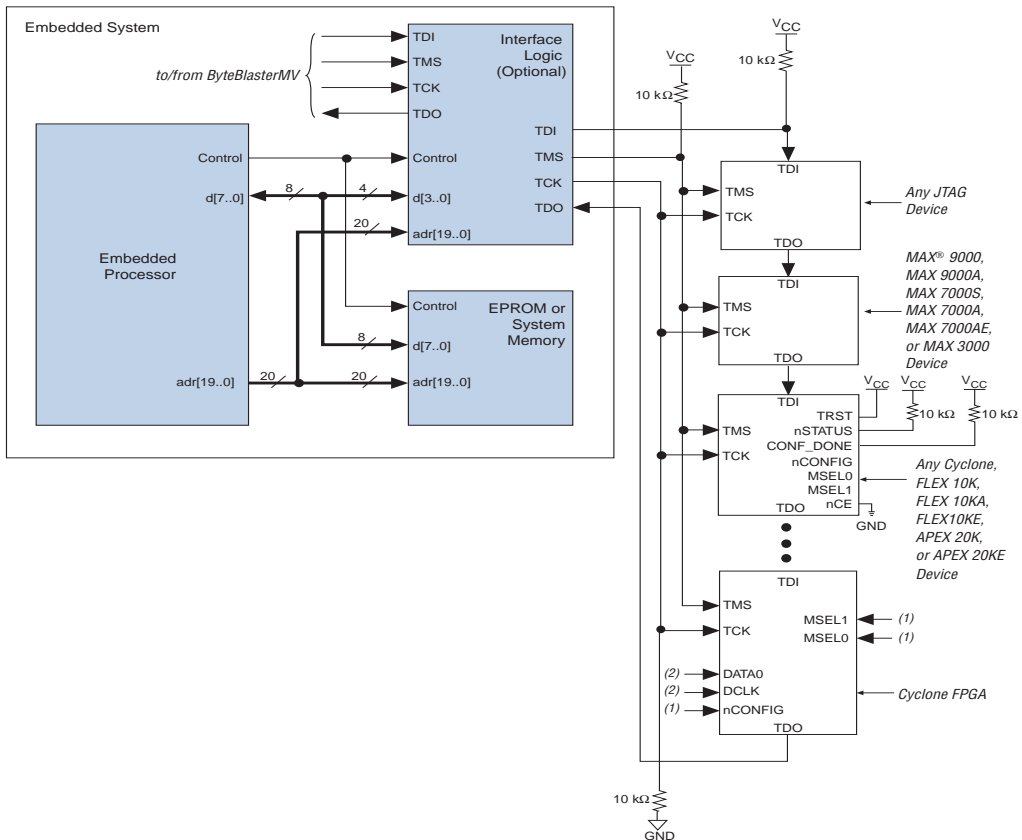
- (1) Connect the nCONFIG, MSEL1, and MSEL0 pins to support a non-JTAG configuration scheme. If your design only uses JTAG configuration, connect the nCONFIG pin to V_{CC} and the MSEL1 and MSEL0 pins to ground.
- (2) Pull DATA0 and DCLK to either high or low.

Connecting the JTAG Chain to the Embedded Processor

There are two ways to connect the JTAG chain to the embedded processor. The most straightforward method is to connect the embedded processor directly to the JTAG chain. In this method, four of the processor pins are dedicated to the JTAG interface, saving board space but reducing the number of available embedded processor pins.

Figure 13–19 illustrates the second method, which is to connect the JTAG chain to an existing bus through an interface programmable logic device (PLD). In this method, the JTAG chain becomes an address on the existing bus. The processor then reads from or writes to the address representing the JTAG chain.

Figure 13–19. Embedded System Block Diagram



Notes to Figure 13–19:

- (1) Connect the nCONFIG, MSEL1, and MSEL0 pins to support a non-JTAG configuration scheme. If your design only uses JTAG configuration, connect the nCONFIG pin to V_{CC} and the MSEL1 and MSEL0 pins to ground.
- (2) Pull DATA0 and DCLK to either high or low.

Configuring Cyclone FPGAs with JRunner

JRunner is a software driver that allows you to configure Altera FPGAs, including Cyclone FPGAs, through the ByteBlaster II or ByteBlasterMV cables in JTAG mode. The programming input file supported is in **.rbf** format. JRunner also requires a Chain Description File (**.cdf**) generated by the Quartus II software. JRunner is targeted for embedded JTAG configuration. The source code has been developed for the Windows NT operating system (OS). You can customize the code to make it run on

other platforms. For more information on the JRunner software driver, see *JRunner Software Driver: An Embedded Solution to the JTAG Configuration* and the source files on the Altera web site.

Jam STAPL

Jam STAPL, JEDEC standard JESD-71, is a standard file format for in-system programmability (ISP) purposes. Jam STAPL supports programming or configuration of programmable devices and testing of electronic systems, using the IEEE 1149.1 JTAG interface. Jam STAPL is a freely licensed open standard.



Both JTAG connection methods should include space for the MasterBlaster or ByteBlasterMV header connection. The header is useful during prototyping because it allows you to verify or modify the Cyclone FPGA's contents. During production, you can remove the header to save cost.

Program Flow

The Jam Player provides an interface for manipulating the IEEE Std. 1149.1 JTAG TAP state machine. The TAP controller is a 16-state, state machine that is clocked on the rising edge of TCK, and uses the TMS pin to control JTAG operation in a device. [Figure 13–20](#) shows the flow of an IEEE Std. 1149.1 TAP controller state machine.

send JTAG data to the device involve moving the TAP controller through either the data register leg or the instruction register leg of the state machine. For example, loading a JTAG instruction involves moving the TAP controller to the `SHIFT_IR` state and shifting the instruction into the instruction register through the TDI pin. Next, the TAP controller is moved to the `RUN_TEST/IDLE` state where a delay is implemented to allow the instruction time to be latched. This process is identical for data register scans, except that the data register leg of the state machine is traversed.

The high-level Jam instructions are the `DRSCAN` instruction for scanning the JTAG data register, the `IRSCAN` instruction for scanning the instruction register, and the `WAIT` command that causes the state machine to sit idle for a specified period of time. Each leg of the TAP controller is scanned repeatedly, according to instructions in the `.jbc` file, until all of the target devices are programmed.

Figure 13–21 illustrates the functional behavior of the Jam Player when it parses the `.jbc` file. When the Jam Player encounters a `DRSCAN`, `IRSCAN`, or `WAIT` instruction, it generates the proper data on TCK, TMS, and TDI to complete the instruction. The flow diagram shows branches for the `DRSCAN`, `IRSCAN`, and `WAIT` instructions. Although the Jam Player supports other instructions, they are omitted from the flow diagram for simplicity.

Figure 13–21. Jam Player Flow Diagram (Part 1 of 2)

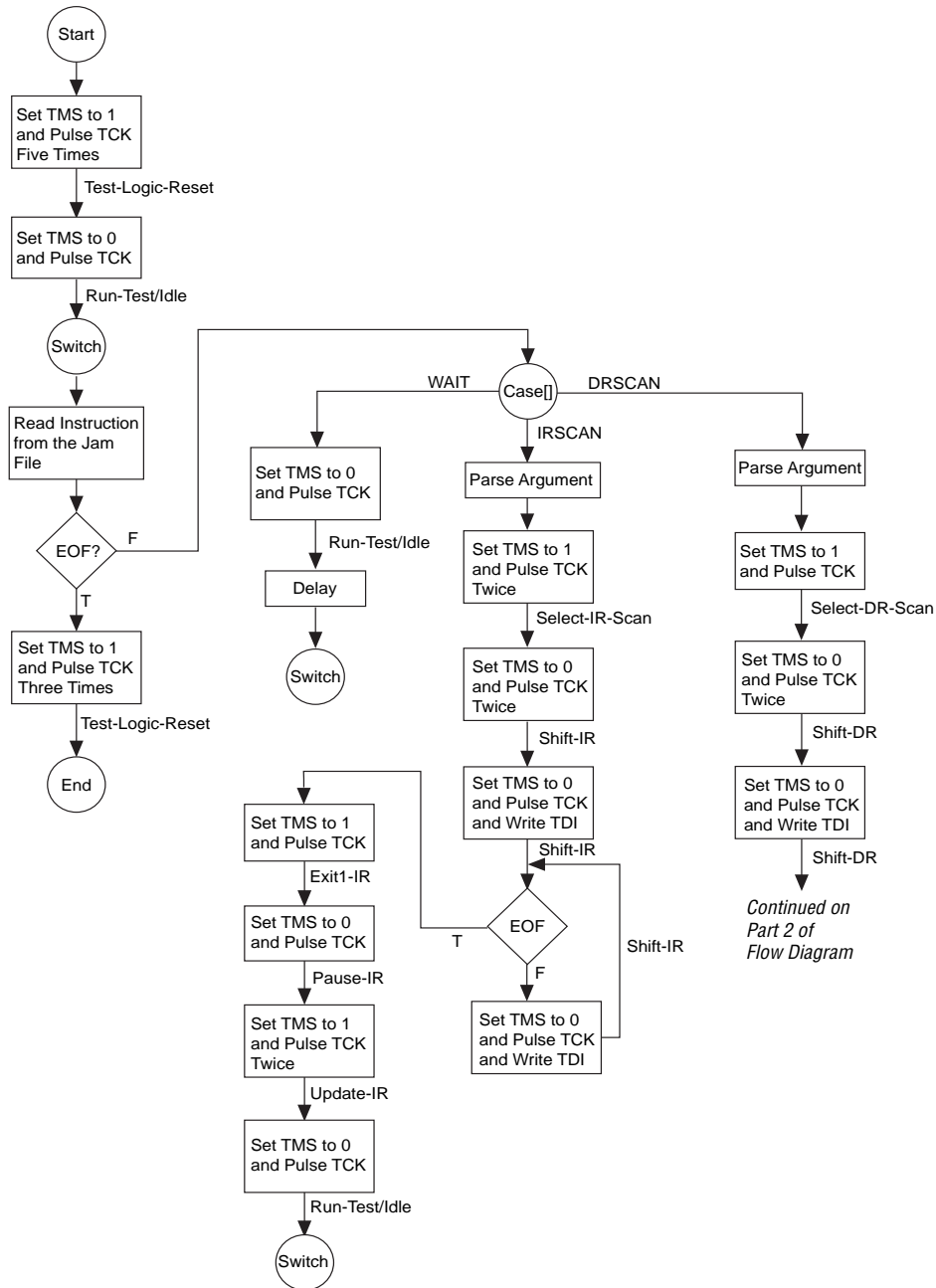
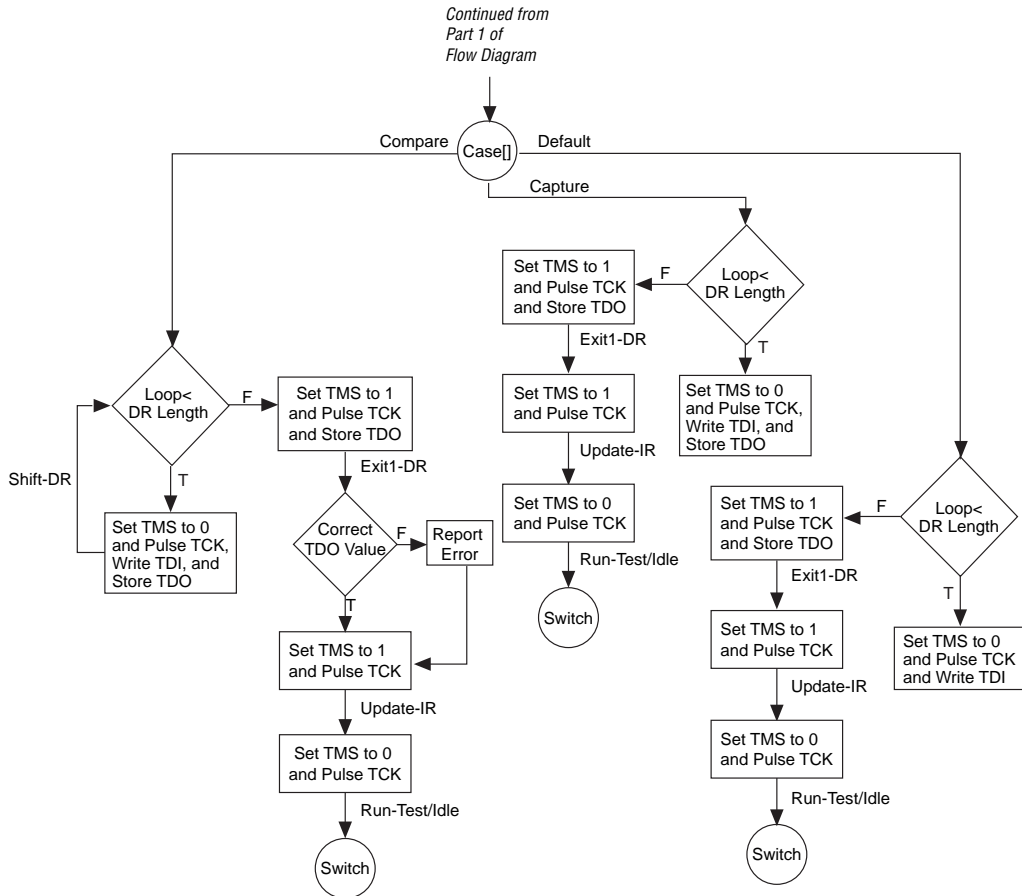


Figure 13–22. Jam Player Flow Diagram (Part 2 of 2)



Execution of a Jam program starts at the beginning of the program. The program flow is controlled using GOTO, CALL/RETURN, and FOR/NEXT structures. The GOTO and CALL statements refer to labels that are symbolic names for program statements located elsewhere in the Jam program. The language itself enforces almost no constraints on the organizational structure or control flow of a program.



The Jam language does not support linking multiple Jam programs together or including the contents of another file into a Jam program.

Jam Instructions

Each Jam statement begins with one of the instruction names listed in [Table 13–8](#). The instruction names, including the names of the optional instructions, are reserved keywords that you cannot use as variable or label identifiers in a Jam program.

Table 13–8. Instruction Names

BOOLEAN	INTEGER	PREIR
CALL	IRSCAN	PRINT
CRC	IRSTOP	PUSH
DRSCAN	LET	RETURN
DRSTOP	NEXT	STATE
EXIT	NOTE	WAIT
EXPORT	POP	VECTOR (1)
FOR	POSTDR	VMAP (1)
GOTO	POSTIR	–
IF	PREDR	–

Note to Table 13–8:

- (1) This instruction name is an optional language extension.

[Table 13–9](#) shows the state names that are reserved keywords in the Jam language. These keywords correspond to the state names specified in the IEEE Std. 1149.1 JTAG specification.

Table 13–9. Reserved Keywords (Part 1 of 2)

IEEE Std. 1149.1 JTAG State Names	Jam Reserved State Names
Test-Logic-Reset	RESET
Run-Test-Idle	IDLE
Select-DR-Scan	DRSELECT
Capture-DR	DRCAPTURE
Shift-DR	DRSHIFT
Exit1-DR	DREXIT1
Pause-DR	DRPAUSE
Exit2-DR	DREXIT2
Update-DR	DRUPDATE
Select-IR-Scan	IRSELECT
Capture-IR	IRCAPTURE

Table 13–9. Reserved Keywords (Part 2 of 2)

IEEE Std. 1149.1 JTAG State Names	Jam Reserved State Names
Shift-IR	IRSHIFT
Exit1-IR	IREXIT1
Pause-IR	IRPAUSE
Exit2-IR	IREXIT2
Update-IR	IRUPDATE

Example Jam File that Reads the IDCODE

The following illustrates the flexibility and utility of the Jam STAPL. The example code reads the IDCODE out of a single device in a JTAG chain.



The array variable, `I_IDCODE`, is initialized with the IDCODE instruction bits ordered the LSB first (on the left) to most significant bit (MSB) (on the right). This order is important because the array field in the IRSCAN instruction is always interpreted and sent, MSB to LSB.

Example Jam File Reading IDCODE

```

BOOLEAN read_data[32];
BOOLEAN I_IDCODE[10] = BIN 1001101000; `assumed
BOOLEAN ONES_DATA[32] = HEX FFFFFFFF;
INTEGER i;
`Set up stop state for IRSCAN
IRSTOP IRPAUSE;
`Initialize device
STATE RESET;
IRSCAN 10, I_IDCODE[0..9]; `LOAD IDCODE INSTRUCTION
STATE IDLE;
WAIT 5 USEC, 3 CYCLES;
DRSCAN 32, ONES_DATA[0..31], CAPTURE read_data[0..31];
`CAPTURE IDCODE
PRINT "IDCODE:";
FOR i=0 to 31;
PRINT read_data[i];
NEXT i;
EXIT 0;

```

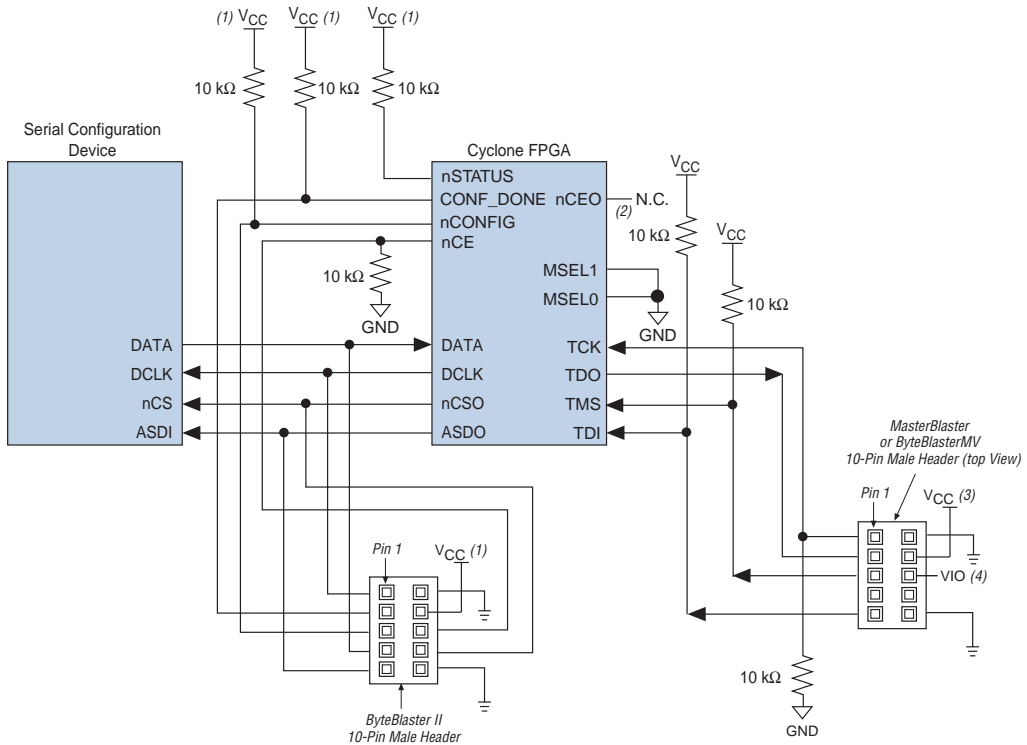
Combining Configuration Schemes

This section shows you how to configure Cyclone FPGAs using multiple configuration schemes on the same board.

Active Serial & JTAG

You can combine the AS configuration scheme with JTAG-based configuration. Set the `MSEL[1..0]` pins to 00 in this setup, as shown in [Figure 13–23](#). This setup uses two 10-pin download cable headers on the board. The first header programs the serial configuration device in-system via the AS programming interface, and the second header configures the Cyclone FPGA directly via the JTAG interface.

If you try configuring the device using both schemes simultaneously, JTAG configuration takes precedence and AS configuration will be terminated.

Figure 13–23. Combining AS & JTAG Configuration**Notes to Figure 13–23:**

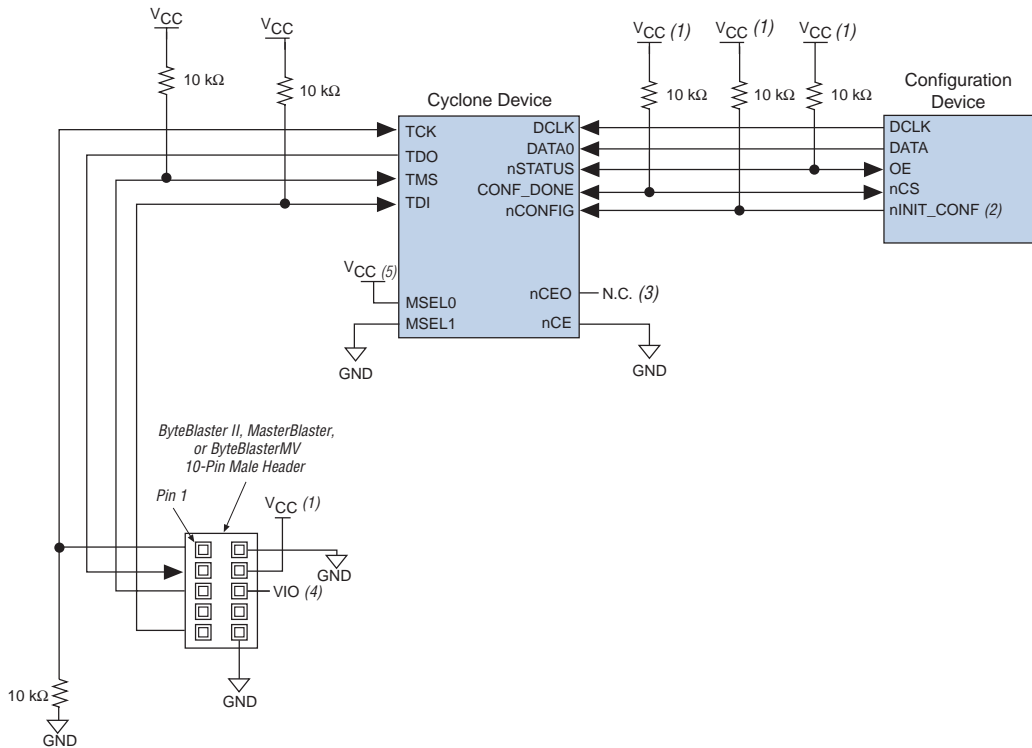
- (1) Connect these pull-up resistors to 3.3 V.
- (2) The nCEO pin is left unconnected.
- (3) You should connect the pull-up resistor to the same supply voltage as the download cable.
- (4) V_{IO} is a reference voltage for the MasterBlaster output driver. V_{IO} should match the device's V_{CCIO}. Refer to the *MasterBlaster Serial/USB Communications Cable Data Sheet* for this value.

Passive Serial & JTAG

The PS- and JTAG-based configuration are also supported on the same board. Set the MSEL[1..0] pins to 01 in this setup. [Figure 13–24](#) shows the pin connections required for configuring Cyclone FPGAs using PS and JTAG interfaces on the same board. The JTAG chain only connects to the Cyclone FPGA in [Figure 13–24](#), but could also connect to the configuration device for in-system programming of that device.

If you try configuring the device using both schemes simultaneously, JTAG configuration takes precedence and PS configuration will be terminated.

Figure 13–24. Combining PS & JTAG Configuration



Notes to Figure 13–24:

- (1) The pull-up resistor should be connected to the same supply voltage as the configuration device. The EPC16, EPC8, EPC4, and EPC2 devices' OE and nCS pins have internal, user-configurable pull-up resistors. If you use internal pull-up resistors, do not use external pull-up resistors on these pins.
- (2) The nINIT_CONF pin is available on EPC16, EPC8, EPC4, and EPC2 devices. If nINIT_CONF is not used, nCONFIG must be pulled to V_{CC} through a resistor.
- (3) The nCEO pin is left unconnected for the last device in the chain.
- (4) V_{IO} is a reference voltage for the MasterBlaster output driver. V_{IO} should match the device's V_{CCIO}. Refer to the *MasterBlaster Serial/USB Communications Cable Data Sheet* for this value.
- (5) Connect MSEL0 to the V_{CC} supply voltage of the I/O Bank it resides in.

Device Options

You can set Cyclone FPGA options in Altera's Quartus II development software using the **Device & Pin Options** dialog box. Select **Compiler Settings** (Processing menu), then click on the **Chips & Devices** tab. Figure 13–25 shows the **Device & Pin Options** dialog box.

Figure 13–25. Configuration Options Dialog Box

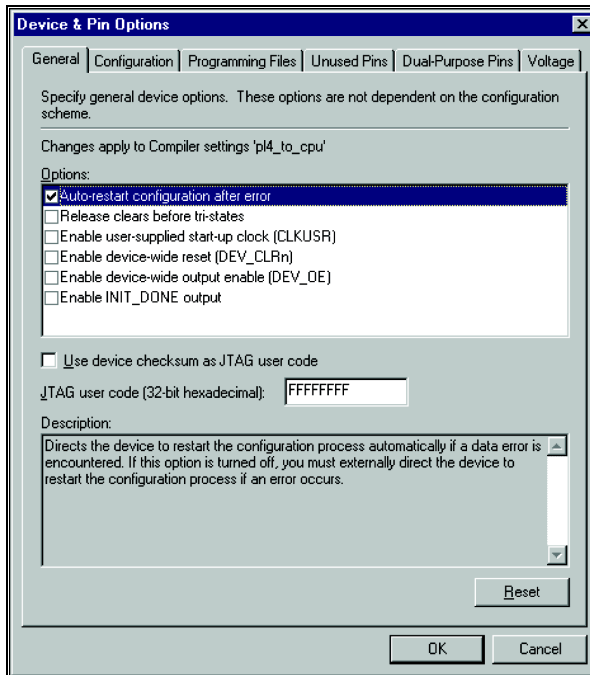


Table 13–10 summarizes each of these options.

Table 13–10. Cyclone Configuration Option Bits (Part 1 of 2)			
Device Option	Option Usage	Default Configuration (Option Off)	Modified Configuration (Option On)
Auto-restart configuration on frame error	If a data error occurs during configuration, you can choose how to restart configuration.	The configuration process stops until you direct the device to restart configuration. The <code>nSTATUS</code> pin is driven low when an error occurs. When <code>nCONFIG</code> is pulled low and then high, the device begins to reconfigure.	<p>The configuration process restarts automatically. The <code>nSTATUS</code> pin drives low and releases. The <code>nSTATUS</code> pin is then pulled to V_{CC} by the pull-up resistor, indicating that configuration can restart.</p> <p>In the configuration device scheme, if the target device's <code>nSTATUS</code> pin is tied to the configuration device's <code>OE</code> pin, the <code>nSTATUS</code> reset pulse resets the configuration device automatically. The configuration device then releases its <code>OE</code> pin (which is pulled high) and reconfiguration begins.</p> <p>If an error occurs during passive configuration, the device can be reconfigured without the system having to pulse <code>nCONFIG</code>. After <code>nSTATUS</code> goes high, reconfiguration can begin.</p>
Release clears before tri-states	During configuration, the device I/O pins are tri-stated. During initialization, you choose the order for releasing the tri-states and clearing the registers.	The device releases the tri-states on its I/O pins before releasing the clear signal on its registers.	The device releases the clear signals on its registers before releasing the tri-states. You can use this option to allow the design to operate before it drives out, so all outputs do not start up low.
Enable chip-wide reset	Enables a single pin to reset all device registers.	Chip-wide reset is not enabled. The <code>DEV_CLRn</code> pin is available as a user I/O pin.	Chip-wide reset is enabled for all registers in the device. All registers are cleared when the <code>DEV_CLRn</code> pin is driven low.

Table 13–10. Cyclone Configuration Option Bits (Part 2 of 2)

Device Option	Option Usage	Default Configuration (Option Off)	Modified Configuration (Option On)
Enable chip-wide output enable	Enables a single pin to control all device tri-states.	Chip-wide output enable is not enabled. The DEV_OE pin is available as a user I/O pin.	Chip-wide output enable is enabled for all device tri-states. After configuration, all user I/O pins are tri-stated when DEV_OE is low.
Enable INIT_DONE output	Enables a pin to drive out a signal when the initialization process is complete and the device has entered user mode.	The INIT_DONE signal is not available. The INIT_DONE pin is available as a user I/O pin.	The INIT_DONE signal is available on the open-drain INIT_DONE pin. This pin drives low during configuration. After initialization, it is released and pulled high externally. The INIT_DONE pin must be connected to a 10-k Ω pull-up resistor. If the INIT_DONE output is used, the INIT_DONE pin cannot be used as a user I/O pin.
Data Compression	Enables Cyclone FPGAs to receive compressed configuration bit stream in Active and PS configuration schemes.	The Quartus II software generates uncompressed programming files and Cyclone FPGAs do not decompress data.	The Quartus II software generates compressed programming files and Cyclone FPGAs decompress the bit stream during configuration.

Device Configuration Pins

Table 13–11 summarizes the Cyclone FPGA configuration pins.

<i>Table 13–11. Pin Functions (Part 1 of 3)</i>				
Pin Name	User Mode	Configuration Scheme	Pin Type	Description
MSEL1 MSEL0	–	All	Input	Two-bit configuration input. Sets the Cyclone device configuration scheme. After configuration, the Cyclone FPGA is not affected by logic levels on this pin.
nSTATUS	–	All	Bidirectional open-drain	The device drives nSTATUS low immediately after power-up and releases it within 5 μ s. (When using a configuration device, the configuration device holds nSTATUS low for up to 200 ms.) The nSTATUS pin must be pulled up to V _{CC} with a 10-k Ω resistor. If an error occurs during configuration, nSTATUS is pulled low by the target device. If an external source drives the nSTATUS pin low during configuration or initialization, the target device enters an error state. Driving nSTATUS low after configuration and initialization does not affect the configured device. However, if a configuration device is used, driving nSTATUS low will cause that device to attempt to configure the Cyclone FPGA.
nCONFIG	–	All	Input	Configuration control input. A low transition resets the target device; a low-to-high transition begins configuration. All I/O pins go tri-state when setting nCONFIG low.

Table 13–11. Pin Functions (Part 2 of 3)

Pin Name	User Mode	Configuration Scheme	Pin Type	Description
CONF_DONE	–	All	Bidirectional open-drain	<p>Status output. The target device drives the CONF_DONE pin low before and during configuration. Once all configuration data is received without error and the initialization clock cycle starts, the target device releases CONF_DONE.</p> <p>Status input. After all data is received and CONF_DONE goes high, the target device initializes and enters user mode.</p> <p>The CONF_DONE pin must be pulled to V_{CC} with a 10-kΩ resistor. An external source can drive this pin low to delay the initialization process, except when configuring with a configuration device. Driving CONF_DONE low after configuration and initialization does not affect the configured device.</p>
DCLK	–	PS AS	Input (PS) Output (AS)	In PS configuration, the clock input clocks data from an external source into the target device. In AS configuration, DCLK is an output from the Cyclone FPGA that provides timing for the configuration interface. After configuration, the logic levels on this pin do not affect the Cyclone FPGA.
ASDO	I/O	AS	Output	Control signal from the Cyclone FPGA to the serial configuration device in AS mode used to read out configuration data.
nCSO	I/O	AS	Output	Control signal from the Cyclone FPGA to the serial configuration device in AS mode that enables the configuration device.
nCE	–	All	Input	Active-low chip enables. The nCE pin activates the device with a low signal to allow configuration and should be tied low for single device configuration. The nCE pin must be held low during configuration, initialization, and user mode.
nCEO	I/O	Multi-device	Output	Output that drives low when device configuration is complete. During multi-device configuration, this pin feeds a subsequent device's nCE pin.
CLKUSR	I/O	All	Input	Optional user-supplied clock input. Synchronizes the initialization of one or more devices.

