Data Sheet
May, 2006

ORCA® Series 4 FPGAs

Introduction

Built on the Series 4 reconfigurable embedded system-on-a-chip (SoC) architecture, Lattice introduces its new family of generic Field-Programmable Gate Arrays (FPGAs). The high-performance and highly versatile architecture brings a new dimension to bringing network system designs to market in less time than ever before. This new device family offers many new features and architectural enhancements not available in any earlier FPGA generations. Bringing together highly flexible SRAM-based programmable logic, powerful system features, a rich hierarchy of routing and interconnect resources, and meeting multiple interface standards, the Series 4 FPGA accommodates the most complex and high-performance intellectual property (IP) network designs.

Programmable Features

- High-performance platform design:
  - 0.16 μm 7-level metal technology.
  - Internal performance of >250 MHz.
  - I/O performance of >420 MHz.
  - Meets multiple I/O interface standards.
  - 1.5 V operation (30% less power than 1.8 V operation) translates to greater performance.
- Traditional I/O selections:
  - LVTTL (3.3V) and LVCMOS (2.5 V and 1.8 V) I/Os.
  - Per pin-selectable I/O clamping diodes provide 3.3 V PCI compliance.
  - Individually programmable drive capability: 24 mA sink/12 mA source, 12 mA sink/6 mA source, or 6 mA sink/3 mA source.
  - Two slew rates supported (fast and slew-limited).
  - Fast-capture input latch and input flip-flop (FF)/latch for reduced input setup time and zero hold time.
  - Fast open-drain drive capability.
  - Capability to register 3-state enable signal.
  - Off-chip clock drive capability.
  - Two-input function generator in output path.
- New programmable high-speed I/O:
  - Single-ended: GTL, GTL+, PECL, SSTL3/2 (class I and II), HSTL (Class I, III, and IV), ZBT, and DDR.
  - Double-ended: LDVS, bused-LVDS, and LVPECL. Programmable (on/off) internal parallel termination (100 Ω) also supported for these I/Os.

Table 1. *ORCA* Series 4—Available FPGA Logic

Device	Rows	Columns	PFUs	User I/O	LUTs	EBR Blocks	EBR Bits (K)	Usable* Gates (K)
OR4E02	26	24	624	405	4,992	8	74	201—397
OR4E04	36	36	1,296	466	10,368	12	111	333—643
OR4E06	46	44	2,024	466	16,192	16	148	471—899

* The embedded system bus and MPI are not included in the above gate counts. The System Gate ranges are derived from the following: minimum system gates assumes 100% of the PFUs are used for logic only (no PFU RAM) with 40% EBR usage and 2 PLLs. Maximum system gates assumes 80% of the PFUs are for logic, 20% are used for PFU RAM, with 80% EBR usage and 6 PLLs.

Note: Devices are not pinout compatible with *ORCA* Series 2/3.

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Programmable Features (continued)

- New capability to (de)multiplex I/O signals:
  - — New double data rate on both input and output at rates up to 350 MHz (700 MHz effective rate).
  - — New 2x and 4x downlink and uplink capability per I/O (i.e., 50 MHz internal to 200 MHz I/O).
- Enhanced twin-quad programmable function unit (PFU):
  - — Eight 16-bit look-up tables (LUTs) per PFU.
  - — Nine user registers per PFU, one following each LUT and organized to allow two nibbles to act independently, plus one extra for arithmetic operations.
  - — New register control in each PFU has two independent programmable clocks, clock enables, local set/reset, and data selects.
  - — New LUT structure allows flexible combinations of LUT4, LUT5, new LUT6, 4 to 1 MUX, new 8 to 1 MUX, and ripple mode arithmetic functions in the same PFU.
  - — 32 x 4 RAM per PFU, configurable as single- or dual-port. Create large, fast RAM/ROM blocks (128 x 8 in only eight PFUs) using the SLIC decoders as bank drivers.
  - — Soft-wired LUTs (SWL) allow fast cascading of up to three levels of LUT logic in a single PFU through fast internal routing which reduces routing congestion and improves speed.
  - — Flexible fast access to PFU inputs from routing.
  - — Fast-carry logic and routing to all four adjacent PFUs for nibble-, byte-wide, or longer arithmetic functions, with the option to register the PFU carry-out.
- Abundant high-speed buffered and nonbuffered routing resources provide 2x average speed improvements over previous architectures.
- Hierarchical routing optimized for both local and global routing with dedicated routing resources. This results in faster routing times with predictable and efficient performance.
- SLIC provides eight 3-statable buffers, up to 10-bit decoder, and *PAL*™-like and-or-invert (AOI) in each programmable logic cell.
- Improved built-in clock management with programmable phase-locked loops (PPLLs) provide optimum clock modification and conditioning for phase, frequency, and duty cycle from 15 MHz up to 420 MHz. Multiplication of the input frequency up to 64x, and division of the input frequency down to 1/64x possible.
- New 200 MHz embedded quad-port RAM blocks, two read ports, two write ports, and two sets of byte lane enables. Each embedded RAM block can be configured as:
  - — 1-512 x 18 (quad-port, two read/two write) with optional built in arbitration.
  - — 1-256 x 36 (dual-port, one read/one write).
  - — 1-1K x 9 (dual-port, one read/one write).
  - — 2-512 x 9 (dual-port, one read/one write for each).
  - — 2 RAMS with arbitrary number of words whose sum is 512 or less by 18 (dual-port, one read/one write).
  - — Supports joining of RAM blocks.
  - — Two 16 x 8-bit content addressable memory (CAM) support.
  - — FIFO 512 x 18, 256 x 36, 1K x 9 or dual 512 x 9.
  - — Constant multiply (8 x 16 or 16 x 8).
  - — Dual-variable multiply (8 x 8).
- Embedded 32-bit internal system bus plus 4-bit parity interconnects FPGA logic, microprocessor interface (MPI), embedded RAM blocks, and embedded standard cell blocks with 100 MHz bus performance. Included are built-in system registers that act as the control and status center for the device.
- Built-in testability:
  - — Full boundary scan (*IEEE* ®1149.1 and Draft 1149.2 joint test access group (JTAG)).
  - — Programming and readback through boundary scan port compliant to *IEEE* Draft 1532:D1.7.
  - — TS_ALL testability function to 3-state all I/O pins.
  - — New temperature sensing diode.
- New cycle stealing capability allows a typical 15% to 40% internal speed improvement after final place and route. This feature also enables compliance with many setup/hold and clock-to-out I/O specifications and may provide reduced ground bounce for output buses by allowing flexible delays of switching output buffers.

System Features

- PCI local bus compliant.
- Improved *PowerPC*® /PowerQUICC MPC860 and *PowerPC* II MPC8260 high-speed synchronous microprocessor interface can be used for configuration, readback, device control, and device status, as well as for a general-purpose interface to the FPGA logic, RAMs, and embedded standard cell blocks. Glueless interface to synchronous *PowerPC* processors with user-configurable address space provided.
- New embedded *AMBA*™ specification 2.0 AHB system bus (*ARM* ™ processor) facilitates communication among the microprocessor interface, configuration logic, embedded block RAM, FPGA logic, and embedded standard cell blocks.
- New network PLLs meet ITU-T G.811 specifications and provide clock conditioning for DS-1/E-1 and STS-3/STM-1 applications.
- Variable size bused readback of configuration data capability with the built-in microprocessor interface and system bus.
- Internal, 3-state, bidirectional buses with simple control provided by the SLIC.
- New clock routing structures for global and local clocking significantly increases speed and reduces skew (<200 ps for OR4E04).
- New local clock routing structures allow creation of localized clock trees.
- Two new edge clock routing structures allow up to six high-speed clocks on each edge of the device for improved setup/hold and clock to out performance.
- New double-data rate (DDR) and zero-bus turnaround (ZBT) memory interfaces support the latest high-speed memory interfaces.
- New 2x/4x uplink and downlink I/O capabilities interface high-speed external I/Os to reduced speed internal logic.
- Meets universal test and operations PHY interface for ATM (UTOPIA) Levels 1, 2, and 3. Also meets proposed specifications for UTOPIA level 4, POS-PHY Level 3 (2.5 Gbits/s), and POS-PHY 4 (10 Gbits/s) interface standards for packet-over-SONET as defined by the Saturn Group.
- ispLEVER development system software. Supported by industry-standard CAE tools for design entry, synthesis, simulation, and timing analysis.

Product Description

Architecture Overview

The *ORCA* Series 4 architecture is a new generation of SRAM-based programmable devices from Lattice. It includes enhancements and innovations geared toward today's high-speed systems on a single chip. Designed with networking applications in mind, the Series 4 family incorporates system-level features that can further reduce logic requirements and increase system speed. *ORCA* Series 4 devices contain many new patented enhancements and are offered in a variety of packages, and speed grades.

The hierarchical architecture of the logic, clocks, routing, RAM and system level blocks create a seamless merge of FPGA and ASIC designs. Modular hardware and software technologies enable system-on-chip integration with True Plug and Play design implementation.

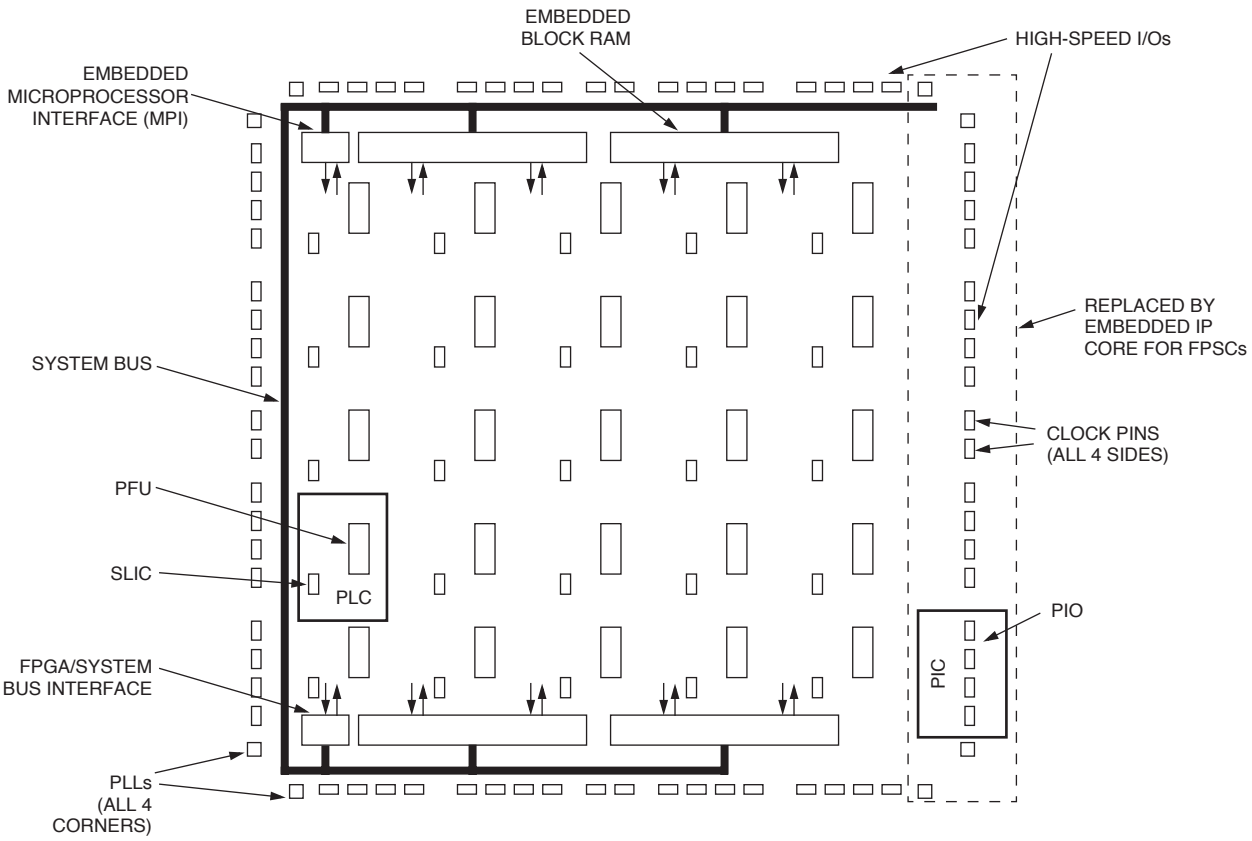
The architecture consists of four basic elements: programmable logic cells (PLCs), programmable input/output cells (PIOs), embedded block RAMs (EBRs), and system-level features. A high-level block diagram is shown in Figure 1. These elements are interconnected with a rich routing fabric of both global and local wires. An array of PLCs and its associated resources are surrounded by common interface blocks (CIBs) which provide an abundant interface to the adjacent PIOs or system blocks. Routing congestion around these critical blocks is eliminated by the use of the same routing fabric implemented within the programmable logic core. PICS provide the logical interface to the PIOs which provide the boundary interface off and onto the device. Also the interquad routing blocks
(hIQ, vIQ) separate the quadrants of the PLC array and provide the global routing and clocking elements. Each PLC contains a PFU, SLIC, local routing resources, and configuration RAM. Most of the FPGA logic is performed in the PFU, but decoders, *PAL*-like functions, and 3-state buffering can be performed in the SLIC. The PIOs provide device inputs and outputs and can be used to register signals and to perform input demultiplexing, output multiplexing, uplink and downlink functions, and other functions on two output signals.

The Series 4 architecture integrates macrocell blocks of memory known as EBR. The blocks run horizontally across the PLC array and provide flexible memory functionality. Large blocks of 512x18 quad-port RAM compliment the existing distributed PFU memory. The RAM blocks can be used to implement RAM, ROM, FIFO, multiplier, and CAM, typically without the use of PFUs for implementation.

System-level functions such as a microprocessor interface, PLLs, embedded system bus elements (located in the corners of the array), the routing resources, and configuration RAM are also integrated elements of the architecture.

For Series 4 FPSCs, all PIO buffers and logic are replaced by the embedded logic core on the side of the device. The four PLLs on the right side of the device (two in the upper right corner and two in the lower right corner) are removed and the embedded system bus extends into the FPSC section.

Product Description (continued)



Note: For FPSCs, all I/Os and the four PLLs on the right side of the device are replaced with the embedded core.

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Figure 1. Series 4 Top Level Diagram

Programmable Logic Cells

The PLCs are arranged in an array of rows and columns. The location of a PLC is indicated by its row and column so that a PLC in the second row and the third column is R2C3. The array of actual PLCs for every device begins with R3C2 in all Series 4 generic FPGAs. PIOs are located on all four sides of the FPGA. Every group of four PIOs on the device edge have an associated PIC.