Table 13–11. Pin Functions (Part 3 of 3)

Pin Name	User Mode	Configuration Scheme	Pin Type	Description
DATA0	–	Configuration device PS PPA FPP	Input	Data input. In serial configuration mode, bit-wide configuration data is presented to the target device on the DATA0 pin.
INIT_DONE	I/O	All	Output open-drain	Status pin. Can be used to indicate when the device has initialized and is in user mode. The INIT_DONE pin must be pulled to V _{CC} with a 10-k ohm resistor. The INIT_DONE pin drives low during configuration. Before and after configuration, the INIT_DONE pin is released and is pulled to V _{CC} by an external pull-up resistor. Because INIT_DONE is tri-stated before configuration, it is pulled high by the external pull-up resistor. Thus, the monitoring circuitry must be able to detect a low-to-high transition. This option is set in the Quartus II software.
DEV_OE	I/O	All	Input	Optional pin that allows the user to override all tri-states on the device. When this pin is driven low, all I/O pins are tri-stated; when this pin is driven high, all I/O pins behave as programmed. This option is set in the Quartus II software.
DEV_CLRn	I/O	All	Input	Optional pin that allows you to override all clears on all device registers. When this pin is driven low, all registers are cleared; when this pin is driven high, all registers behave as programmed. This option is set in the Quartus II software.
TDI	JTAG pins	All	Input	JTAG pins. JTAG pins must be kept stable before and during configuration. JTAG pin stability prevents accidental loading of JTAG instructions.
TDO			Output	
TMS			Input	
TCK			Input	

Device Configuration Files

The Quartus II software can create one or more configuration and programming files to support the configuration schemes discussed in this application note. This section describes these files.

SRAM Object File (.sof)

You should use an .sof during PS and JTAG configuration when the data is downloaded directly from the ByteBlaster II, MasterBlaster, or ByteBlasterMV download cables. For Cyclone FPGAs, the Quartus II

Compiler's Assembler module automatically creates the **.sof** file for each device in your design. The Quartus II software controls the configuration sequence and automatically inserts the appropriate headers into the configuration data stream. All other configuration files are created from the **.sof**.

Programmer Object File (.pof)

A **.pof** is used by the Altera programming hardware to program a configuration device, including serial configuration devices and enhanced configuration devices. A **.pof** is automatically generated when a Cyclone project is compiled for the configuration device selected in the **Configuration** dialog box.

Raw Binary File (.rbf)

The **.rbf** is a binary file (e.g., one byte of **.rbf** data is eight configured bits 10000101 (85 Hex)) containing the configuration data. Store data so that the LSB of each data byte is loaded first. A mass storage device can store the converted image. The microprocessor can then read data from the binary file and load it into device. You can also use the microprocessor to perform real-time conversion during configuration. In the PS configuration scheme, the data is shifted in serially, LSB first.

Hexadecimal (Intel-Format) File (.hex)

A **.hex** file is an ASCII file in the Intel hexadecimal format. Third-party programmers use this file to program Altera's serial configuration devices. Microprocessors can also use the **.hex** file to store and transmit configuration data using the PS configuration scheme.

Tabular Text File (.ttf)

The **.ttf** file is a tabular ASCII file that provides a comma-separated version of the configuration data for the bit-wide PS configuration scheme. In some applications, the storage device containing the configuration data is neither dedicated to nor connected directly to the target device. For example, a configuration device can also contain executable code for a system (e.g., BIOS routines) and other data. The **.ttf** allows you to include the configuration data as part of the microprocessor's source code using the **include** or **source** commands. The microprocessor can access this data from a configuration device or mass-storage device and load it into the target device. A **.ttf** can be imported into nearly any assembly language or high-level language compiler.

Configuration Reliability

Jam File (.jam)

A **.jam** file is an ASCII text file in the Jam device programming language that stores device programming information. These files are used to program, verify, and blank-check one or more devices in the Quartus II Programmer or in an embedded processor-type environment.

Jam Byte-Code File (.jbc)

A **.jbc** file is a binary version of a Jam file in a byte-code representation. The **.jbc** file stores device programming information used to program, verify, and blank-check one or more devices.

The Cyclone architecture is designed to minimize the effects of power supply and data noise in a system, and to ensure that the configuration data is not corrupted during configuration or normal user-mode operation. A number of circuit design features ensure the highest possible level of reliability from this SRAM technology.

Cyclic redundancy code (CRC) circuitry validates each data frame (i.e., sequence of data bits) as it is loaded into the target device. If the CRC generated by the device does not match the data stored in the data stream, the configuration process is halted, and the `nSTATUS` pin is pulled and held low to indicate an error condition. CRC circuitry ensures that noisy systems will not cause errors that yield an incorrect or incomplete configuration.

The Cyclone FPGA architecture also provides a very high level of reliability in low-voltage brown-out conditions. Cyclone FPGA SRAM blocks require a certain V_{CC} level to maintain accurate data. This voltage threshold is significantly lower than the voltage required to activate the device's POR circuitry. Therefore, the target device stops operating if the V_{CC} starts to fail, and indicates an operation error by pulling and holding the `nSTATUS` pin low. You must then reconfigure the device before it can resume operation as a logic device. In active configuration schemes in which `nCONFIG` is tied to V_{CC} , reconfiguration begins as soon as V_{CC} returns to an acceptable level. The low pulse on `nSTATUS` resets the configuration device by driving `OE` low. In passive configuration schemes, the host system starts the reconfiguration process.

These device features ensure that Cyclone FPGAs have the highest possible reliability in a wide variety of environments, and provide the same high level of system reliability that exists in other Altera PLDs.

Board Layout Tips

Even though the DCLK signal (used in PS and AS configuration schemes) is fairly low-frequency, it drives edge-triggered pins on the Cyclone FPGA. Therefore, any overshoot, undershoot, ringing, or other noise can affect configuration. When designing the board, lay out the DCLK trace using the same techniques as laying out a clock line, including appropriate buffering. If more than five devices are used, Altera recommends using buffers to split the fan-out on the DCLK signal.

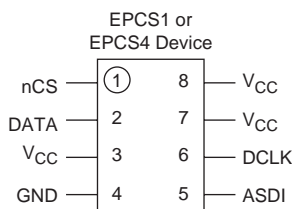
Features

The serial configuration devices provide the following features:

- 1- and 4-Mbit flash memory devices that serially configure Cyclone™ FPGAs
- Easy-to-use four-pin interface
- Low cost, low pin count and non-volatile memory
- Low current during configuration and near-zero standby mode current
- 3.3-V operation
- Available in 8-pin small outline integrated circuit (SOIC) package
- Enables the Nios® processor to access unused flash memory through active serial (AS) memory interface
- Re-programmable memory with more than 100,000 erase/program cycles
- Programming support with ByteBlaster™ II download cable
- Additional programming support with the Altera® Programming Unit (APU) and programming hardware from BP Microsystems, System General, and other vendors
- Software design support with the Altera Quartus® II development system for Windows-based PCs as well as Sun SPARC station and HP 9000 Series 700/800
- Delivered with the memory array erased (all the bits set to 1)

Figure 14–1 shows the Altera serial configuration device 8-pin SOIC package and its pin-out diagram.

Figure 14–1. Altera Serial Configuration Device Package Pin-Out Diagram



Whenever the term “serial configuration device(s)” is used in this document, it refers to Altera EPCS1 and EPCS4 devices.

Functional Description

With SRAM-based devices such as Cyclone FPGAs, configuration data must be reloaded each time the system initializes, or when a new configuration is needed. Serial configuration devices are flash memory devices with a serial interface that can store configuration data for a Cyclone device and reload the data to the device upon power-up or reconfiguration. [Table 14–1](#) lists the serial configuration devices.

Device	Memory Size (Bits)
EPCS1	1,048,576
EPCS4	4,194,304

[Table 14–2](#) lists the serial configuration device used with each Cyclone FPGA and the configuration file size.

Cyclone Device	Configuration File Size (Mbits) <i>(1)</i>	Serial Configuration Device	
		EPCS1	EPCS4
EP1C3	0.628	✓	✓
EP1C4	0.925	✓	✓
EP1C6	1.167	✓	✓
EP1C12	2.324		✓
EP1C20	3.559		✓

Note to [Table 14–2](#):

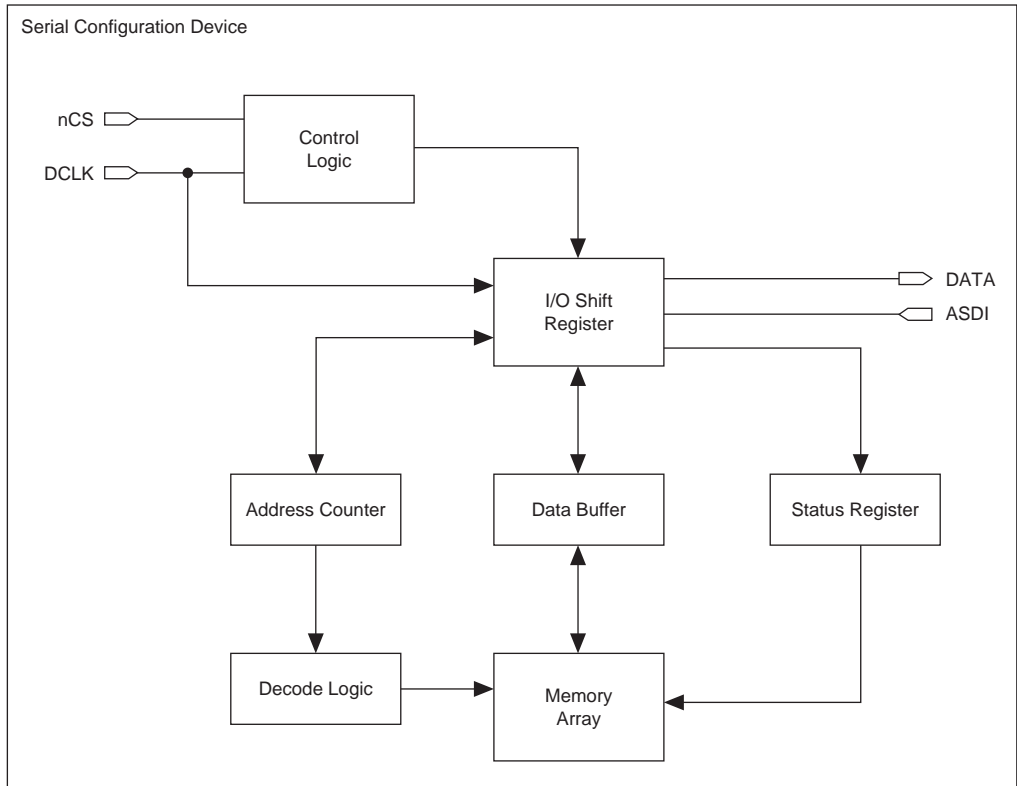
(1) These are preliminary, uncompressed file sizes.

With the new data-decompression feature in the Cyclone FPGA family, designers can use smaller serial configuration devices to configure larger Cyclone FPGAs. Serial configuration devices cannot be cascaded.



See [Chapter 13, Configuring Cyclone FPGAs](#) for more information regarding the Cyclone FPGA decompression feature in AS mode.

The serial configuration devices are designed to configure Cyclone FPGAs and cannot configure other existing device families. [Figure 14–2](#) shows the serial configuration device block diagram.

Figure 14–2. Serial Configuration Device Block Diagram

Accessing Memory in Serial Configuration Devices

A designer can access the unused memory locations of the serial configuration device through the Nios processor and SOPC Builder to store/retrieve data or configuration files. SOPC Builder is an Altera tool for creating bus-based (especially microprocessor-based) systems in Altera devices. SOPC Builder assembles library components like processors and memories into custom microprocessor systems.

SOPC Builder includes an interface core specifically for the serial configuration device. Using this core, a designer can create a system with a Nios embedded processor that allows software access to any memory location within the serial configuration device.



For more information on accessing memory within the serial configuration device, contact Altera Applications.

Pin Description

As shown in [Figure 14-1](#), the serial configuration device is an 8-pin device. The control pins on the serial configuration device are: serial data output (DATA), active serial data input (ASDI), serial clock (DCLK), and chip select (nCS). [Table 14-3](#) shows the serial configuration device's pin descriptions.

Table 14-3. Serial Configuration Device Pin Description

Pin Name	Pin Number	Pin Type	Description
DATA	2	Output	DATA output signal transfers the data serially out of the serial configuration device into the Cyclone FPGA during read/configuration operation. During a read/configuration operation, the serial configuration device is enabled by pulling nCS low. The DATA signal transitions on the falling edge of DCLK.
ASDI	5	Input	Active serial data input signal is used to transfer data serially into the serial configuration device. It receives the data that should be programmed into the serial configuration device. Values register on the rising edge of DCLK.
nCS	1	Input	Active low chip select input signal toggles at the beginning and end of a valid instruction. When this signal is high, the device is deselected and the DATA signal is tri-stated. When the signal is low, it enables the device and puts the device in an active mode. After power up, the serial configuration device requires a falling edge on the nCS signal before beginning any operation.
DCLK	6	Input	DCLK is provided by the Cyclone FPGA. This signal provides the timing of the serial interface. The data presented at ASDI are latched in to the serial configuration device, at the rising edge of DCLK. Data on the DATA pin changes after the falling edge of DCLK and is latched into the Cyclone FPGA on the rising edge.
VCC	3, 7, 8	Power	Power pins connect to 3.3 V.
GND	4	Ground	Ground pin.

Programming & Configuration File Support

The Quartus II design software provides programming support for serial configuration devices. After selecting the serial configuration device, the Quartus II software automatically generates the Programmer Object File (.pof) to program the device. The software allows users to select the appropriate serial configuration device density that most efficiently stores the configuration data for a selected Cyclone FPGA.

Serial configuration devices are programmed using the APU with the appropriate programming adapter (PLMSEPC-8) via the Quartus II software or the ByteBlaster II download cable via the Quartus II software. In addition, many third-party programmers, such as BP Microsystems and System General, offer programming hardware that supports serial configuration devices.

During in-system programming of a serial configuration device via the ByteBlaster II download cable, the cable pulls $nCONFIG$ low to reset the Cyclone device and overrides the 10-k Ω pull-down resistors on the Cyclone device's nCE pin (see Figure 14–5). The download cable then uses the four interface pins (DATA, nCS , ASDI, and DCLK) to program the serial configuration device memory. Once the programming is complete, the download cable releases the serial configuration device's four interface pins and the Cyclone device's nCE pin, and pulses $nCONFIG$ to start configuration.

Figure 14–3 shows the timing waveform for write operation to the serial configuration device.

Figure 14–3. Write Operation Timing

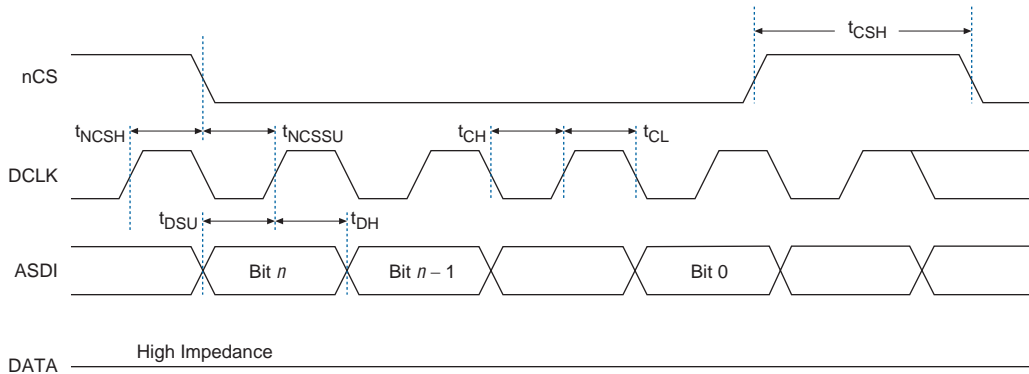


Table 14–4 defines the serial configuration device timing parameters for write operation.

Symbol	Parameter	Min	Max	Unit
f_{WCLK}	Write clock frequency (from Cyclone FPGA or ByteBlaster II cable)		20	MHz
t_{CH}	DCLK high time	25		ns
t_{CL}	DCLK low time	25		ns
t_{NCSSU}	Chip select (nCS) setup time	10		ns
t_{NCSH}	Chip select (nCS) hold time	10		ns
t_{DSU}	Data (ASDI) in setup time before rising edge on DCLK	5		ns

Table 14–4. Write Operation Parameters (Part 2 of 2)

Symbol	Parameter	Min	Max	Unit
t_{DH}	Data (ASDI) hold time after rising edge on DCLK	5		ns
t_{CSH}	Chip select high time	100		ns

Figure 14–4 shows the timing waveform for the serial configuration device's read operation.

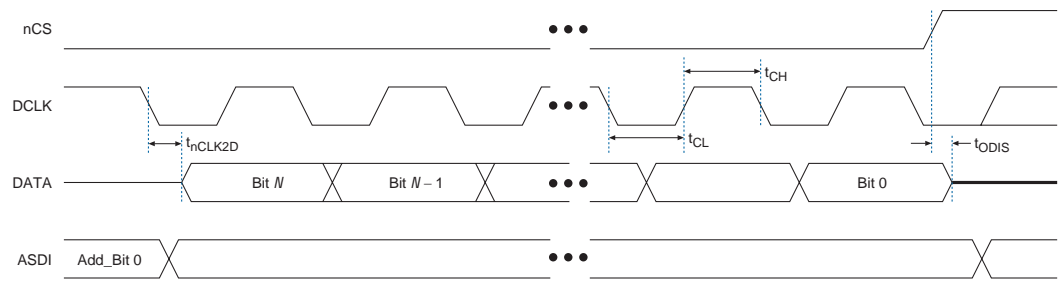
Figure 14–4. Read Operation Timing

Table 14–5 defines the serial configuration device timing parameters for read operation.

Table 14–5. Read Operation Parameters

Symbol	Parameter	Min	Max	Unit
f_{RCLK}	Read clock frequency (from Cyclone FPGA)		20	MHz
t_{CH}	DCLK high time	25		ns
t_{CL}	DCLK low time	25		ns
t_{ODIS}	Output disable time after read		15	ns
t_{nCLK2D}	Clock falling edge to data		15	ns



For more information on programming and configuration support, see the following documents:

- *Altera Programming Hardware Data Sheet*
- *Programming Hardware Manufacturers*
- *ByteBlaster II Parallel Port Download Cable Data Sheet*

Cyclone FPGA Configuration

Cyclone FPGAs can be configured with a serial configuration device through AS configuration mode. There are four signals on the serial configuration device that interface directly with the Cyclone device's control signals. The serial configuration device signals DATA, DCLK, ASDI, and nCS interface with DATA0, DCLK, ASDO, and nCSO control signals on a Cyclone FPGA, respectively. Figure 14-5 shows a serial configuration device programmed via a download cable configuring a Cyclone FPGA in AS mode. Figure 14-6 shows a serial configuration device programmed using the APU or a third-party programmer configuring a Cyclone FPGA in AS configuration mode.

Figure 14-5. Cyclone Configuration in AS Mode (Serial Configuration Device Programmed Using Download Cable)

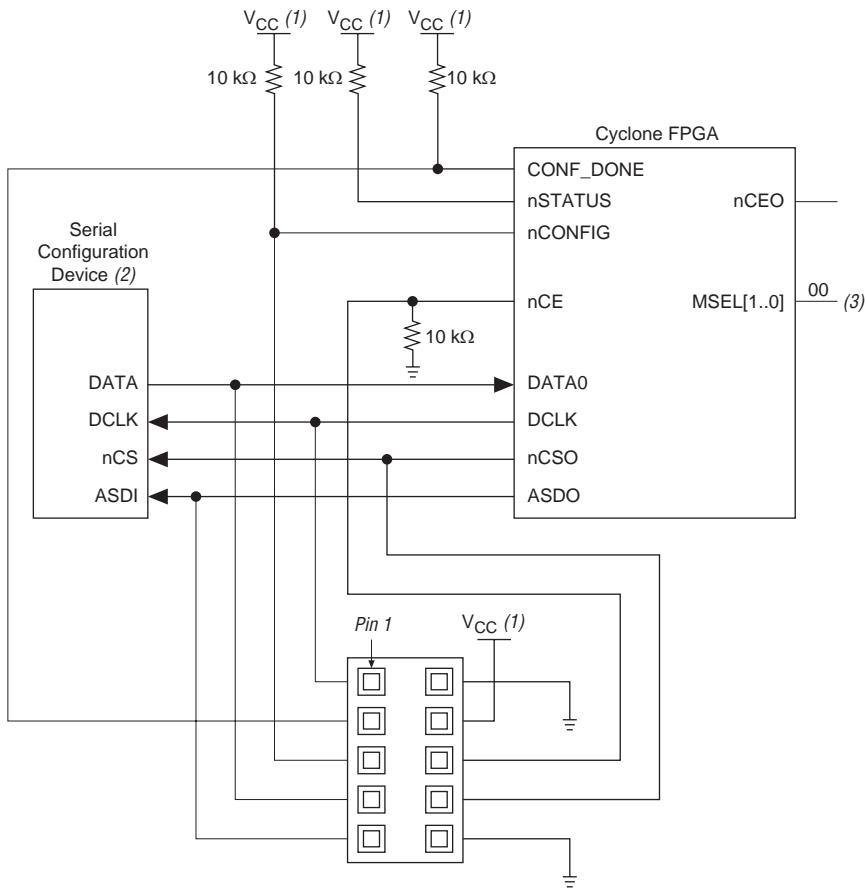
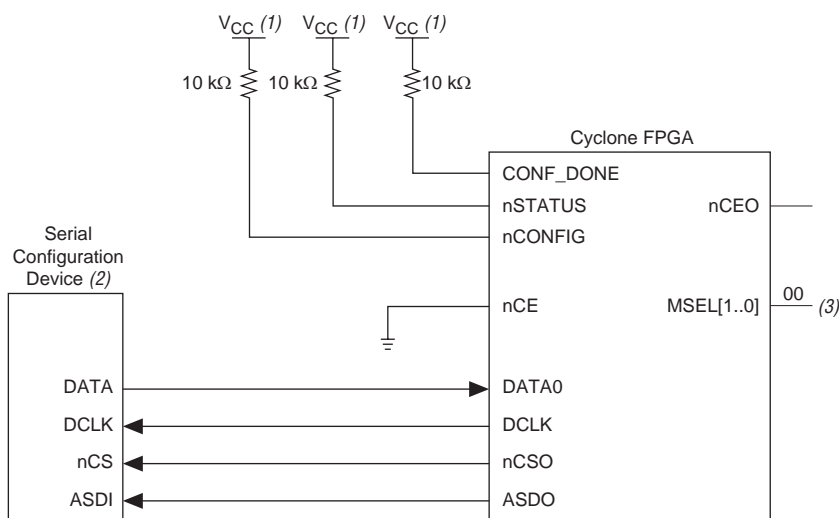


Figure 14–6. Cyclone Configuration in AS Mode (Serial Configuration Device Programmed by APU or Third-Party Programmer)



Notes to Figures 14–5 and 14–6:

- (1) $V_{CC} = 3.3\text{-V}$.
- (2) Serial configuration devices cannot be cascaded.
- (3) Set MSEL0 to 0 and MSEL1 to 0 for AS configuration mode.

The Cyclone FPGA acts as the configuration master in the configuration flow and provides the DCLK to the serial configuration device. The Cyclone device enables the serial configuration device by pulling the nCS signal low via the nCSO signal (See Figures 14–5 and 14–6). Consequently, the Cyclone FPGA sends the instructions and addresses to the serial configuration device via the ASDO signal. The serial configuration device responds to the instructions by sending the configuration data to the Cyclone FPGA's DATA0 pin on the falling edge of DCLK. The data is latched into the Cyclone device's DCLK signal's rising edge.

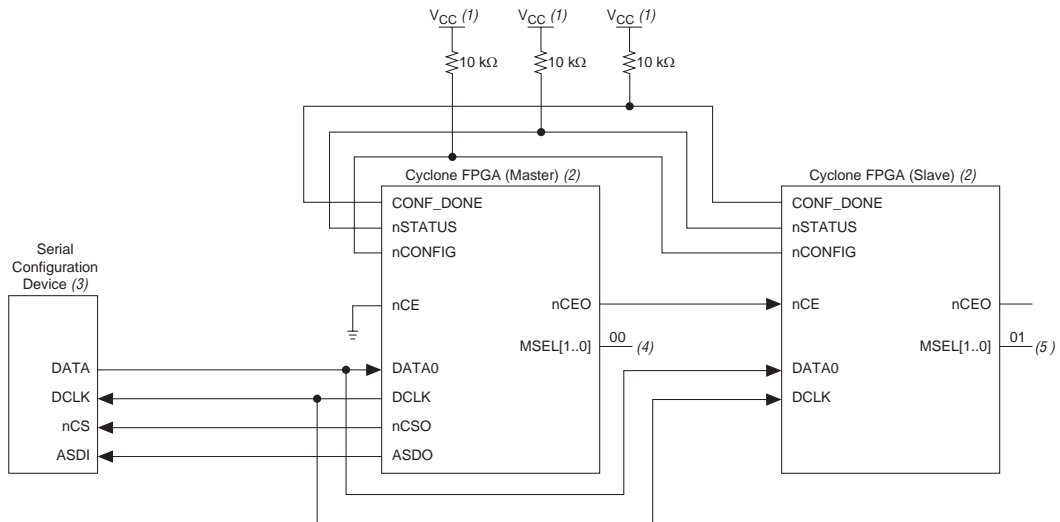
The Cyclone FPGA controls the nSTATUS and CONF_DONE pins during configuration in AS mode. If the CONF_DONE signal does not go high at the end of configuration or if the signal goes high too early, the Cyclone FPGA will pulse its nSTATUS pin low to start reconfiguration. Upon successful configuration, the Cyclone FPGA releases the CONF_DONE pin, allowing the external 10-kΩ resistor to pull this signal high. Initialization begins after the CONF_DONE goes high and completes within 136 clock cycles. After initialization, the Cyclone FPGA enters user mode.



For more information on configuring Cyclone FPGAs in AS mode or other configuration modes, see [Chapter 13, Configuring Cyclone FPGAs](#).

Serial configuration devices cannot be cascaded. Therefore, when a design requires multiple Cyclone FPGAs, the Cyclone FPGAs are configured by a single serial configuration device. Check [Table 14-1](#) to ensure the programming file size of the cascaded Cyclone FPGAs does not exceed the capacity of a serial configuration device. Designers can choose any serial configuration device according to the system requirements. [Figure 14-7](#) shows the AS configuration scheme with multiple Cyclone FPGAs in the chain. In AS configuration mode, all the devices in the chain must be Cyclone devices.

Figure 14-7. Multiple Devices in AS Mode



Notes to Figure 14-7:

- (1) $V_{CC} = 3.3\text{-V}$.
- (2) In AS mode, the first Cyclone device in the chain is the master device. The other Cyclone devices in the chain are slave devices and must be in passive serial (PS) configuration mode.
- (3) Serial configuration devices cannot be cascaded.
- (4) Set MSEL0 to 0 and MSEL1 to 0 to select AS mode in the Cyclone device.
- (5) Set MSEL0 to 0 and MSEL1 to 1 to select PS mode in the Cyclone device.

Figure 14–8 shows the timing waveform for Cyclone FPGA AS configuration scheme using a serial configuration device.

Figure 14–8. AS Configuration Timing

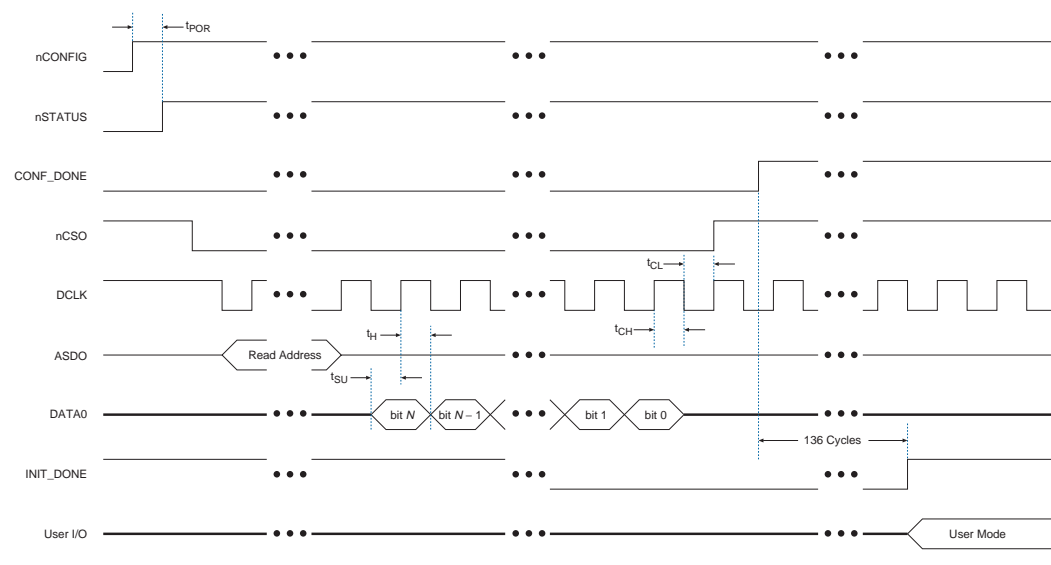


Table 14–6 shows the timing parameters for AS configuration mode.

Symbol	Parameter	Min	Typ	Max	Unit
f_{CLK}	DCLK frequency (from Cyclone FPGA)		15	20	MHz
t_{CH}	DCLK high time	25			ns
t_{CL}	DCLK low time	25			ns
t_H	Data hold time after rising edge on DCLK	0			ns
t_{SU}	Data set up time before rising edge on DCLK	5			ns
t_{POR}	POR delay			100	ms

Power & Operation

This section describes the power modes, power-on reset (POR) delay, error detection, and initial programming state of serial configuration devices.

Power Mode

Serial configuration devices support active power and standby power modes. When nCS is low, the device is enabled and is in active power mode. The Cyclone FPGA is configured while in active power mode. When nCS is high, the device is disabled but could remain in active power mode until all internal cycles have completed (such as program or erase operations). The serial configuration device then goes into stand-by power mode. The I_{CC1} parameter specifies the V_{CC} supply current when the device is in active power mode and the I_{CC0} parameter specifies the current when the device is in stand-by power mode (see [Table 14-10](#)).

Power-On Reset

During initial power-up, a POR delay occurs to help stabilize the system voltage levels. In AS configuration, the Cyclone FPGA controls the configuration and has a longer POR delay than the serial configuration device. Therefore, the POR delay is governed by the Cyclone FPGA (typically 100 ms).

Error Detection

In AS configuration with the serial configuration device, the Cyclone FPGA monitors the configuration status through the $nSTATUS$ and $CONF_DONE$ pins. If an error condition occurs ($nSTATUS$ driven low) or if the $CONF_DONE$ pin does not go high, the Cyclone FPGA will initiate reconfiguration by pulsing the $nSTATUS$ and $nCS0$ signals, which controls the chip select pin on the serial configuration device (nCS).

After an error, configuration automatically restarts if the *Auto-Restart Upon Frame Error* option is turned on in the Quartus II software.

Operating Conditions

Tables 14–7 through 14–11 provide information on absolute maximum ratings, recommended operating conditions, DC operating conditions, and capacitance for serial configuration devices.

Table 14–7. Absolute Maximum Ratings *Note (1)*

Symbol	Parameter	Condition	Min	Max	Unit
V_{CC}	Supply voltage	With respect to ground	–0.6	4.0	V
V_I	DC input voltage	With respect to ground	–0.6	4.0	V
I_{MAX}	DC V_{CC} or GND current			15	mA
I_{OUT}	DC output current per pin		–25	25	mA
P_D	Power dissipation			54	mW
T_{STG}	Storage temperature	No bias	–65	150	°C
T_{AMB}	Ambient temperature	Under bias	–65	135	°C
T_J	Junction temperature	Under bias		135	°C

Table 14–8. Recommended Operating Conditions

Symbol	Parameter	Conditions	Min	Max	Unit
V_{CC}	Supply voltage	(2)	3.0	3.6	V
V_I	Input voltage	Respect to GND	–0.3	$0.3 + V_{CC}$	V
V_O	Output voltage		0	V_{CC}	V
T_A	Operating temperature	For commercial use	0	70	°C
		For industrial use	–40	85	°C
t_R	Input rise time			5	ns
t_F	Input fall time			5	ns

Table 14–9. DC Operating Conditions

Symbol	Parameter	Conditions	Min	Max	Unit
V_{IH}	High-level input voltage		$0.7 \times V_{CC}$	$V_{CC} + 0.4$	V
V_{IL}	Low-level input voltage		–0.5	$0.3 \times V_{CC}$	V
V_{OH}	High-level output voltage	$I_{OH} = -100 \mu\text{A}$ (3)	$V_{CC} - 0.2$		V
V_{OL}	Low-level output voltage	$I_{OL} = 1.6 \text{ mA}$ (3)		0.4	V
I_I	Input leakage current	$V_I = V_{CC}$ or GND	–10	10	μA
I_{OZ}	Tri-state output off-state current	$V_O = V_{CC}$ or GND	–10	10	μA

Table 14–10. I_{CC} Supply Current

Symbol	Parameter	Conditions	Min	Max	Unit
I_{CC0}	V_{CC} supply current (standby)			50	μA
I_{CC1}	V_{CC} supply current (during active power mode)		5	14	mA

Table 14–11. Capacitance *Note (4)*

Symbol	Parameter	Conditions	Min	Max	Unit
C_{IN}	Input pin capacitance	$V_{IN} = 0 \text{ V}$		6	pF
C_{OUT}	Output pin capacitance	$V_{OUT} = 0 \text{ V}$		8	pF

Notes to Table 14–7 through 14–11:

- (1) See the *Operating Requirements for Altera Devices Data Sheet*.
- (2) Maximum V_{CC} rise time is 100 ms.
- (3) The I_{OH} parameter refers to high-level TTL or CMOS output current; the I_{OL} parameter refers to low-level TTL or CMOS output current.
- (4) Capacitance is sample-tested only at $T_A = 25 \text{ }^\circ\text{C}$ and at a 20-MHz frequency.

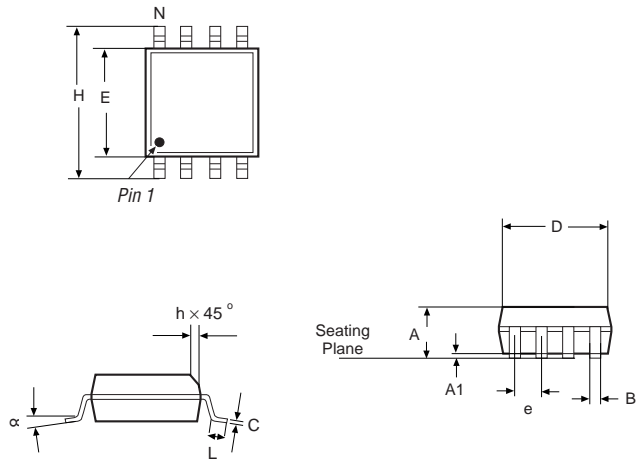
Package

All serial configuration devices are available in 8-pin plastic SOIC package. [Figure 14–9](#) shows the mechanical drawing and specifications for this package.



For more information on Altera device packaging, see [Chapter 6, Package Information for Cyclone Devices](#).

Figure 14–9. 8-Pin SOIC Serial Configuration Device Package Notes (1), (2)



Symbol	Dimensions (mm)		
	Min.	Nom.	Max.
A	–	1.35	1.75
A1	–	0.10	0.25
B	–	0.33	0.51
C	–	0.19	0.25
D	–	4.80	5.00
E	–	3.80	4.00
e	1.27 BSC		
H	–	5.80	6.20
h	–	0.25	0.50
L	–	0.40	0.90
N	8		
α	–	0°C	8°C

Notes to Figure 14–9:

- (1) All dimensions and tolerances conform to ANSI Y14.5M - 1982.
- (2) JEDEC reference MS-013 option AE.

Ordering Code

Table 14–12 shows the ordering codes for serial configuration devices.

Table 14–12. Serial Configuration Device Ordering Codes	
Device	Ordering Code
EPCS1	EPCS1SI8
EPCS4	EPCS4SI8

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Cyclone Device Handbook, Volume 2



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Chapter Revision Dates

The chapters in this book, *Cyclone Device Handbook, Volume 2*, were revised on the following dates. Where chapters or groups of chapters are available separately, part numbers are listed.

Chapter 1. Cyclone EP1C3T100 Device Pin Information

Revised: *May 2003*
Part number: *C52001-1.0*

Chapter 2. Cyclone EP1C3T144 Device Pin Information

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Part number: *C52002-1.0*

Chapter 3. Cyclone EP1C6 Device Pin Information

Revised: *May 2003*
Part number: *C52003-1.0*

Chapter 4. Cyclone EP1C12 Device Pin Information

Revised: *May 2003*
Part number: *C52004-1.0*

Chapter 5. Cyclone EP1C20 Device Pin Information

Revised: *May 2003*
Part number: *C52005-1.0*

Chapter 6. Package Information for Cyclone Devices

Revised: *May 2003*
Part number: *C52006-1.0*

Chapter 7. Designing with FineLine BGA Packages

Revised: *May 2003*
Part number: *C52007-1.0*



About this Handbook

This handbook provides comprehensive information about the Altera® Cyclone family of devices.

How to Find Information

You can find more information in the following ways:

- The Adobe Acrobat Find feature, which searches the text of a PDF document. Click the binoculars toolbar icon to open the Find dialog box.
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Typographic Conventions

This document uses the typographic conventions shown below.

Visual Cue	Meaning
Bold Type with Initial Capital Letters	Command names, dialog box titles, checkbox options, and dialog box options are shown in bold, initial capital letters. Example: Save As dialog box.
bold type	External timing parameters, directory names, project names, disk drive names, filenames, filename extensions, and software utility names are shown in bold type. Examples: f_{MAX} , lqdesigns directory, d: drive, chiptrip.gdf file.
<i>Italic Type with Initial Capital Letters</i>	Document titles are shown in italic type with initial capital letters. Example: <i>AN 75: High-Speed Board Design</i> .
<i>Italic type</i>	Internal timing parameters and variables are shown in italic type. Examples: <i>t_{PIA}</i> , <i>n + 1</i> . Variable names are enclosed in angle brackets (< >) and shown in italic type. Example: <file name>, <project name>.pdf file.
Initial Capital Letters	Keyboard keys and menu names are shown with initial capital letters. Examples: Delete key, the Options menu.
"Subheading Title"	References to sections within a document and titles of on-line help topics are shown in quotation marks. Example: "Typographic Conventions."
Courier type	Signal and port names are shown in lowercase Courier type. Examples: data1, tdi, input. Active-low signals are denoted by suffix n, e.g., resetn. Anything that must be typed exactly as it appears is shown in Courier type. For example: c:\qdesigns\tutorial\chiptrip.gdf. Also, sections of an actual file, such as a Report File, references to parts of files (e.g., the AHDL keyword SUBDESIGN), as well as logic function names (e.g., TRI) are shown in Courier.
1., 2., 3., and a., b., c., etc.	Numbered steps are used in a list of items when the sequence of the items is important, such as the steps listed in a procedure.
	Bullets are used in a list of items when the sequence of the items is not important.
	The checkmark indicates a procedure that consists of one step only.
	The hand points to information that requires special attention.
	The angled arrow indicates you should press the Enter key.
	The feet direct you to more information on a particular topic.

This section provides information for board layout designers to successfully layout their boards for Cyclone devices. It contains the required PCB layout guidelines, device pin tables, and package specifications.

This section includes the following chapters:

- [Chapter 1. Cyclone EP1C3T100 Device Pin Information](#)
- [Chapter 2. Cyclone EP1C3T144 Device Pin Information](#)
- [Chapter 3. Cyclone EP1C6 Device Pin Information](#)
- [Chapter 4. Cyclone EP1C12 Device Pin Information](#)
- [Chapter 5. Cyclone EP1C20 Device Pin Information](#)
- [Chapter 6. Package Information for Cyclone Devices](#)
- [Chapter 7. Designing with FineLine BGA Packages](#)

Revision History

The table below shows the revision history for [Chapter 7](#).

Chapter(s)	Date / Version	Changes Made
12	May 2003 v1.0	Updated Table 7–6 .
	v1.03	Updated the “ PCB Layout for FineLine BGA Packages ” section and Table 7–6 .
	v1.02	Minor updates.
	v1.01	Updated Table 7–6 .



1. Cyclone EP1C3T100 Device Pin Information

C52001-1.0

Introduction

The following tables contain pin information for the Cyclone EP1C3T100 device, organized into the following sections:

Section	Page
Pin List	1-2
Pin Definitions	1-7
PLL & Bank Diagram	1-10

Pin List

Table 1–1 shows the complete pin list for the Cyclone EP1C3T100 device:

Table 1–1. Pin List for the Cyclone EP1C3T100 Device (Part 1 of 5)						
Pin Name / Function	Optional Function(s)	Device			Package	
		Configuration Function	Bank Number	VREF Bank	100-Pin Thin Quad Flat Pack	DQS for X8 in 100-Pin Thin Quad Flat Pack
IO		INIT_DONE	B1	VREF0B1	1	
IO			B1	VREF0B1	2	
IO		CLKUSR	B1	VREF0B1	3	
IO	VREF0B1		B1	VREF0B1	4	
VCCIO1			B1	VREF0B1		
GND			B1	VREF0B1		
IO	VREF1B1		B1	VREF1B1	5	
IO		nCSO	B1	VREF1B1	6	
DATA0		DATA0	B1	VREF1B1	7	
nCONFIG		nCONFIG	B1	VREF1B1	8	
VCCA_PLL1				VREF1B1	9	
CLK0			B1	VREF1B1	10	
GND_A_PLL1				VREF1B1	11	
nCEO		nCEO	B1	VREF1B1	12	
nCE		nCE	B1	VREF1B1	13	
MSEL0		MSEL0	B1	VREF1B1	14	
MSEL1		MSEL1	B1	VREF1B1	15	
DCLK		DCLK	B1	VREF1B1	16	
IO		ASDO	B1	VREF1B1	17	
VCCIO1			B1	VREF2B1	18	
GND			B1	VREF2B1	19	

Table 1-1. Pin List for the Cyclone EP1C3T100 Device (Part 2 of 5)						
Pin Name / Function	Device				Package	DQS for X8 in 100-Pin Thin Quad Flat Pack
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank		
IO	VREF2B1		B1	VREF2B1	20	
IO			B1	VREF2B1	21	
IO			B1	VREF2B1	22	
IO			B1	VREF2B1	23	
IO			B1	VREF2B1	24	
IO			B1	VREF2B1	25	
IO			B4	VREF2B4	26	
IO			B4	VREF2B4	27	DQ1B7
IO			B4	VREF2B4	28	DQ1B6
IO			B4	VREF2B4	29	DQ1B5
GND			B4	VREF2B4	30	
VCCIO4			B4	VREF2B4	31	
GND				VREF2B4	32	
VCCINT				VREF2B4	33	
IO	DPCLK7		B4	VREF2B4	34	DQS1B
IO	VREF2B4		B4	VREF2B4	35	
IO			B4	VREF2B4	36	DQ1B4
IO			B4	VREF1B4	37	
IO	VREF1B4		B4	VREF1B4	38	
IO			B4	VREF1B4	39	DM1B
IO			B4	VREF1B4	40	
IO	VREF0B4		B4	VREF0B4	41	
IO	DPCLK6		B4	VREF0B4	42	

Table 1-1. Pin List for the Cyclone EP1C3T100 Device (Part 3 of 5)

Pin Name / Function	Device					Package 100-Pin Thin Quad Flat Pack	DQS for X8 in 100-Pin Thin Quad Flat Pack
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	Pin Number		
GND				VREF0B4	43		
VCCINT				VREF0B4	44		
GND			B4	VREF0B4	45		
VCCIO4			B4	VREF0B4	46		
IO			B4	VREF0B4	47		DQ1B3
IO			B4	VREF0B4	48		DQ1B2
IO			B4	VREF0B4	49		DQ1B1
IO			B4	VREF0B4	50		DQ1B0
IO			B3	VREF2B3	51		
IO			B3	VREF2B3	52		
IO			B3	VREF2B3	53		DQ0R7
IO			B3	VREF2B3	54		DQ0R6
IO			B3	VREF2B3	55		DQ0R5
IO			B3	VREF2B3	56		DQ0R4
IO	VREF2B3		B3	VREF2B3	57		
GND			B3	VREF2B3	58		
VCCIO3			B3	VREF2B3	59		
CONF_DONE		CONF_DONE	B3	VREF1B3	60		
nSTATUS		nSTATUS	B3	VREF1B3	61		
TCK		TCK	B3	VREF1B3	62		
TMS		TMS	B3	VREF1B3	63		
TDO		TDO	B3	VREF1B3	64		
IO			B3	VREF1B3	65		DM0R

Table 1-1. Pin List for the Cyclone EP1C3T100 Device (Part 4 of 5)						
Pin Name / Function	Optional Function(s)	Device			Package	DQS for X8 in 100-Pin Thin Quad Flat Pack
		Configuration Function	Bank Number	VREF Bank		
CLK2			B3	VREF1B3	66	
TDI		TDI	B3	VREF1B3	67	
IO	VREF1B3		B3	VREF1B3	68	
IO			B3	VREF0B3	69	DQ0R3
IO			B3	VREF0B3	70	DQ0R2
IO			B3	VREF0B3	71	DQ0R1
IO	DPCLK4		B3	VREF0B3	72	DQS0R
GND			B3	VREF0B3		
VCCIO3			B3	VREF0B3		
IO	VREF0B3		B3	VREF0B3	73	
IO			B3	VREF0B3	74	DQ0R0
IO			B3	VREF0B3	75	
IO			B2	VREF0B2	76	DQ1T0
IO			B2	VREF0B2	77	DQ1T1
IO			B2	VREF0B2	78	DQ1T2
IO			B2	VREF0B2	79	DQ1T3
VCCIO2			B2	VREF0B2	80	
GND			B2	VREF0B2	81	
VCCINT				VREF0B2	82	
GND				VREF0B2	83	
IO	DPCLK3		B2	VREF0B2	84	
IO	VREF0B2		B2	VREF0B2	85	
IO			B2	VREF1B2	86	

Table 1-1. Pin List for the Cyclone EP1C3T100 Device (Part 5 of 5)

Device							Package	DQS for X8 in 100-Pin Thin Quad Flat Pack
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	100-Pin Thin Quad Flat Pack			
IO			B2	VREF1B2	87			
IO	VREF1B2		B2	VREF1B2	88			
IO			B2	VREF1B2	89			
IO			B2	VREF2B2	90	DM1T		
IO	VREF2B2		B2	VREF2B2	91			
IO	DPCLK2		B2	VREF2B2	92	DQS1T		
VCCINT				VREF2B2	93			
GND				VREF2B2	94			
VCCIO2			B2	VREF2B2	95			
GND			B2	VREF2B2	96			
IO			B2	VREF2B2	97	DQ1T4		
IO			B2	VREF2B2	98	DQ1T5		
IO		DEV_OE	B2	VREF2B2	99	DQ1T6		
IO		DEV_CLRn	B2	VREF2B2	100	DQ1T7		

Table 1–2 shows pin definitions for the EP1C3T100 device.

Pin Definitions

<i>Table 1–2. Pin Definitions for the Cyclone EP1C3T100 Device (Part 1 of 3)</i>		
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
Supply and Reference Pins		
VCCIO[1..4]	Power	These are I/O supply voltage pins for banks 1 through 4. Each bank can support a different voltage level. VCCIO supplies power to the output buffers for all I/O standards. VCCIO also supplies power to the input buffers used for the LVTTTL, LVCMOS, 1.5-V, 1.8-V, 2.5-V, and 3.3-V PCI I/O standards.
VCCINT	Power	These are internal logic array voltage supply pins. VCCINT also supplies power to the input buffers used for the LVDS, SSTL2, and SSTL3 I/O standards.
VREF[0..2][1..4]	I/O, Input	Input reference voltage for banks 1-4. If a bank uses a voltage-referenced I/O standard, then these pins are used as the voltage-reference pins for the bank. If voltage reference I/O standards are not used in the bank, the VREF pins are available as user I/O pins.
VCCA_PLL[1..2]	Power	Analog power for PLLs[1..2]. The designer must connect this pin to 1.5 V, even if the PLL is not used.
GND_A_PLL[1..2]	Ground	Analog ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.
Configuration and JTAG Pins		
CONF_DONE	Bidirectional (open-drain)	This is a dedicated configuration status pin; it is not available as a user I/O pin.
nSTATUS	Bidirectional (open-drain)	This is a dedicated configuration status pin; it is not available as a user I/O pin.
nCONFIG	Input	Dedicated configuration control input. A low transition resets the target device; a low-to-high transition begins configuration. All I/O pins tri-state when nCONFIG is driven low.
DCLK	Input (PS mode), Output (AS mode)	In passive serial configuration mode, DCLK is a clock input used to clock configuration data from an external source into the Cyclone device. In active serial configuration mode, DCLK is a clock output from the Cyclone device (the Cyclone device acts as master in this mode). This is a dedicated pin used for configuration.
DATA0	Input	Dedicated configuration data input pin.

Table 1–2. Pin Definitions for the Cyclone EP1C3T100 Device (Part 2 of 3)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
nCE	Input	Active-low chip enable. Dedicated chip enable input used to detect which device is active in a chain of devices. When nCE is low, the device is enabled. When nCE is high, the device is disabled.
nCEO	Output	Output that drives low when device configuration is complete. During multi-device configuration, this pin feeds a subsequent device's nCE pin.
ASDO	I/O, Output	Active serial data output from the Cyclone device. This output pin is utilized during active serial configuration mode. The Cyclone device controls configuration and drives address and control information out on ASDO. In passive serial configuration, this pin is available as a user I/O pin.
nCSO	I/O, Output	Chip select output that enables/disables a serial configuration device. This output is utilized during active serial configuration mode. The Cyclone device controls configuration and enables the serial configuration device by driving nCSO low. In passive serial configuration, this pin is available as a user I/O pin.
INIT_DONE	I/O, Output (open-drain)	This is a dual-purpose pin and can be used as an I/O pin when not enabled as INIT_DONE. When enabled, the pin indicates when the device has entered user mode. This pin can be used as a user I/O pin after configuration.
CLKUSR	I/O, Input	Optional user-supplied clock input. Synchronizes the initialization of one or more devices. This pin can be used as a user I/O pin after configuration.
DEV_CLRn	I/O, Input	Dual-purpose pin that can override all clears on all device registers. When this pin is driven low, all registers are cleared; when this pin is driven high, all registers behave as defined in the design.
DEV_OE	I/O, Input	Dual-purpose pin that can override all tri-states on the device. When this pin is driven low, all I/O pins are tri-stated; when this pin is driven high, all I/O pins behave as defined in the design.
MSEL[1..0]	Input	Dedicated mode select control pins that set the configuration mode for the device.
TMS	Input	This is a dedicated JTAG input pin.
TDI	Input	This is a dedicated JTAG input pin.
TCK	Input	This is a dedicated JTAG input pin.
TDO	Output	This is a dedicated JTAG output pin.

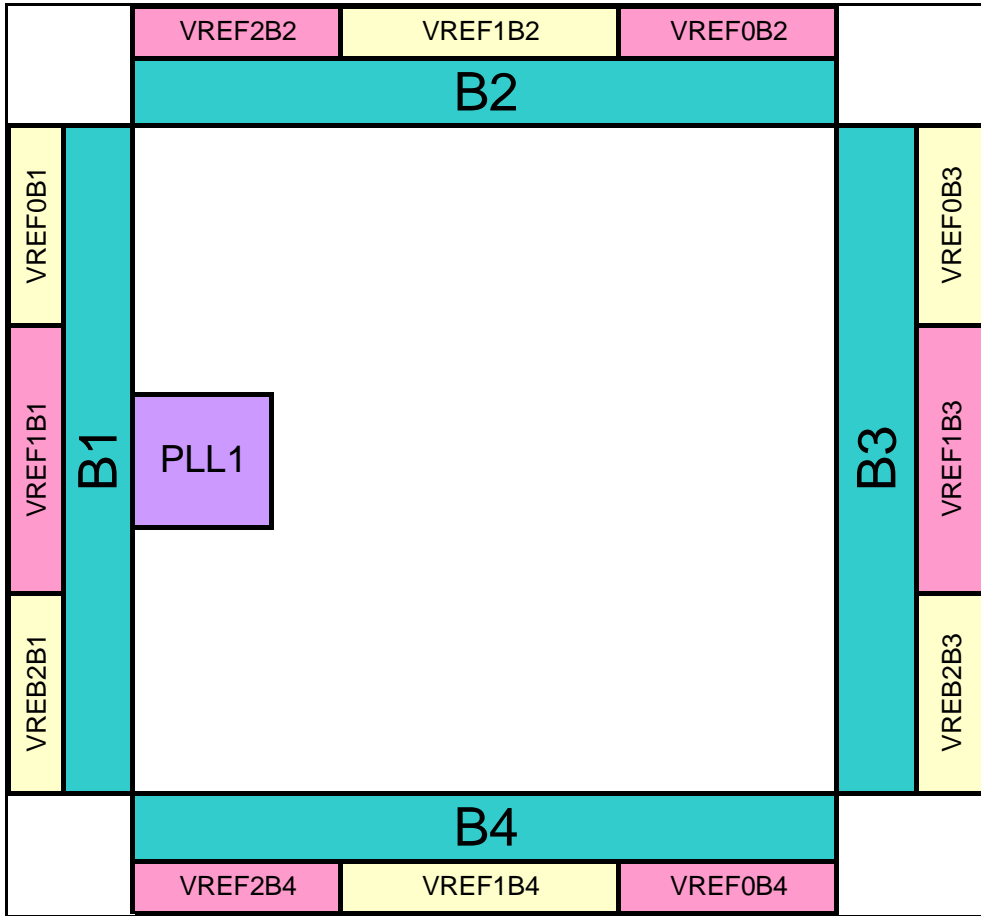
Table 1–2. Pin Definitions for the Cyclone EP1C3T100 Device (Part 3 of 3)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
Clock and PLL Pins		
CLK0	Input	Dedicated global clock input. The dual-function of CLK0 is LVDSCLK1p, which is used for differential input to PLL1.
CLK2	Input	Dedicated global clock input. The dual-function of CLK2 is LVDSCLK2p, which is used for differential input to PLL2.
DPCLK[7..0]	I/O	Dual-purpose clock pins that can connect to the global clock network. These pins can be used for high fan-out control signals, such as clocks, clears, IRDY, TRDY, or DQS signals. These pins are also available as user I/O pins.
Dual-Purpose External Memory Interface Pins		
DQS[0..1][L,R,T,B]	I/O	Optional data strobe signal for use in external memory interfacing. These pins also function as DPCLK pins; therefore, the DQS signals can connect to the global clock network. A programmable delay chain is used to shift the DQS signals by 90 or 72 degrees.
DQ[0..7][L,R,T,B]	I/O	Optional data signal for use in external memory interfacing.
DM[0..1][L,R,T,B]	I/O	Optional data mask output signal for use in external memory interfacing.

PLL & Bank Diagram

Figure 1–1 shows the PLL and Bank locations for the EP1C3T100 device.

Figure 1–1. PLL and Bank Diagram (1), (2)



Notes for Figure 1–1:

- (1) This is a top view of the silicon die.
- (2) This is a pictorial representation only to get an idea of placement on the device. Refer to the pin-list and



2. Cyclone EP1C3T144 Device Pin Information

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Introduction

The following tables contain pin information for the Cyclone EP1C3T144 device, organized into the following sections:

Section	Page
Pin List	2-2
Pin Definitions	2-9
PLL & Bank Diagram	2-13

Table 2-1 shows the complete pin list for the Cyclone EP1C3T144 device:

Pin List

Table 2-1. Pin List for the Cyclone EP1C3T144 Device (Part 1 of 7)						
Pin Name/ Function	Optional Function(s)	Device			Package	
		Configuration Function	Bank Number	VREF Bank	144-Pin Thin Quad Flat Pack	DQS for X8 in 144-Pin Thin Quad Flat Pack
IO	LVDS4p	INIT_DONE	B1	VREF0B1	1	DM1L
IO	LVDS4n		B1	VREF0B1	2	DQ1L0
IO	LVDS3p	CLKUSR	B1	VREF0B1	3	DQ1L1
IO	LVDS3n		B1	VREF0B1	4	
IO	VREF0B1		B1	VREF0B1	5	
IO	LVDS2p		B1	VREF0B1	6	DQ1L2
IO	LVDS2n		B1	VREF0B1	7	DQ1L3
VCCIO1			B1	VREF0B1	8	
GND			B1	VREF0B1	9	
IO	DPCLK1		B1	VREF0B1	10	
IO	VREF1B1		B1	VREF1B1	11	
IO		nCSO	B1	VREF1B1	12	
DATA0		DATA0	B1	VREF1B1	13	
nCONFIG		nCONFIG	B1	VREF1B1	14	
VCCA_PLL1				VREF1B1	15	
CLK0	LVDSCLK1p		B1	VREF1B1	16	
CLK1	LVDSCLK1n		B1	VREF1B1	17	
GND_A_PLL1				VREF1B1	18	
GNDG_PLL1				VREF1B1	19	
nCEO		nCEO	B1	VREF1B1	20	
nCE		nCE	B1	VREF1B1	21	

Table 2-1. Pin List for the Cyclone EP1C3T144 Device (Part 2 of 7)						
Pin Name/ Function	Optional Function(s)	Device			Package 144-Pin Thin Quad Flat Pack	DQS for X8 in 144-Pin Thin Quad Flat Pack
		Configuration Function	Bank Number	VREF Bank		
MSEL0		MSEL0	B1	VREF1B1	22	
MSEL1		MSEL1	B1	VREF1B1	23	
DCLK		DCLK	B1	VREF1B1	24	
IO		ASDO	B1	VREF1B1	25	
IO	PLL1_OUTp		B1	VREF1B1	26	
IO	PLL1_OUTn		B1	VREF1B1	27	
IO	DPCLK0		B1	VREF2B1	28	DQS1L
VCCIO1			B1	VREF2B1	29	
GND			B1	VREF2B1	30	
IO	VREF2B1		B1	VREF2B1	31	
IO			B1	VREF2B1	32	DQ1L4
IO	LVDS1p		B1	VREF2B1	33	DQ1L5
IO	LVDS1n		B1	VREF2B1	34	DQ1L6
IO	LVDS0p		B1	VREF2B1	35	DQ1L7
IO	LVDS0n		B1	VREF2B1	36	
IO	LVDS33p		B4	VREF2B4	37	
IO	LVDS33n		B4	VREF2B4	38	
IO	LVDS32p		B4	VREF2B4	39	DQ1B7
IO	LVDS32n		B4	VREF2B4	40	DQ1B6
IO	LVDS31p		B4	VREF2B4	41	DQ1B5
IO	LVDS31n		B4	VREF2B4	42	DQ1B4
GND			B4	VREF2B4	43	
VCCIO4			B4	VREF2B4	44	

Table 2-1. Pin List for the Cyclone EP1C3T144 Device (Part 3 of 7)

Device						
Pin Name/ Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	Package 144-Pin Thin Quad Flat Pack	DQS for X8 in 144-Pin Thin Quad Flat Pack
GND				VREF2B4	45	
VCCINT				VREF2B4	46	
IO	DPCLK7		B4	VREF2B4	47	DQS1B
IO	VREF2B4		B4	VREF2B4	48	
IO			B4	VREF2B4	49	
IO	LVDS30p		B4	VREF2B4	50	
IO	LVDS30n		B4	VREF2B4	51	
IO	LVDS29p		B4	VREF1B4	52	
IO	LVDS29n		B4	VREF1B4	53	
IO	LVDS28p		B4	VREF1B4	54	
IO	LVDS28n		B4	VREF1B4	55	
IO	VREF1B4		B4	VREF1B4	56	
IO	LVDS27p		B4	VREF1B4	57	DM1B
IO	LVDS27n		B4	VREF1B4	58	
IO	LVDS26p		B4	VREF1B4	59	
IO	LVDS26n		B4	VREF0B4	60	
IO	VREF0B4		B4	VREF0B4	61	
IO	DPCLK6		B4	VREF0B4	62	
GND				VREF0B4	63	
VCCINT				VREF0B4	64	
GND			B4	VREF0B4	65	
VCCIO4			B4	VREF0B4	66	
IO	LVDS25p		B4	VREF0B4	67	DQ1B3

Table 2-1. Pin List for the Cyclone EP1C3T144 Device (Part 4 of 7)

Pin Name/ Function	Optional Function(s)	Device				Package 144-Pin Thin Quad Flat Pack	DQS for X8 in 144-Pin Thin Quad Flat Pack
		Configuration Function	Bank Number	VREF Bank	Bank Number		
IO	LVDS25n		B4	VREF0B4	68	DQ1B2	
IO	LVDS24p		B4	VREF0B4	69	DQ1B1	
IO	LVDS24n		B4	VREF0B4	70	DQ1B0	
IO	LVDS23p		B4	VREF0B4	71		
IO	LVDS23n		B4	VREF0B4	72		
IO	LVDS22n		B3	VREF2B3	73		
IO	LVDS22p		B3	VREF2B3	74		
IO	LVDS21n		B3	VREF2B3	75		
IO	LVDS21p		B3	VREF2B3	76		
IO	LVDS20n		B3	VREF2B3	77	DQ1R7	
IO	LVDS20p		B3	VREF2B3	78	DQ1R6	
IO	VREF2B3		B3	VREF2B3	79		
GND			B3	VREF2B3	80		
VCCIO3			B3	VREF2B3	81		
IO	DPCLK5		B3	VREF2B3	82	DQS1R	
IO	LVDS19n		B3	VREF2B3	83	DQ1R5	
IO	LVDS19p		B3	VREF2B3	84	DQ1R4	
IO			B3	VREF2B3	85	DM1R	
CONF_DONE		CONF_DONE	B3	VREF1B3	86		
nSTATUS		nSTATUS	B3	VREF1B3	87		
TCK		TCK	B3	VREF1B3	88		
TMS		TMS	B3	VREF1B3	89		
TDO		TDO	B3	VREF1B3	90		

Table 2-1. Pin List for the Cyclone EP1C3T144 Device (Part 5 of 7)						
Pin Name/ Function	Optional Function(s)	Configuration Function	Device			DQS for X8 in 144-Pin Thin Quad Flat Pack
			Bank Number	VREF Bank	Package 144-Pin Thin Quad Flat Pack	
IO			B3	VREF1B3	91	
CLK3	LVDSCLK2n		B3	VREF1B3	92	
CLK2	LVDSCLK2p		B3	VREF1B3	93	
IO			B3	VREF1B3	94	
TDI		TDI	B3	VREF1B3	95	
IO	VREF1B3		B3	VREF1B3	96	
IO			B3	VREF0B3	97	DQ1R3
IO	LVDS18n		B3	VREF0B3	98	DQ1R2
IO	LVDS18p		B3	VREF0B3	99	DQ1R1
IO	DPCLK4		B3	VREF0B3	100	
GND			B3	VREF0B3	101	
VCCIO3			B3	VREF0B3	102	
IO			B3	VREF0B3	103	DQ1R0
IO	VREF0B3		B3	VREF0B3	104	
IO	LVDS17n		B3	VREF0B3	105	
IO	LVDS17p		B3	VREF0B3	106	
IO	LVDS16n		B3	VREF0B3	107	
IO	LVDS16p		B3	VREF0B3	108	
IO	LVDS15n		B2	VREF0B2	109	
IO	LVDS15p		B2	VREF0B2	110	
IO	LVDS14n		B2	VREF0B2	111	DQ0T0
IO	LVDS14p		B2	VREF0B2	112	DQ0T1
IO	LVDS13n		B2	VREF0B2	113	DQ0T2

Table 2-1. Pin List for the Cyclone EP1C3T144 Device (Part 6 of 7)

Pin Name/ Function	Device					Package		DQS for X8 in 144-Pin Thin Quad Flat Pack
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Thin Quad Flat Pack	144-Pin Thin Quad Flat Pack		
IO	LVDS13p		B2	VREF0B2	114	DQ0T3		
VCCIO2			B2	VREF0B2	115			
GND			B2	VREF0B2	116			
VCCINT				VREF0B2	117			
GND				VREF0B2	118			
IO	DPCLK3		B2	VREF0B2	119	DQS0T		
IO	VREF0B2		B2	VREF0B2	120			
IO	LVDS12n		B2	VREF0B2	121			
IO	LVDS12p		B2	VREF1B2	122			
IO	LVDS11n		B2	VREF1B2	123	DM0T		
IO	LVDS11p		B2	VREF1B2	124			
IO	VREF1B2		B2	VREF1B2	125			
IO	LVDS10n		B2	VREF1B2	126			
IO	LVDS10p		B2	VREF1B2	127			
IO	LVDS9n		B2	VREF1B2	128			
IO	LVDS9p		B2	VREF1B2	129			
IO	LVDS8n		B2	VREF2B2	130			
IO	LVDS8p		B2	VREF2B2	131			
IO			B2	VREF2B2	132			
IO	VREF2B2		B2	VREF2B2	133			
IO	DPCLK2		B2	VREF2B2	134			
VCCINT				VREF2B2	135			
GND				VREF2B2	136			

Table 2-1. Pin List for the Cyclone EP1C3T144 Device (Part 7 of 7)

Pin Name/ Function	Optional Function(s)	Device				Package	
		Configuration Function	Bank Number	VREF Bank	144-Pin Thin Quad Flat Pack	DQS for X8 in 144-Pin Thin Quad Flat Pack	
VCCIO2			B2	VREF2B2	137		
GND			B2	VREF2B2	138		
IO	LVDS7n		B2	VREF2B2	139	DQ0T4	
IO	LVDS7p		B2	VREF2B2	140	DQ0T5	
IO	LVDS6n		B2	VREF2B2	141	DQ0T6	
IO	LVDS6p		B2	VREF2B2	142	DQ0T7	
IO	LVDS5n	DEV_OE	B2	VREF2B2	143		
IO	LVDS5p	DEV_CLRn	B2	VREF2B2	144		

Table 2-2 shows pin definitions for the EP1C3T144 device.