The PLC consists of a PFU, SLIC, and routing resources. Each PFU within a PLC contains eight 4-input (16-bit) LUTs, eight latches/FFs, and one additional FF that may be used independently or with arithmetic functions. The PFU is the main logic element of the PLC, containing elements for both combinatorial and sequential logic. Combinatorial logic is done in LUTs located in the PFU. The PFU can be used in different modes to meet different logic requirements. The LUTs twin-quad architecture provides a configurable medium-/large-grain architecture that can be used to implement from one to eight independent combinatorial logic functions or a large number of complex logic functions using multiple LUTs. The flexibility of the LUT to handle wide input functions, as well as multiple smaller input functions, maximizes the gate count per PFU while increasing system speed.

The PFU is organized in a twin-quad fashion: two sets of four LUTs and FFs that can be controlled independently. Each PFU has two independent programmable clocks, clock enables, local set/reset, and data selects.

LUTs may also be combined for use in arithmetic functions using fast-carry chain logic in either 4-bit or 8-bit modes. The carry-out of either mode may be registered in the ninth FF for pipelining. Each PFU may also be configured as a synchronous 32x4 single- or dual-port RAM or ROM. The FFs (or latches) may obtain input from LUT outputs or directly from invertible PFU inputs, or they can be tied high or tied low. The FFs also have programmable clock polarity, clock enables, and local set/reset.

Programmable Logic Cells (continued)

The LUTs can be programmed to operate in one of three modes: combinatorial, ripple, or memory. In combinatorial mode, the LUTs can realize any 4-, 5-, or 6-input logic function and many multilevel logic functions using *ORCA*'s SWL connections. In ripple mode, the high-speed carry logic is used for arithmetic functions, comparator functions, or enhanced data path functions. In memory mode, the LUTs can be used as a 32x4 synchronous read/write or ROM, in either single- or dual-port mode.

The SLIC is connected from PLC routing resources and from the outputs of the PFU. It contains eight 3-state, bidirectional buffers and logic to perform up to a 10-bit AND function for decoding, or an AND-OR with optional INVERT to perform *PAL*-like functions. The 3-state drivers in the SLIC and their direct connections from the PFU outputs make fast, True 3-state buses possible within the FPGA.

Programmable Function Unit

The PFUs are used for logic. Each PFU has 53 external inputs and 20 outputs and can operate in several modes. The functionality of the inputs and outputs depends on the operating mode.

The PFU uses 36 data input lines for the LUTs, eight data input lines for the latches/FFs, eight control inputs (CLK[1:0], CE[1:0], LSR[1:0], SEL[1:0]), and a carry input (CIN) for fast arithmetic functions and general-purpose data input for the ninth FF. There are eight combinatorial data outputs (one from each LUT), eight latched/registered outputs (one from each latch/FF), a carry-out (COUT), and a registered carry-out (REGCOUT) that comes from the ninth FF. The carry-out signals are used principally for fast arithmetic functions. There are also two dedicated F6 mode outputs which are for the 6-input LUT function and 8 to 1 MUX.

Figure 2 and Figure 3 show high-level and detailed views of the ports in the PFU, respectively. The eight sets of LUT inputs are labeled as K0 through K7 with each of the four inputs to each LUT having a suffix of _x, where x is a number from 0 to 3.

There are four F5 inputs labeled A through D. These are used for additional LUT inputs for 5- and 6-input LUTs or as a selector for multiplexing two 4-input LUTs. Four adjacent LUT4s can also be multiplexed together with a 4 to 1 MUX to create a 6-input LUT. The eight direct data inputs to the latches/FFs are labeled as DIN[7:0]. Registered LUT outputs are shown as Q[7:0], and combinatorial LUT outputs are labeled as F[7:0].

The PFU implements combinatorial logic in the LUTs and sequential logic in the latches/FFs. The LUTs are static random access memory (SRAM) and can be used for read/write or ROM.

Each latch/FF can accept data from its associated LUT. Alternatively, the latches/FFs can accept direct data from DIN[7:0], eliminating the LUT delay if no combinatorial function is needed. Additionally, the CIN input can be used as a direct data source for the ninth FF. The LUT outputs can bypass the latches/FFs, which reduces the delay out of the PFU. It is possible to use the LUTs and latches/FFs more or less independently, allowing, for instance, a comparator function in the LUTs simultaneously with a shift register in the FFs.

Programmable Logic Cells (continued)

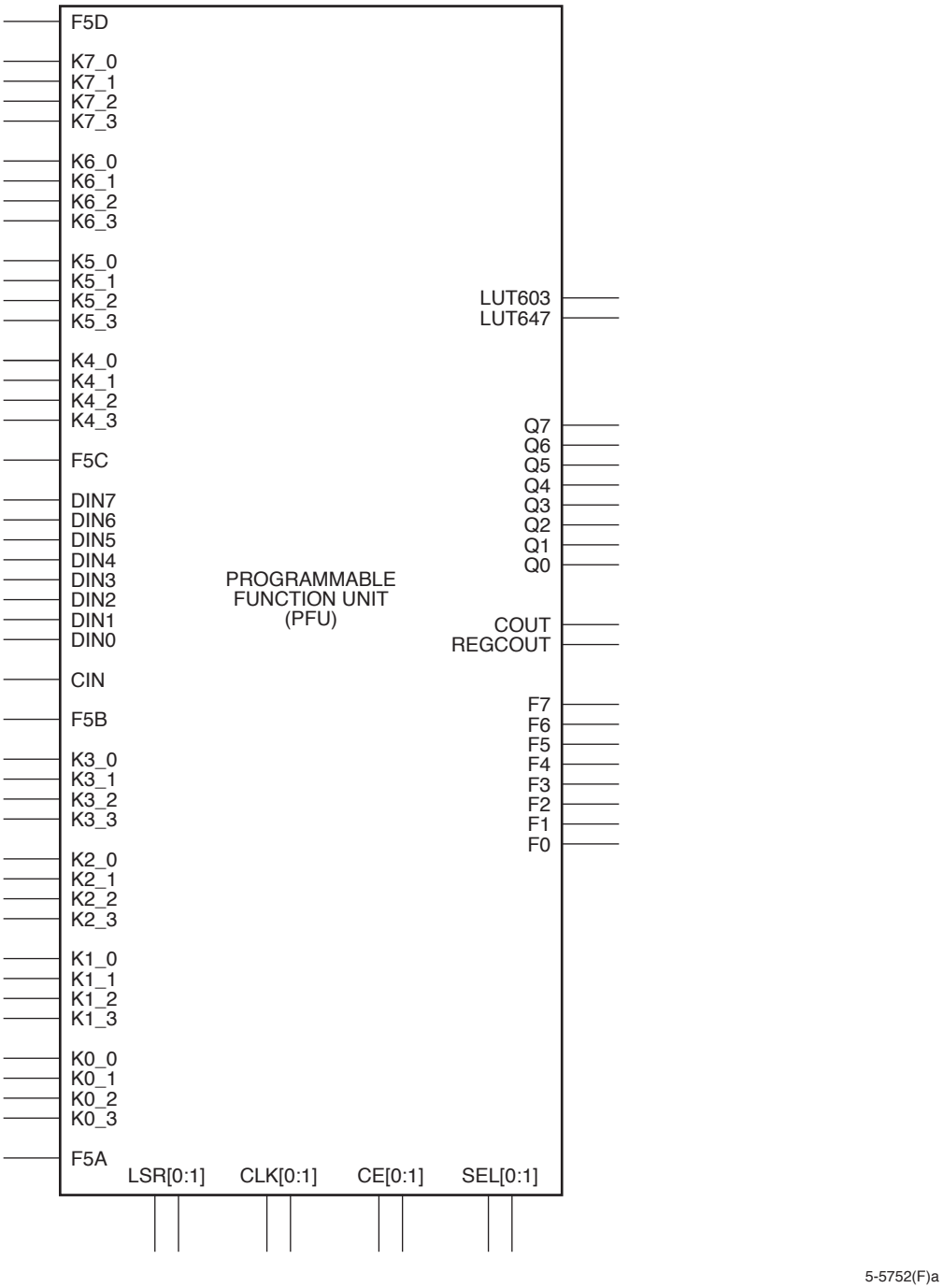

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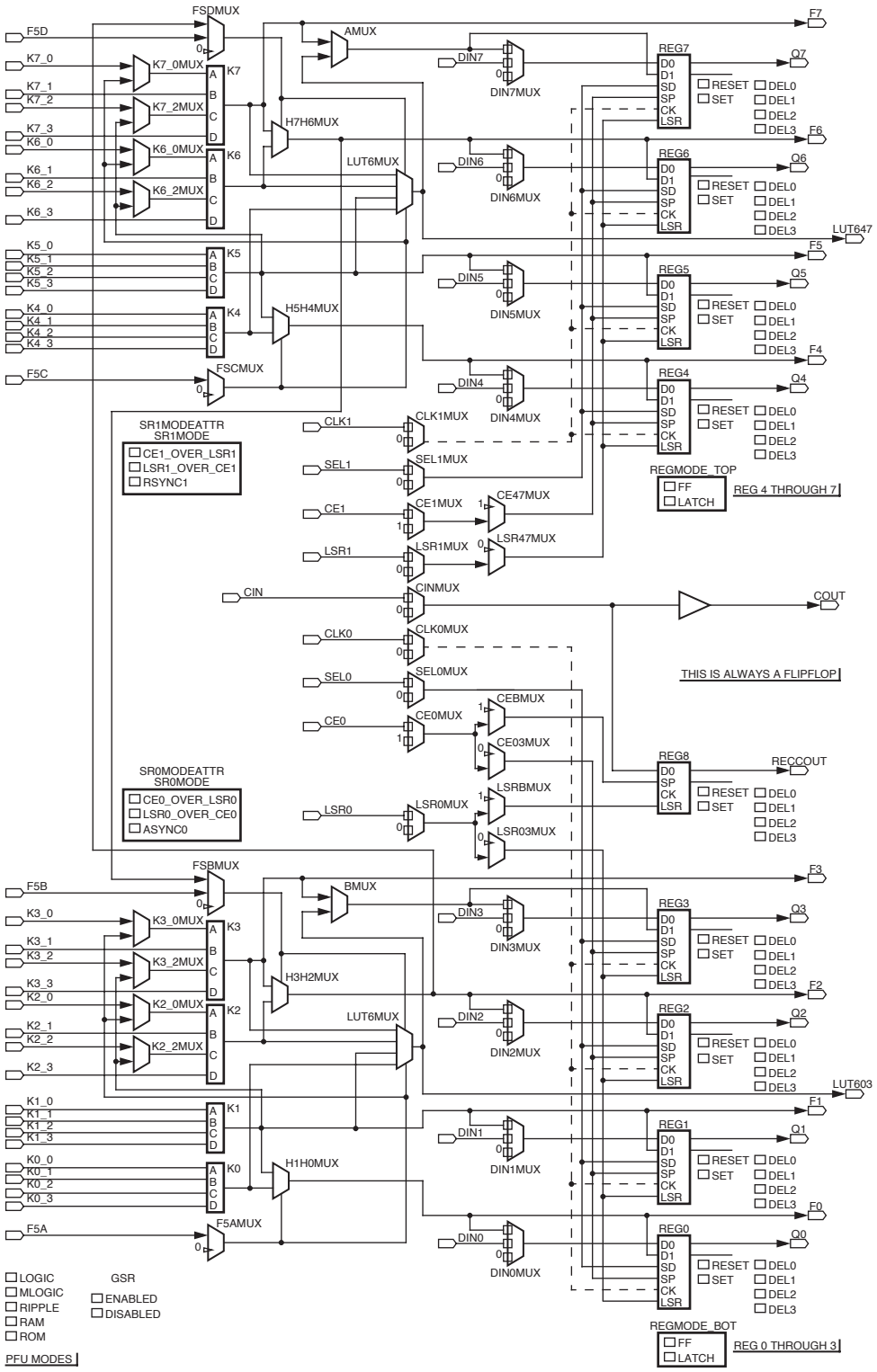
Figure 2. PFU Ports

The PFU can be configured to operate in four modes: logic mode, half-logic mode, ripple mode, and memory (RAM/ROM) mode. In addition, ripple mode has four submodes and RAM mode can be used in either a single- or dual-port memory fashion. These submodes of operation are discussed in the following sections.

Programmable Logic Cells (continued)



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Note: All multiplexers without select inputs are configuration selector multiplexers.

Figure 3. Simplified PFU Diagram

Programmable Logic Cells (continued)

Look-Up Table Operating Modes

The operating mode affects the functionality of the PFU input and output ports and internal PFU routing. For example, in some operating modes, the DIN[7:0] inputs are direct data inputs to the PFU latches/FFs. In memory mode, the same DIN[7:0] inputs are used as a 4-bit write data input bus and a 4-bit write address input bus into LUT memory.

Table 2 lists the basic operating modes of the LUT. Figure 4—Figure 7 show block diagrams of the LUT operating modes. The accompanying descriptions demonstrate each mode's use for generating logic.

Table 2. Look-Up Table Operating Modes

Mode	Function
Logic	4-, 5-, and 6-input LUTs; softwired LUTs; latches/FFs with direct input or LUT input; CIN as direct input to ninth FF or as pass through to COUT.
Half Logic/ Half Ripple	Upper four LUTs and latches/FFs in logic mode; lower four LUTs and latches/FFs in ripple mode; CIN and ninth FF for logic or ripple functions.
Ripple	All LUTs combined to perform ripple-through data functions. Eight LUT registers available for direct-in use or to register ripple output. Ninth FF dedicated to ripple out, if used. The submodes of ripple mode are adder/subtractor, counter, multiplier, and comparator.
Memory	All LUTs and latches/FFs used to create a 32x4 synchronous dual-port RAM. Can be used as single-port or as ROM.

PFU Control Inputs

Each PFU has eight routable control inputs and an active-low, asynchronous global set/reset (GSRN) signal that affects all latches and FFs in the device. The eight control inputs are CLK[1:0], LSR[1:0], CE[1:0], and SEL[1:0], and their functionality for each logic mode of the PFU is shown in Table 3. The clock signal to the PFU is CLK, CE stands for clock enable, which is its primary function. LSR is the local set/reset signal that can be configured as synchronous or asynchronous. The selection of set or reset is made for each latch/FF and is not a function of the signal itself. SEL is used to dynamically select between direct PFU input and LUT output data as the input to the latches/FFs.