Pin Definitions

Table 2-2. Pin Definitions for the EP1C3T144 Device (Part 1 of 4)		
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
Supply and Reference Pins		
VCCIO[1..4]	Power	These are I/O supply voltage pins for banks 1 through 4. Each bank can support a different voltage level. VCCIO supplies power to the output buffers for all I/O standards. VCCIO also supplies power to the input buffers used for the LVTTL, LVCMOS, 1.5-V, 1.8-V, 2.5-V, and 3.3-V PCI I/O standards.
VCCINT	Power	These are internal logic array voltage supply pins. VCCINT also supplies power to the input buffers used for the LVDS, SSTL2, and SSTL3 I/O standards.
VREF[0..2][1..4]	I/O, Input	Input reference voltage for banks 1-4. If a bank uses a voltage-referenced I/O standard, then these pins are used as the voltage-reference pins for the bank. If voltage reference I/O standards are not used in the bank, the VREF pins are available as user I/O pins.
VCCA_PLL[1..2]	Power	Analog power for PLLs[1..2]. The designer must connect this pin to 1.5 V, even if the PLL is not used.
GND_A_PLL[1..2]	Ground	Analog ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.
GNDG_PLL[1..2]	Ground	Guard ring ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.
Configuration and JTAG Pins		
CONF_DONE	Bidirectional (open-drain)	This is a dedicated configuration status pin; it is not available as a user I/O pin.
nSTATUS	Bidirectional (open-drain)	This is a dedicated configuration status pin; it is not available as a user I/O pin.
nCONFIG	Input	Dedicated configuration control input. A low transition resets the target device; a low-to-high transition begins configuration. All I/O pins tri-state when nCONFIG is driven low.
DCLK	Input (PS mode), Output (AS mode)	In passive serial configuration mode, DCLK is a clock input used to clock configuration data from an external source into the Cyclone device. In active serial configuration mode, DCLK is a clock output from the Cyclone device (the Cyclone device acts as master in this mode). This is a dedicated pin used for configuration.

Table 2-2. Pin Definitions for the EP1C3T144 Device (Part 2 of 4)		
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
DATA0	Input	Dedicated configuration data input pin.
nCE	Input	Active-low chip enable. Dedicated chip enable input used to detect which device is active in a chain of devices. When nCE is low, the device is enabled. When nCE is high, the device is disabled.
nCEO	Output	Output that drives low when device configuration is complete. During multi-device configuration, this pin feeds a subsequent device's nCE pin.
ASDO	I/O, Output	Active serial data output from the Cyclone device. This output pin is utilized during active serial configuration mode. The Cyclone device controls configuration and drives address and control information out on ASDO. In passive serial configuration, this pin is available as a user I/O pin.
nCSO	I/O, Output	Chip select output that enables/disables a serial configuration device. This output is utilized during active serial configuration mode. The Cyclone device controls configuration and enables the serial configuration device by driving nCSO low. In passive serial configuration, this pin is available as a user I/O pin.
INIT_DONE	I/O, Output (open-drain)	This is a dual-purpose pin and can be used as an I/O pin when not enabled as INIT_DONE. When enabled, the pin indicates when the device has entered user mode. This pin can be used as a user I/O pin after configuration.
CLKUSR	I/O, Input	Optional user-supplied clock input. Synchronizes the initialization of one or more devices. This pin can be used as a user I/O pin after configuration.
DEV_CLRn	I/O, Input	Dual-purpose pin that can override all clears on all device registers. When this pin is driven low, all registers are cleared; when this pin is driven high, all registers behave as defined in the design.
DEV_OE	I/O, Input	Dual-purpose pin that can override all tri-states on the device. When this pin is driven low, all I/O pins are tri-stated; when this pin is driven high, all I/O pins behave as defined in the design.
MSEL[1..0]	Input	Dedicated mode select control pins that set the configuration mode for the device.
TMS	Input	This is a dedicated JTAG input pin.
TDI	Input	This is a dedicated JTAG input pin.
TCK	Input	This is a dedicated JTAG input pin.

Table 2-2. Pin Definitions for the EP1C3T144 Device (Part 3 of 4)

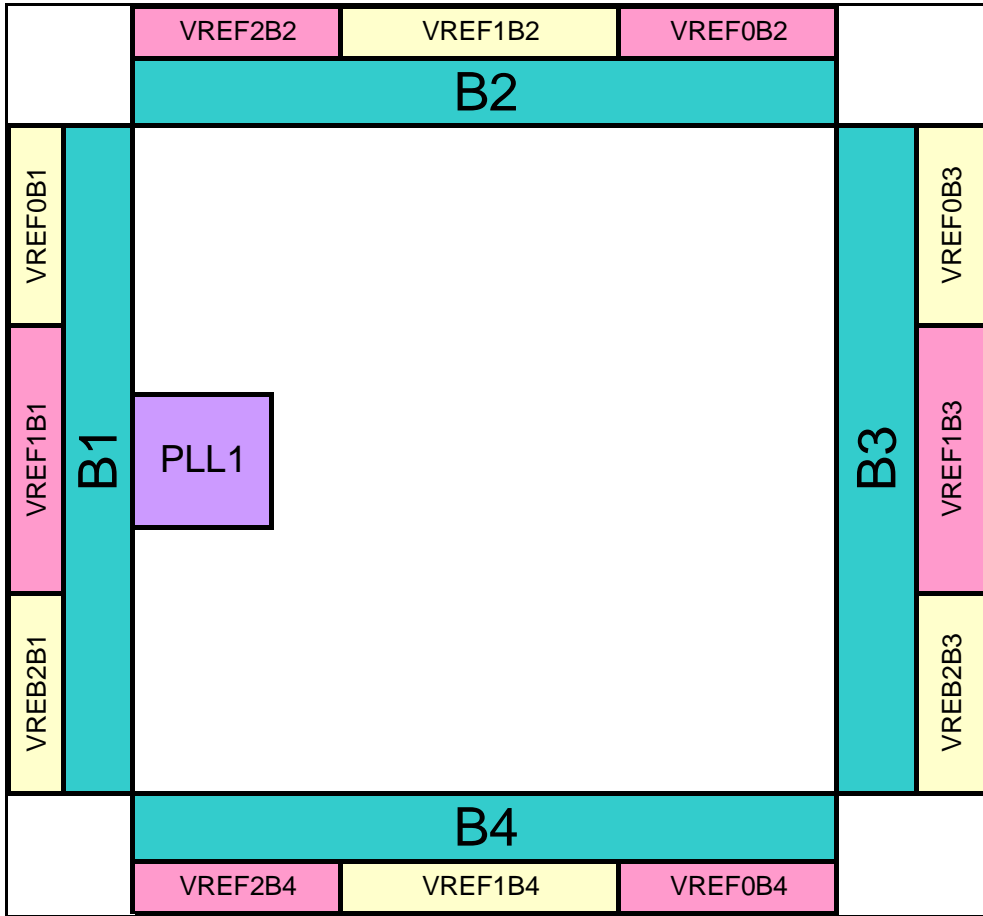
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
TDO	Output	This is a dedicated JTAG output pin.
Clock and PLL Pins		
CLK0	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK0 is LVDSCLK1p, which is used for differential input to PLL1.
CLK1	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK1 is LVDSCLK1n, which is used for differential input to PLL1. The EP1C3T100 does not support this clock pin.
CLK2	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK2 is LVDSCLK2p, which is used for differential input to PLL2.
CLK3	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK3 is LVDSCLK2n, which is used for differential input to PLL2. The EP1C3T100 does not support this clock pin.
DPCLK[7..0]	I/O	Dual-purpose clock pins that can connect to the global clock network. These pins can be used for high fan-out control signals, such as clocks, clears, IRDY, TRDY, or DQS signals. These pins are also available as user I/O pins.
PLL1_OUTp	I/O, Output	External clock output from PLL 1. This pin can be used with differential or single ended I/O standards. If clock output from PLL1 is not used, this pin is available as a user I/O pin. The EP1C3T100 does not support this output pin.
PLL1_OUTn	I/O, Output	Negative terminal for external clock output from PLL1. If the clock output is single ended, this pin is available as a user I/O pin. The EP1C3T100 does not support this output pin.

Table 2-2. Pin Definitions for the EP1C3T144 Device (Part 4 of 4)		
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
Dual-Purpose LVDS & External Memory Interface Pins		
LVDS[0..33]p	I/O, LVDS RX or TX	Dual-purpose LVDS I/O channels 0 to 33. These channels can be used for receiving or transmitting LVDS compatible signals. Pins with a "p" suffix carry the positive signal for the differential channel. If not used for LVDS interfacing, these pins are available as user I/O pins. The EP1C3T100 does not support LVDS I/O interfacing.
LVDS[0..33]n	I/O, LVDS RX or TX	Dual-purpose LVDS I/O channels 0 to 33. These channels can be used for receiving or transmitting LVDS compatible signals. Pins with an "n" suffix carry the negative signal for the differential channel. If not used for LVDS interfacing, these pins are available as user I/O pins. The EP1C3T100 does not support LVDS I/O interfacing.
LVDSCLK1p	Input, LVDS Input	Dual-purpose LVDS clock input to PLL1. If differential input to PLL1 is not required, this pin is available as the CLK0 input pin.
LVDSCLK1n	Input, LVDS Input	Dual-purpose LVDS clock input to PLL1. If differential input to PLL1 is not required, this pin is available as the CLK1 input pin. The EP1C3T100 does not support this clock pin.
LVDSCLK2p	Input, LVDS Input	Dual-purpose LVDS clock input to PLL2. If differential input to PLL2 is not required, this pin is available as the CLK2 input pin.
LVDSCLK2n	Input, LVDS Input	Dual-purpose LVDS clock input to PLL2. If differential input to PLL2 is not required, this pin is available as the CLK3 input pin. The EP1C3T100 does not support this clock pin.
DQS[0..1][L,R,T,B]	I/O	Optional data strobe signal for use in external memory interfacing. These pins also function as DPCLK pins; therefore, the DQS signals can connect to the global clock network. A programmable delay chain is used to shift the DQS signals by 90 or 72 degrees.
DQ[0..7][L,R,T,B]	I/O	Optional data signal for use in external memory interfacing.
DM[0..1][L,R,T,B]	I/O	Optional data mask output signal for use in external memory interfacing.

PLL & Bank Diagram

Figure 2-1 shows the PLL and Bank locations for the EP1C3T144 device.

Figure 2-1. PLL and Bank Diagram (1), (2)



Notes for Figure 2-1:

- (1) This is a top view of the silicon die.
- (2) This is a pictorial representation only to get an idea of placement on the device. Refer to the pin-list and



3. Cyclone EP1C6 Device Pin Information

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Introduction

The following tables contain pin information for the Cyclone EP1C6 device, organized into the following sections:

Section	Page
Pin List	3-2
Pin Definitions	3-16
PLL & Bank Diagram	3-20

Pin List

Table 3-1 shows the complete pin list for the device Cyclone EP1C6 device:

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 1 of 14)										
Pin Name / Function	Device				Package			DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin TQFP	240-Pin PQFP	256-Pin Fineline BGA			
IO	LVDS14p	INIT_DONE	B1	VREF0B1	1	D4	DM1L			
IO	LVDS14n		B1	VREF0B1	2	C3	DQ1L0			
IO	LVDS13p	CLKUSR	B1	VREF0B1	3	C2	DQ1L1			
IO	LVDS13n		B1	VREF0B1	4	B1				
IO	VREF0B1		B1	VREF0B1	5	G5				
IO			B1	VREF0B1	6	F4	DQ1L2			
IO	LVDS12p		B1	VREF0B1	7	D3	DQ1L3	DQ0L0	DQ0L0	
IO	LVDS12n		B1	VREF0B1	8	E4		DQ0L1	DQ0L1	
VCCIO1			B1	VREF0B1	8					
GND			B1	VREF0B1	9					
IO	DPCLK1		B1	VREF0B1	10	F5		DQS0L	DQS0L	
IO	LVDS11p		B1	VREF0B1		E3		DQ0L2	DQ0L2	
IO	LVDS11n		B1	VREF0B1		D2		DQ0L3	DQ0L3	
IO	LVDS10p		B1	VREF0B1		E2				
IO	LVDS10n		B1	VREF0B1		D1				
IO	LVDS9p		B1	VREF0B1		F3				
IO	LVDS9n		B1	VREF0B1		G3				
IO	LVDS8p		B1	VREF0B1		F2				
IO	LVDS8n		B1	VREF0B1		E1				
IO	LVDS7p		B1	VREF0B1		G2				

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 2 of 14)										
Device					Package			DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin TQFP	240-Pin PQFP	256-Pin FineLine BGA			
IO	LVDS7n		B1	VREF0B1		21	F1		DMOL	DMOL
VCCIO1			B1	VREF0B1		22				
IO	VREF1B1		B1	VREF1B1	11	23	H5			
IO		nCSO	B1	VREF1B1	12	24	G4			
DATA0		DATA0	B1	VREF1B1	13	25	H2			
nCONFIG		nCONFIG	B1	VREF1B1	14	26	H3			
VCCA_PLL1				VREF1B1	15	27	H6			
CLK0	LVDSCLK1p		B1	VREF1B1	16	28	G1			
CLK1	LVDSCLK1n		B1	VREF1B1	17	29	H1			
GND_A_PLL1				VREF1B1	18	30	J6			
GND_G_PLL1				VREF1B1	19	31	J5			
nCEO		nCEO	B1	VREF1B1	20	32	H4			
nCE		nCE	B1	VREF1B1	21	33	J4			
MSEL0		MSEL0	B1	VREF1B1	22	34	J3			
MSEL1		MSEL1	B1	VREF1B1	23	35	J2			
DCLK		DCLK	B1	VREF1B1	24	36	K4			
IO		ASDO	B1	VREF1B1	25	37	K3			
IO	PLL1_OUTp		B1	VREF1B1	26	38	J1			
IO	PLL1_OUTn		B1	VREF1B1	27	39	K2			
GND			B1	VREF2B1		40				
IO			B1	VREF2B1		41	L3			
IO	LVDS6p		B1	VREF2B1		42	K1			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 3 of 14)										
		Device				Package				
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Pin TQFP	240-Pin Pin PQFP	256-Pin Fineline BGA	DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
IO	LVDS6n		B1	VREF2B1		43	L1			
IO	LVDS5p		B1	VREF2B1		44	L2			
IO	LVDS5n		B1	VREF2B1		45	M1			
IO	LVDS4p		B1	VREF2B1		46	N1			
IO	LVDS4n		B1	VREF2B1		47	M2			
IO	LVDS3p		B1	VREF2B1		48	N2		DQ0L4	DQ0L4
IO	LVDS3n		B1	VREF2B1		49	M3		DQ0L5	DQ0L5
IO	DPCLK0		B1	VREF2B1	28	50	L5	DQS1L		
VCCIO1			B1	VREF2B1	29	51				
GND			B1	VREF2B1	30	52				
IO	LVDS2p		B1	VREF2B1		53	M4		DQ0L6	DQ0L6
IO	LVDS2n		B1	VREF2B1		54	N3		DQ0L7	DQ0L7
IO	VREF2B1		B1	VREF2B1	31	55	K5			
IO			B1	VREF2B1	32	56	L4	DQ1L4		
IO	LVDS1p		B1	VREF2B1	33	57	R1	DQ1L5		
IO	LVDS1n		B1	VREF2B1	34	58	P2	DQ1L6		
IO	LVDS0p		B1	VREF2B1	35	59	P3	DQ1L7		
IO	LVDS0n		B1	VREF2B1	36	60	N4			
IO	LVDS71p		B4	VREF2B4	37	61	R2			
IO	LVDS71n		B4	VREF2B4	38	62	T2			
IO	LVDS70p		B4	VREF2B4		63	R3			
IO	LVDS70n		B4	VREF2B4		64	P4			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 4 of 14)

Pin Name / Function	Device				Package			DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Pin TQFP	240-Pin Pin PQFP	256-Pin Fineline BGA			
IO	LVDS69p		B4	VREF2B4	39	65	R4	DQ1B7		
IO	LVDS69n		B4	VREF2B4	40	66	T4	DQ1B6		
IO	LVDS68p		B4	VREF2B4	41	67	R5	DQ1B5	DQ1B7	DQ1B7
IO	LVDS68n		B4	VREF2B4	42	68	P5	DQ1B4	DQ1B6	DQ1B6
GND			B4	VREF2B4	43	69				
VCCIO4			B4	VREF2B4	44	70				
GND				VREF2B4	45	71				
VCCINT				VREF2B4	46	72				
IO	DPCLK7		B4	VREF2B4	47	73	M5	DQS1B	DQS1B	DQS1B
IO	VREF2B4		B4	VREF2B4	48	74	M6			
IO	LVDS67p		B4	VREF2B4	49	75	N5			
IO	LVDS67n		B4	VREF2B4		76	N6		DQ1B5	DQ1B5
IO	LVDS66p		B4	VREF2B4		77	P6		DQ1B4	DQ1B4
IO	LVDS66n		B4	VREF2B4		78	R6			
IO			B4	VREF2B4		79	M7			
IO	LVDS65p		B4	VREF2B4		80	T6			
IO	LVDS65n		B4	VREF2B4		81	R7			
IO	LVDS64p		B4	VREF2B4		82	P7			
IO	LVDS64n		B4	VREF2B4		83	N7			
IO	LVDS63p		B4	VREF2B4	50	84	R8			
IO	LVDS63n		B4	VREF2B4	51	85	T8			
IO	LVDS62p		B4	VREF1B4	52	86	N8			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 5 of 14)										
Device					Package			DQS for X8		
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Pin TQFP	240-Pin Pin PQFP	256-Pin Fineline BGA	DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
IO	LVDS62n		B4	VREF1B4	53	87	P8			
IO			B4	VREF1B4		88	M8			
GND				VREF1B4	54	89				
VCCINT				VREF1B4	55	90				
GND			B4	VREF1B4	91					
VCCIO4			B4	VREF1B4	92					
IO	VREF1B4		B4	VREF1B4	56	93	M10			
IO	LVDS61p		B4	VREF1B4	57	94	R9	DM1B	DM1B	DM1B
IO	LVDS61n		B4	VREF1B4	58	95	T9			
IO	LVDS60p		B4	VREF1B4	96	96	P9			
IO	LVDS60n		B4	VREF1B4	97	97	N9			
IO	LVDS59p		B4	VREF1B4	98	98	R10			
IO	LVDS59n		B4	VREF1B4	59	99	T11			
IO	LVDS58p		B4	VREF1B4	100	100	N10			
IO	LVDS58n		B4	VREF1B4	101	101	P10			
IO	LVDS57p		B4	VREF0B4	102	102	R11			
IO	LVDS57n		B4	VREF0B4	103	103	P11			
IO	LVDS56p		B4	VREF0B4	104	104	N11			
IO	LVDS56n		B4	VREF0B4	105	105	N12			
IO			B4	VREF0B4	60	106	M9			
IO	VREF0B4		B4	VREF0B4	61	107	M11			
IO	DPCLK6		B4	VREF0B4	62	108	M12			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 6 of 14)										
		Device				Package				
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Pin TQFP	240-Pin Pin PQFP	256-Pin Fineline BGA	DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
GND				VREF0B4	63	109				
VCCINT				VREF0B4	64	110				
GND			B4	VREF0B4	65	111				
VCCIO4			B4	VREF0B4	66	112				
IO	LVDS55p		B4	VREF0B4	67	113	P12	DQ1B3	DQ1B3	DQ1B3
IO	LVDS55n		B4	VREF0B4	68	114	R12	DQ1B2	DQ1B2	DQ1B2
IO	LVDS54p		B4	VREF0B4	69	115	T13	DQ1B1	DQ1B1	DQ1B1
IO	LVDS54n		B4	VREF0B4	70	116	R13	DQ1B0	DQ1B0	DQ1B0
IO	LVDS53p		B4	VREF0B4		117	R14			
IO	LVDS53n		B4	VREF0B4		118	P13			
IO	LVDS52p		B4	VREF0B4	71	119	T15			
IO	LVDS52n		B4	VREF0B4	72	120	R15			
IO	LVDS51n		B3	VREF2B3	73	121	N13			
IO	LVDS51p		B3	VREF2B3	74	122	P14			
IO	LVDS50n		B3	VREF2B3	75	123	P15			
IO	LVDS50p		B3	VREF2B3	76	124	R16			
IO	LVDS49n		B3	VREF2B3	77	125	N15	DQ1R7	DQ1R7	DQ1R7
IO	LVDS49p		B3	VREF2B3	78	126	N16	DQ1R6		
IO	VREF2B3		B3	VREF2B3	79	127	K12			
IO			B3	VREF2B3		128	K14		DQ1R6	DQ1R6
GND			B3	VREF2B3	80	129				
VCCIO3			B3	VREF2B3	81	130				

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 7 of 14)										
Device					Package					
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Pin TQFP	240-Pin Pin PQFP	256-Pin Fineline BGA	DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
IO	DPCLK5		B3	VREF2B3	82	131	L12	DQS1R	DQS1R	DQS1R
IO	LVDS48n		B3	VREF2B3	83	132	N14	DQ1R5	DQ1R5	DQ1R5
IO	LVDS48p		B3	VREF2B3	84	133	M13	DQ1R4	DQ1R4	DQ1R4
IO	LVDS47n		B3	VREF2B3	85	134	M14	DM1R		
IO	LVDS47p		B3	VREF2B3		135	L13			
IO	LVDS46n		B3	VREF2B3		136	M15			
IO	LVDS46p		B3	VREF2B3		137	M16			
IO	LVDS45n		B3	VREF2B3		138	L14			
IO	LVDS45p		B3	VREF2B3		139	L15			
IO	LVDS44n		B3	VREF2B3		140	L16			
IO	LVDS44p		B3	VREF2B3		141	K16			
GND			B3	VREF2B3		142				
IO	PLL2_OUT1n		B3	VREF1B3		143	K15			
IO	PLL2_OUT1p		B3	VREF1B3		144	J16			
CONF_DON E		CONF_DON E	B3	VREF1B3	86	145	K13			
nSTATUS		nSTATUS	B3	VREF1B3	87	146	J13			
TCK		TCK	B3	VREF1B3	88	147	J14			
TMS		TMS	B3	VREF1B3	89	148	J15			
TDO		TDO	B3	VREF1B3	90	149	H15			
GNDG_PLL2				VREF1B3	91	150	J12			
GNDG_PLL2				VREF1B3		151	J11			
CLK3	LVDSCLK2n		B3	VREF1B3	92	152	H16			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 8 of 14)

Pin Name / Function		Device				Package				DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin TQFP	240-Pin PQFP	256-Pin FineLine BGA				
CLK2	LVDSCLK2p			B3	VREF1B3	93	153	G16				
VCCA_PLL2					VREF1B3	94	154	H11				
TDI		TDI		B3	VREF1B3	95	155	H14				
IO	VREF1B3			B3	VREF1B3	96	156	H12				
VCCIO3				B3	VREF0B3		157					
IO	LVDS43n			B3	VREF0B3		158	G14		DM1R	DM1R	
IO	LVDS43p			B3	VREF0B3		159	G13				
IO	LVDS42n			B3	VREF0B3		160	G15				
IO	LVDS42p			B3	VREF0B3		161	F16				
IO	LVDS41n			B3	VREF0B3		162	F14				
IO	LVDS41p			B3	VREF0B3		163	F13				
IO	LVDS40n			B3	VREF0B3		164	F15				
IO	LVDS40p			B3	VREF0B3		165	E16				
IO	LVDS39n			B3	VREF0B3		166	E15				
IO	LVDS39p			B3	VREF0B3	97	167	D16	DQ1R3			
IO	LVDS38n			B3	VREF0B3	98	168	D15	DQ1R2			
IO	LVDS38p			B3	VREF0B3	99	169	E14	DQ1R1	DQ1R3	DQ1R3	
IO	DPCLK4			B3	VREF0B3	100	170	F12				
GND				B3	VREF0B3	101	171					
VCCIO3				B3	VREF0B3	102	172					
IO	LVDS37n			B3	VREF0B3		173	E13		DQ1R2	DQ1R2	
IO	LVDS37p			B3	VREF0B3		174	D14		DQ1R1	DQ1R1	

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 9 of 14)										
		Device				Package				
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Pin TQFP	240-Pin Pin PQFP	256-Pin Fineline BGA	DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
IO			B3	VREF0B3	103	175	H13	DQ1R0	DQ1R0	DQ1R0
IO	VREF0B3		B3	VREF0B3	104	176	G12			
IO	LVDS36n		B3	VREF0B3	105	177	B16			
IO	LVDS36p		B3	VREF0B3	106	178	C15			
IO	LVDS35n		B3	VREF0B3	107	179	C14			
IO	LVDS35p		B3	VREF0B3	108	180	D13			
IO	LVDS34n		B2	VREF0B2	109	181	B15			
IO	LVDS34p		B2	VREF0B2	110	182	A15			
IO	LVDS33n		B2	VREF0B2		183	B14			
IO	LVDS33p		B2	VREF0B2		184	C13			
IO	LVDS32n		B2	VREF0B2	111	185	B13	DQ0T0	DQ0T0	DQ0T0
IO	LVDS32p		B2	VREF0B2	112	186	A13	DQ0T1	DQ0T1	DQ0T1
IO	LVDS31n		B2	VREF0B2	113	187	B12	DQ0T2	DQ0T2	DQ0T2
IO	LVDS31p		B2	VREF0B2	114	188	C12	DQ0T3	DQ0T3	DQ0T3
VCCIO2			B2	VREF0B2	115	189				
GND			B2	VREF0B2	116	190				
VCCINT				VREF0B2	117	191				
GND				VREF0B2	118	192				
IO	DPCLK3		B2	VREF0B2	119	193	E12	DQS0T	DQS0T	DQS0T
IO	VREF0B2		B2	VREF0B2	120	194	E11			
IO			B2	VREF0B2	121	195	E9			
IO	LVDS30n		B2	VREF0B2		196	D12			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 10 of 14)										
		Device				Package				
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Pin TQFP	240-Pin Pin PQFP	256-Pin Fineline BGA	DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
IO	LVDS30p		B2	VREF0B2		197	D11			
IO	LVDS29n		B2	VREF0B2		198	C11			
IO	LVDS29p		B2	VREF0B2		199	B11			
IO	LVDS28n		B2	VREF1B2		200	A11			
IO	LVDS28p		B2	VREF1B2		201	B10			
IO	LVDS27n		B2	VREF1B2	122	202	C10			
IO	LVDS27p		B2	VREF1B2		203	D10			
IO	LVDS26n		B2	VREF1B2		204	A9			
IO	LVDS26p		B2	VREF1B2		205	B9			
IO	LVDS25n		B2	VREF1B2	123	206	D9	DM0T	DM0T	DM0T
IO	LVDS25p		B2	VREF1B2	124	207	C9			
IO	VREF1B2		B2	VREF1B2	125	208	E10			
VCCIO2			B2	VREF1B2		209				
GND			B2	VREF1B2		210				
VCCINT				VREF1B2	126	211				
GND				VREF1B2	127	212				
IO			B2	VREF1B2		213	E8			
IO	LVDS24n		B2	VREF1B2	128	214	C8			
IO	LVDS24p		B2	VREF1B2	129	215	D8			
IO	LVDS23n		B2	VREF2B2	130	216	A8			
IO	LVDS23p		B2	VREF2B2	131	217	B8			
IO	LVDS22n		B2	VREF2B2		218	D7			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 11 of 14)										
		Device				Package				
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin TQFP	240-Pin PQFP	256-Pin Fineline BGA	DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
IO	LVDS22p		B2	VREF2B2		219	C7			
IO	LVDS21n		B2	VREF2B2		220	B7			
IO	LVDS21p		B2	VREF2B2		221	A6			
IO			B2	VREF2B2		222	E7			
IO	LVDS20n		B2	VREF2B2		223	B6			
IO	LVDS20p		B2	VREF2B2		224	C6			
IO	LVDS19n		B2	VREF2B2		225	D6			
IO	LVDS19p		B2	VREF2B2	132	226	D5			
IO	VREF2B2		B2	VREF2B2	133	227	E6			
IO	DPCLK2		B2	VREF2B2	134	228	E5			
VCCINT				VREF2B2	135	229				
GND				VREF2B2	136	230				
VCCIO2			B2	VREF2B2	137	231				
GND			B2	VREF2B2	138	232				
IO	LVDS18n		B2	VREF2B2	139	233	C5	DQ0T4	DQ0T4	DQ0T4
IO	LVDS18p		B2	VREF2B2	140	234	B5	DQ0T5	DQ0T5	DQ0T5
IO	LVDS17n		B2	VREF2B2	141	235	A4	DQ0T6	DQ0T6	DQ0T6
IO	LVDS17p		B2	VREF2B2	142	236	B4	DQ0T7	DQ0T7	DQ0T7
IO	LVDS16n		B2	VREF2B2		237	C4			
IO	LVDS16p		B2	VREF2B2		238	B3			
IO	LVDS15n	DEV_OE	B2	VREF2B2	143	239	A2			
IO	LVDS15p	DEV_CLRn	B2	VREF2B2	144	240	B2			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 13 of 14)

Pin Name / Function	Device				Package			DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin Pin TQFP	240-Pin Pin PQFP	256-Pin Fineline BGA			
VCCIO2							A14			
VCCIO2							F10			
VCCIO2							F7			
VCCIO2							A3			
GND							A1			
GND							A16			
GND							A5			
GND							A12			
GND							F6			
GND							F8			
GND							F9			
GND							F11			
GND							G7			
GND							G9			
GND							G11			
GND							H8			
GND							H10			
GND							J7			
GND							J9			
GND							K6			
GND							K8			
GND							K10			

Table 3-1. Pin List for the Cyclone EP1C6 Device (Part 14 of 14)

Pin Name / Function	Device				Package			DQS for X8 in 144-Pin TQFP	DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin Fineline BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	144-Pin TQFP	240-Pin PQFP	256-Pin Fineline BGA			
GND						L6				
GND						L8				
GND						L9				
GND						L11				
GND						T1				
GND						T5				
GND						T12				
GND						T16				

Pin Definitions

Table 3–2 shows pin definitions for the EP1C6 device.