All of the control signals can be disabled and/or inverted via the configuration logic. A disabled clock enable indicates that the clock is always enabled. A disabled LSR indicates that the latch/FF never sets/resets (except from GSRN). A disabled SEL input indicates that DIN[7:0] PFU inputs are routed to the latches/FFs.

Table 3. Control Input Functionality

Mode	**CLK**[1:0]	**LSR**[1:0]	**CE**[1:0]	**SEL**[1:0]
Logic	CLK to all latches/ FFs	LSR to all latches/FFs, enabled per nibble and for ninth FF	CE to all latches/FFs, selectable per nibble and for ninth FF	Select between LUT input and direct input for eight latches/FFs
Half Logic/ Half Ripple	CLK to all latches/ FFs	LSR to all latches/FF, enabled per nibble and for ninth FF	CE to all latches/FFs, selectable per nibble and for ninth FF	Select between LUT input and direct input for eight latches/FFs
Ripple	CLK to all latches/ FFs	LSR to all latches/FFs, enabled per nibble and for ninth FF	CE to all latches/FFs, selectable per nibble and for ninth FF	Select between LUT input and direct input for eight latches/FFs
Memory (RAM)	CLK to RAM	LSR0 Port enable 2	CE1 RAM write enable CE0 Port enable 1	Not used
Memory (ROM)	Optional for synchronous outputs	Not used	Not used	Not used

Programmable Logic Cells (continued)

Logic Mode

The PFU diagram of Figure 3 represents the logic mode of operation. In logic mode, the eight LUTs are used individually or in flexible groups to implement user logic functions. The latches/FFs may be used in conjunction with the LUTs or separately with the direct PFU data inputs. There are three basic submodes of LUT operation in PFU logic mode: F4 mode, F5 mode, and the F6 mode. Combinations of the submodes are possible in each PFU.

F4 mode, shown simplified in Figure 4, illustrates the uses of the basic 4-input LUTs in the PFU. The output of an F4 LUT can be passed out of the PFU, captured at the LUTs associated latch/FF, or multiplexed with the adjacent F4 LUT output using one of the F5[A:D] inputs to the PFU. Only adjacent LUT pairs (K_0 and K_1, K_2 and K_3, K_4 and K_5, K_6 and K_7) can be multiplexed, and the output always goes to the even-numbered output of the pair.

The F5 submode of the LUT operation, shown simplified in Figure 4, indicates the use of 5-input LUTs to implement logic. 5-input LUTs are created from two 4-input LUTs and a multiplexer. The F5 LUT is the same as the multiplexing of two F4 LUTs described previously with the constraint that the inputs to the F4 LUTs be the same. The F5[A:D] input is then used as the fifth LUT input. The equations for the two F4 LUTs will differ by the assumed value for the F5[A:D] input, one F4 LUT assuming that the F5[A:D] input is zero, and the other assuming it is a one. The selection of the appropriate F4 LUT output in the F5 MUX by the F5[A:D] signal creates a 5-input LUT. Any combination of F4 and F5 LUTs is allowed per PFU using the eight 16-bit LUTs. Examples are eight F4 LUTs, four F5 LUTs, and a combination of four F4 plus two F5 LUTs.

Two 6-input LUTs are created by shorting together the input of four 4-input LUTs (K0:3 and K4:7) which are multiplexed together. The F5 inputs of the adjacent F4 LUTs derive the fifth and sixth inputs of the F6 mode. The F6 outputs, LUT603 and LUT647, are dedicated to the F6 mode or can be used as the outputs of MUX8x1. MUX8x1 modes are created by programming adjacent 4-input LUTs to 2x1 MUXs and multiplexing down to create MUX8x1. Both F6 mode and MUX8x1 are available in the upper and lower PFU nibbles.

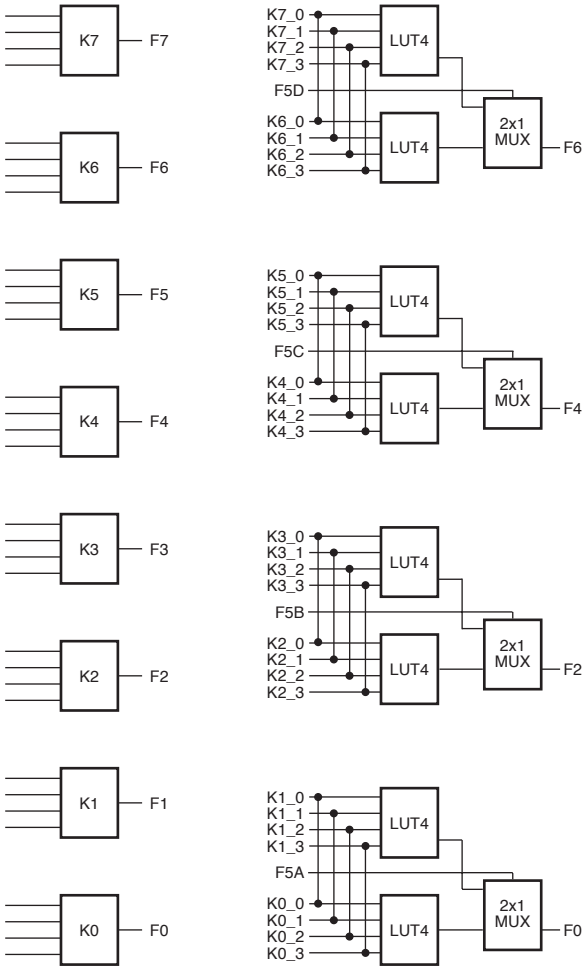

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Figure 4. Simplified F4 and F5 Logic Modes

Programmable Logic Cells (continued)

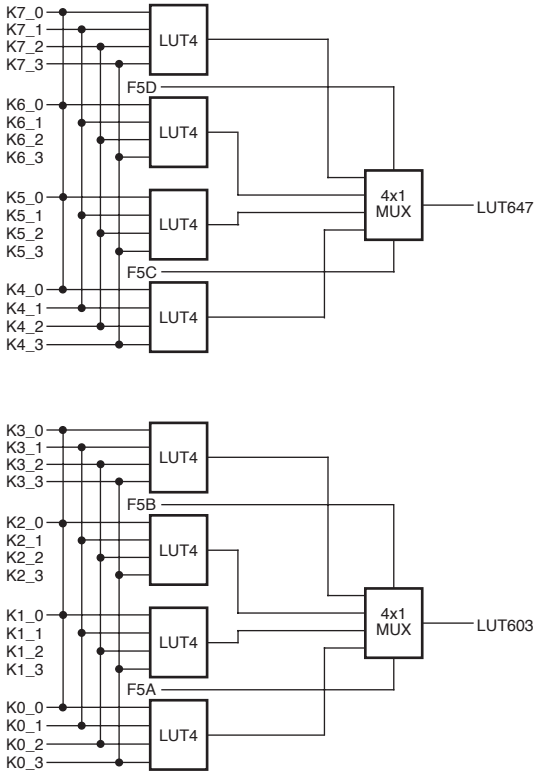

Figure 5. Simplified F6 Logic Modes

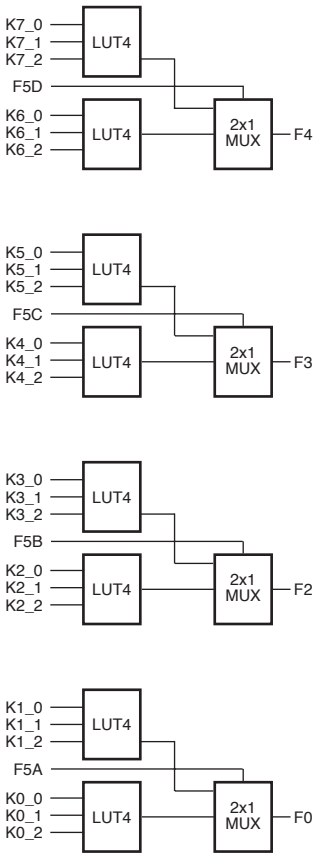

Figure 6. MUX 4x1

Programmable Logic Cells (continued)

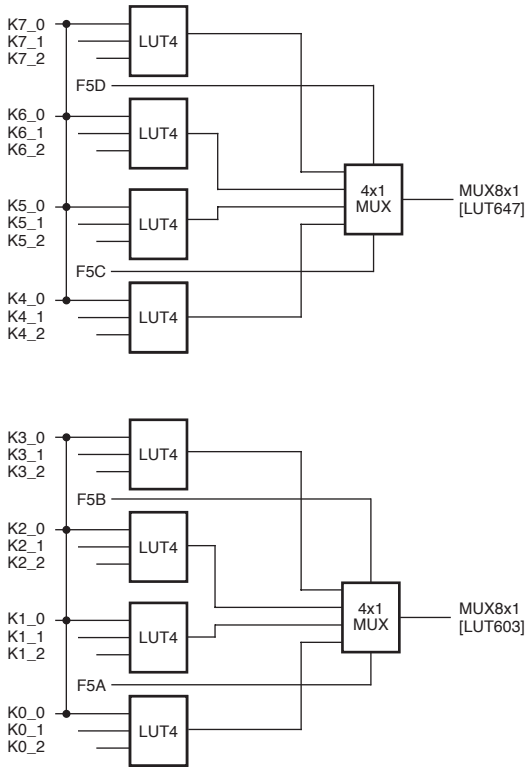

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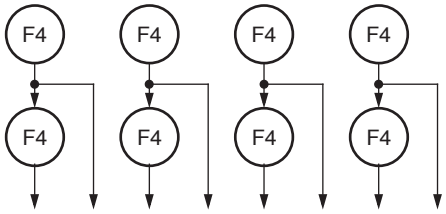
Figure 7. MUX 8x1

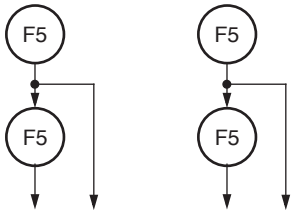
Softwired LUT submode uses F4, F5 and F6 LUTs and internal PFU feedback routing to generate complex logic functions up to three LUT-levels deep. Multiplexers can be independently configured to route certain LUT outputs to the input of other LUTs. In this manner, very complex logic functions, some of up to 22 inputs, can be implemented in a single PFU at greatly enhanced speeds.

It is important to note that an LUT output that is fed back for softwired use is still available to be registered or output from the PFU. This means, for instance, that a logic equation that is needed by itself and as a term in a larger equation need only be generated once, and PLC routing resources will not be required to use it in the larger equation.

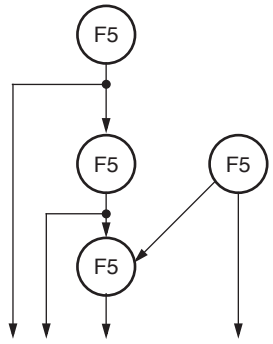
Programmable Logic Cells (continued)



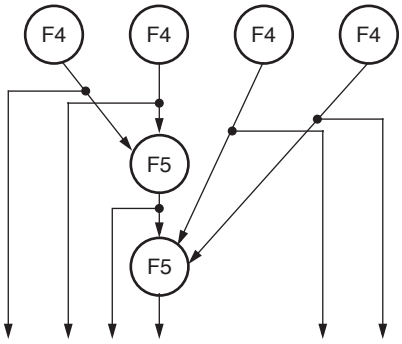
FOUR 7-INPUT FUNCTIONS IN ONE PFU



TWO 9-INPUT FUNCTIONS IN ONE PFU



ONE 17-INPUT FUNCTION IN ONE PFU



ONE 21-INPUT FUNCTION IN ONE PFU

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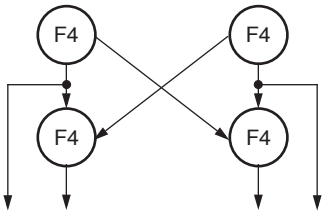
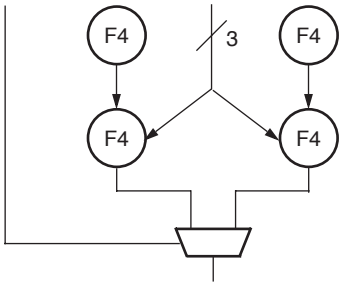
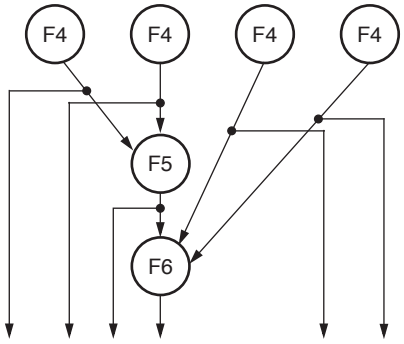


TWO 10-INPUT FUNCTIONS IN ONE PFU



ONE OF TWO 21-INPUT FUNCTIONS IN ONE PFU



ONE 22-INPUT FUNCTION IN ONE PFU

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Figure 8. Softwired LUT Topology Examples

Programmable Logic Cells (continued)

Half-Logic Mode

Series 4 FPGAs are based upon a twin-quad architecture in the PFUs. The byte-wide nature (eight LUTs, eight latches/FFs) may just as easily be viewed as two nibbles (two sets of four LUTs, four latches/FFs). The two nibbles of the PFU are organized so that any nibble-wide feature (excluding some softwired LUT topologies) can be swapped with any other nibble-wide feature in another PFU. This provides for very flexible use of logic and for extremely flexible routing. The half-logic mode of the PFU takes advantage of the twin-quad architecture and allows half of a PFU, $K_{[7:4]}$ and associated latches/FFs, to be used in logic mode while the other half of the PFU, $K_{[3:0]}$ and associated latches/FFs, is used in ripple mode. In half-logic mode, the ninth FF may be used as a general-purpose FF or as a register in the ripple mode carry chain.

Ripple Mode

The PFU LUTs can be combined to do byte-wide ripple functions with high-speed carry logic. Each LUT has a dedicated carry-out net to route the carry to/from any adjacent LUT. Using the internal carry circuits, fast arithmetic, counter, and comparison functions can be implemented in one PFU. Similarly, each PFU has carry-in (CIN, FCIN) and carry-out (COUT, FCOUT) ports for fast-carry routing between adjacent PFUs.

The ripple mode is generally used in operations on two data buses. A single PFU can support an 8-bit ripple function. Data buses of 4 bits and less can use the nibble-wide ripple chain that is available in half-logic mode. This nibble-wide ripple chain is also useful for longer ripple chains where the length modulo 8 is four or less. For example, a 12-bit adder (12 modulo 8 = 4) can be implemented in one PFU in ripple mode (8 bits) and one PFU in half-logic mode (4 bits), freeing half of a PFU for general logic mode functions.

Each LUT has two operands and a ripple (generally carry) input, and provides a result and ripple (generally carry) output. A single bit is rippled from the previous LUT and is used as input into the current LUT. For LUT K_0, the ripple input is from the PFU CIN or FCIN port. The CIN/FCIN data can come from either the fast-carry routing (FCIN) or the PFU input (CIN), or it can be tied to logic 1 or logic 0.

In the following discussions, the notations LUT K_7/K_3 and F[7:0]/F[3:0] are used to denote the LUT that provides the carry-out and the data outputs for full PFU ripple operation (K_7, F[7:0]) and half-logic ripple operation (K_3, F[3:0]), respectively. The ripple mode diagram (Figure 9) shows full PFU ripple operation, with half-logic ripple connections shown as dashed lines.

The result output and ripple output are calculated by using generate/propagate circuitry. In ripple mode, the two operands are input into K_Z[1] and K_Z[0] of each LUT. The result bits, one per LUT, are F[7:0]/F[3:0] (see Figure 9). The ripple output from LUT K_7/K_3 can be routed on dedicated carry circuitry into any of four adjacent PLCs, and it can be placed on the PFU COUT/FCOUT outputs. This allows the PLCs to be cascaded in the ripple mode so that nibble-wide ripple functions can be expanded easily to any length.

Result outputs and the carry-out may optionally be registered within the PFU. The capability to register the ripple results, including the carry output, provides for improved counter performance and simplified pipelining in arithmetic functions.

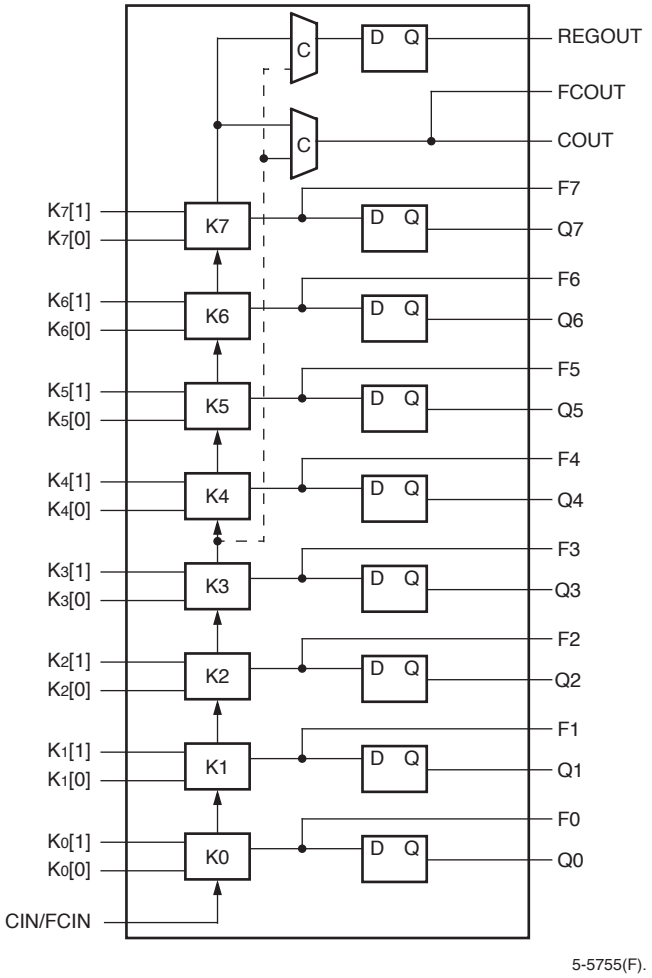

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Figure 9. Ripple Mode

Programmable Logic Cells (continued)

The ripple mode can be used in one of four submodes. The first of these is **adder-subtractor submode**. In this submode, each LUT generates three separate outputs. One of the three outputs selects whether the carry-in is to be propagated to the carry-out of the current LUT or if the carry-out needs to be generated. If the carry-out needs to be generated, this is provided by the second LUT output. The result of this selection is placed on the carry-out signal, which is connected to the next LUT carry-in or the COUT/FCOUT signal, if it is the last LUT (K_7/K_3). Both of these outputs can be any equation created from Kz[1] and Kz[0], but in this case, they have been set to the propagate and generate functions.

The third LUT output creates the result bit for each LUT output connected to F[7:0]/F[3:0]. If an adder/subtractor is needed, the control signal to select addition or subtraction is input on F5A/F5C inputs. These inputs generate the controller input AS. When AS = 0 this function performs the adder, A + B. When AS = 1 the function performs the subtractor, A – B. The result bit is created in one-half of the LUT from a single bit from each input bus Kz[1:0], along with the ripple input bit.

The second submode is the **counter submode** (see Figure 10). The present count, which may be initialized via the PFU DIN inputs to the latches/FFs, is supplied to input Kz[0], and then output F[7:0]/F[3:0] will either be incremented by one for an up counter or decremented by one for a down counter. If an up/down counter is needed, the control signal to select the direction (up or down) is input on F5A and F5C. When F5[A:C], respectively per nibble, is a logic 1, this indicates a down counter and a logic 0 indicates an up counter.

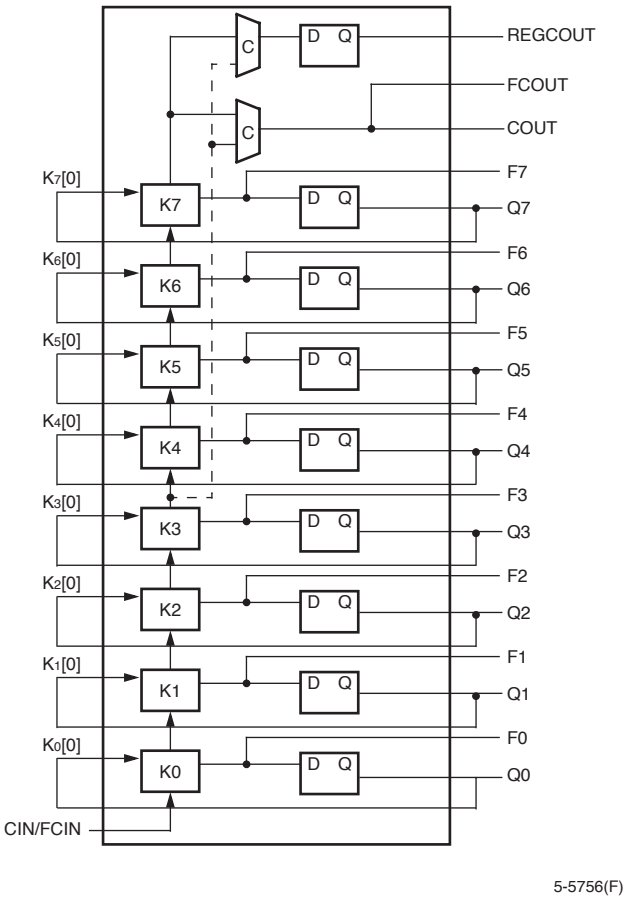


Figure 10. Counter Submode

Programmable Logic Cells (continued)

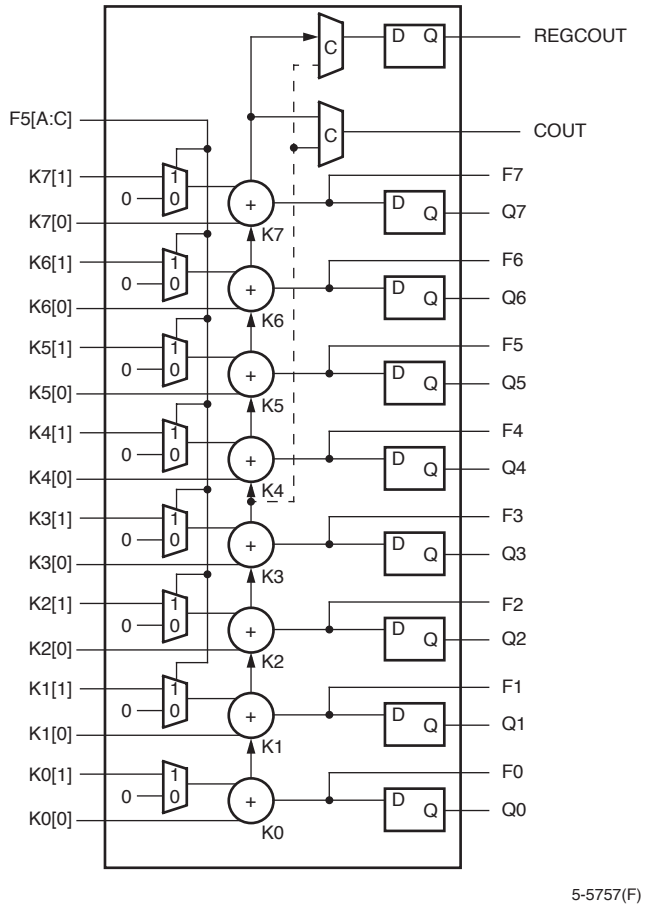
In the third submode, **multiplier submode**, a single PFU can affect an 8x1 bit (4x1 for half-ripple mode) multiply and sum with a partial product (see Figure 11). The multiplier bit is input at F5[A:C], respectively per nibble, and the multiplicand bits are input at Kz[1], where K7[1] is the most significant bit (MSB). Kz[0] contains the partial product (or other input to be summed) from a previous stage. If F5[A:C] is logical 1, the multiplicand is added to the partial product. If F5[A:C] is logical 0, 0 is added to the partial product, which is the same as passing the partial product. CIN/FCIN can bring the carry-in from the less significant PFUs if the multiplicand is wider than 8 bits, and COUT/FCOUT holds any carry-out from the multiplication, which may then be used as part of the product or routed to another PFU in multiplier mode for multiplicand width expansion.

Ripple mode's fourth submode features **equality comparators.** The functions that are explicitly available are A ≥ B, A ≠ B, and A ≤ B, where the value for A is input on Kz[0], and the value for B is input on Kz[1]. A value of 1 on the carry-out signals valid argument. For example, a carry-out equal to 1 in AB submode indicates that the value on Kz[0] is greater than or equal to the value on Kz[1]. Conversely, the functions A ≤ B, A + B, and A > B are available using the same functions but with a 0 output expected. For example, A > B with a 0 output indicates A ≤ B. Table 4 shows each function and the output expected.

If larger than 8 bits, the carry-out signal can be cascaded using fast-carry logic to the carry-in of any adjacent PFU. The use of this submode could be shown using Figure 9, except that the CIN/FCIN input for the least significant PFU is controlled via configuration.

Table 4. Ripple Mode Equality Comparator Functions and Outputs

Equality Function	ispLEVER Submode	True, if Carry-Out Is:
A ≥ B	A ≥ B	1
A ≤ B	A ≤ B	1
A ≠ B	A ≠ B	1
A < B	A ≥ B	0
A > B	A ≤ B	0
A = B	A ≠ B	0



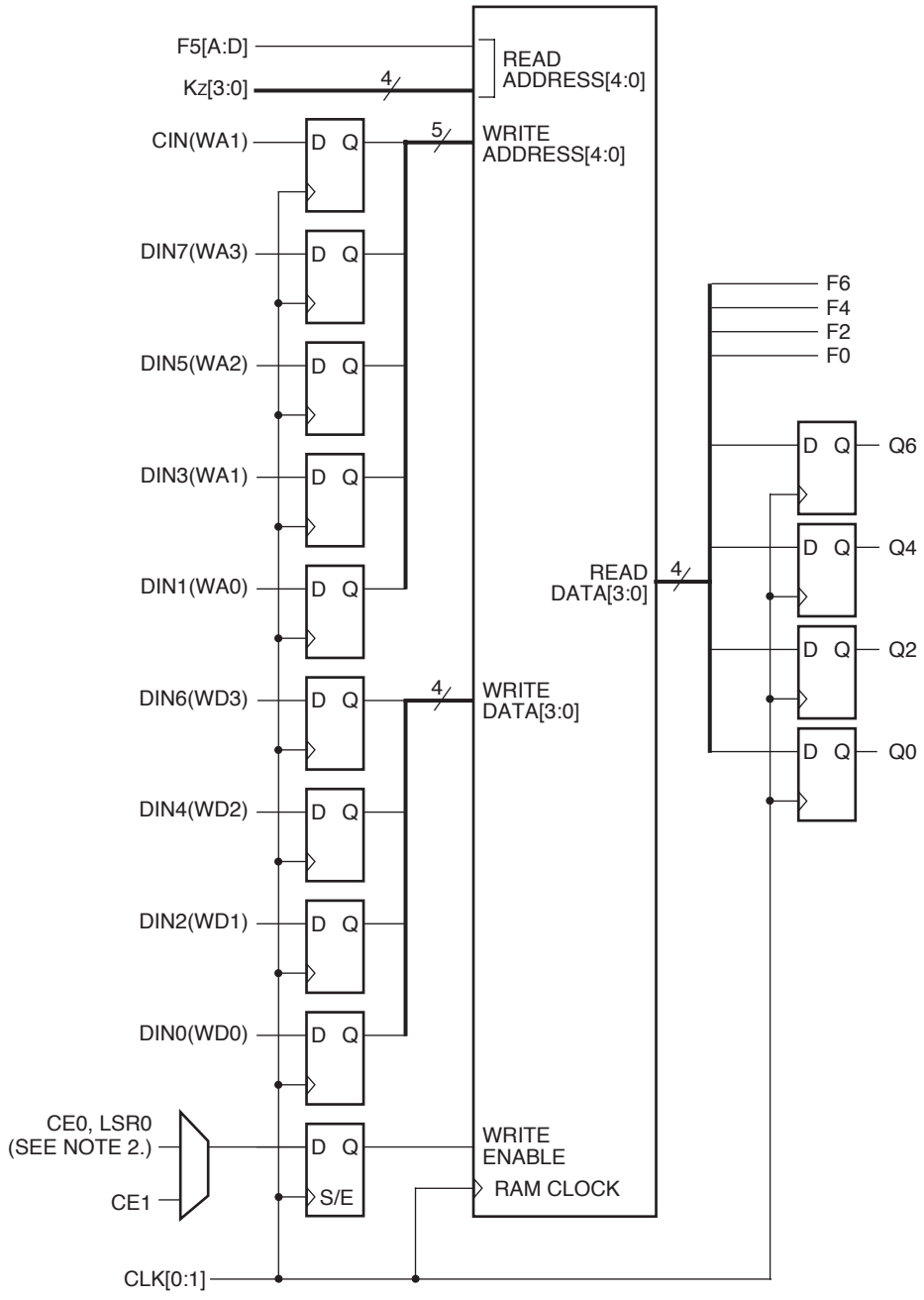
Key: C = configuration data.
Note: F5[A:C] shorted together

Figure 11. Multiplier Submode

Programmable Logic Cells (continued)

Memory Mode

The Series 4 PFU can be used to implement a 32x4 (128-bit) synchronous, dual-port RAM). A block diagram of a PFU in memory mode is shown in Figure 12. This RAM can also be configured to work as a single-port memory and because initial values can be loaded into the RAM during configuration, it can also be used as a ROM.