Table 3–2. Pin Definitions for the EP1C6 Device (Part 1 of 4)		
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
Supply and Reference Pins		
VCCIO[1..4]	Power	These are I/O supply voltage pins for banks 1 through 4. Each bank can support a different voltage level. VCCIO supplies power to the output buffers for all I/O standards. VCCIO also supplies power to the input buffers used for the LVTTL, LVCMOS, 1.5-V, 1.8-V, 2.5-V, and 3.3-V PCI I/O standards.
VCCINT	Power	These are internal logic array voltage supply pins. VCCINT also supplies power to the input buffers used for the LVDS, SSTL2, and SSTL3 I/O standards.
VREF[0..2][1..4]	I/O, Input	Input reference voltage for banks 1–4. If a bank uses a voltage-referenced I/O standard, then these pins are used as the voltage-reference pins for the bank. If voltage reference I/O standards are not used in the bank, the VREF pins are available as user I/O pins.
VCCA_PLL[1..2]	Power	Analog power for PLLs[1..2]. The designer must connect this pin to 1.5 V, even if the PLL is not used.
GND_A_PLL[1..2]	Ground	Analog ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.
GNDG_PLL[1..2]	Ground	Guard ring ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.
Configuration and JTAG Pins		
CONF_DONE	Bidirectional (open-drain)	This is a dedicated configuration status pin; it is not available as a user I/O pin.
nSTATUS	Bidirectional (open-drain)	This is a dedicated configuration status pin; it is not available as a user I/O pin.
nCONFIG	Input	Dedicated configuration control input. A low transition resets the target device; a low-to-high transition begins configuration. All I/O pins tri-state when nCONFIG is driven low.
DCLK	Input (PS mode), Output (AS mode)	In passive serial configuration mode, DCLK is a clock input used to clock configuration data from an external source into the Cyclone device. In active serial configuration mode, DCLK is a clock output from the Cyclone device (the Cyclone device acts as master in this mode). This is a dedicated pin used for configuration.

Table 3-2. Pin Definitions for the EP1C6 Device (Part 2 of 4)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
DATA0	Input	Dedicated configuration data input pin.
nCE	Input	Active-low chip enable. Dedicated chip enable input used to detect which device is active in a chain of devices. When nCE is low, the device is enabled. When nCE is high, the device is disabled.
nCEO	Output	Output that drives low when device configuration is complete. During multi-device configuration, this pin feeds a subsequent device's nCE pin.
ASDO	I/O, Output	Active serial data output from the Cyclone device. This output pin is utilized during active serial configuration mode. The Cyclone device controls configuration and drives address and control information out on ASDO. In passive serial configuration, this pin is available as a user I/O pin.
nCSO	I/O, Output	Chip select output that enables/disables a serial configuration device. This output is utilized during active serial configuration mode. The Cyclone device controls configuration and enables the serial configuration device by driving nCSO low. In passive serial configuration, this pin is available as a user I/O pin.
INIT_DONE	I/O, Output (open-drain)	This is a dual-purpose pin and can be used as an I/O pin when not enabled as INIT_DONE. When enabled, the pin indicates when the device has entered user mode. This pin can be used as a user I/O pin after configuration.
CLKUSR	I/O, Input	Optional user-supplied clock input. Synchronizes the initialization of one or more devices. This pin can be used as a user I/O pin after configuration.
DEV_CLRn	I/O, Input	Dual-purpose pin that can override all clears on all device registers. When this pin is driven low, all registers are cleared; when this pin is driven high, all registers behave as defined in the design.
DEV_OE	I/O, Input	Dual-purpose pin that can override all tri-states on the device. When this pin is driven low, all I/O pins are tri-stated; when this pin is driven high, all I/O pins behave as defined in the design.
MSEL[1..0]	Input	Dedicated mode select control pins that set the configuration mode for the device.
TMS	Input	This is a dedicated JTAG input pin.
TDI	Input	This is a dedicated JTAG input pin.
TCK	Input	This is a dedicated JTAG input pin.
TDO	Output	This is a dedicated JTAG output pin.

Table 3-2. Pin Definitions for the EP1C6 Device (Part 3 of 4)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
Clock and PLL Pins		
CLK0	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK0 is LVDSCLK1p, which is used for differential input to PLL1.
CLK1	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK1 is LVDSCLK1n, which is used for differential input to PLL1.
CLK2	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK2 is LVDSCLK2p, which is used for differential input to PLL2.
CLK3	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK3 is LVDSCLK2n, which is used for differential input to PLL2.
DPCLK[7..0]	I/O	Dual-purpose clock pins that can connect to the global clock network. These pins can be used for high fan-out control signals, such as clocks, clears, IRDY, TRDY, or DQS signals. These pins are also available as user I/O pins.
PLL1_OUTp	I/O, Output	External clock output from PLL 1. This pin can be used with differential or single ended I/O standards. If clock output from PLL 1 is not used, this pin is available as a user I/O pin.
PLL1_OUTn	I/O, Output	Negative terminal for external clock output from PLL 1. If the clock output is single ended, this pin is available as a user I/O pin.
PLL2_OUTp	I/O, Output	External clock output from PLL 2. This pin can be used with differential or single ended I/O standards. If clock output from PLL2 is not used, this pin is available as a user I/O pin. The EP1C6T144 does not support this output pin.
PLL2_OUTn	I/O, Output	Negative terminal for external clock output from PLL2. If the clock output is single ended, this pin is available as a user I/O pin. The EP1C6T144 does not support this output pin.
Dual-Purpose LVDS & External Memory Interface Pins		
LVDS[0..7]p	I/O, LVDS RX or TX	Dual-purpose LVDS I/O channels 0 to 71. These channels can be used for receiving or transmitting LVDS compatible signals. Pins with a "p" suffix carry the positive signal for the differential channel. If not used for LVDS interfacing, these pins are available as user I/O pins.

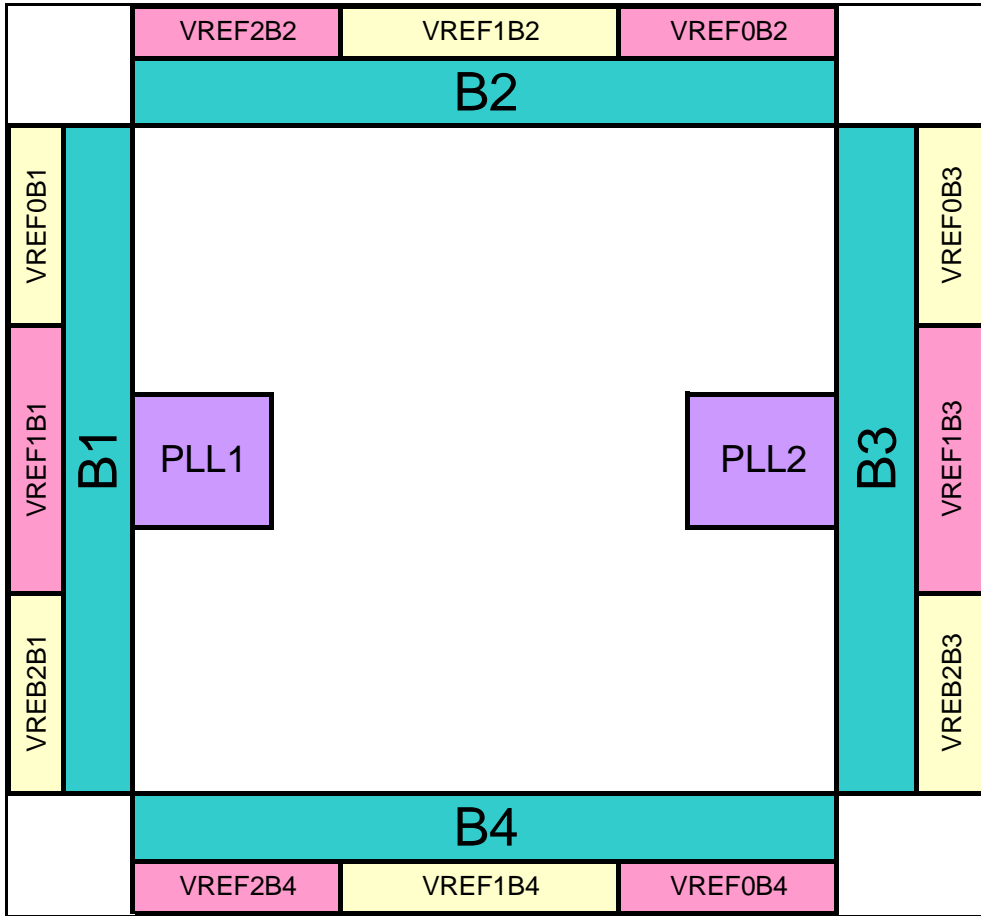
Table 3-2. Pin Definitions for the EP1C6 Device (Part 4 of 4)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
LVDS[0..7]n	I/O, LVDS RX or TX	Dual-purpose LVDS I/O channels 0 to 71. These channels can be used for receiving or transmitting LVDS compatible signals. Pins with an "n" suffix carry the negative signal for the differential channel. If not used for LVDS interfacing, these pins are available as user I/O pins.
LVDSCLK1p	Input, LVDS Input	Dual-purpose LVDS clock input to PLL1. If differential input to PLL1 is not required, this pin is available as the CLK0 input pin.
LVDSCLK1n	Input, LVDS Input	Dual-purpose LVDS clock input to PLL1. If differential input to PLL1 is not required, this pin is available as the CLK1 input pin.
LVDSCLK2p	Input, LVDS Input	Dual-purpose LVDS clock input to PLL2. If differential input to PLL2 is not required, this pin is available as the CLK2 input pin.
LVDSCLK2n	Input, LVDS Input	Dual-purpose LVDS clock input to PLL2. If differential input to PLL2 is not required, this pin is available as the CLK3 input pin.
DQS[0..1][L,R,T,B]	I/O	Optional data strobe signal for use in external memory interfacing. These pins also function as DPCLK pins; therefore, the DQS signals can connect to the global clock network. A programmable delay chain is used to shift the DQS signals by 90 or 72 degrees.
DQ[0..7][L,R,T,B]	I/O	Optional data signal for use in external memory interfacing.
DM[0..1][L,R,T,B]	I/O	Optional data mask output signal for use in external memory interfacing.

PLL & Bank Diagram

Figure shows the PLL and Bank locations for the EP1C6 device.

Figure 3-1. PLL and Bank Diagram (1), (2)



Notes for Figure:

- (1) This is a top view of the silicon die.
- (2) This is a pictorial representation only to get an idea of placement on the device. Refer to the pin-list and



4. Cyclone EP1C12 Device Pin Information

C52004-1.0

Introduction

The following tables contain pin information for the Cyclone EP1C12 device, organized into the following sections:

Section	Page
Pin List	4-2
Pin Definitions	4-20
PLL & Bank Diagram	4-24

Pin List

Table 4-1 shows the complete pin list for the device Cyclone EP1C12 device:

Pin Name / Function		Device			Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA			
IO	LVDS23p		INIT_DONE	B1	VREF0B1	1		D4		
IO	LVDS23n			B1	VREF0B1	2		C3		
IO	LVDS22p		CLKUSR	B1	VREF0B1	3		C2		
IO	LVDS22n			B1	VREF0B1	4		B1		
IO	VREF0B1			B1	VREF0B1	5		G5		
IO				B1	VREF0B1	6		F4		
IO	LVDS21p			B1	VREF0B1	7		D3		DQ0L0
IO	LVDS21n			B1	VREF0B1	8		E4		DQ0L1
VCCIO1				B1	VREF0B1	9				
GND				B1	VREF0B1	10				
IO	DPCLK1			B1	VREF0B1	11		F5		DQS0L
IO	LVDS20p			B1	VREF0B1	12		E3		DQS0L
IO	LVDS20n			B1	VREF0B1	13		D2		DQ0L2
IO	LVDS19p			B1	VREF0B1	14		E2		DQ0L3
IO	LVDS19n			B1	VREF0B1	15		D1		
IO	LVDS18p			B1	VREF0B1	16		F3		
IO	LVDS18n			B1	VREF0B1	17		G3		
IO	LVDS17p			B1	VREF0B1	18		F2		
IO	LVDS17n			B1	VREF0B1	19		E1		
IO	LVDS16p			B1	VREF0B1	20		G2		

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 2 of 18)											
Pin Name / Function		Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO	LVDS16n			B1	VREF0B1	21	F1	F7	DM0L		
IO	LVDS15p			B1	VREF0B1			G3			
IO	LVDS15n			B1	VREF0B1			G4		DQ0L4	
IO	LVDS14p			B1	VREF0B1			G5		DQ0L5	
IO	LVDS14n			B1	VREF0B1			G6		DQ0L6	
IO				B1	VREF0B1			H1		DQ0L7	
VCCIO1				B1	VREF0B1	22					
GND				B1	VREF0B1						
IO	LVDS13p			B1	VREF1B1			H2			
IO	LVDS13n			B1	VREF1B1			H3			
IO	LVDS12p			B1	VREF1B1			H4			
IO	LVDS12n			B1	VREF1B1			H5		DM0L	
IO	VREF1B1			B1	VREF1B1	23	H5	H6			
IO			nCS0	B1	VREF1B1	24	G4	J1			
DATA0			DATA0	B1	VREF1B1	25	H2	H7			
nCONFIG			nCONFIG	B1	VREF1B1	26	H3	J2			
VCCA_PLL1					VREF1B1	27	H6	J5			
CLK0	LVDSCLK1p			B1	VREF1B1	28	G1	J3			
CLK1	LVDSCLK1n			B1	VREF1B1	29	H1	J4			
GND_A_PLL1					VREF1B1	30	J6	K1			
GNDG_PLL1					VREF1B1	31	J5	J6			
nCEO			nCEO	B1	VREF1B1	32	H4	K2			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 3 of 18)											
Pin Name / Function		Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
nCE			nCE	B1	VREF1B1	33	J4	J7			
MSEL0			MSEL0	B1	VREF1B1	34	J3	K3			
MSEL1			MSEL1	B1	VREF1B1	35	J2	K7			
DCLK			DCLK	B1	VREF1B1	36	K4	L1			
IO			ASDO	B1	VREF1B1	37	K3	K6			
IO			PLL1_OUTp	B1	VREF1B1	38	J1	K4			
IO			PLL1_OUTn	B1	VREF1B1	39	K2	K5			
IO			LVDS11p	B1	VREF1B1			L7		DM1L	
IO			LVDS11n	B1	VREF1B1			L6			
IO			LVDS10p	B1	VREF1B1			L2			
IO			LVDS10n	B1	VREF1B1			L3			
IO			LVDS9p	B1	VREF1B1			L5			
IO			LVDS9n	B1	VREF1B1			L4			
VCCIO1				B1	VREF2B1						
GND				B1	VREF2B1	40					
IO				B1	VREF2B1			M1		DQ1L0	
IO				B1	VREF2B1			M3		DQ1L1	
IO			LVDS8p	B1	VREF2B1			M2		DQ1L2	
IO			LVDS8n	B1	VREF2B1			M5		DQ1L3	
IO			LVDS7p	B1	VREF2B1			M4			
IO			LVDS7n	B1	VREF2B1	41	L3				
IO			LVDS6p	B1	VREF2B1	42	K1	N1			
IO			LVDS6n	B1	VREF2B1	43	L1	N2			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 4 of 18)										
Pin Name / Function	Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO	LVDS5p		B1	VREF2B1	44	L2	M6			
IO	LVDS5n		B1	VREF2B1	45	M1	N7			
IO	LVDS4p		B1	VREF2B1	46	N1	N5			
IO	LVDS4n		B1	VREF2B1	47	M2	N6			
IO	LVDS3p		B1	VREF2B1	48	N2	N3	DQ0L4	DQ0L4	DQ1L4
IO	LVDS3n		B1	VREF2B1	49	M3	N4	DQ0L5	DQ0L5	DQ1L5
IO	DPCLK0		B1	VREF2B1	50	L5	P5			DQS1L
VCCIO1			B1	VREF2B1	51					
GND			B1	VREF2B1	52					
IO	LVDS2p		B1	VREF2B1	53	M4	P2	DQ0L6	DQ0L6	DQ1L6
IO	LVDS2n		B1	VREF2B1	54	N3	P3	DQ0L7	DQ0L7	DQ1L7
IO	VREF2B1		B1	VREF2B1	55	K5	R1			
IO			B1	VREF2B1	56	L4	P4			
IO	LVDS1p		B1	VREF2B1	57	R1	R2			
IO	LVDS1n		B1	VREF2B1	58	P2	R3			
IO	LVDS0p		B1	VREF2B1	59	P3	T2			
IO	LVDS0n		B1	VREF2B1	60	N4	T3			
IO	LVDS102p		B4	VREF2B4	61	R2	U3			
IO	LVDS102n		B4	VREF2B4	62	T2	V4			
IO	LVDS101p		B4	VREF2B4	63	R3	M8			
IO	LVDS101n		B4	VREF2B4	64	P4	N8			
IO	LVDS100p		B4	VREF2B4	65	R4	T4			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 5 of 18)

Pin Name / Function		Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO	LVDS100n			B4	VREF2B4	66	T4	U4			
IO	LVDS99p			B4	VREF2B4	67	R5	T5	DQ1B7	DQ1B7	DQ1B7
IO	LVDS99n			B4	VREF2B4	68	P5	U5	DQ1B6	DQ1B6	DQ1B6
GND				B4	VREF2B4	69					
VCCIO4				B4	VREF2B4	70					
GND					VREF2B4	71					
VCCINT					VREF2B4	72					
IO	DPCLK7			B4	VREF2B4	73	M5	R4	DQS1B	DQS1B	DQS1B
IO	VREF2B4			B4	VREF2B4	74	M6	R5			
IO	LVDS98p			B4	VREF2B4	75	N5	V6			
IO	LVDS98n			B4	VREF2B4	76	N6	U6	DQ1B5	DQ1B5	DQ1B5
IO	LVDS97p			B4	VREF2B4	77	P6	P6	DQ1B4	DQ1B4	DQ1B4
IO	LVDS97n			B4	VREF2B4	78	R6	P7			
IO	LVDS96p			B4	VREF2B4	79	M7	T6			
IO	LVDS96n			B4	VREF2B4			R6			
GND					VREF2B4	80					
VCCINT					VREF2B4	81					
IO	LVDS95p			B4	VREF2B4	82	T6	U7			DQ1B3
IO	LVDS95n			B4	VREF2B4	83	R7	V7			DQ1B2
IO	LVDS94p			B4	VREF2B4	84	P7	T7			DQ1B1
IO	LVDS94n			B4	VREF2B4	85	N7	R7			DQ1B0
IO	LVDS93p			B4	VREF1B4	86	R8	U8			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 6 of 18)											
Pin Name / Function		Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO		LVDS93n		B4	VREF1B4	87	T8	V8			
IO		LVDS92p		B4	VREF1B4	88	M8	T8			
IO		LVDS92n		B4	VREF1B4			R8			
GND					VREF1B4	89					
VCCINT					VREF1B4	90					
GND				B4	VREF1B4	91					
VCCIO4				B4	VREF1B4	92					
IO		LVDS91p		B4	VREF1B4			U9			
IO		LVDS91n		B4	VREF1B4			V9			
IO		LVDS90p		B4	VREF1B4		N8	R9		DM1B	
IO		LVDS90n		B4	VREF1B4		P8	T9			
IO		LVDS89p		B4	VREF1B4			M9			
IO		LVDS89n		B4	VREF1B4			N9			
IO		VREF1B4		B4	VREF1B4	93	M10	P9			
IO		LVDS88p		B4	VREF1B4			U10			
IO		LVDS88n		B4	VREF1B4			V10			
IO		LVDS87p		B4	VREF1B4	94	R9	T10	DM1B		
IO		LVDS87n		B4	VREF1B4	95	T9	R10			
GND					VREF1B4	96					
VCCINT					VREF1B4	97					
IO				B4	VREF1B4			P10			
IO		LVDS86p		B4	VREF1B4	98	P9	R11			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 7 of 18)											
Pin Name / Function		Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO		LVDS86n		B4	VREF1B4	99	N9	T11			
IO		LVDS85p		B4	VREF1B4	100	R10	U11		DM0B	
IO		LVDS85n		B4	VREF1B4	101	T11	V11			
GND				B4	VREF1B4						
VCCIO4				B4	VREF1B4						
IO		LVDS84p		B4	VREF1B4		N10	V12			
IO		LVDS84n		B4	VREF1B4		P10	U12			
GND					VREF0B4	102					
VCCINT					VREF0B4	103					
IO		LVDS83p		B4	VREF0B4		R11	T12		DQ0B7	
IO		LVDS83n		B4	VREF0B4		P11	R12		DQ0B6	
IO		LVDS82p		B4	VREF0B4			V13		DQ0B5	
IO		LVDS82n		B4	VREF0B4			U13		DQ0B4	
IO		LVDS81p		B4	VREF0B4			T13			
IO		LVDS81n		B4	VREF0B4			R13			
IO		LVDS80p		B4	VREF0B4	104	N11	N10			
IO		LVDS80n		B4	VREF0B4	105	N12	M10			
IO				B4	VREF0B4	106	M9	P12			
IO		VREF0B4		B4	VREF0B4	107	M11	P13			
IO		DPCLK6		B4	VREF0B4	108	M12	U14		DQS0B	
GND					VREF0B4	109					
VCCINT					VREF0B4	110					

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 8 of 18)

Pin Name / Function	Device			Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA			
GND			B4	VREF0B4	111				
VCCIO4			B4	VREF0B4	112				
IO	LVDS79p		B4	VREF0B4	113	P12	DQ1B3	DQ1B3	DQ0B3
IO	LVDS79n		B4	VREF0B4	114	R12	DQ1B2	DQ1B2	DQ0B2
IO	LVDS78p		B4	VREF0B4	115	T13	DQ1B1	DQ1B1	DQ0B1
IO	LVDS78n		B4	VREF0B4	116	R13	DQ1B0	DQ1B0	DQ0B0
IO	LVDS77p		B4	VREF0B4	117	R14			
IO	LVDS77n		B4	VREF0B4	118	P13			
IO	LVDS76p		B4	VREF0B4	119	T15			
IO	LVDS76n		B4	VREF0B4	120	R15			
IO	LVDS75n		B3	VREF2B3	121	N13			
IO	LVDS75p		B3	VREF2B3	122	P14			
IO	LVDS74n		B3	VREF2B3	123	P15			
IO	LVDS74p		B3	VREF2B3	124	R16			
IO	LVDS73n		B3	VREF2B3	125	N15	DQ1R7	DQ1R7	DQ1R7
IO	LVDS73p		B3	VREF2B3	126	N16			
IO	VREF2B3		B3	VREF2B3	127	K12			
IO			B3	VREF2B3	128	K14	DQ1R6	DQ1R6	DQ1R6
GND			B3	VREF2B3	129				
VCCIO3			B3	VREF2B3	130				
IO	DPCLK5		B3	VREF2B3	131	L12	DQS1R	DQS1R	DQS1R
IO	LVDS72n		B3	VREF2B3	132	N14	DQ1R5	DQ1R5	DQ1R5

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 9 of 18)										
Pin Name / Function	Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO	LVDS72p		B3	VREF2B3	133	M13	N14	DQ1R4	DQ1R4	DQ1R4
IO	LVDS71n		B3	VREF2B3	134	M14	N18			
IO	LVDS71p		B3	VREF2B3	135	L13	N17			
IO	LVDS70n		B3	VREF2B3	136	M15	N13			
IO	LVDS70p		B3	VREF2B3	137	M16	N12			
IO	LVDS69n		B3	VREF2B3	138	L14	N16			
IO	LVDS69p		B3	VREF2B3	139	L15	N15			
IO	LVDS68n		B3	VREF2B3	140	L16	M18			
IO	LVDS68p		B3	VREF2B3	141	K16	M17			DQ1R3
IO	LVDS67n		B3	VREF2B3			M14			DQ1R2
IO	LVDS67p		B3	VREF2B3			M15			DQ1R1
IO			B3	VREF2B3			M16			DQ1R0
GND			B3	VREF2B3	142					
VCCIO3			B3	VREF2B3						
IO	LVDS66n		B3	VREF1B3			L18			
IO	LVDS66p		B3	VREF1B3			L17			
IO	LVDS65n		B3	VREF1B3			M13			
IO	LVDS65p		B3	VREF1B3			L13			
IO	LVDS64n		B3	VREF1B3			L16			DM1R
IO	LVDS64p		B3	VREF1B3			L15			
IO			B3	VREF1B3			L14			
IO	PLL2_OUTn		B3	VREF1B3	143	K15	K16			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 10 of 18)											
Pin Name / Function		Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO		PLL2_OUTp		B3	VREF1B3	144	J16	K15			
CONF_DONE			CONF_DONE	B3	VREF1B3	145	K13	K17			
nSTATUS			nSTATUS	B3	VREF1B3	146	J13	L12			
TCK			TCK	B3	VREF1B3	147	J14	K18			
TMS			TMS	B3	VREF1B3	148	J15	K14			
TDO			TDO	B3	VREF1B3	149	H15	K13			
GNDG_PLL2					VREF1B3	150	J12	J18			
GND_A_PLL2					VREF1B3	151	J11	K12			
CLK3		LVDSCLK2h		B3	VREF1B3	152	H16	J16			
CLK2		LVDSCLK2p		B3	VREF1B3	153	G16	J15			
VCCA_PLL2					VREF1B3	154	H11	J12			
TDI			TDI	B3	VREF1B3	155	H14	J17			
IO		VREF1B3		B3	VREF1B3	156	H12	J14			
IO		LVDS63n		B3	VREF1B3			J13			
IO		LVDS63p		B3	VREF1B3			H13		DM0R	
IO		LVDS62n		B3	VREF1B3			H14			
IO		LVDS62p		B3	VREF1B3			H15			
IO		LVDS61n		B3	VREF1B3			H16			
IO		LVDS61p		B3	VREF1B3			H17			
GND				B3	VREF0B3						
VCCIO3				B3	VREF0B3	157					
IO				B3	VREF0B3			H18		DQ0R7	

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 11 of 18)											
Pin Name / Function		Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO		LVDS60n			B3	VREF0B3					DQ0R6
IO		LVDS60p			B3	VREF0B3					DQ0R5
IO		LVDS59n			B3	VREF0B3	158	G14	DM1R	DM1R	DQ0R4
IO		LVDS59p			B3	VREF0B3	159	G13			
IO		LVDS58n			B3	VREF0B3	160	G15			
IO		LVDS58p			B3	VREF0B3	161	F16			
IO		LVDS57n			B3	VREF0B3	162	F14			
IO		LVDS57p			B3	VREF0B3	163	F13			
IO		LVDS56n			B3	VREF0B3	164	F15			
IO		LVDS56p			B3	VREF0B3	165	E16			
IO		LVDS55n			B3	VREF0B3	166	E15			
IO		LVDS55p			B3	VREF0B3	167	D16			
IO		LVDS54n			B3	VREF0B3	168	D15			
IO		LVDS54p			B3	VREF0B3	169	E14	DQ1R3	DQ1R3	DQ0R3
IO		DPCLK4			B3	VREF0B3	170	F12			DQS0R
GND					B3	VREF0B3	171				
VCCIO3					B3	VREF0B3	172				
IO		LVDS53n			B3	VREF0B3	173	E13	DQ1R2	DQ1R2	DQ0R2
IO		LVDS53p			B3	VREF0B3	174	D14	DQ1R1	DQ1R1	DQ0R1
IO					B3	VREF0B3	175	H13	DQ1R0	DQ1R0	DQ0R0
IO		VREF0B3			B3	VREF0B3	176	G12			
IO		LVDS52n			B3	VREF0B3	177	B16			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 12 of 18)									
Pin Name / Function	Device			Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA			
IO	LVDS52p		B3	VREF0B3	178	C15	D15		
IO	LVDS51n		B3	VREF0B3	179	C14	C17		
IO	LVDS51p		B3	VREF0B3	180	D13	D17		
IO	LVDS50n		B2	VREF0B2	181	B15	C16		
IO	LVDS50p		B2	VREF0B2	182	A15	B16		
IO	LVDS49n		B2	VREF0B2	183	B14	G11		
IO	LVDS49p		B2	VREF0B2	184	C13	F11		
IO	LVDS48n		B2	VREF0B2	185	B13	B15	DQ0T0	DQ0T0
IO	LVDS48p		B2	VREF0B2	186	A13	A15	DQ0T1	DQ0T1
IO	LVDS47n		B2	VREF0B2	187	B12	C15	DQ0T2	DQ0T2
IO	LVDS47p		B2	VREF0B2	188	C12	D14	DQ0T3	DQ0T3
VCCIO2			B2	VREF0B2	189				
GND			B2	VREF0B2	190				
VCCINT				VREF0B2	191				
GND				VREF0B2	192				
IO	DPCLK3		B2	VREF0B2	193	E12	B14	DQS0T	DQS0T
IO	VREF0B2		B2	VREF0B2	194	E11	C14		
IO			B2	VREF0B2	195	E9	E13		
IO	LVDS46n		B2	VREF0B2	196	D12	G10		
IO	LVDS46p		B2	VREF0B2	197	D11	F10		
IO	LVDS45n		B2	VREF0B2			B13		
IO	LVDS45p		B2	VREF0B2			A13		

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 13 of 18)										
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
					240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO	LVDS44n		B2	VREF0B2						DQ0T4
IO	LVDS44p		B2	VREF0B2						DQ0T5
IO	LVDS43n		B2	VREF0B2						DQ0T6
IO	LVDS43p		B2	VREF0B2		C11				DQ0T7
VCCINT				VREF0B2	198					
GND				VREF0B2	199					
IO	LVDS42n		B2	VREF1B2		A11				B12
IO	LVDS42p		B2	VREF1B2		B10				A12
VCCIO2			B2	VREF1B2						
GND			B2	VREF1B2						
IO	LVDS41n		B2	VREF1B2	200	C10				C11
IO	LVDS41p		B2	VREF1B2	201	D10				D11
IO	LVDS40n		B2	VREF1B2	202	A9				B11
IO	LVDS40p		B2	VREF1B2	203	B9				A11
IO			B2	VREF1B2						E11
VCCINT				VREF1B2	204					
GND				VREF1B2	205					
IO	LVDS39n		B2	VREF1B2	206	D9				C10
IO	LVDS39p		B2	VREF1B2	207	C9				D10
IO	LVDS38n		B2	VREF1B2						B10
IO	LVDS38p		B2	VREF1B2						A10
IO	VREF1B2		B2	VREF1B2	208	E10				E10

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 14 of 18)									
Pin Name / Function	Device			Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA			
IO	LVDS37n		B2	VREF1B2				G9	
IO	LVDS37p		B2	VREF1B2				F9	
IO	LVDS36n		B2	VREF1B2		C8		D9	DM1T
IO	LVDS36p		B2	VREF1B2		D8		C9	
IO	LVDS35n		B2	VREF1B2				A9	
IO	LVDS35p		B2	VREF1B2				B9	
VCCIO2			B2	VREF1B2	209				
GND			B2	VREF1B2	210				
VCCINT				VREF1B2	211				
GND				VREF1B2	212				
IO	LVDS34n		B2	VREF1B2				D8	
IO	LVDS34p		B2	VREF1B2	213	E8		C8	
IO	LVDS33n		B2	VREF1B2	214	A8		A8	
IO	LVDS33p		B2	VREF1B2	215	B8		B8	
IO	LVDS32n		B2	VREF2B2	216	D7		E8	DQ1T0
IO	LVDS32p		B2	VREF2B2	217	C7		E7	DQ1T1
IO	LVDS31n		B2	VREF2B2	218	B7		A7	DQ1T2
IO	LVDS31p		B2	VREF2B2	219	A6		B7	DQ1T3
VCCINT				VREF2B2	220				
GND				VREF2B2	221				
IO	LVDS30n		B2	VREF2B2				D7	
IO	LVDS30p		B2	VREF2B2	222	E7		C7	

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 15 of 18)										
Pin Name / Function	Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
IO	LVDS29n		B2	VREF2B2	223	B6	E6			
IO	LVDS29p		B2	VREF2B2	224	C6	D6			
IO	LVDS28n		B2	VREF2B2	225	D6	B6			
IO	LVDS28p		B2	VREF2B2	226	D5	C6			
IO	VREF2B2		B2	VREF2B2	227	E6	A6			
IO	DPCLK2		B2	VREF2B2	228	E5	B5			DQS1T
VCCINT				VREF2B2	229					
GND				VREF2B2	230					
VCCIO2			B2	VREF2B2	231					
GND			B2	VREF2B2	232					
IO	LVDS27n		B2	VREF2B2	233	C5	C5	DQ0T4	DQ0T4	DQ1T4
IO	LVDS27p		B2	VREF2B2	234	B5	D5	DQ0T5	DQ0T5	DQ1T5
IO	LVDS26n		B2	VREF2B2	235	A4	A4	DQ0T6	DQ0T6	DQ1T6
IO	LVDS26p		B2	VREF2B2	236	B4	B4	DQ0T7	DQ0T7	DQ1T7
IO	LVDS25n		B2	VREF2B2	237	C4	F8			
IO	LVDS25p		B2	VREF2B2	238	B3	G8			
IO	LVDS24n	DEV_OE	B2	VREF2B2	239	A2	B3			
IO	LVDS24p	DEV_CLRn	B2	VREF2B2	240	B2	C4			
VCCINT						A7	A17			
VCCINT						A10	A2			
VCCINT						G8	B1			
VCCINT						G10	B18			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 16 of 18)									
Pin Name / Function	Device			Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA			
VCCINT									
VCCINT							H7	H10	
VCCINT							H9	J9	
VCCINT							J8	K10	
VCCINT							J10	L9	
VCCINT							K7	U1	
VCCINT							K9	U18	
VCCINT							T7	V17	
VCCINT							T10	V2	
VCCIO1							C1		
VCCIO1							G6	E1	
VCCIO1							P1	G7	
VCCIO1								M7	
VCCIO1								P1	
VCCIO4							T3		
VCCIO4							L7	P11	
VCCIO4							L10	P8	
VCCIO4							T14	V14	
VCCIO4								V5	
VCCIO3							P16		
VCCIO3							K11	E18	
VCCIO3							C16	H12	
VCCIO3								M12	

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 17 of 18)										
Pin Name / Function	Device				Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA	324-Pin FineLine BGA			
VCCIO3										
VCCIO2						A14				
VCCIO2						F10	A14			
VCCIO2						F7	A5			
VCCIO2						A3	E12			
VCCIO2							E9			
GND						A1	A1			
GND						A16	A16			
GND						A5	A18			
GND						A12	A3			
GND						F6	B17			
GND						F8	B2			
GND						F9	C1			
GND						F11	C18			
GND						G7	H11			
GND						G9	H8			
GND						G11	H9			
GND						H8	J10			
GND						H10	J11			
GND						J7	J8			
GND						J9	K11			
GND						K6	K8			

Table 4-1. Pin List for the Cyclone EP1C12 Device (Part 18 of 18)									
Pin Name / Function	Device			Package			DQS for X8 in 240-Pin PQFP	DQS for X8 in 256-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Num.	VREF Bank	240-Pin PQFP	256-Pin FineLine BGA			
GND					K8	K9			
GND					K10	L10			
GND					L6	L11			
GND					L8	L8			
GND					L9	T1			
GND					L11	T18			
GND					T1	U17			
GND					T5	U2			
GND					T12	V1			
GND					T16	V16			
GND						V18			
GND						V3			

Pin Definitions

Table 4–2 shows pin definitions for the EP1C12 device.