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1. CLK[0:1] are commonly connected in memory mode.
2. CE1 = write enable = wren; wren = 0 (no write enable); wren = 1 (write enabled).
   CE0 = write port enable 0; CE0 = 0, wren = 0; CE0 = 1, wren = CE1.
   LSR0 = write port enable 1; LSR0 = 0, wren = CE0; LSR0 = 1, wren = CE1.

Figure 12. Memory Mode

Programmable Logic Cells (continued)

The PFU memory mode uses all LUTs and latches/FFs including the ninth FF in its implementation as shown in Figure 12. The read address is input at the Kz[3:0] and F5[A:D] inputs where Kz[0] is the LSB and F5[A:D] is the MSB, and the write address is input on CIN (MSB) and DIN[7, 5, 3, 1], with DIN[1] being the LSB. Write data is input on DIN[6, 4, 2, 0], where DIN[6] is the MSB, and read data is available combinatorially on F[6, 4, 2, 0] and registered on Q[6, 4, 2, 0] with F[6] and Q[6] being the MSB. The write enable controlling ports are input on CE0, CE1, and LSR0. CE1 is the active-high write enable (CE1 = 1, RAM is write enabled). The first write port is enabled by CE0. The second write port is enabled with LSR0. The PFU CLK (CLK0) signal is used to synchronously write the data. The polarities of the clock, write enable, and port enables are all programmable. Write-port enables may be disabled if they are not to be used.

Data is written to the write data, write address, and write enable registers on the active edge of the clock, but data is not written into the RAM until the next clock edge one-half cycle later. The read port is actually asynchronous, providing the user with read data very quickly after setting the read address, but timing is also provided so that the read port may be treated as fully synchronous for write then read applications. If the read and write address lines are tied together (maintaining MSB to MSB, etc.), then the dual-port RAM operates as a synchronous single-port RAM. If the write enable is disabled, and an initial memory contents is provided at configuration time, the memory acts as a ROM (the write data and write address ports and write port enables are not used).

Wider memories can be created by operating two or more memory mode PFUs in parallel, all with the same address and control signals, but each with a different nibble of data. To increase memory word depth above 32, two or more PLCs can be used. Figure 12 shows a 128x8 dual-port RAM that is implemented in eight PLCs. This figure demonstrates data path width expansion by placing two memories in parallel to achieve an 8-bit data path. Depth expansion is applied to achieve 128 words deep using the 32-word deep PFU memories. In addition to the PFU in each PLC, the SLIC (described in the next section) in each PLC is used for read address decodes and 3-state drivers. The 128x8 RAM shown could be made to operate as a single-port RAM by tying (bit-for-bit) the read and write addresses.

To achieve depth expansion, one or two of the write address bits (generally the MSBs) are routed to the write port enables as in Figure 12. For 2 bits, the bits select which 32-word bank of RAM of the four available from a decode of two WPE inputs is to be written. Similarly, 2 bits of the read address are decoded in the SLIC and are used to control the 3-state buffers through which the read data passes. The write data bus is common, with separate nibbles for width expansion, across all PLCs, and the read data bus is common (again, with separate nibbles) to all PLCs at the output of the 3-state buffers.

Figure 13 also shows the capability to provide a read enable for RAMs/ROMs using the SLIC cell. The read enable will 3-state the read data bus when inactive, allowing the write data and read data buses to be tied together if desired.

Programmable Logic Cells (continued)

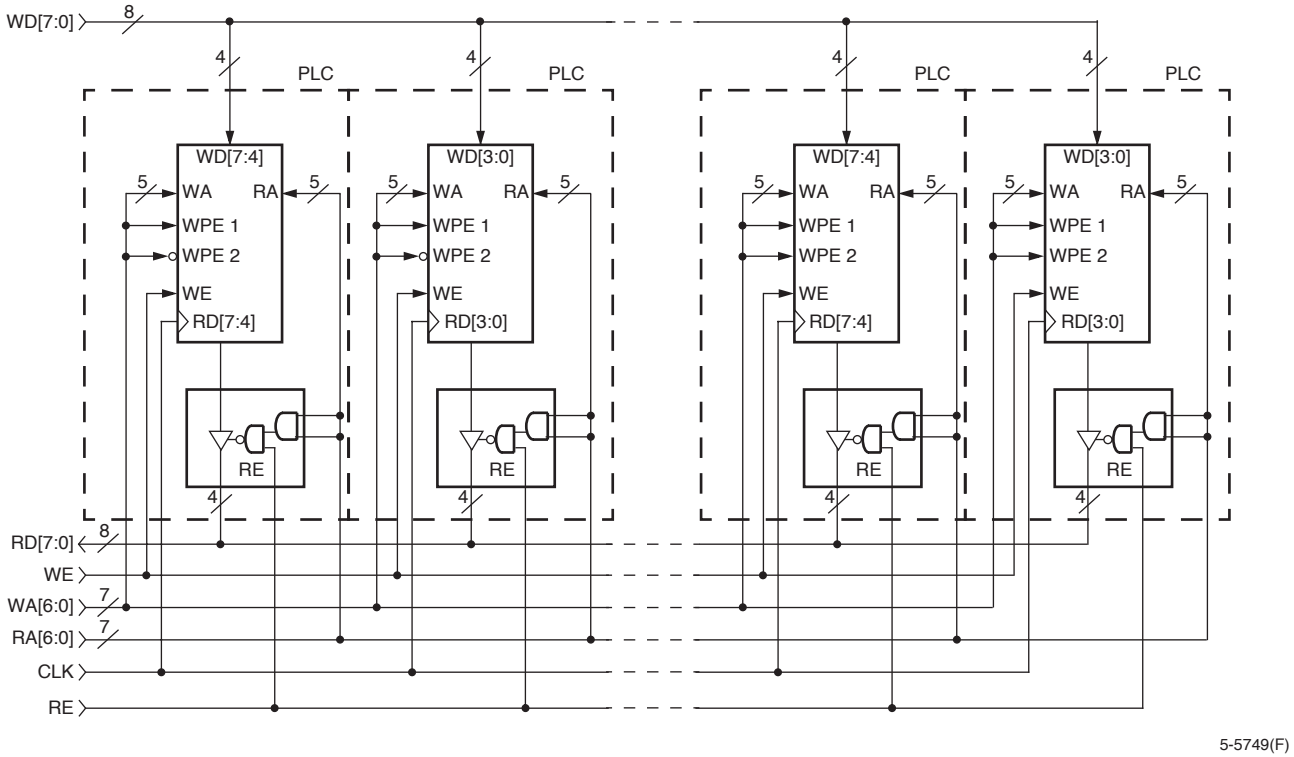

Figure 13. Memory Mode Expansion Example—128x8 RAM

Supplemental Logic and Interconnect Cell

Each PLC contains a SLIC embedded within the PLC routing, outside of the PFU. As its name indicates, the SLIC performs both logic and interconnect (routing) functions. Its main features are 3-statable, bidirectional buffers, and a *PAL*-like decoder capability. Figure 14 shows a diagram of a SLIC with all of its features shown. All modes of the SLIC are not available at one time.

The ten SLIC inputs can be sourced directly from the PFU or from the general routing fabric. SI[0:9] inputs can come from the horizontal or vertical routing and I[0:9} comes from the PFU outputs O[9:0]. These inputs can also be tied to a logical 1 or 0 constant. The inputs are twin-quad in nature and are segregated into two groups of four nibbles and a third group of two inputs for control. Each input nibble groups also have 3-state capability, however the third pair does not.

There is one 3-state control (TRI) for each SLIC, with the capability to invert or disable the 3-state control for each group of four BIDIs. Separate 3-state control for each nibble-wide group is achievable by using the SLICs decoder (DEC) output, driven by the group of two BIDIs, to control the 3-state of one BIDI nibble while using the TRI signal to control the 3-state of the other BIDI nibble. Figure 15 shows the SLIC in buffer mode with available 3-state control from the TRI and DEC signals. If the entire SLIC is acting in a buffer capacity, the DEC output may be used to generate a constant logic 1 (V_{HI}) or logic 0 (V_{LO}) signal for general use.

The SLIC may also be used to generate *PAL*-like AND-OR with optional INVERT (AOI) functions or a decoder of up to 10 bits. Each group of buffers can feed into an AND gate (4-input AND for the nibble groups and 2-input AND for the other two buffers). These AND gates then feed into a 3-input gate that can be configured as either an AND gate or an OR gate. The output of the 3-input gate is invertible and is output at the DEC output of the SLIC. Figure 19 shows the SLIC in full decoder mode.

The functionality of the SLIC is parsed by the two nibble-wide groups and the 2-bit buffer group. Each of these groups may operate independently as BIDI buffers (with or without 3-state capability for the nibble-wide groups) or as a *PAL*/decoder.

Programmable Logic Cells (continued)

As discussed in the memory mode section, if the SLIC is placed into one of the modes where it contains both buffers and a decode or AOI function (e.g., BUF_BUF_DEC mode), the DEC output can be gated with the 3-state input signal. This allows up to a 6-input decode (e.g., BUF_DEC_DEC mode) plus the 3-state input to control the enable/disable of up to four buffers per SLIC Figure 15—Figure 19 show several configurations of the SLIC, while Table 5 shows all of the possible modes.

Table 5. SLIC Modes

Mode No.	Mode	BUF [3:0]	BUF [7:4]	BUF [9:8]
1	BUFFER	Buffer	Buffer	Buffer
2	BUF_BUF_DEC	Buffer	Buffer	Decoder
3	BUF_DEC_BUF	Buffer	Decoder	Buffer
4	BUF_DEC_DEC	Buffer	Decoder	Decoder
5	DEC_BUF_BUF	Decoder	Buffer	Buffer
6	DEC_BUF_DEC	Decoder	Buffer	Decoder
7	DEC_DEC_BUF	Decoder	Decoder	Buffer
8	DECODER	Decoder	Decoder	Decoder

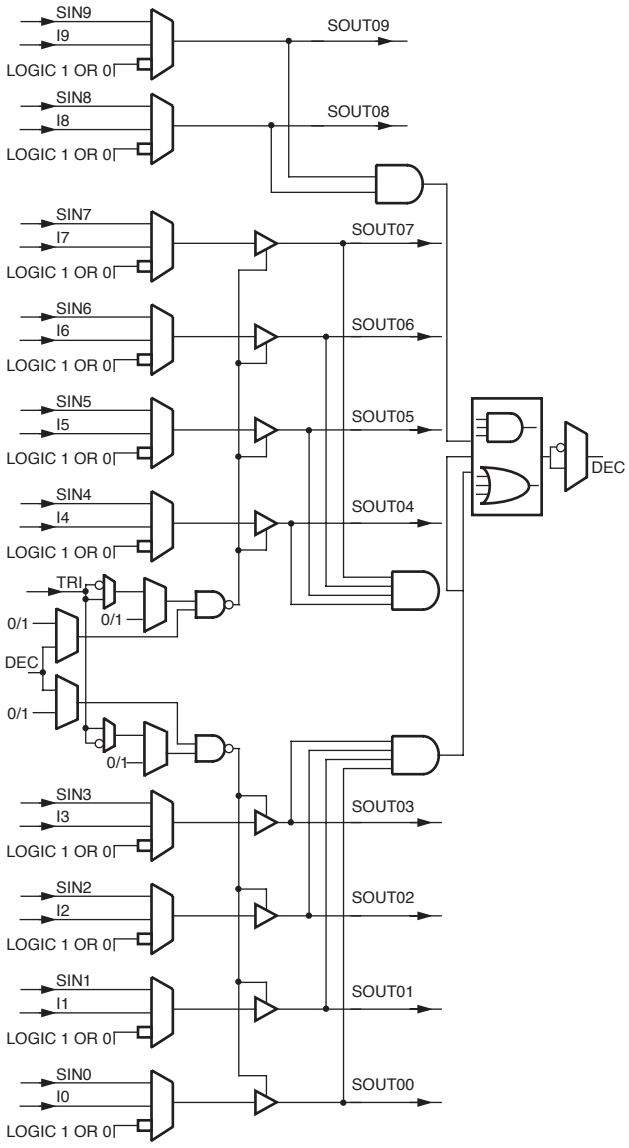

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Figure 14. SLIC All Modes Diagram

Programmable Logic Cells (continued)

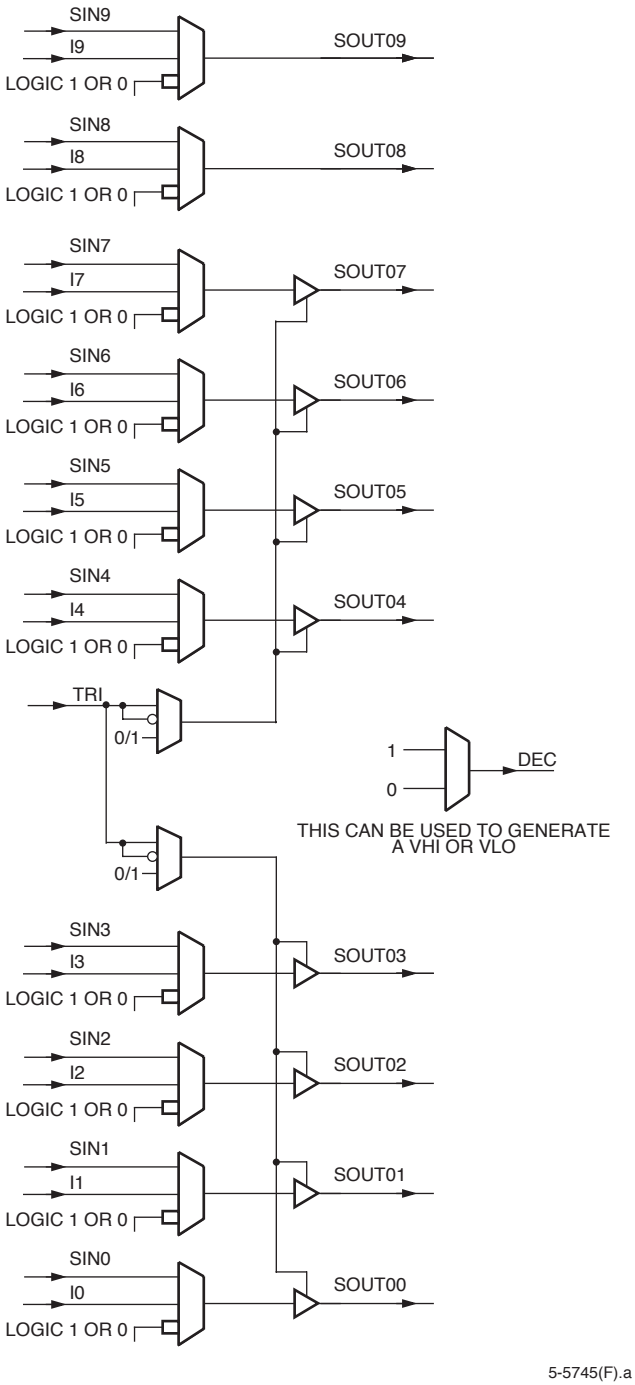

Figure 15. Buffer Mode

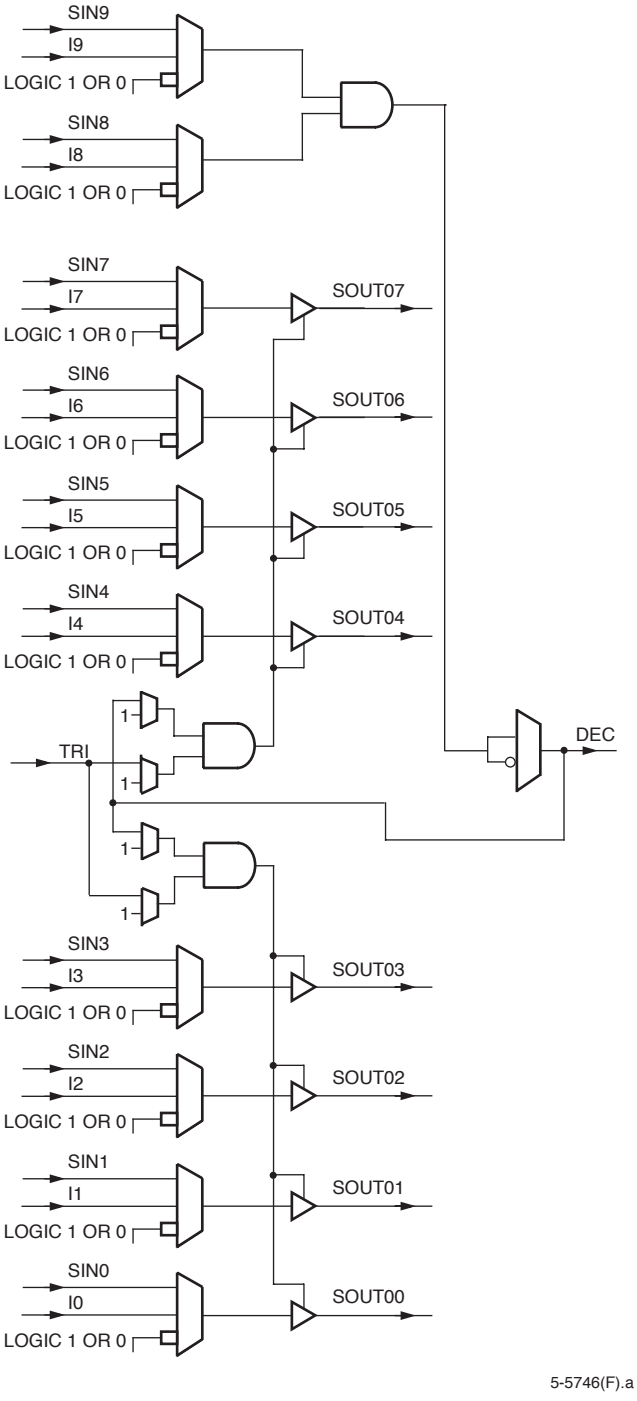

Figure 16. Buffer-Buffer-Decoder Mode

Programmable Logic Cells (continued)

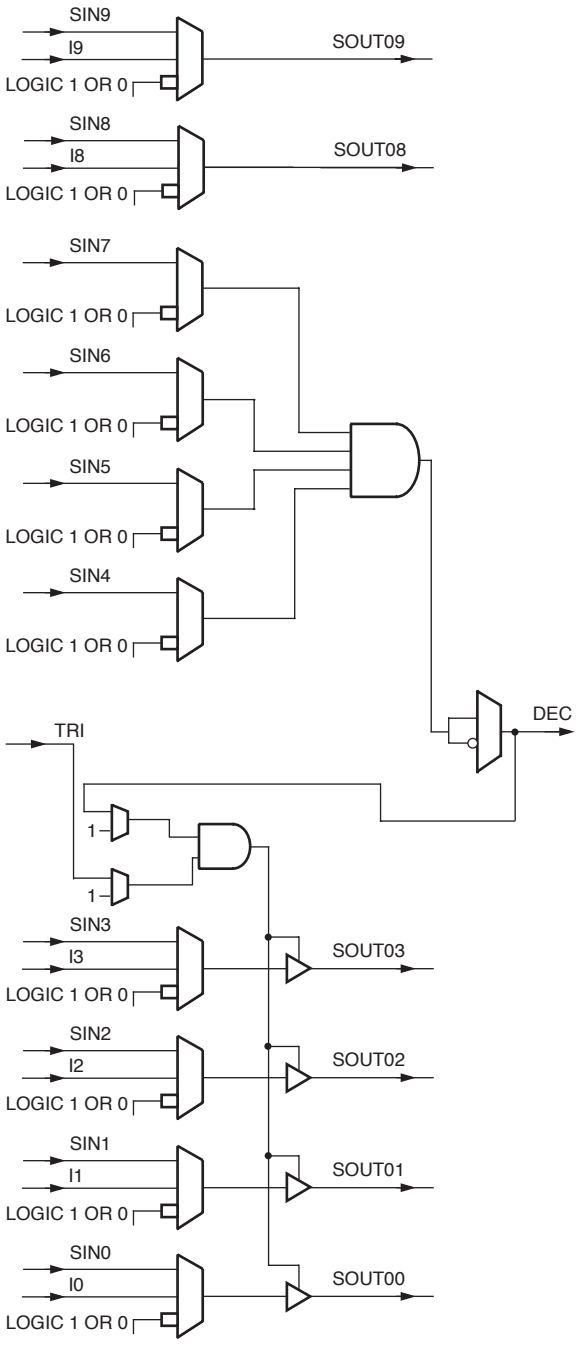

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Figure 17. Buffer-Decoder-Buffer Mode

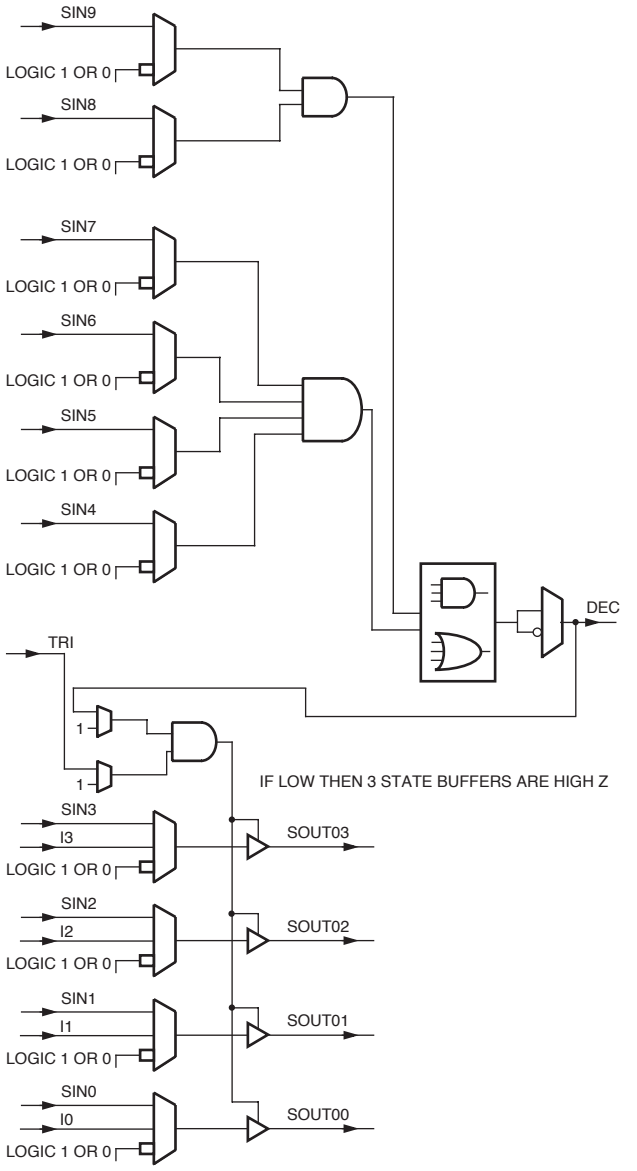

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Figure 18. Buffer-Decoder-Decoder Mode

Programmable Logic Cells (continued)

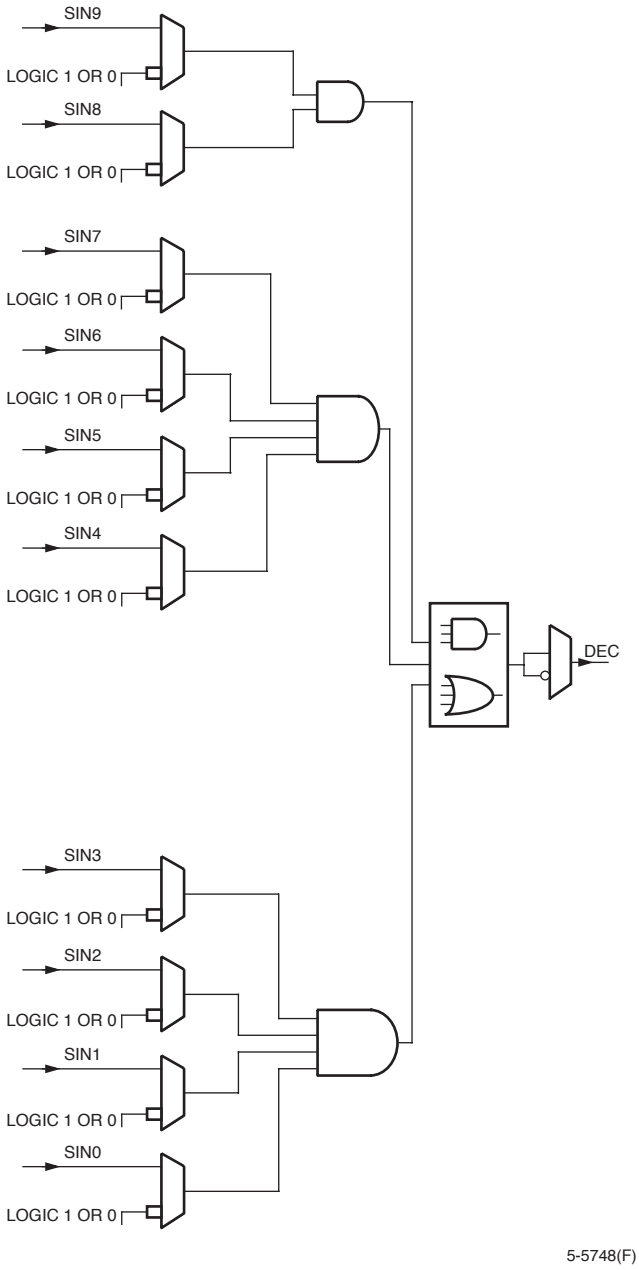


Figure 19. Decoder Mode

PLC Latches/Flip-Flops

The eight general-purpose latches/FFs in the PFU can be used in a variety of configurations. In some cases, the configuration options apply to all eight latches/FFs in the PFU and some apply to the latches/FFs on a nibble-wide basis where the ninth FF is considered independently. For other options, each latch/FF is independently programmable. In addition, the ninth FF can be used for a variety of functions.

Table 6 summarizes these latch/FF options. The latches/FFs can be configured as either positive- or negative-level sensitive latches, or positive or negative edge-triggered FFs (the ninth register can only be a FF). All latches/FFs in a given PFU share the same clock, and the clock to these latches/FFs can be inverted. The input into each latch/FF is from either the corresponding LUT output (F[7:0]) or the direct data input (DIN[7:0]). The latch/FF input can also be tied to logic 1 or to logic 0, which is the default.

Table 6. Configuration RAM Controlled Latch/ Flip-Flop Operation

Function	Options
Common to All Latches/FFs in PFU	
LSR Operation	Asynchronous or synchronous.
Clock Polarity	Noninverted or inverted.
Front-end Select*	Direct (DIN[7:0]) or from LUT (F[7:0]).
LSR Priority	Either LSR or CE has priority.
Latch/FF Mode	Latch or FF.
Enable GSRN	GSRN enabled or has no effect on PFU latches/FFs.
Set Individually in Each Latch/FF in PFU	
Set/Reset Mode	Set or reset.
By Group (Latch/FF[3:0], Latch/FF[7:4], and FF[8])	
Clock Enable	CE or none.
LSR Control	LSR or none.

* Not available for FF[8].

Each PFU has two independent programmable clocks, clock enable CE[1:0], local set/reset LSR[1:0], and front end data selects SEL[1:0]. When CE is disabled, each latch/FF retains its previous value when clocked. The clock enable, LSR, and SEL inputs can be inverted to be active-low.

Programmable Logic Cells (continued)

The set/reset operation of the latch/FF is controlled by two parameters: reset mode and set/reset value. When the GSRN and local set/reset (LSR) signals are not asserted, the latch/FF operates normally. The reset mode is used to select a synchronous or asynchronous LSR operation. If synchronous, LSR has the option to be enabled only if clock enable (CE) is active or for LSR to have priority over the clock enable input, thereby setting/resetting the FF independent of the state of the clock enable. The clock enable is supported on FFs, not latches. It is implemented by using a 2-input multiplexer on the FF input, with one input being the previous state of the FF and the other input being the new data applied to the FF. The select of this 2-input multiplexer is clock enable (CE), which selects either the new data or the previous state. When the clock enable is inactive, the FF output does not change when the clock edge arrives.