Table 4–2. Pin Definitions for the EP1C12 Device (Part 1 of 4)		
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
Supply and Reference Pins		
VCCIO[1..4]	Power	These are I/O supply voltage pins for banks 1 through 4. Each bank can support a different voltage level. VCCIO supplies power to the output buffers for all I/O standards. VCCIO also supplies power to the input buffers used for the LVTTL, LVCMOS, 1.5-V, 1.8-V, 2.5-V, and 3.3-V PCI I/O standards.
VCCINT	Power	These are internal logic array voltage supply pins. VCCINT also supplies power to the input buffers used for the LVDS, SSTL2, and SSTL3 I/O standards.
VREF[0..2]B[1..4]	I/O, Inputz	Input reference voltage for banks 1-4. If a bank uses a voltage-referenced I/O standard, then these pins are used as the voltage-reference pins for the bank. If voltage reference I/O standards are not used in the bank, the VREF pins are available as user I/O pins.
VCCA_PLL[1..2]	Power	Analog power for PLLs[1..2]. The designer must connect this pin to 1.5 V, even if the PLL is not used.
GND_A_PLL[1..2]	Ground	Analog ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.
GNDG_PLL[1..2]	Ground	Guard ring ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.
Configuration and JTAG Pins		
CONF_DONE	Bidirectional (open-drain)	This is a dedicated configuration status pin; it is not available as a user I/O pin.
nSTATUS	Bidirectional (open-drain)	This is a dedicated configuration status pin; it is not available as a user I/O pin.
nCONFIG	Input	Dedicated configuration control input. A low transition resets the target device; a low-to-high transition begins configuration. All I/O pins tri-state when nCONFIG is driven low.
DCLK	Input (PS mode), Output (AS mode)	In passive serial configuration mode, DCLK is a clock input used to clock configuration data from an external source into the Cyclone device. In active serial configuration mode, DCLK is a clock output from the Cyclone device (the Cyclone device acts as master in this mode). This is a dedicated pin used for configuration.
DATA0	Input	Dedicated configuration data input pin.

Table 4-2. Pin Definitions for the EP1C12 Device (Part 2 of 4)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
nCE	Input	Active-low chip enable. Dedicated chip enable input used to detect which device is active in a chain of devices. When nCE is low, the device is enabled. When nCE is high, the device is disabled.
nCEO	Output	Output that drives low when device configuration is complete. During multi-device configuration, this pin feeds a subsequent device's nCE pin.
ASDO	I/O, Output	Active serial data output from the Cyclone device. This output pin is utilized during active serial configuration mode. The Cyclone device controls configuration and drives address and control information out on ASDO. In passive serial configuration, this pin is available as a user I/O pin.
nCSO	I/O, Output	Chip select output that enables/disables a serial configuration device. This output is utilized during active serial configuration mode. The Cyclone device controls configuration and enables the serial configuration device by driving nCSO low. In passive serial configuration, this pin is available as a user I/O pin.
INIT_DONE	I/O, Output (open-drain)	This is a dual-purpose pin and can be used as an I/O pin when not enabled as INIT_DONE. When enabled, the pin indicates when the device has entered user mode. This pin can be used as a user I/O pin after configuration.
CLKUSR	I/O, Input	Optional user-supplied clock input. Synchronizes the initialization of one or more devices. This pin can be used as a user I/O pin after configuration.
DEV_CLRn	I/O, Input	Dual-purpose pin that can override all clears on all device registers. When this pin is driven low, all registers are cleared; when this pin is driven high, all registers behave as defined in the design.
DEV_OE	I/O, Input	Dual-purpose pin that can override all tri-states on the device. When this pin is driven low, all I/O pins are tri-stated; when this pin is driven high, all I/O pins behave as defined in the design.
MSEL[1..0]	Input	Dedicated mode select control pins that set the configuration mode for the device.
TMS	Input	This is a dedicated JTAG input pin.
TDI	Input	This is a dedicated JTAG input pin.
TCK	Input	This is a dedicated JTAG input pin.
TDO	Output	This is a dedicated JTAG output pin.
Clock and PLL Pins		
CLK0	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK0 is LVDSCLK1p, which is used for differential input to PLL1.

Table 4-2. Pin Definitions for the EP1C12 Device (Part 3 of 4)

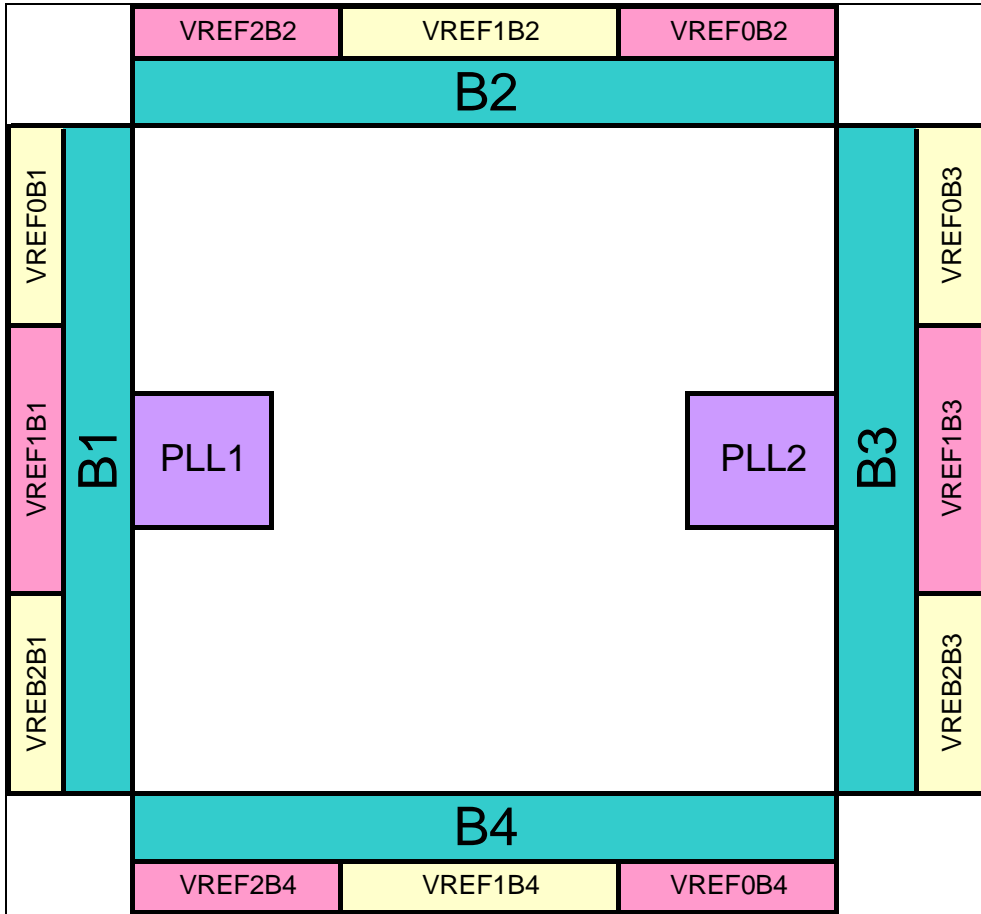
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
CLK1	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK1 is LVDSCLK1n, which is used for differential input to PLL1.
CLK2	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK2 is LVDSCLK2p, which is used for differential input to PLL2.
CLK3	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK3 is LVDSCLK2n, which is used for differential input to PLL2.
DPCLK[7..0]	I/O	Dual-purpose clock pins that can connect to the global clock network. These pins can be used for high fan-out control signals, such as clocks, clears, IRDY, TRDY, or DQS signals. These pins are also available as user I/O pins.
PLL1_OUTp	I/O, Output	External clock output from PLL 1. This pin can be used with differential or single ended I/O standards. If clock output from PLL1 is not used, this pin is available as a user I/O pin.
PLL1_OUTn	I/O, Output	Negative terminal for external clock output from PLL1. If the clock output is single ended, this pin is available as a user I/O pin.
PLL2_OUTp	I/O, Output	External clock output from PLL 2. This pin can be used with differential or single ended I/O standards. If clock output from PLL2 is not used, this pin is available as a user I/O pin.
PLL2_OUTn	I/O, Output	Negative terminal for external clock output from PLL2. If the clock output is single ended, this pin is available as a user I/O pin.
Dual-Purpose LVDS & External Memory Interface Pins		
LVDS[0..102]p	I/O, LVDS RX or TX	Dual-purpose LVDS I/O channels 0 to 102. These channels can be used for receiving or transmitting LVDS compatible signals. Pins with a "p" suffix carry the positive signal for the differential channel. If not used for LVDS interfacing, these pins are available as user I/O pins.
LVDS[0..102]n	I/O, LVDS RX or TX	Dual-purpose LVDS I/O channels 0 to 102. These channels can be used for receiving or transmitting LVDS compatible signals. Pins with an "n" suffix carry the negative signal for the differential channel. If not used for LVDS interfacing, these pins are available as user I/O pins.
LVDSCLK1p	Input, LVDS Input	Dual-purpose LVDS clock input to PLL1. If differential input to PLL1 is not required, this pin is available as the CLK0 input pin.
LVDSCLK1n	Input, LVDS Input	Dual-purpose LVDS clock input to PLL1. If differential input to PLL1 is not required, this pin is available as the CLK1 input pin.

Table 4-2. Pin Definitions for the EP1C12 Device (Part 4 of 4)		
Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
LVDSCLK2p	Input, LVDS Input	Dual-purpose LVDS clock input to PLL2. If differential input to PLL2 is not required, this pin is available as the CLK2 input pin.
LVDSCLK2n	Input, LVDS Input	Dual-purpose LVDS clock input to PLL2. If differential input to PLL2 is not required, this pin is available as the CLK3 input pin.
DQS[0..7][L,R,T,B]	I/O	Optional data strobe signal for use in external memory interfacing. These pins also function as DPCLK pins; therefore, the DQS signals can connect to the global clock network. A programmable delay chain is used to shift the DQS signals by 90 or 72 degrees.
DQ[0..7][L,R,T,B]	I/O	Optional data signal for use in external memory interfacing.
DM[0..1][L,R,T,B]	I/O	Optional data mask output signal for use in external memory interfacing.

PLL & Bank Diagram

Figure 4-1 shows the PLL and bank locations for the EP1C12 device.

Figure 4-1. PLL and Bank Diagram (1), (2)



Notes for Figure 4-1:

- (1) This is a top view of the silicon die.
- (2) This is a pictorial representation only to get an idea of placement on the device. Refer to the pin-list and the Quartus II software for exact locations.



5. Cyclone EP1C20 Device Pin Information

C52005-1.0

Introduction

The following tables contain pin information for the Cyclone EP1C20 device, organized into the following sections:

Section	Page
Pin List	5-2
Pin Definitions	5-22
PLL & Bank Diagram	5-26

Pin List

Table 5-1 shows the complete pin list for the device Cyclone EP1C20 device:

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 1 of 20)									
Pin Name / Function	Optional Function(s)	Device			Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA	
		Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA			
IO	LVDS31p	INIT_DONE	B1	VREF0B1	C3	C3			
IO	LVDS31n		B1	VREF0B1	C2	C2			
IO	LVDS30p	CLKUSR	B1	VREF0B1	D3	D3			
IO	LVDS30n		B1	VREF0B1	D2	D2			
IO	VREF0B1		B1	VREF0B1	D4	D4			
IO			B1	VREF0B1	D1	D1			
IO	LVDS29p		B1	VREF0B1	E3	E4	DQ0L0		
IO	LVDS29n		B1	VREF0B1	E2	E5	DQ0L1		
VCCIO1			B1	VREF0B1					
GND			B1	VREF0B1					
IO	DPCLK1		B1	VREF0B1	F1	F3	DQS0L		
IO	LVDS28p		B1	VREF0B1	E4	E3	DQ0L2		
IO	LVDS28n		B1	VREF0B1	E5	E2	DQ0L3		
IO	LVDS27p		B1	VREF0B1	F2	F4			
IO	LVDS27n		B1	VREF0B1	F3	F5			
IO	LVDS26p		B1	VREF0B1	F4	F2			
IO	LVDS26n		B1	VREF0B1	F5	F1			
IO	LVDS25p		B1	VREF0B1	G1	F6			
IO	LVDS25n		B1	VREF0B1	G2	G5			
IO	LVDS24p		B1	VREF0B1	F6	G1			
IO	LVDS24n		B1	VREF0B1	F7	G2			

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 2 of 20)

Pin Name / Function		Device				Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
		Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA		
IO		LVDS23p		B1	VREF0B1	G3	G6		
IO		LVDS23n		B1	VREF0B1	G4	G7	DQ0L4	DQ0L4
IO		LVDS22p		B1	VREF0B1	G5	G3	DQ0L5	DQ0L5
IO		LVDS22n		B1	VREF0B1	G6	G4	DQ0L6	DQ0L6
IO				B1	VREF0B1	H1	H7	DQ0L7	DQ0L7
VCCIO1				B1	VREF0B1				
GND				B1	VREF0B1				
IO		LVDS21p		B1	VREF1B1	H2	H1		
IO		LVDS21n		B1	VREF1B1	H3	H2		
IO		LVDS20p		B1	VREF1B1	H4	H3		
IO		LVDS20n		B1	VREF1B1	H5	H4	DM0L	DM0L
IO		LVDS19p		B1	VREF1B1		J1		
IO		LVDS19n		B1	VREF1B1		J2		
IO		LVDS18p		B1	VREF1B1		H5		
IO		LVDS18n		B1	VREF1B1		H6		
IO		LVDS17p		B1	VREF1B1		J3		
IO		LVDS17n		B1	VREF1B1		J4		
IO		LVDS16p		B1	VREF1B1		J5		
IO		LVDS16n		B1	VREF1B1		J6		
IO				B1	VREF1B1		J7		
IO		VREF1B1		B1	VREF1B1	H6	J8		
VCCIO1				B1	VREF1B1				
IO			nCS0	B1	VREF1B1	J1	K2		

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 3 of 20)

Pin Name / Function	Device			Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA		
DATA0		DATA0	B1	VREF1B1	H7	K3	
nCONFIG		nCONFIG	B1	VREF1B1	J2	K1	
VCCA_PLL1				VREF1B1	J5	K4	
CLK0	LVDSCLK1p		B1	VREF1B1	J3	K5	
CLK1	LVDSCLK1n		B1	VREF1B1	J4	K6	
GND_A_PLL1				VREF1B1	K1	K7	
GND_G_PLL1				VREF1B1	J6	L7	
nCEO		nCEO	B1	VREF1B1	K2	L2	
nCE		nCE	B1	VREF1B1	J7	L5	
MSEL0		MSEL0	B1	VREF1B1	K3	L1	
MSEL1		MSEL1	B1	VREF1B1	K7	L6	
DCLK		DCLK	B1	VREF1B1	L1	L3	
IO		ASDO	B1	VREF1B1	K6	L4	
GND			B1	VREF1B1			
IO	PLL1_OUTp		B1	VREF1B1	K4	L8	
IO	PLL1_OUTn		B1	VREF1B1	K5	M8	
IO	LVDS15p		B1	VREF1B1		M2	
IO	LVDS15n		B1	VREF1B1		M1	
IO	LVDS14p		B1	VREF1B1		M5	
IO	LVDS14n		B1	VREF1B1		M6	
IO	LVDS13p		B1	VREF1B1		M4	
IO	LVDS13n		B1	VREF1B1		M3	
IO	LVDS12p		B1	VREF1B1	L7	M7	DM1L

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 4 of 20)

Pin Name / Function	Device				Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA		
IO	LVDS12n		B1	VREF1B1	L6	N6		
IO	LVDS11p		B1	VREF1B1	L2	N1		
IO	LVDS11n		B1	VREF1B1	L3	N2		
IO	LVDS10p		B1	VREF1B1	L5	N4		
IO	LVDS10n		B1	VREF1B1	L4	N3		
VCCIO1			B1	VREF2B1				
GND			B1	VREF2B1				
IO			B1	VREF2B1	M1	N5	DQ1L0	DQ1L0
IO	LVDS9p		B1	VREF2B1		N7		
IO	LVDS9n		B1	VREF2B1		P7		
IO	LVDS8p		B1	VREF2B1	M3	P2	DQ1L1	DQ1L1
IO	LVDS8n		B1	VREF2B1	M2	P1	DQ1L2	DQ1L2
IO	LVDS7p		B1	VREF2B1	M5	P6	DQ1L3	DQ1L3
IO	LVDS7n		B1	VREF2B1	M4	P5		
IO	LVDS6p		B1	VREF2B1	N1	P3		
IO	LVDS6n		B1	VREF2B1	N2	P4		
IO	LVDS5p		B1	VREF2B1	M6	R1		
IO	LVDS5n		B1	VREF2B1	N7	R2		
IO	LVDS4p		B1	VREF2B1	N5	R6		
IO	LVDS4n		B1	VREF2B1	N6	R5		
IO	LVDS3p		B1	VREF2B1	N3	R3	DQ1L4	DQ1L4
IO	LVDS3n		B1	VREF2B1	N4	R4	DQ1L5	DQ1L5
IO	DPCLK0		B1	VREF2B1	P5	T4	DQS1L	DQS1L

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 5 of 20)									
Pin Name / Function	Device				Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA	
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA			
VCCIO1			B1	VREF2B1					
GND			B1	VREF2B1					
IO	LVDS2p		B1	VREF2B1	P2	T2	DQ1L6	DQ1L6	
IO	LVDS2n		B1	VREF2B1	P3	T3	DQ1L7	DQ1L7	
IO	VREF2B1		B1	VREF2B1	R1	U1			
IO			B1	VREF2B1	P4	U4			
IO	LVDS1p		B1	VREF2B1	R2	U2			
IO	LVDS1n		B1	VREF2B1	R3	U3			
IO	LVDS0p		B1	VREF2B1	T2	V2			
IO	LVDS0n		B1	VREF2B1	T3	V3			
IO	LVDS128p		B4	VREF2B4	U3	W3			
IO	LVDS128n		B4	VREF2B4	V4	Y4			
IO	LVDS127p		B4	VREF2B4	T4	V4			
IO	LVDS127n		B4	VREF2B4	U4	W4			
IO	LVDS126p		B4	VREF2B4	T5	T5	DQ1B7	DQ1B7	
IO	LVDS126n		B4	VREF2B4	U5	U5	DQ1B6	DQ1B6	
IO	LVDS125p		B4	VREF2B4		V5			
IO	LVDS125n		B4	VREF2B4		W5			
GND			B4	VREF2B4					
VCCIO4			B4	VREF2B4					
IO	DPCLK7		B4	VREF2B4	R4	T6	DQS1B	DQS1B	
IO	VREF2B4		B4	VREF2B4	R5	T7			
IO	LVDS124p		B4	VREF2B4	V6	W6			

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 6 of 20)

Pin Name / Function	Device				Package		DQS for X8 in 400-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin	400-Pin		
					FineLine BGA	FineLine BGA		
IO	LVDS124n		B4	VREF2B4	U6	Y6	DQ1B5	DQ1B5
IO	LVDS123p		B4	VREF2B4	P6	U6	DQ1B4	DQ1B4
IO	LVDS123n		B4	VREF2B4	P7	V6		
IO	LVDS122p		B4	VREF2B4	T6	W7		
IO	LVDS122n		B4	VREF2B4	R6	Y7		
IO	LVDS121p		B4	VREF2B4	U7	R7	DQ1B3	DQ1B3
IO	LVDS121n		B4	VREF2B4	V7	T8	DQ1B2	DQ1B2
IO	LVDS120p		B4	VREF2B4	T7	V7	DQ1B1	DQ1B1
IO	LVDS120n		B4	VREF2B4	R7	U7	DQ1B0	DQ1B0
IO	LVDS119p		B4	VREF1B4	U8	V8		
IO	LVDS119n		B4	VREF1B4	V8	U8		
IO	LVDS118p		B4	VREF1B4	T8	W8		
IO	LVDS118n		B4	VREF1B4	R8	Y8		
GND			B4	VREF1B4				
VCCIO4			B4	VREF1B4				
IO	LVDS117p		B4	VREF1B4	U9	U9		
IO	LVDS117n		B4	VREF1B4	V9	V9		
IO	LVDS116p		B4	VREF1B4	R9	T9	DM1B	DM1B
IO	LVDS116n		B4	VREF1B4	T9	R9		
IO	LVDS115p		B4	VREF1B4		Y9		
IO	LVDS115n		B4	VREF1B4		W9		
IO	LVDS114p		B4	VREF1B4		T10		
IO	LVDS114n		B4	VREF1B4		U10		

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 7 of 20)									
		Device				Package			
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA	
IO	VREF1B4		B4	VREF1B4	P9	V10			
IO	LVDS113p		B4	VREF1B4		W10			
IO	LVDS113n		B4	VREF1B4		Y10			
GND			B4	VREF1B4					
VCCIO4			B4	VREF1B4					
IO	LVDS112p		B4	VREF1B4	U10	V11			
IO	LVDS112n		B4	VREF1B4	V10	U11			
IO	LVDS111p		B4	VREF1B4	T10	W11			
IO	LVDS111n		B4	VREF1B4	R10	Y11			
IO			B4	VREF1B4		R11			
IO	LVDS110p		B4	VREF1B4		Y12			
IO	LVDS110n		B4	VREF1B4	P10	W12			
IO	LVDS109p		B4	VREF1B4	R11	T11			
IO	LVDS109n		B4	VREF1B4	T11	T12			
IO	LVDS108p		B4	VREF1B4	U11	U12	DM0B	DM0B	
IO	LVDS108n		B4	VREF1B4	V11	V12			
GND			B4	VREF1B4					
VCCIO4			B4	VREF1B4					
IO	LVDS107p		B4	VREF1B4	V12	T13			
IO	LVDS107n		B4	VREF1B4	U12	R13			
IO	LVDS106p		B4	VREF0B4	T12	Y13	DQ0B7	DQ0B7	
IO	LVDS106n		B4	VREF0B4	R12	W13	DQ0B6	DQ0B6	
IO	LVDS105p		B4	VREF0B4	V13	U13	DQ0B5	DQ0B5	

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 8 of 20)										
		Device				Package		DQS for X8 in	DQS for X8 in	
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA		
IO	LVDS105n		B4	VREF0B4	U13	V13	DQ0B4	DQ0B4		
IO	LVDS104p		B4	VREF0B4	T13	R14				
IO	LVDS104n		B4	VREF0B4	R13	T14				
IO	LVDS103p		B4	VREF0B4		W14				
IO	LVDS103n		B4	VREF0B4		Y14				
IO	LVDS102p		B4	VREF0B4		U14				
IO	LVDS102n		B4	VREF0B4		V14				
IO	LVDS101p		B4	VREF0B4		V15				
IO	LVDS101n		B4	VREF0B4	P12	U15				
IO	VREF0B4		B4	VREF0B4	P13	Y15				
IO	DPCLK6		B4	VREF0B4	U14	W15	DQS0B	DQS0B		
GND			B4	VREF0B4						
VCCIO4			B4	VREF0B4						
IO	LVDS100p		B4	VREF0B4		T15				
IO	LVDS100n		B4	VREF0B4		T16				
IO	LVDS99p		B4	VREF0B4	T14	W16	DQ0B3	DQ0B3		
IO	LVDS99n		B4	VREF0B4	R14	V16	DQ0B2	DQ0B2		
IO	LVDS98p		B4	VREF0B4	V15	V17	DQ0B1	DQ0B1		
IO	LVDS98n		B4	VREF0B4	U15	U16	DQ0B0	DQ0B0		
IO	LVDS97p		B4	VREF0B4	U16	Y17				
IO	LVDS97n		B4	VREF0B4	T15	W17				
IO	LVDS96n		B3	VREF2B3	T16	W18				
IO	LVDS96p		B3	VREF2B3	T17	V18				

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 9 of 20)									
		Device				Package			
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA	
IO	LVDS95n		B3	VREF2B3	R17	V19			
IO	LVDS95p		B3	VREF2B3	R18	U20			
IO	LVDS94n		B3	VREF2B3	R15	U18	DQ1R7	DQ1R7	
IO	LVDS94p		B3	VREF2B3	R16	U19			
IO	VREF2B3		B3	VREF2B3	P16	U17			
IO			B3	VREF2B3	P17	T18	DQ1R6	DQ1R6	
GND			B3	VREF2B3					
VCCIO3			B3	VREF2B3					
IO	DPCLK5		B3	VREF2B3	P15	T19	DQS1R	DQS1R	
IO	LVDS93n		B3	VREF2B3	P14	T17	DQ1R5	DQ1R5	
IO	LVDS93p		B3	VREF2B3	N14	R16	DQ1R4	DQ1R4	
IO	LVDS92n		B3	VREF2B3	N18	R19			
IO	LVDS92p		B3	VREF2B3	N17	R20			
IO	LVDS91n		B3	VREF2B3	N13	R17			
IO	LVDS91p		B3	VREF2B3	N12	R18			
IO	LVDS90n		B3	VREF2B3	N16	R15			
IO	LVDS90p		B3	VREF2B3	N15	P14			
IO	LVDS89n		B3	VREF2B3	M18	P18			
IO	LVDS89p		B3	VREF2B3	M17	P17	DQ1R3	DQ1R3	
IO	LVDS88n		B3	VREF2B3	M14	P16	DQ1R2	DQ1R2	
IO	LVDS88p		B3	VREF2B3	M15	P15	DQ1R1	DQ1R1	
IO	LVDS87n		B3	VREF2B3		P19			
IO	LVDS87p		B3	VREF2B3		P20			

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 10 of 20)

Pin Name / Function	Device				Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA		
IO			B3	VREF2B3	M16	N14	DQ1R0	DQ1R0
GND			B3	VREF2B3				
VCCIO3			B3	VREF2B3				
IO	LVDS86n		B3	VREF1B3	L18	N18		
IO	LVDS86p		B3	VREF1B3	L17	N17		
IO	LVDS85n		B3	VREF1B3	M13	N19		
IO	LVDS85p		B3	VREF1B3	L13	N20		
IO	LVDS84n		B3	VREF1B3	L16	N16	DM1R	DM1R
IO	LVDS84p		B3	VREF1B3	L15	N15		
IO	LVDS83n		B3	VREF1B3		M18		
IO	LVDS83p		B3	VREF1B3		M17		
IO	LVDS82n		B3	VREF1B3		M15		
IO	LVDS82p		B3	VREF1B3		M16		
IO	LVDS81n		B3	VREF1B3		M20		
IO	LVDS81p		B3	VREF1B3		M19		
IO			B3	VREF1B3	L14	M14		
IO	PLL2_OUTn		B3	VREF1B3	K16	M13		
IO	PLL2_OUTp		B3	VREF1B3	K15	L13		
CONF_DONE		CONF_DONE	B3	VREF1B3	K17	L18		
nSTATUS		nSTATUS	B3	VREF1B3	L12	L17		
TCK		TCK	B3	VREF1B3	K18	L19		
TMS		TMS	B3	VREF1B3	K14	L16		
TDO		TDO	B3	VREF1B3	K13	L20		

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 11 of 20)										
		Device					Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA				
GNDG_PLL2				VREF1B3	J18	L15				
GND_A_PLL2				VREF1B3	K12	K20				
CLK3	LVDSCLK2n		B3	VREF1B3	J16	K14				
CLK2	LVDSCLK2p		B3	VREF1B3	J15	L14				
VCCA_PLL2				VREF1B3	J12	K17				
TDI		TDI	B3	VREF1B3	J17	K18				
VCCIO3			B3	VREF1B3						
IO	VREF1B3		B3	VREF1B3	J14	K19				
IO			B3	VREF1B3		J13				
IO	LVDS80n		B3	VREF1B3		K16				
IO	LVDS80p		B3	VREF1B3		K15				
IO	LVDS79n		B3	VREF1B3		J18				
IO	LVDS79p		B3	VREF1B3		J17				
IO	LVDS78n		B3	VREF1B3		J14				
IO	LVDS78p		B3	VREF1B3		H14				
IO	LVDS77n		B3	VREF1B3		J20				
IO	LVDS77p		B3	VREF1B3		J19				
IO	LVDS76n		B3	VREF1B3	J13	J15				
IO	LVDS76p		B3	VREF1B3	H13	J16	DM0R	DM0R		
IO	LVDS75n		B3	VREF1B3	H14	H20				
IO	LVDS75p		B3	VREF1B3	H15	H19				
IO	LVDS74n		B3	VREF1B3	H16	H17				
IO	LVDS74p		B3	VREF1B3	H17	H18				