The GSRN signal is only asynchronous, and it sets/resets all latches/FFs in the FPGA based upon the set/reset configuration bit for each latch/FF. The set/reset value determines whether GSRN and LSR are set or reset inputs. The set/reset value is independent for each latch/FF. An option is available to disable the GSRN function per PFU after initial device configuration.

The latch/FF can be configured to have a data front-end select. Two data inputs are possible in the front-end select mode, with the SEL signal used to select which data input is used. The data input into each latch/FF is from the output of its associated LUT, F[7:0], or direct from DIN[7:0], bypassing the LUT. In the front-end data select mode, both signals are available to the latches/FFs.

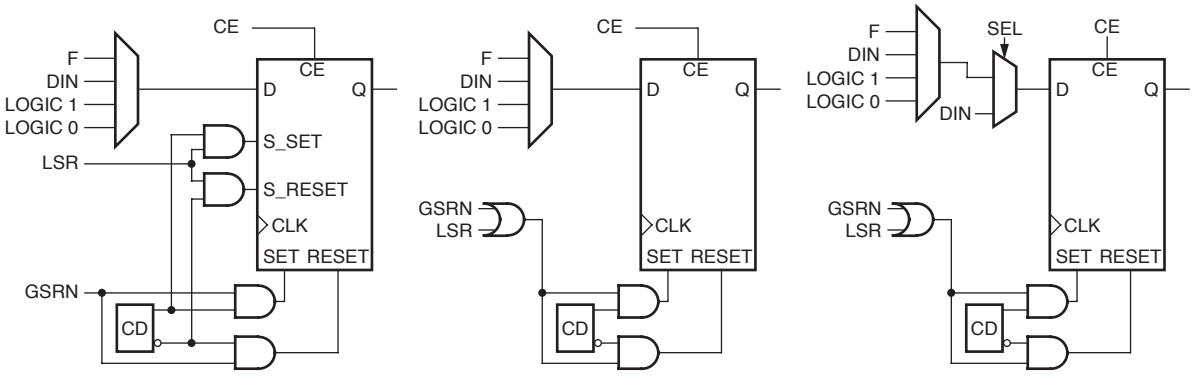
If either or both of these inputs is unused or is unavailable, the latch/FF data input can be tied to a logic 0 or logic 1 instead (the default is logic 0).

The latches/FFs can be configured in three basic modes:

- Local synchronous set/reset: the input into the PFU's LSR port is used to synchronously set or reset each latch/FF.
- Local asynchronous set/reset: the input into LSR asynchronously sets or resets each latch/FF.
- Latch/FF with front-end select, LSR either synchronous or asynchronous: the data select signal selects the input into the latches/FFs between the LUT output and direct data in.

For all three modes, each latch/FF can be independently programmed as either set or reset. Figure 20 provides the logic functionality of the front-end select, global set/reset, and local set/reset operations.

The ninth PFU FF, which is generally associated with registering the carry-out signal in ripple mode functions, can be used as a general-purpose FF. It is only an FF and is not capable of being configured as a latch. Because the ninth FF is not associated with an LUT, there is no front-end data select. The data input to the ninth FF is limited to the CIN input, logic 1, logic 0, or the carry-out in ripple and half-logic modes.



Key: C = configuration data.

Figure 20. Latch/FF Set/Reset Configurations

Embedded Block RAM (EBR)

The *ORCA* Series 4 devices compliment the distributed PFU RAM with large blocks of memory macrocells. The memory is available in 512 words by 18 bits/word blocks with 2 read and 2 write ports with two byte lane enables which operate with quad-port functionality. Additional logic has been incorporated for FIFO, multiplier, and CAM implementations. The RAM blocks are organized along the PLC rows and are added in proportion to the FPGA array sizes as shown in Table 7. The contents of the RAM blocks may be optionally initialized during FPGA configuration.

Table 7. *ORCA* Series 4— Available Embedded Block RAM

Device	Number of Blocks	Number of EBR Bits
OR4E02	8	74K
OR4E04	12	111K
OR4E06	16	147K

Each highly flexible 512x18 (quad-port, two read/two write) RAM block can be programmed by the user to meet their particular function. Each of the EBR configurations use the physical signals as shown in Table 8. Quad-port addressing permits simultaneous read and write operations on all four ports.

The EBR ports are written synchronously on the positive-edge of CKW. Synchronous read operations uses the positive-edge of CKR. Options are available to use synchronous read address registers and read output registers, or to bypass these registers and have the RAM read operate asynchronously. Detailed information about the EBR blocks is found in various application notes.

ispLEVER provides SCUBA as a RAM generation tool for EBR RAMs. Many of the EBR sub-modes are supported and the initialization values can also be defined.

EBR Features

Quad Port RAM Modes (Two Read/Two Write)

- One 512 x 18 RAM with optional built-in write arbitration.
- One 1024 x 18 RAM built on two blocks with built-in decode logic for simplified implementation.

Dual Port RAM Modes (One Read/One Write)

- One 256 x 36 RAM.
- One 1K x 9 RAM.
- Two independent 512 x 9 RAMs built in one EBR with separate read clocks, write clocks and enables.
- Two independent RAMS with arbitrary number of words whose sum is 512 words or less by 18 bits/word or less.

The joining of RAM blocks is supported to create wider deeper memories. The adjacent routing interface provided by the CIBs allow the cascading of blocks together with minimal penalties due to routing delays.

It is also possible to connect any or all of the EBR RAM blocks together through the embedded system bus, which is discussed in a later section of this data sheet.

Arbitration logic is optionally programmed by the user to signal occurrences of data collisions as well as to block both ports from writing at the same time. The arbitration logic prioritizes PORT1. When utilizing the arbiter, the signal BUSY indicates data is being written to PORT1. This BUSY output signals PORT1 activity by driving a high output. If the arbiter is turned off both ports could be written at the same time and the data would be corrupt. In this scenario the BUSY signal will indicate a possible error.

There is also a user option which dedicates PORT 1 to communications to the system bus. In this mode the user logic only has access to PORT0 and arbitration logic is enabled. The system bus utilizes the priority given to it by the arbiter therefore the system bus will always be able to write to the EBR.

Embedded Block RAM (EBR) (continued)

FIFO Modes

FIFOs can be configured to 256, 512, or 1K depths and 36, 18, or 9 widths respectively but also can be expanded using multiple blocks. FIFO works synchronously with the same read and write clock where the read port can be registered on the output or not registered. It can also be optionally configured asynchronously with different read and write clocks and the same read port register options.

Integrated flags allow the user the ability to fully utilize the EBR for FIFO, without the need to dedicate an address for providing distinct full/empty status. There are four programmable flags provided for each FIFO: Empty, partially empty, full, and partially full FIFO status. The partially empty and partially full flags are programmable with the flexibility to program the flags to any value from the full or empty threshold. The programmed values can be set to a fixed value through the bitstream or a dynamic value can be controlled by input pins of the EBR FIFO. When the FIFO is in asynchronous mode, the FIFO flags use grey code counters to ensure proper glitch-free operation.

Multiplier Modes

The *ORCA* Series 4 EBR supports two variations of multiplier functions. Constant coefficient MULTIPLY [KCM] mode will produce a 24-bit output of a fixed 8-bit constant multiply of a 16-bit number or a fixed 16-bit constant multiply of an 8-bit number. This KCM multiplies a constant times a 16- or 8-bit number and produces a product as a 24-bit result. The coefficient and multiplication tables are stored in memory. The input can be configured to be registered for pipelining. Both write ports are available during MULTIPLY mode so that the user logic can update and modify the coefficients for dynamic coefficient updates. The *SCUBA* program in ispLEVER should be used to create the KCM multipliers, including the input of initial coefficients.

An 8 x 8 MULTIPLY mode is configurable to either a pipelined or combinatorial multiplier function of two 8-bit numbers. Two 8-bit operands are multiplied to yield a 16-bit product. The input can be registered in pipeline mode.

CAM Mode

The CAM block is a binary content address memory that provides fast address searches by receiving data input and returning addresses that contain the data. Implemented in each EBR are two 16-word x 8-bit CAM function blocks.

The CAM has three modes, single match, multiple match and clear, which are all achieved in one clock cycle. In single match mode, a 8-bit data input is internally decoded and reports a match when data is present in a particular RAM address. Its result is reported by a corresponding single address bit. In multiple match the same occurs with the exception of multiple address lines report the match. Clear mode is used to clear the CAM contents by erasing all locations one cycle per location. The EBR blocks in CAM mode may be cascaded to produce larger CAMs.

Embedded Block RAM (EBR) (continued)

Table 8. RAM Signals

Port Signals	I/O	Function
PORT 0		
AR0[#:0]	I	Address to be read (variable width depending on RAM size).
AW0[#:0]	I	Address to be written (variable width depending on RAM size).
BW0<1:0>	I	Byte-write enable. Byte = 8-bits + parity bit. <1> = bits[17, 15:9] <0> = bits[16, 7:0]
CKR0	I	Positive-edge asynchronous read clock.
CKW0	I	Positive-edge synchronous write clock.
CSR0	I	Enables read to output. Active high.
CSW0	I	Enables write to output. Active high.
D [#:0]	I	Input data to be written to RAM (variable width depending on RAM size).
Q [#:0]	O	Output data of memory contents at referenced address (variable width depending on RAM size).
PORT 1		
AR1[#:0]	I	Address to be read (variable width depending on RAM size).
AW1[#:0]	I	Address to be written (variable width depending on RAM size).
BW1<1:0>	I	Byte-write enable. Byte = 8-bits + parity bit. <1> = bits[17, 15:9] <0> = bits[16, 7:0]
CKR1	I	Positive-edge asynchronous read clock.
CKW1	I	Positive-edge synchronous write clock.
CSR1	I	Enables read to output. Active high.
CSW1	I	Enables write to output. Active high.
D [#:0]	I	Input data to be written to RAM (variable width depending on RAM size).
Q [#:0]	O	Output data of memory contents at referenced address (variable width depending on RAM size).
Control		
BUSY	O	PORT1 writing. Active high.
RESET	I	Data output registers cleared. Memory contents unaffected. Active-low.

Embedded Block RAM (continued)

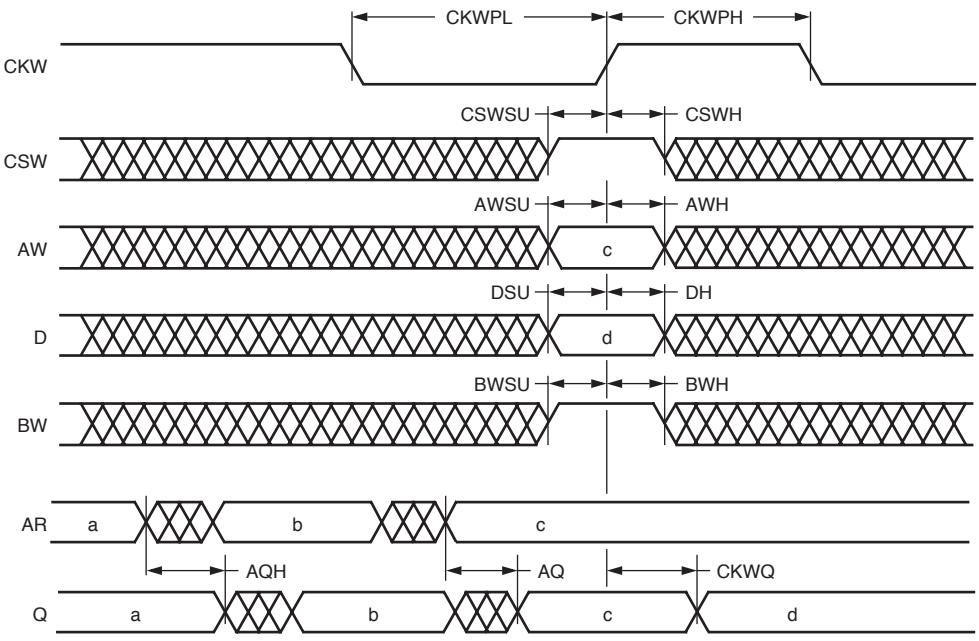


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Figure 21. EBR Read and Write Cycles with Write Through and Nonregistered Read Port

Table 9. FIFO Signals

Port Signals	I/O	Function
AR0[5:0]	I	Programs FIFO flags. Used for partially empty flag size.
AR1[9:0]	I	Programs FIFO flags. Used for partially full flag size.
FF	O	Full Flag.
PFF	O	Partially Full Flag.
PEF	O	Partially Empty Flag.
EF	O	Empty Flag.
D0[17:0]	I	Data inputs for all configurations.
D1[17:0]	I	Data inputs for 256x36 configurations only.
CKW[0:1]	I	Positive-edge write port clock. Port 1 only used for 256x36 configurations.
CKR[0:1]	I	Positive-edge read port clock. Port 1 only used for 256x36 configurations.
CSW[1:0]	I	Active-high write enable. Port 1 only used for 256x36 configurations.
CSR[1:0]	I	Active-high read enable. Port 1 only used for 256x36 configurations.
RESET	I	Active-low Resets FIFO pointers.
Q0[17:0]	O	Data outputs for all configurations.
Q1[17:0]	O	Data outputs for 256x36 configurations.

Embedded Block RAM (continued)

Table 10. Constant Multiplier Signals

Port Signals	I/O	Function
AR0[15:0]	I	Data input–operand.
AW(1:0)[8:0]	I	Address bits.
D(1:0)[17:0]	I	Data inputs to load memory or change coefficient.
CKW[0:1]	I	Positive-edge write port clock.
CKR[0:1]	I	Positive-edge read port clock. Used for synchronous multiply mode.
CSW[1:0]	I	Active-high write enable.
CSR[1:0]	I	Active-high read enable.
Q[23:0]	O	Data outputs–product result.

Table 11. 8x8 Multiplier Signals

Port Signals	I/O	Function
AR0[7:0]	I	Data input-Multiplicand.
AR1[7:0]	I	Data input-Multiplier.
CKR[0:1]	I	Positive-edge read port clock. Used for synchronous multiply mode.
CSR[1:0]	I	Active-high read enable.
Q[15:0]	O	Data outputs-product.