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 12 of 20)

Pin Name / Function	Device					Package		DQS for X8 in 400-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA			
GND			B3	VREF0B3					
VCCIO3			B3	VREF0B3					
IO			B3	VREF0B3	H18	H16	DQ0R7	DQ0R7	
IO	LVDS73n		B3	VREF0B3	G18	G17	DQ0R6	DQ0R6	
IO	LVDS73p		B3	VREF0B3	G17	G18	DQ0R5	DQ0R5	
IO	LVDS72n		B3	VREF0B3	G13	H15	DQ0R4	DQ0R4	
IO	LVDS72p		B3	VREF0B3	G14	G14			
IO	LVDS71n		B3	VREF0B3	G15	G19			
IO	LVDS71p		B3	VREF0B3	G16	G20			
IO	LVDS70n		B3	VREF0B3	G12	G15			
IO	LVDS70p		B3	VREF0B3	F12	G16			
IO	LVDS69n		B3	VREF0B3	F18	F20			
IO	LVDS69p		B3	VREF0B3	F17	F19			
IO	LVDS68n		B3	VREF0B3	F13	F15			
IO	LVDS68p		B3	VREF0B3	F14	F16			
IO	LVDS67n		B3	VREF0B3	F16	E19			
IO	LVDS67p		B3	VREF0B3	F15	E18	DQ0R3	DQ0R3	
IO	DPCLK4		B3	VREF0B3	E17	F18	DQS0R	DQS0R	
GND			B3	VREF0B3					
VCCIO3			B3	VREF0B3					
IO	LVDS66n		B3	VREF0B3	E16	F17	DQ0R2	DQ0R2	
IO	LVDS66p		B3	VREF0B3	E15	E17	DQ0R1	DQ0R1	
IO			B3	VREF0B3	D18	D20	DQ0R0	DQ0R0	

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 13 of 20)										
		Device				Package		DQS for X8 in	DQS for X8 in	
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA		
IO	VREF0B3		B3	VREF0B3	E14	D17				
IO	LVDS65n		B3	VREF0B3	D16	D19				
IO	LVDS65p		B3	VREF0B3	D15	D18				
IO	LVDS64n		B3	VREF0B3	C17	C19				
IO	LVDS64p		B3	VREF0B3	D17	C18				
IO	LVDS63n		B2	VREF0B2	C16	C17				
IO	LVDS63p		B2	VREF0B2	B16	B18				
IO	LVDS62n		B2	VREF0B2	B15	B17	DQ0T0	DQ0T0		
IO	LVDS62p		B2	VREF0B2	A15	A17	DQ0T1	DQ0T1		
IO	LVDS61n		B2	VREF0B2	C15	C16	DQ0T2	DQ0T2		
IO	LVDS61p		B2	VREF0B2	D14	B16	DQ0T3	DQ0T3		
IO	LVDS60n		B2	VREF0B2		D16				
IO	LVDS60p		B2	VREF0B2		E16				
VCCIO2			B2	VREF0B2						
GND			B2	VREF0B2						
IO	DPCLK3		B2	VREF0B2	B14	C15	DQS0T	DQS0T		
IO	VREF0B2		B2	VREF0B2	C14	D15				
IO	LVDS59n		B2	VREF0B2	E13	B15				
IO	LVDS59p		B2	VREF0B2		A15				
IO	LVDS58n		B2	VREF0B2		E15				
IO	LVDS58p		B2	VREF0B2		F14				
IO	LVDS57n		B2	VREF0B2		A14				
IO	LVDS57p		B2	VREF0B2		B14				

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 14 of 20)									
Pin Name / Function	Device					Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA			
IO	LVDS56n		B2	VREF0B2	B13	E14			
IO	LVDS56p		B2	VREF0B2	A13	E13			
IO	LVDS55n		B2	VREF0B2	D13	C14	DQ0T4	DQ0T4	
IO	LVDS55p		B2	VREF0B2	C13	D14	DQ0T5	DQ0T5	
IO	LVDS54n		B2	VREF0B2	D12	A13	DQ0T6	DQ0T6	
IO	LVDS54p		B2	VREF0B2	C12	B13	DQ0T7	DQ0T7	
IO	LVDS53n		B2	VREF1B2	B12	C13			
IO	LVDS53p		B2	VREF1B2	A12	D13			
VCCIO2			B2	VREF1B2					
GND			B2	VREF1B2					
IO	LVDS52n		B2	VREF1B2	C11	E12			
IO	LVDS52p		B2	VREF1B2	D11	F12			
IO	LVDS51n		B2	VREF1B2	B11	A12			
IO	LVDS51p		B2	VREF1B2	A11	B12	DM0T	DM0T	
IO	LVDS50n		B2	VREF1B2	E11	D12			
IO	LVDS50p		B2	VREF1B2		C12			
IO			B2	VREF1B2		E11			
IO	LVDS49n		B2	VREF1B2	C10	A11			
IO	LVDS49p		B2	VREF1B2	D10	B11			
IO	LVDS48n		B2	VREF1B2	B10	D11			
IO	LVDS48p		B2	VREF1B2	A10	C11			
VCCIO2			B2	VREF1B2					
GND			B2	VREF1B2					

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 15 of 20)									
Pin Name / Function	Device				Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA	
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA			
IO	LVDS47n		B2	VREF1B2		D10			
IO	LVDS47p		B2	VREF1B2		C10			
IO	VREF1B2		B2	VREF1B2	E10	F10			
IO	LVDS46n		B2	VREF1B2		A10			
IO	LVDS46p		B2	VREF1B2		B10			
IO	LVDS45n		B2	VREF1B2		E10			
IO	LVDS45p		B2	VREF1B2		E9			
IO	LVDS44n		B2	VREF1B2	D9	C9	DM1T		
IO	LVDS44p		B2	VREF1B2	C9	D9			
IO	LVDS43n		B2	VREF1B2	A9	A9			
IO	LVDS43p		B2	VREF1B2	B9	B9			
VCCIO2			B2	VREF1B2					
GND			B2	VREF1B2					
IO	LVDS42n		B2	VREF1B2	D8	C8			
IO	LVDS42p		B2	VREF1B2	C8	D8			
IO	LVDS41n		B2	VREF1B2	A8	A8			
IO	LVDS41p		B2	VREF1B2	B8	B8			
IO	LVDS40n		B2	VREF2B2	E8	E8	DQ1T0		
IO	LVDS40p		B2	VREF2B2	E7	F8	DQ1T1		
IO	LVDS39n		B2	VREF2B2	A7	C7	DQ1T2		
IO	LVDS39p		B2	VREF2B2	B7	D7	DQ1T3		
IO	LVDS38n		B2	VREF2B2	D7	A7			
IO	LVDS38p		B2	VREF2B2	C7	B7			

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 16 of 20)

Pin Name / Function	Device				Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA		
IO	LVDS37n		B2	VREF2B2	E6	E7		
IO	LVDS37p		B2	VREF2B2	D6	F7		
IO	LVDS36n		B2	VREF2B2	B6	A6		
IO	LVDS36p		B2	VREF2B2	C6	B6		
IO	VREF2B2		B2	VREF2B2	A6	E6		
IO	DPCLK2		B2	VREF2B2	B5	C6	DQS1T	DQS1T
VCCIO2			B2	VREF2B2				
GND			B2	VREF2B2				
IO	LVDS35n		B2	VREF2B2		B5		
IO	LVDS35p		B2	VREF2B2		C5		
IO	LVDS34n		B2	VREF2B2	C5	D6	DQ1T4	DQ1T4
IO	LVDS34p		B2	VREF2B2	D5	D5	DQ1T5	DQ1T5
IO	LVDS33n		B2	VREF2B2	A4	A4	DQ1T6	DQ1T6
IO	LVDS33p		B2	VREF2B2	B4	B4	DQ1T7	DQ1T7
IO	LVDS32n	DEV_OE	B2	VREF2B2	B3	B3		
IO	LVDS32p	DEV_CLRn	B2	VREF2B2	C4	C4		
VCCINT					A17	A19		
VCCINT					A2	A2		
VCCINT					B1	B1		
VCCINT					B18	B20		
VCCINT					F10	H10		
VCCINT					F8	H12		
VCCINT					G11	J11		

<i>Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 17 of 20)</i>									
		Device				Package			
Pin Name / Function	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA	DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA	
VCCINT					G9	J9			
VCCINT					H10	K10			
VCCINT					J9	K12			
VCCINT					K10	L11			
VCCINT					L9	L9			
VCCINT					M10	M10			
VCCINT					M8	M12			
VCCINT					N11	N11			
VCCINT					N9	N9			
VCCINT					U1	W1			
VCCINT					U18	W20			
VCCINT					V17	Y19			
VCCINT					V2	Y2			
VCCIO1					E1	E1			
VCCIO1					E1	H8			
VCCIO1					G7	K8			
VCCIO1					M7	N8			
VCCIO1					P1	T1			
VCCIO4						R10			
VCCIO4					P11	R12			
VCCIO4					P8	R8			
VCCIO4					V14	Y16			
VCCIO4					V5	Y5			

<i>Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 18 of 20)</i>									
Pin Name / Function	Optional Function(s)	Device			Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA	
		Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA			
VCCIO3						E20			
VCCIO3						E18			
VCCIO3						H12			
VCCIO3						M12			
VCCIO3						P18			
VCCIO2						A16			
VCCIO2						A5			
VCCIO2						F11			
VCCIO2						F13			
VCCIO2						F9			
GND						A1			
GND						A16			
GND						A18			
GND						A3			
GND						B17			
GND						B2			
GND						C1			
GND						C18			
GND						F11			
GND						F9			
GND						G10			
GND						G8			
GND						H11			

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 19 of 20)

Pin Name / Function	Device			Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA		
GND					H8	G9	
GND					H9	H11	
GND					J10	H9	
GND					J11	J10	
GND					J8	J12	
GND					K11	K11	
GND					K8	K9	
GND					K9	L10	
GND					L10	L12	
GND					L11	M11	
GND					L8	M9	
GND					M11	N10	
GND					M9	N12	
GND					N10	P10	
GND					N8	P11	
GND					T1	P12	
GND					T18	P13	
GND					U17	P8	
GND					U2	P9	
GND					V1	V1	
GND					V16	V20	
GND					V18	W19	
GND					V3	W2	

Table 5-1. Pin List for the Cyclone EP1C20 Device (Part 20 of 20)

Pin Name / Function	Device				Package		DQS for X8 in 324-Pin FineLine BGA	DQS for X8 in 400-Pin FineLine BGA
	Optional Function(s)	Configuration Function	Bank Number	VREF Bank	324-Pin FineLine BGA	400-Pin FineLine BGA		
GND						Y1		
GND						Y18		
GND						Y20		
GND						Y3		

Pin Definitions

Table 5-2 shows the pin definitions for the EP1C20 device.

Table 5-2. Pin Definitions for the EP1C20 Device (Part 1 of 4)	
Pin Name	Pin Type (1st, 2nd, & 3rd Function)
Supply and Reference Pins	
VCCIO[1..4]	Power
These are I/O supply voltage pins for banks 1 through 4. Each bank can support a different voltage level. VCCIO supplies power to the output buffers for all I/O standards. VCCIO also supplies power to the input buffers used for the LVTTL, LVCMOS, 1.5-V, 1.8-V, 2.5-V, and 3.3-V PCI I/O standards.	
VCCINT	Power
These are internal logic array voltage supply pins. VCCINT also supplies power to the input buffers used for the LVDS, SSTL2, and SSTL3 I/O standards.	
VREF[0..2][1..4]	I/O, Input
Input reference voltage for banks 1-4. If a bank uses a voltage-referenced I/O standard, then these pins are used as the voltage-reference pins for the bank. If voltage reference I/O standards are not used in the bank, the VREF pins are available as user I/O pins.	
VCCA_PLL[1..2]	Power
Analog power for PLLs[1..2]. The designer must connect this pin to 1.5 V, even if the PLL is not used.	
GND_A_PLL[1..2]	Ground
Analog ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.	
GNDG_PLL[1..2]	Ground
Guard ring ground for PLLs[1..2]. The designer can connect this pin to the GND plane on the board.	
Configuration and JTAG Pins	
CONF_DONE	Bidirectional (open-drain)
This is a dedicated configuration status pin; it is not available as a user I/O pin.	
nSTATUS	Bidirectional (open-drain)
This is a dedicated configuration status pin; it is not available as a user I/O pin.	
nCONFIG	Input
Dedicated configuration control input. A low transition resets the target device; a low-to-high transition begins configuration. All I/O pins tri-state when nCONFIG is driven low.	
DCLK	Input (PS mode), Output (AS mode)
In passive serial configuration mode, DCLK is a clock input used to clock configuration data from an external source into the Cyclone device. In active serial configuration mode, DCLK is a clock output from the Cyclone device (the Cyclone device acts as master in this mode). This is a dedicated pin used for configuration.	
DATA0	Input
Dedicated configuration data input pin.	

Table 5-2. Pin Definitions for the EP1C20 Device (Part 2 of 4)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
nCE	Input	Active-low chip enable. Dedicated chip enable input used to detect which device is active in a chain of devices. When nCE is low, the device is enabled. When nCE is high, the device is disabled.
nCEO	Output	Output that drives low when device configuration is complete. During multi-device configuration, this pin feeds a subsequent device's nCE pin.
ASDO	I/O, Output	Active serial data output from the Cyclone device. This output pin is utilized during active serial configuration mode. The Cyclone device controls configuration and drives address and control information out on ASDO. In passive serial configuration, this pin is available as a user I/O pin.
nCSO	I/O, Output	Chip select output that enables/disables a serial configuration device. This output is utilized during active serial configuration mode. The Cyclone device controls configuration and enables the serial configuration device by driving nCSO low. In passive serial configuration, this pin is available as a user I/O pin.
INIT_DONE	I/O, Output (open-drain)	This is a dual-purpose pin and can be used as an I/O pin when not enabled as INIT_DONE. When enabled, the pin indicates when the device has entered user mode. This pin can be used as a user I/O pin after configuration.
CLKUSR	I/O, Input	Optional user-supplied clock input. Synchronizes the initialization of one or more devices. This pin can be used as a user I/O pin after configuration.
DEV_CLRn	I/O, Input	Dual-purpose pin that can override all clears on all device registers. When this pin is driven low, all registers are cleared; when this pin is driven high, all registers behave as defined in the design.
DEV_OE	I/O, Input	Dual-purpose pin that can override all tri-states on the device. When this pin is driven low, all I/O pins are tri-stated; when this pin is driven high, all I/O pins behave as defined in the design.
MSEL[1..0]	Input	Dedicated mode select control pins that set the configuration mode for the device.
TMS	Input	This is a dedicated JTAG input pin.
TDI	Input	This is a dedicated JTAG input pin.
TCK	Input	This is a dedicated JTAG input pin.
TDO	Output	This is a dedicated JTAG output pin.

Table 5-2. Pin Definitions for the EP1C20 Device (Part 3 of 4)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
Clock and PLL Pins		
CLK0	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK0 is LVDSCLK1p, which is used for differential input to PLL1.
CLK1	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK1 is LVDSCLK1n, which is used for differential input to PLL1.
CLK2	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK2 is LVDSCLK2p, which is used for differential input to PLL2.
CLK3	Input, LVDS Input	Dedicated global clock input. The dual-function of CLK3 is LVDSCLK2n, which is used for differential input to PLL2.
DPCLK[7..0]	I/O	Dual-purpose clock pins that can connect to the global clock network. These pins can be used for high fan-out control signals, such as clocks, clears, IRDY, TRDY, or DQS signals. These pins are also available as user I/O pins.
PLL1_OUTp	I/O, Output	External clock output from PLL 1. This pin can be used with differential or single ended I/O standards. If clock output from PLL1 is not used, this pin is available as a user I/O pin.
PLL1_OUTn	I/O, Output	Negative terminal for external clock output from PLL1. If the clock output is single ended, this pin is available as a user I/O pin.
PLL2_OUTp	I/O, Output	External clock output from PLL 2. This pin can be used with differential or single ended I/O standards. If clock output from PLL2 is not used, this pin is available as a user I/O pin.
PLL2_OUTn	I/O, Output	Negative terminal for external clock output from PLL2. If the clock output is single ended, this pin is available as a user I/O pin.
Dual-Purpose LVDS & External Memory Interface Pins		
LVDS[0..128]p	I/O, LVDS RX or TX	Dual-purpose LVDS I/O channels 0 to 128. These channels can be used for receiving or transmitting LVDS compatible signals. Pins with a "p" suffix carry the positive signal for the differential channel. If not used for LVDS interfacing, these pins are available as user I/O pins.
LVDS[0..128]n	I/O, LVDS RX or TX	Dual-purpose LVDS I/O channels 0 to 128. These channels can be used for receiving or transmitting LVDS compatible signals. Pins with an "n" suffix carry the negative signal for the differential channel. If not used for LVDS interfacing, these pins are available as user I/O pins.

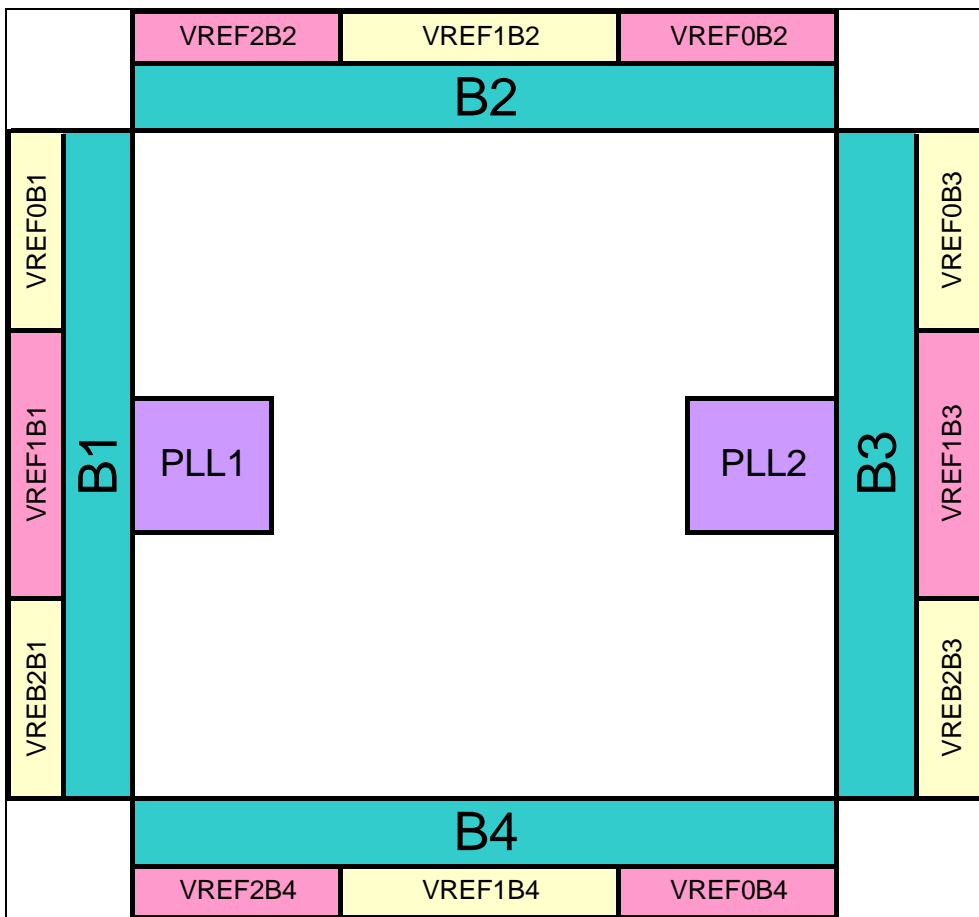
Table 5-2. Pin Definitions for the EP1C20 Device (Part 4 of 4)

Pin Name	Pin Type (1st, 2nd, & 3rd Function)	Pin Description
LVDSCLK1p	Input, LVDS Input	Dual-purpose LVDS clock input to PLL1. If differential input to PLL1 is not required, this pin is available as the CLK0 input pin.
LVDSCLK1n	Input, LVDS Input	Dual-purpose LVDS clock input to PLL1. If differential input to PLL1 is not required, this pin is available as the CLK1 input pin.
LVDSCLK2p	Input, LVDS Input	Dual-purpose LVDS clock input to PLL2. If differential input to PLL2 is not required, this pin is available as the CLK2 input pin.
LVDSCLK2n	Input, LVDS Input	Dual-purpose LVDS clock input to PLL2. If differential input to PLL2 is not required, this pin is available as the CLK3 input pin.
DQS[0..7][L,R,T,B]	I/O	Optional data strobe signal for use in external memory interfacing. These pins also function as DPCLK pins; therefore, the DQS signals can connect to the global clock network. A programmable delay chain is used to shift the DQS signals by 90 or 72 degrees.
DQ[0..7][L,R,T,B]	I/O	Optional data signal for use in external memory interfacing.
DM[0..1][L,R,T,B]	I/O	Optional data mask output signal for use in external memory interfacing.

PLL & Bank Diagram

Figure 5–1 shows the PLL and bank locations for the EP1C20 device.

Figure 5–1. PLL and Bank Diagram (1), (2)



Notes for Figure 5–1:

- (1) This is a top view of the silicon die.
- (2) This is a pictorial representation only to get an idea of placement on the device. Refer to the pin-list and the Quartus II software for exact locations.



6. Package Information for Cyclone Devices

C52006-1.0

Introduction

This data sheet provides package information for Altera® devices. It includes these sections:

Section	Page
Device & Package Cross Reference	6-1
Thermal Resistance	6-2
Package Outlines	6-2

In this data sheet, packages are listed in order of ascending pin count.

Device & Package Cross Reference

Table 6-1 shows which Altera Cyclone™ devices are available in FineLine BGA® packages.

Device	Package	Pins
EP1C4	Non-Thermally Enhanced FineLine BGA	324
	Non-Thermally Enhanced FineLine BGA	400
EP1C6	Non-Thermally Enhanced FineLine BGA	256
EP1C12	Non-Thermally Enhanced FineLine BGA	256
	Non-Thermally Enhanced FineLine BGA	324
EP1C20	Non-Thermally Enhanced FineLine BGA	324
	Non-Thermally Enhanced FineLine BGA	400

Thermal Resistance

Table 6–2 provides θ_{JA} (junction-to-ambient thermal resistance) and θ_{JC} (junction-to-case thermal resistance) values for Altera Cyclone devices.

Table 6–2. Thermal Resistance of Cyclone Devices Notes (1), (2)

Device	Pin Count	Package	θ_{JC} (° C/W)	θ_{JA} (° C/W) Still Air	θ_{JA} (° C/W) 100 ft./min.	θ_{JA} (° C/W) 200 ft./min.	θ_{JA} (° C/W) 400 ft./min.
EP1C3	100	TQFP	11.0	37.5	35.4	33.4	29.8
	144	TQFP	10.0	31.1	29.4	27.9	25.5
EP1C4	324	FineLine BGA	8.3	28.5	24.4	22.1	20.3
	400	FineLine BGA	7.9	20.7	17.5	15.5	13.9
EP1C6	144	TQFP	9.8	29.4	28.0	26.7	24.7
	240	PQFP	4.3	27.2	24.7	22.1	17.8
	256	FineLine BGA	8.8	28.7	24.5	22.3	20.5
EP1C12	240	PQFP	4.0	26.0	23.4	20.8	17.1
	256	FineLine BGA	6.6	24.3	20.2	18.1	16.4
	324	FineLine BGA	6.1	23.0	19.8	17.7	16.1
EP1C20	324	FineLine BGA	5.0	21.0	17.7	15.6	14.1
	400	FineLine BGA	4.7	20.7	17.5	15.5	13.9

Notes to Table 6–2:

- (1) TQFP: thin quad flat pack
- (2) PQFP: plastic quad flat pack

Package Outlines

The package outlines on the following pages are listed in order of ascending pin count. Altera package outlines meet the requirements of JEDEC Publication No. 95.

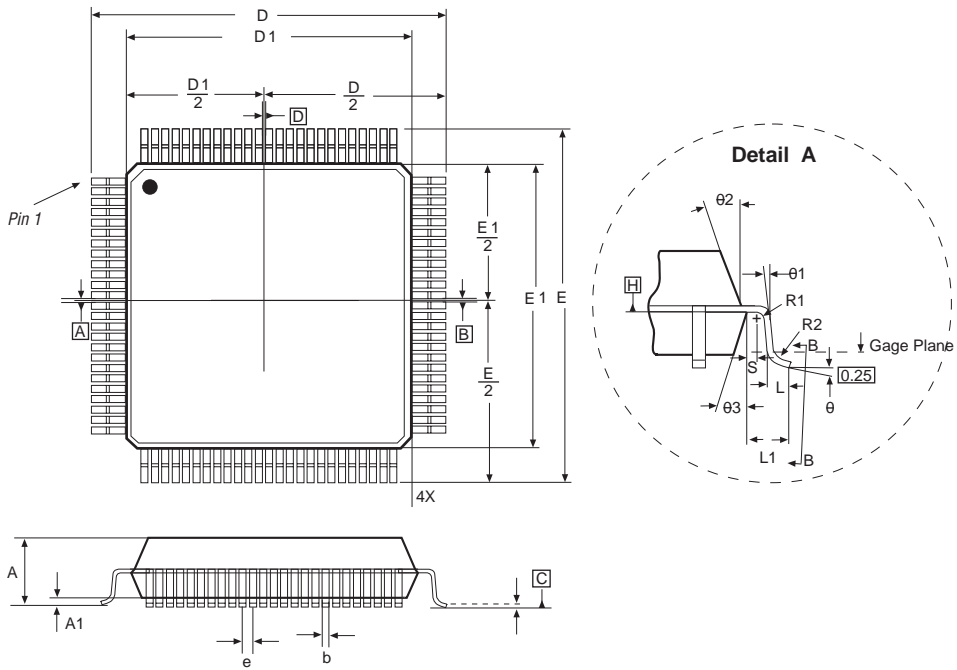
100-Pin Plastic Thin Quad Flat Pack (TQFP)

- All dimensions and tolerances conform to ANSI Y14.5M – 1994.
- Controlling dimension is in millimeters.
- N is the number of leads.

<i>Package Information</i>	
Description	Specification
Ordering Code Reference	T
Package Acronym	TQFP
Lead Material	Copper
Lead Finish	Solder plate (85/15 typical)
JEDEC Outline	MS-026
JEDEC Option	BDE
Maximum Lead Coplanarity	0.003 inches (0.08 mm)
Weight	0.5 g
Moisture Sensitivity Level	Printed on moisture barrier bag

<i>Package Outline Figure Reference</i>			
Symbol	Millimeters		
	Min.	Nom.	Max.
A	–	–	1.27
A1	0.05	–	0.15
b	0.17	0.22	0.27
D	15.80	–	16.20
D1	13.50	–	14.50
E	15.80	–	16.20
E1	13.50	–	14.50
q	0°	3.5°	7°
θ1	0°	–	–
θ2	11°	12°	13°
θ3	11°	12°	13°
C	0.09	–	0.20
L	0.45	0.60	0.75
L1	1.00 REF		
R1	0.08	–	–
R2	0.08	–	0.20
S	0.20	–	–
e	0.50 BSC		
N	100		

Package Outline



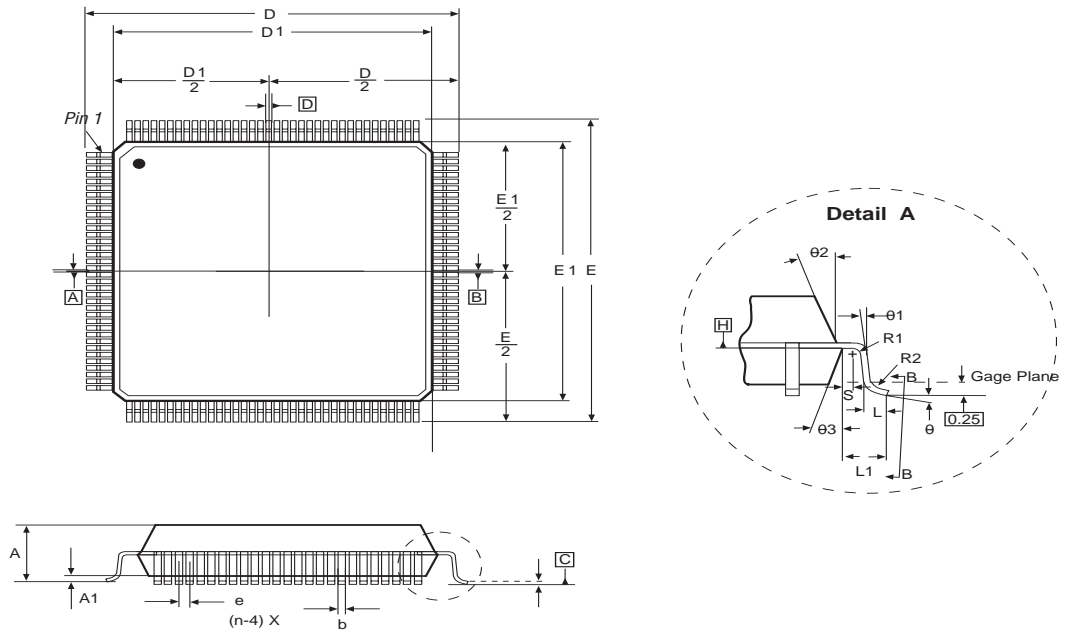
144-Pin Plastic Thin Quad Flat Pack (TQFP)

- All dimensions and tolerances conform to ANSI Y14.5M – 1994.
- Controlling dimension is in millimeters.
- N is the number of leads.

Package Information	
Description	Specification
Ordering Code Reference	T
Package Acronym	TQFP
Lead Material	Copper
Lead Finish	Solder plate (85/15 typical)
JEDEC Outline	MS-026
JEDEC Option	BFB
Maximum Lead Coplanarity	0.003 inches (0.08 mm)
Weight	1.3 g
Moisture Sensitivity Level	Printed on moisture barrier bag

Package Outline Figure Reference			
Symbol	Millimeters		
	Min.	Nom.	Max.
A	–	–	1.60
A1	0.05	–	0.15
b	0.17	0.22	0.27
D	22.00 BSC		
D1	20.00 BSC		
e	0.50 BSC		
E	22.00 BSC		
E1	20.00 BSC		
q	0°	3.5°	7°
θ1	0°	–	–
θ2	11°	12°	13°
θ3	11°	12°	13°
L	0.45	0.60	0.75
L1	1.00 REF		
R1	0.08	–	–
R2	0.08	–	0.20
S	0.20	–	–
N	144		

Package Outline



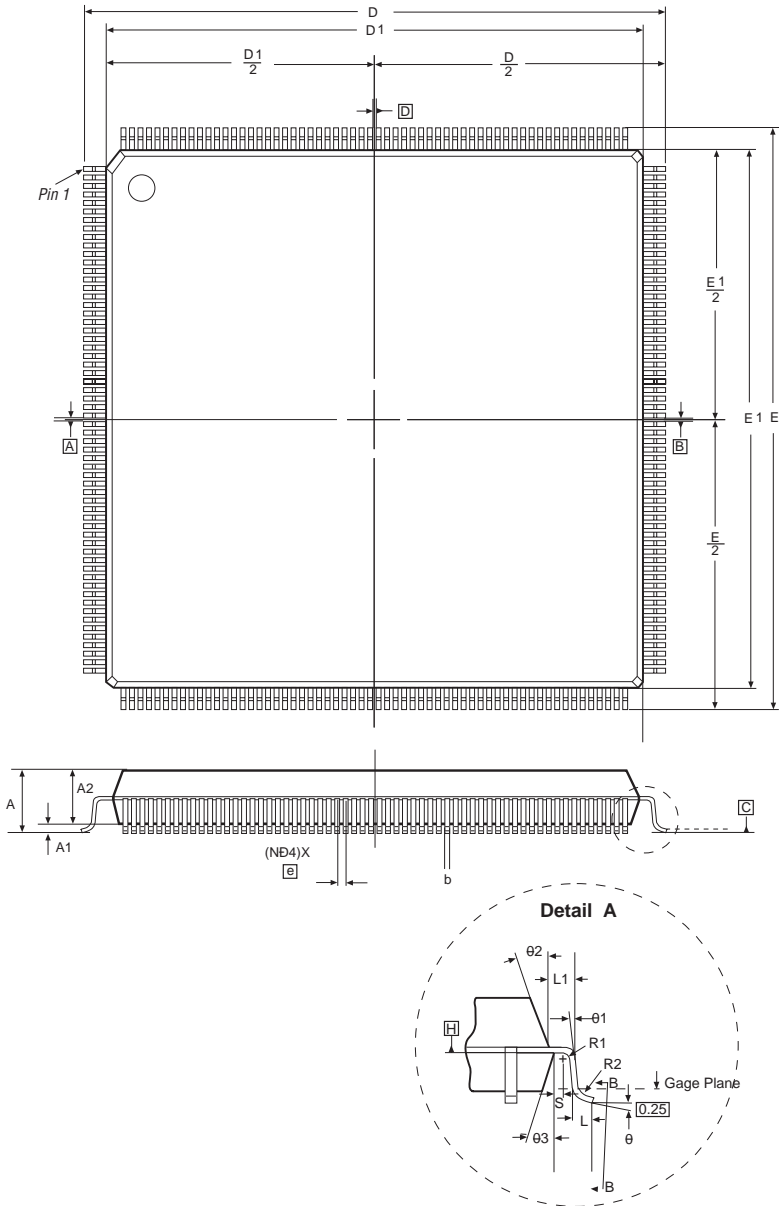
240-Pin Plastic Quad Flat Pack (PQFP)

- All dimensions and tolerances conform to ANSI Y14.5M – 1994.
- Controlling dimension is in millimeters.
- N is the number of leads.

<i>Package Information</i>	
Description	Specification
Ordering Code Reference	Q
Package Acronym	PQFP
Lead Material	Copper
Lead Finish	Solder plate (85/15 typical)
JEDEC Outline	MS-029
JEDEC Option	GA
Maximum Lead Coplanarity	0.003 inches (0.08 mm)
Weight	7.0 g
Moisture Sensitivity Level	Printed on moisture barrier bag

<i>Package Outline Figure Reference</i>			
Symbol	Millimeters		
	Min.	Nom.	Max.
A	–	–	4.10
A1	0.25	–	0.50
A2	3.20	3.40	3.60
D	34.35	–	34.85
D1	31.90	–	32.10
E	34.35	–	34.85
E1	31.90	–	32.10
e	0.50 BSC		
b	0.17	–	0.27
R2	0.08	–	0.25
R1	0.08	–	–
q	0°	3.5°	8°
θ1	0°	–	–
θ2	5°	–	16°
θ3	5°	–	16°
L	0.46	–	0.66
L1	0.40	–	–
S	0.20	–	–
N	240		

Package Outline



256-Pin Non-Thermally Enhanced FineLine Ball-Grid Array

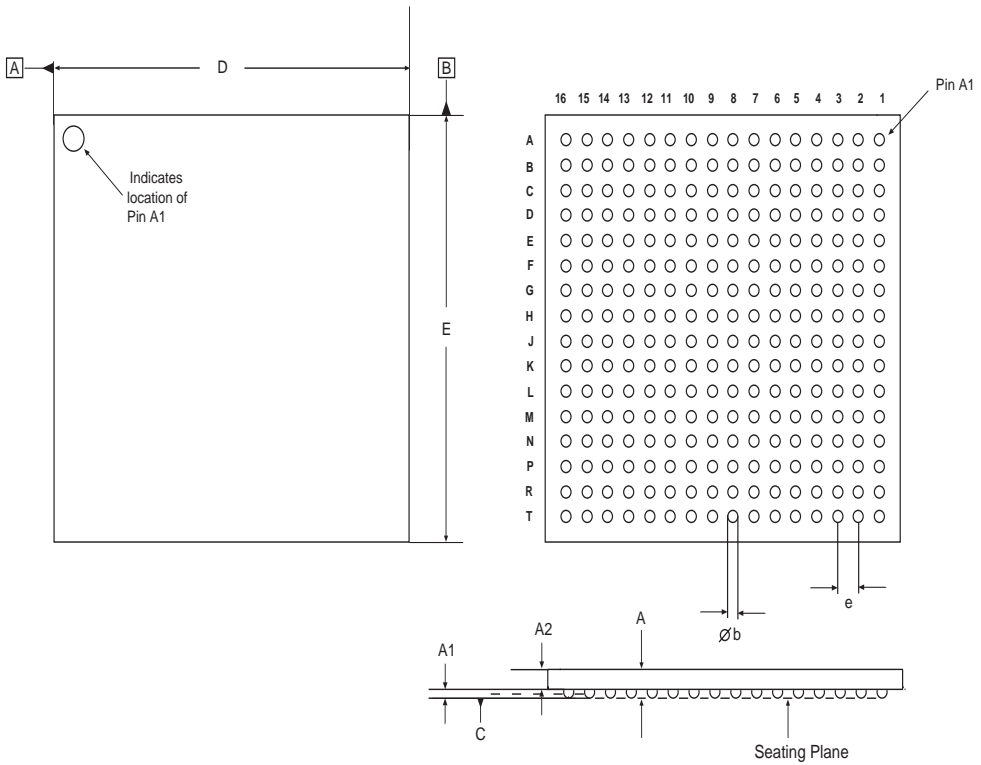
- All dimensions and tolerances conform to ANSI Y14.5M – 1994.
- Controlling dimension is in millimeters.
- M is the maximum solder ball matrix size.

Package Information	
Description	Specification
Ordering Code Reference	F
Package Acronym	FBGA
Lead Material	Tin-lead alloy (63/37)
Lead Finish	N/A
JEDEC Outline	MS-034
JEDEC Option	AAF-1
Maximum Lead Coplanarity	0.008 inches (0.20 mm)
Weight	1.2 g
Moisture Sensitivity Level	Printed on moisture barrier bag

Package Outline Figure Reference			
Symbol	Millimeters		
	Min.	Nom.	Max.
A (3)	–	–	3.50
A1	0.30	–	–
A2	0.25	–	1.10
A3	–	–	2.50
D/E	17.00 BSC		
b	0.50	0.60	0.70
e	1.00 BSC		
M	16		

- (3) Altera's thickness specification for A is 2.6 mm maximum. The Max item for A in the table reflects the JEDEC specification.

Package Outline



324-Pin Non-Thermally Enhanced FineLine Ball-Grid Array

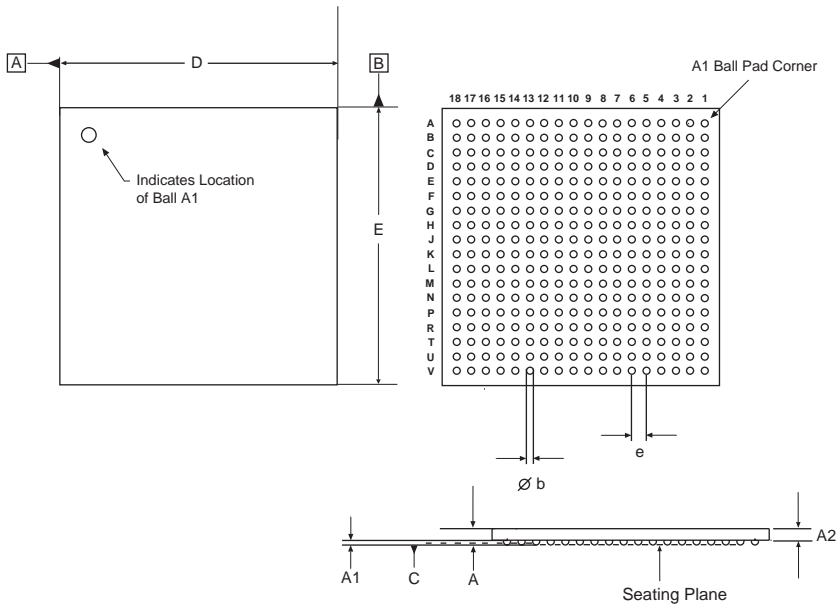
- All dimensions and tolerances conform to ANSI Y14.5M – 1994.
- Controlling dimension is in millimeters.
- M is the maximum solder ball matrix size.

Package Information	
Description	Specification
Ordering Code Reference	F
Package Acronym	FBGA
Lead Material	Tin-lead alloy (63/37)
Lead Finish	N/A
JEDEC Outline	MS-034
JEDEC Option	AAG-1
Maximum Lead Coplanarity	0.008 inches (0.20 mm)
Weight	1.5 g
Moisture Sensitivity Level	Printed on moisture barrier bag

Package Outline Figure Reference			
Symbol	Millimeters		
	Min.	Nom.	Max.
A (4)	1.20	–	3.50
A1	0.30	–	–
A2	0.25	–	3.00
D/E	19.00 BSC		
b	0.50	0.60	0.70
e	1.00 BSC		
M	18		

(4) Altera's thickness specification for A is 2.6 mm maximum. The Max item for A in the table reflects the JEDEC specification.

Package Outline



400-Pin Non-Thermally Enhanced FineLine Ball-Grid Array

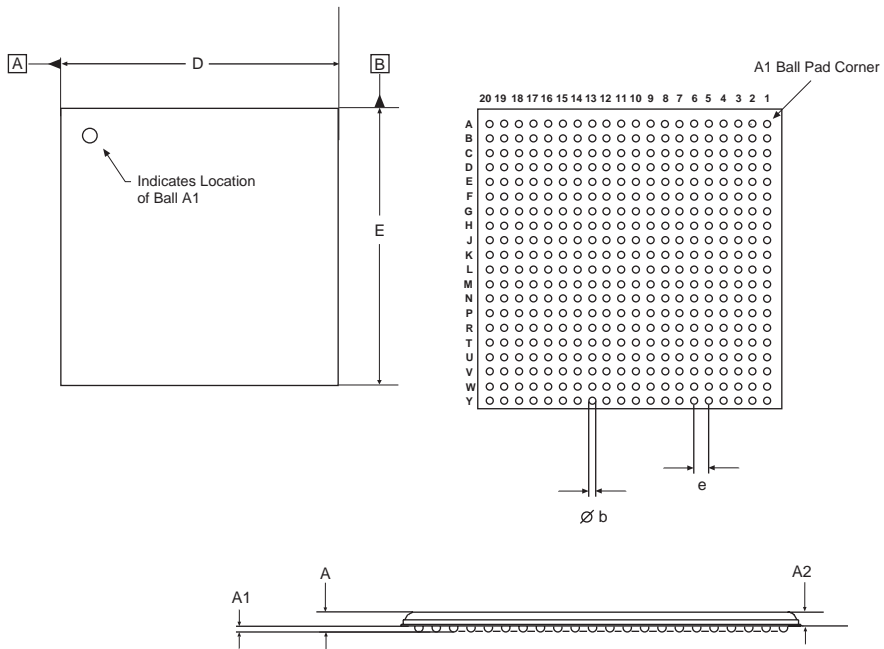
- All dimensions and tolerances conform to ANSI Y14.5M – 1994.
- Controlling dimension is in millimeters.
- M is the maximum solder ball matrix size.

Package Information	
Description	Specification
Ordering Code Reference	F
Package Acronym	FBGA
Lead Material	Tin-lead alloy (63/37)
Lead Finish	N/A
JEDEC Outline	MS-034
JEDEC Option	AAJ-1
Maximum Lead Coplanarity	0.008 inches (0.20 mm)
Weight	1.9 g
Moisture Sensitivity Level	Printed on moisture barrier bag

Package Outline Figure Reference			
Symbol	Millimeters		
	Min.	Nom.	Max.
A (5)	120	–	3.50
A1	0.30	–	–
A2	0.25	–	3.00
D/E	21.00 BSC		
b (6)	0.50	0.60	0.70
e	1.00 BSC		
M	18		

- (5) Altera's thickness specification for 'A' is 2.6 mm maximum. The Max. dimension for 'A' in the table reflects the JEDEC specification.
- (6) Ball size, parameter 'b', can increase to a maximum of 0.74. Contact Altera Applications for more information.

Package Outline



Introduction

As programmable logic devices (PLDs) increase in density and I/O pins, the demand for small packages and diverse packaging options continues to grow. Ball-grid array (BGA) packages are an ideal solution because the I/O connections are on the interior of the device, improving the ratio between pin count and board area. Typical BGA packages contain up to twice as many connections as quad flat pack (QFP) packages for the same area. Further, BGA solder balls are considerably stronger than QFP leads, resulting in robust packages that can tolerate rough handling.

Altera has developed a new BGA solution for users of high-density PLDs called the FineLine BGA® package. The new format requires less than half the board space of standard BGA packages. This application note provides guidelines for designing your printed circuit board (PCB) for Altera's FineLine BGA packages and discusses the following topics:

- Overview of BGA packages
- PCB layout terminology
- PCB layout for FineLine BGA packages

Overview of BGA Packages

As PLDs grow to 1 million gates and beyond, designers require more advanced, flexible packages. BGA packages empower designers by offering the technological benefits and flexibility to meet future system requirements.

In BGA packages, the I/O connections are located on the interior of the device. Leads normally placed along the periphery of the package are replaced with solder balls arranged in a matrix across the bottom of the substrate. The final device is soldered directly to the PCB using assembly processes virtually identical to the standard surface mount technology preferred by system designers.

In addition, BGA packages provide the following advantages:

- *Fewer damaged leads*—BGA leads consist of solid solder balls, which are less likely to suffer damage during handling.
- *More leads per unit area*—Lead counts are increased by moving the solder balls closer to the edges of the package and by decreasing the pitch to 1.0 mm.

- *Less expensive surface mount equipment*—BGA packages can tolerate slightly imperfect placement during mounting, requiring less expensive surface mount equipment. The placement can be imperfect because the BGA packages self-align during solder reflow.
- *Smaller footprints*—BGA packages are usually 20% to 50% smaller than QFP packages, making BGA packages more attractive for applications that require high performance and a smaller footprint.
- *Integrated circuit speed advantages*—BGA packages can operate well into the microwave frequency spectrum and can achieve high electrical performance by using ground planes, ground rings, and power rings in the package construction.
- *Improved heat dissipation*—Because the die is located at the center of the FineLine BGA package and most VCC and GND pins are located at the center of the package, the GND and VCC pins are located under the die. As a result, the heat generated in the device can be transferred out through the GND and VCC pins (i.e., the GND and VCC pins act as a heat sink).

PCB Layout Terminology

This section defines common terms used in PCB layout.

Escape Routing

Escape routing is the method used to route each signal from a package to another element on the PCB.

Multi-Layer PCBs

The increased I/O count associated with BGA packages has made multi-layer PCBs the industry-standard method for performing escape routing. Signals can be routed to other elements on the PCB through various numbers of PCB layers.

Vias

Vias, or plated through holes, are used in multi-layer PCBs to transfer signals from one layer to another. Vias are actual holes drilled through a multi-layer PCB and provide electrical connections between various PCB layers. All vias provide layer-to-layer connections only; device leads or other reinforcing material are not inserted into vias.

Table 7-1 describes the terms used to define via dimensions.

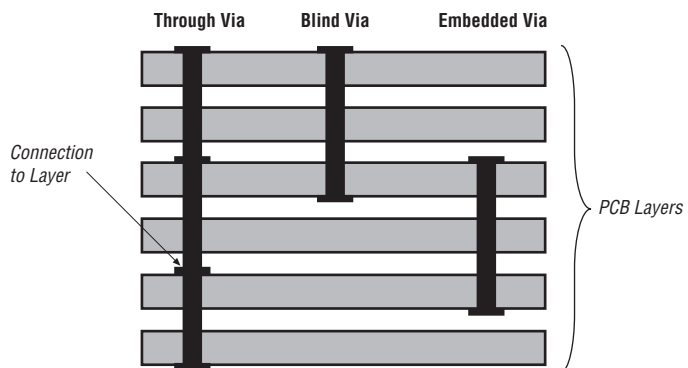
Term	Definition
Aspect ratio	The aspect ratio is the ratio of a via's length or depth to its pre-plated diameter.
Drilled hole diameter	The drilled hole diameter is the diameter of the actual via hole drilled in the board.
Finished via diameter	The finished via diameter is the diameter of a via hole that has been finished.

Table 7-2 shows the three via types typically used on PCBs.

Type	Description
Through via	An interconnection between the top and the bottom layer of a PCB. Through vias can also provide interconnections to inner PCB layers.
Blind via	An interconnection from the top or bottom layer to an inner PCB layer.
Embedded via	An interconnection between any number of inner PCB layers.

Figure 7-1 shows all three via types.

Figure 7-1. Types of Vias



Blind vias and through vias are used more frequently than embedded vias. Blind vias can be more expensive than through vias, but overall costs can be reduced because signal traces can be routed under a blind via, requiring fewer PCB layers. Through vias, on the other hand, do not permit signals to be routed through lower layers, which can increase the required number of PCB layers and overall costs.

Via Capture Pad

Vias are connected electrically to PCB layers through via capture pads, which surround each via.

Surface Land Pad

Surface land pads are the areas on the PCB to which the BGA solder balls adhere. The size of these pads affects the space available for vias and escape routing. In general, surface land pads are available in the following two basic designs:

- Non solder mask defined (NSMD), also known as copper defined
- Solder mask defined (SMD)

The main differences between the two surface land pad types are the size of the trace and space, the type of vias you can use, and the shape of the solder balls after solder reflow.

Non Solder Mask Defined Pad

In the non solder mask defined (NSMD) pad, the solder mask opening is larger than the copper pad. Thus, the surface land pad's copper surface is completely exposed, providing greater area to which the BGA solder ball can adhere (see [Figure 7-2](#)). Altera recommends that you use a NSMD pad for most applications because it provides more flexibility, fewer stress points, and more line-routing space between pads.

Solder Mask Defined Pad

In the solder mask defined (SMD) pad, the solder mask overlaps the surface land pad's copper surface (see [Figure 7-2](#)). This overlapping provides greater adhesion strength between the copper pad and the PCB's epoxy/glass laminate, which can be important under extreme bending and during accelerated thermal cycling tests. However, the solder mask overlap shrinks the amount of copper surface available for the BGA solder ball.

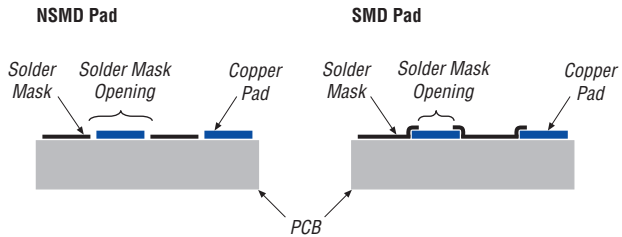
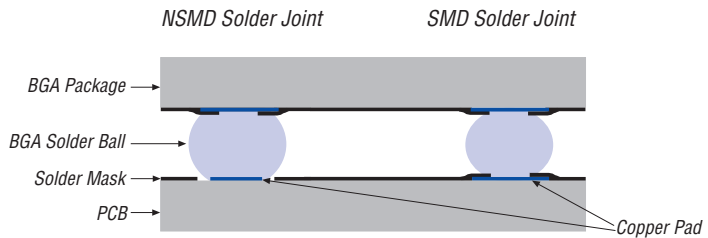
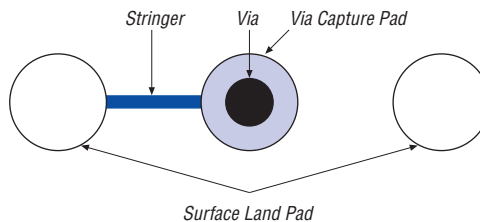
Figure 7-2. Side View of NSMD & SMD Land Pads

Figure 7-3 shows the side view for an NSMD and SMD solder joint.

Figure 7-3. Side View of NSMD & SMD Solder Joints

Stringer

Stringers are rectangular or square interconnect segments that electrically connect via capture pads and surface land pads. Figure 7-4 shows the connection between vias, via capture pads, surface land pads, and stringers.

Figure 7-4. Via, Land Pad, Stringer & Via Capture Pad

PCB Layout for FineLine BGA Packages

When designing a PCB for FineLine BGA packages, consider the following factors:

- Surface land pad dimension
- Via capture pad layout and dimension
- Signal line space and trace width
- Number of PCB layers

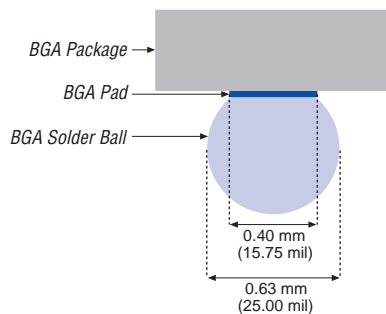


For all FineLine BGA figures, the controlling dimension is millimeters.

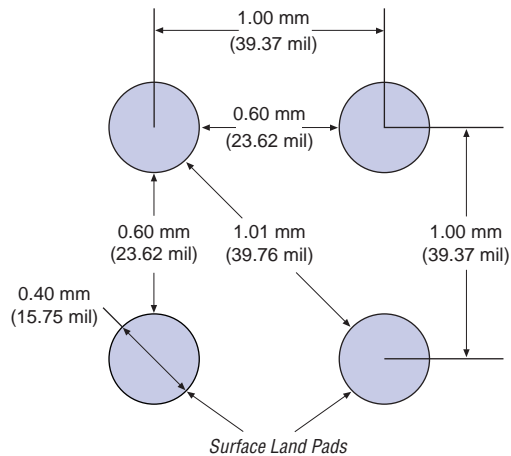
Surface Land Pad Dimension

Surface land pads should be the same size as the BGA pad to provide a balanced stress on solder joints. For this reason, Altera recommends using a 15.75-mil surface land pad, because it is the same size as the BGA pad. [Figure 7-5](#) shows a 15.75-mil BGA pad.

Figure 7-5. 15.75-Mil BGA Pad



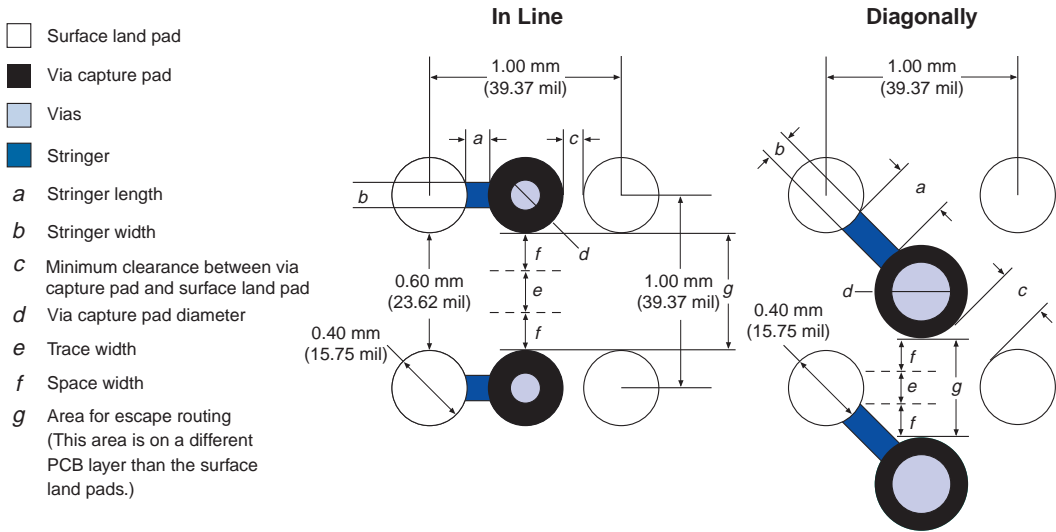
[Figure 7-6](#) shows how much space is available for vias and escape routing when you use 15.75-mil surface land pads.

Figure 7-6. Space Available for 15.75-Mil Surface Land Pads

Via Capture Pad Layout & Dimension

The size and layout of via capture pads affect the amount of space available for escape routing. In general, you can layout via capture pads in the following two ways: in-line with the surface land pads or in the diagonal of surface land pads. [Figure 7-7](#) shows both layouts.

Figure 7-7. Placement of Via Capture Pad



The decision to place the via capture pads diagonally or in-line with the surface lands pads is based on the following factors:

- Diameter of the via capture pad
- Stringer length
- Clearance between via capture pad and surface land pad

To decide how to lay out your PCB, use the information shown in [Figure 7-7](#) and [Table 7-3](#). If your PCB design guidelines do not conform to either equation in [Table 7-3](#), contact Altera Applications for further assistance.

Layout	Formula
In-line	$a + c + d \geq 23.62 \text{ mil}$
Diagonally	$a + c + d \geq 39.76 \text{ mil}$

[Table 7-3](#) shows that you can place a larger via capture pad diagonally than in-line with the surface land pads.

Via capture pad size also affects how many traces can be routed on a PCB. Figure 7–8 shows sample layouts of typical and premium via capture pads. The typical layout shows a via capture pad size of 27 mil, a via size of 8 mil, and an inner space/trace of 4 mil. With this layout, only one trace can be routed between the vias. If more traces are required, you must reduce the via capture pad size or the space/trace size.

The premium layout shows a via capture pad size of 20 mil, a via size of 5 mil, and an inner space/trace of 3 mil. This layout provides enough space to route two traces between the vias.

Figure 7–8. Typical & Premium Via Capture Pad Sizes

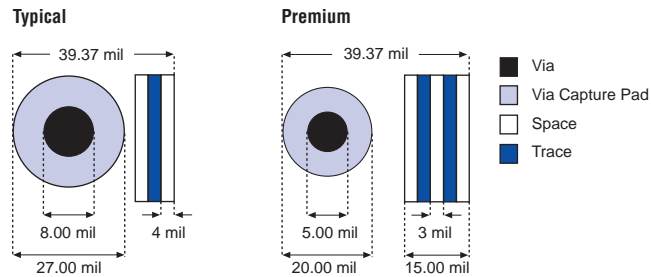


Table 7–4 shows the typical and premium layout specifications used by most PCB vendors.

Specification	Typical (Mil)	Premium (Mil)
Trace/space width	5/5	3/3
Drilled hole diameter	12	10
Finished via diameter	8	ø 5
Via capture pad	25.5	20
Aspect ratio	7:1	10:1



For detailed information on drill sizes, via sizes, space/trace sizes, or via capture pad sizes, contact your PCB vendor directly.

Signal Line Space & Trace Width

The ability to perform escape routing is defined by the width of the trace and the minimum space required between traces. The minimum area for signal routing is the smallest area that the signal must be routed through (i.e., the distance between two vias, or g in Figure 7-7). This area is calculated by the following formula:

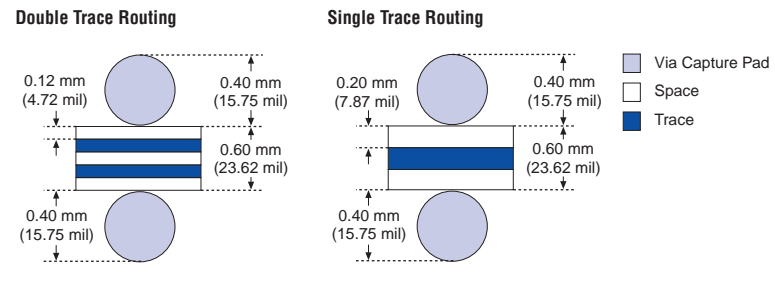
$$g = 39.37 - d$$

The number of traces that can be routed through this area is based on the permitted line trace and space widths. You can use Table 7-5 to determine the total number of traces that can be routed through g .

Number of Traces	Formula
1	$g \geq [2 \times (\text{space width})] + \text{trace width}$
2	$g \geq [3 \times (\text{space width})] + [2 \times (\text{trace width})]$
3	$g \geq [5 \times (\text{space width})] + [3 \times (\text{trace width})]$

Figure 7-9 shows that by reducing the trace and space size, you can route more traces through g . Increasing the number of traces reduces the required number of PCB layers and decreases the overall cost.

Figure 7-9. Escape Routing for Double & Single Traces



Number of PCB Layers

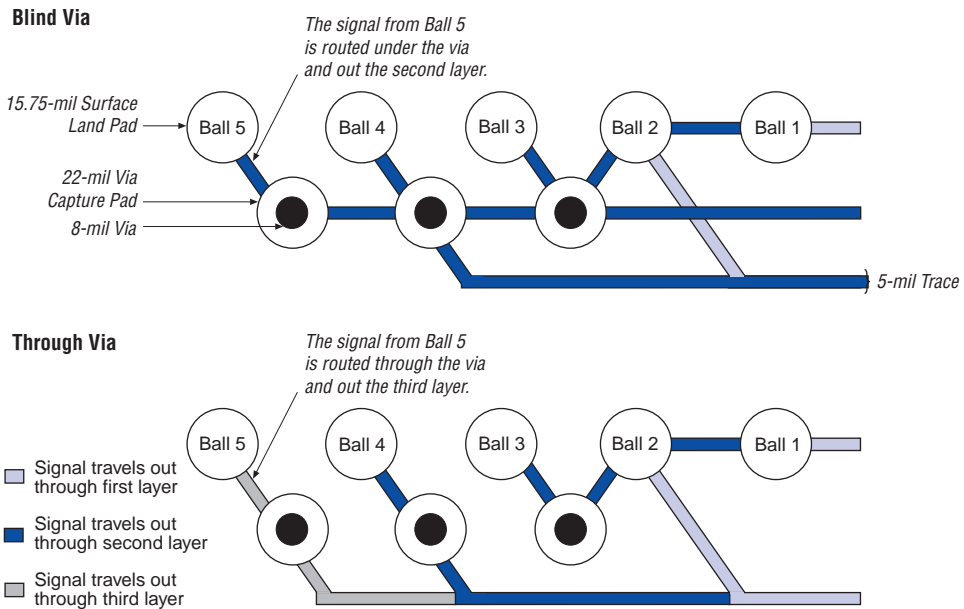
In general, the number of PCB layers required to route signals is inversely proportional to the number of traces between vias (i.e., the greater the number of traces, the fewer the number of PCB layers required). You can estimate the number of layers your PCB requires by first determining:

- Trace and space size
- Number of traces routed between the via capture pads
- Type of vias used

Table 7–6 shows the number of PCB layers required to route signals for various FineLine BGA packages in EPF10K50E devices, assuming the use of a power plane, ground plane, and all I/O pins. This table shows that using double traces and blind vias reduces the required number of layers.

FineLine BGA Package (Balls)	Single Trace		Double Trace	
	Blind Vias (Layers)	Through Vias (Layers)	Blind Vias (Layers)	Through Vias (Layers)
100	2	2	1	1
256	2	2	2	2
484	2	3	2	2
672	3	4	2	3

Using fewer I/O pins than the maximum can reduce the required number of layers. Via type can also reduce the number of layers required. To see how the via type can affect the required number of PCB layers, consider the sample layouts shown in Figure 7–10.

Figure 7–10. Sample PCB Layout

The blind via layout in [Figure 7–10](#) requires only two PCB layers. The signals from the first two balls can be routed directly through the first layer. The signals from the third and fourth balls can be routed through a via and out the second layer, and the signal from the fifth ball can be routed under the vias for Ball 4 and Ball 3 and out the second layer. Together, only two PCB layers are required.

In contrast, the through via layout in [Figure 7–10](#) requires three PCB layers, because signals cannot be routed under through vias. The signals from the third and fourth balls can still be routed through a via and out the second layer, but the signal from the fifth ball must be routed through a via and out the third layer. Using blind vias rather than through vias in this example saves one PCB layer.

Conclusion

Altera has taken a leadership position in PLD packaging with the recent introduction of 1.00-mm FineLine BGA packages. These packages use a reduced PCB area while maintaining a very high pin count. By using the information in this application note, you can easily design PCBs to use FineLine BGA packages, and take advantage of the package's reduced size.