Table 12. CAM Signals

Port Signals	I/O	Function
AR(1:0)[7:0]	I	Data Match.
AW(1:0)[8:0]	I	Data Write.
D(1:0)[17]	I	Clear data active high.
D(1:0)[16]	I	Single match active high.
D(1:0)[3:0]	I	CAM address for data write.
CSW[1:0]	I	Active-high write enable. Enable for CAM data write.
CSR[1:0]	I	Active-high read enable. Enable for CAM data match.
Q(1:0)15:0]	O	Decoded Data outputs. “1” corresponds to a data match at that address location.

Routing Resources

The abundant routing resources of the Series 4 architecture are organized to route signals individually or as buses with related control signals. Both local and global signals utilize high-speed buffered and nonbuffered routes. One PLC segmented (x1), six PLC segmented (x6), and bused half chip (xHL) routes are patterned together to provide high connectivity with fast software routing times and high-speed system performance.

x1 routes cross width of one PLC and provide local connectivity to PFU and SLIC inputs and outputs. x6 lines cross width of 6 PLCs and are unidirectional and buffered with taps in the middle and on the end. Segments allow connectivity to PFU/SLIC outputs (driven at one end-point), other x6 lines (at end-points), and x1 lines for access to PFU/SLIC inputs. xH lines run vertically and horizontally the distance of half the device and are useful for driving medium/long distance 3-state routing.

The improved routing resources offer great flexibility in moving signals to and from the logic core. This flexibility translates into an improved capability to route designs at the required speeds even when the I/O signals have been locked to specific pins. The buffered routing capability also allows a very large fanout to be driven from each logic output, thus greatly reducing the amount of logic replication required by synthetic tools.

Generally, the ispLEVER Development System is used to automatically route interconnections. Interactive routing with the ispLEVER design editor (EPIC) is also available for design optimization.

The routing resources consist of switching circuitry and metal interconnect segments. Generally, the metal lines which carry the signals are designated as routing segments. The switching circuitry connects the routing segments, providing one or more of three basic functions: signal switching, amplification, and isolation. A net running from a PFU, EBR, or PIO output (source) to a PLC, EBR, or PIO input (destination) consists of one or more routing segments, connected by switching circuitry called configurable interconnect points (CIPs).

Clock Distribution Network

Clock distribution is made up of three types of clock networks: primary, secondary, and edge clocks. these are described below and more information is available in the *Series 4 Clocking Strategies* application note.

Global Primary Clock Nets

The Series 4 FPGAs provide eight fully distributed global primary clock net routing resources. The scheme dedicates four of the eight resources to provide fast primary nets and four are available for general primary nets. The fast primary nets are targeted toward low-skew and small injection times while the general primary nets are also targeted toward low-skew but have more source connection flexibility. Fast access to the global primary nets can be sourced from two pairs of pads located in the center of each side of the device, from the programmable PLLs and dedicated network PLLs located in the corners, or from general routing at the center of the device or at the middle of any side of the device. The I/O pads are semi-dedicated in pairs for use of differential I/O clocking or single-ended I/O clock sources. However if these pads are not needed to source the clock network they can be utilized for general I/O. The clock routing scheme is patterned using vertical and horizontal routes which provide connectivity to all PLC columns.

Secondary Clock and Control Nets

Secondary clock control and routing provides flexible clocking and control signalling for local regions. Since secondary nets usually have high fanouts and require low skew, the Series 4 devices utilize a spine and branch that uses x6 segments with high-speed connections provided from the spines to the branches. The branches then have high-speed connections to PLC, PIO, and EBR clock and control signals. This strategy provides a flexible connectivity and routes can be sourced from any I/O pin, all PLLs, or from PLC or EBR logic.

Secondary Edge Clock Nets and Fast Edge Clock Nets

Six secondary edge clock nets per side are distributed around the edges of the device and are available for every PIO. All PIOs and PLLs can drive the secondary edge clocks and are used in conjunction with the secondary spines discussed above to drive the same edge clock signal into the internal logic array. The edge secondary clocks provide fast injection to the PLC array and I/O registers. One of the six secondary edge clocks provided per side of the device is a special fast edge clock net that only clocks input registers for further reduced setup/hold times.This timing path can only be driven from one of the four PIO input pins in each PIC.

Routing Resources (continued)

Cycle Stealing

A new feature in Series 4 FPGAs is the ability to steal time from one register-to-register path and use that time in either the previous path before the first register or in a later path after the last register. This is done through selectable clock delays for every PLC register, EBR register, and PIO register. There are four programmable delay settings, including the default zero added delay value. This allows performance increases on typical critical paths from 15% to 40%. ispLEVER includes software to automatically take advantage of this capability to increase overall system speed. This is done after place and route is completed and uses timing driven algorithms based on the customer's preference file. A hold time check is also performed to verify no minimum hold time issues are introduced. More information on this clocking feature, including how it can be used to improve device setup times, hold times, clock-to-out delays and can reduce ground bounce caused by switching outputs can be found in the Cycle Stealing application note.

Programmable Input/Output Cells (PIC)

Programmable I/O

The Series 4 programmable I/O addresses the demand for the flexibility to select I/O that meets system interface requirements. I/Os can be programmed in the same manner as in previous *ORCA* devices with the addition of new features which allow the user the flexibility to select new I/O types that support high-speed interfaces.

Each PIC contains up to four programmable I/O (PIO) pads and are interfaced through a common interface block (CIB) to the FPGA array. The PIC is split into two pairs of I/O pads with each pair having independent clocks, clock enables, local set/reset, and global set/reset enable/disable.

On the input side, each PIO contains a programmable latch/FF which enables very fast latching of data from any pad. The combination provides for very low setup requirements and zero hold times for signals coming on-chip. It may also be used to demultiplex an input signal, such as a multiplexed address/data signal, and register the signals without explicitly building a demultiplexer with a PFU.

On the output side of each PIO, an output from the PLC array can be routed to each output FF, and logic can be associated with each I/O pad. The output logic associated with each pad allows for multiplexing of output signals and other functions of two output signals.

The output FF, in combination with output signal multiplexing, is particularly useful for registering address signals to be multiplexed with data, allowing a full clock cycle for the data to propagate to the output. The output buffer signal can be inverted, and the 3-state control can be made active-high, active-low, or always enabled. In addition, this 3-state signal can be registered or nonregistered.

The Series 4 I/O logic has been enhanced to include modes for high-speed uplink and downlink capabilities. These modes are supported through shift register logic which divides down incoming data or multiplies up outgoing data. This new logic block also supports high-speed DDR mode requirements where data is clocked into and out of the I/O buffers on both edges of the clock.

The new programmable I/O cell allows designers to select I/Os which meet many new communication standards permitting the device to hook up directly without any external interface translation. They support traditional FPGA standards as well as high-speed single-ended and differential pair signaling (as shown in Table 13). Based on a programmable, bank-oriented I/O ring architecture, designs can be implemented using 3.3 V, 2.5 V, 1.8 V, and 1.5 V I/O levels.

The I/O on the OR4Exx Series devices allows compliance with PCI local bus (Rev. 2.2) 3.3 V signaling environments. The signaling environment used for each input buffer can be selected on a per-pin basis. The selection provides the appropriate I/O clamping diodes for PCI compliance.

More information on the Series 4 programmable I/O structure is available in the various application notes.

Programmable Input/Output Cells (continued)

Table 13. Series 4 Programmable I/O Standards

Standard	V_{DDIO} (V)	V_{REF} (V)	Interface Usage
LVTTL	3.3	NA	General purpose.
LVCMOS2	2.5	NA	
LVCMOS18	1.8	NA	
PCI	3.3	NA	PCI.
LVDS	2.5	NA	Point to point and multi-drop backplanes, high noise immunity.
Bused-LVDS	2.5	NA	Network backplanes, high noise immunity, bus architecture backplanes.
LVPECL	3.3	NA	Network backplanes, differential 100 MHz+ clocking, optical transceiver, high-speed networking.
PECL	3.3	2.0	Backplanes.
GTL	3.3	0.8	Backplane or processor interface.
GTL+	3.3	1.0	
HSTL-class I	1.5	0.75	High-speed SRAM and networking interfaces.
HTSL-class III and IV	1.5	0.9	
STTL3-class I and II	3.3	1.5	Synchronous DRAM interface.
SSTL2-class I and II	2.5	1.25	

Note: interfaces to DDR and *ZBT* memories are supported through the interface standards shown above.

The PIOs are located along the perimeter of the device. The PIO name is represented by a two-letter designation to indicate the side of the device on which it is located followed by a number to indicate the row or column in which it is located. The first letter, P, designates that the cell is a PIO and not a PLC. The second letter indicates the side of the array where the PIO is located. The four sides are left (L), right (R), top (T), and bottom (B). A number follows to indicate the PIC row or column. The individual I/O pad is indicated by a single letter (either A, B, C, or D) placed at the end of the PIO name. As an example, PL10A indicates a pad located on the left side of the array in the tenth row.

Each PIC interfaces to four bond pads through four PIOs and contains the necessary routing resources to provide an interface between I/O pads and the CIBs. Each PIC contains input buffers, output buffers, routing resources, latches/FFs, and logic and can be configured as an input, output, or bidirectional I/O. Any PIO is capable of supporting the I/O standards listed in Table 13.

The CIBs that connect to the PICs have significant local routing resources, similar to routing in the PLCs. This new routing increases the ability to fix user pinouts prior to placement and routing of a design and still maintain routability. The flexibility provided by the routing also provides for increased signal speed due to a greater variety of optimal signal paths.

Included in the routing interface is a fast path from the input pins to the PFU logic. This feature allows for input signals to be very quickly processed by the SLIC decoder function and used on-chip or sent back off of the FPGA.

A diagram of a single PIO is shown in Figure 22, and Table 14 provides an overview of the programmable functions in an I/O cell.

Programmable Input/Output Cells (continued)

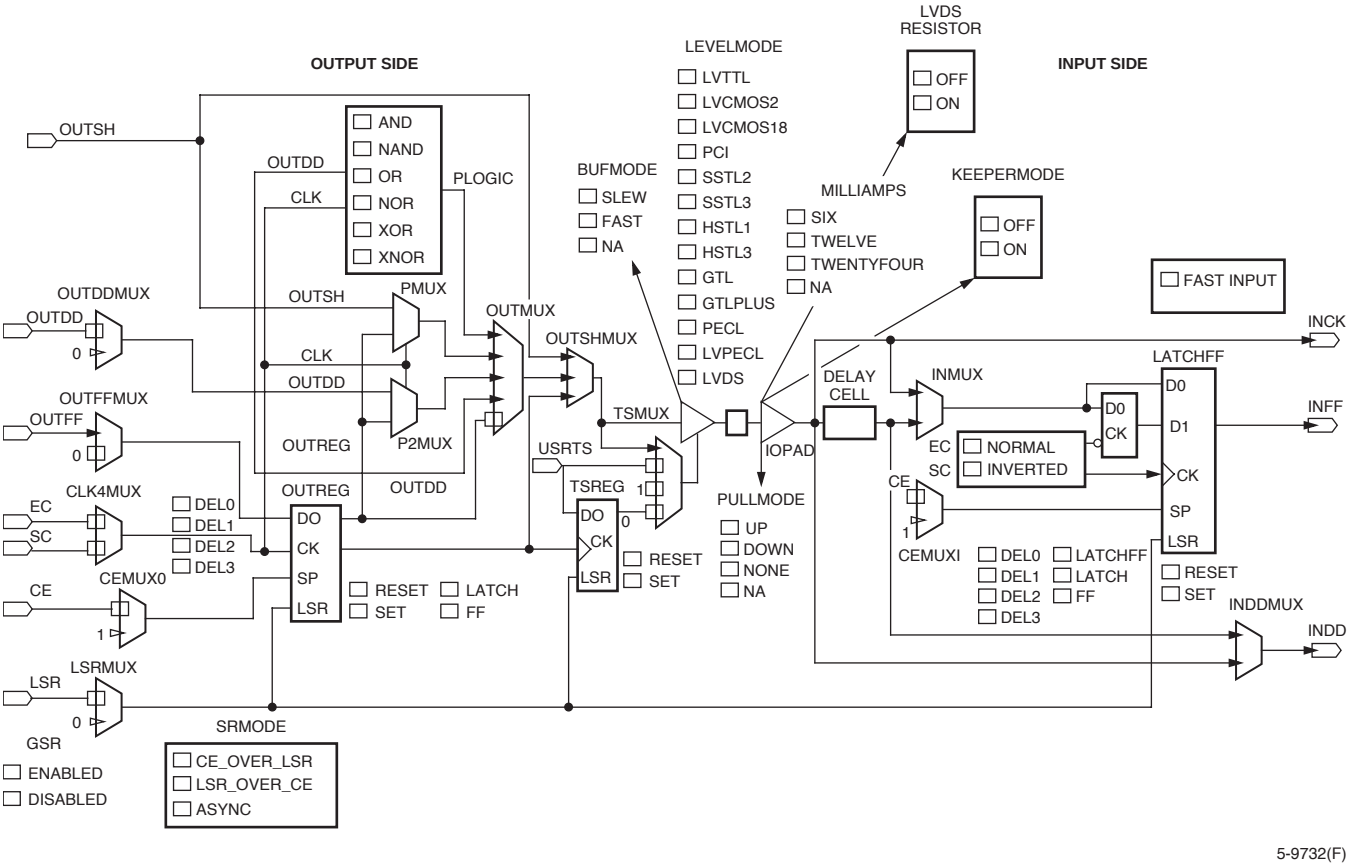

Figure 22. Series 4 PIO Image from ispLEVER Design Software

Programmable Input/Output Cells

(continued)

Inputs

There are many major options on the PIO inputs that can be selected in the ispLEVER tools listed in Table 14. Inputs may have a pull-up or pull-down resistor selected on an input for signal stabilization and power management. Input signals in a PIO are passed to CIB routing and/or a fast route into the clock routing system. A fast input from one PIO per PIC is also available to drive the edge clock network for fast I/O timing to other nearby PIOs.

There is also a programmable delay available on the input. When enabled, this delay affects the INFF and INDD signals of each PIO, but not the clock input. The delay allows any signal to have a guaranteed zero hold time when input.

Inputs should have transition times of less than 100 ns and should not be left floating. For full swing inputs, the timing characterization is done for rise/fall times of ≥ 1 V/ns. If any pin is not used, it is 3-stated with an internal pull-up resistor enabled automatically after configuration. Floating inputs increase power consumption, produce oscillations, and increase system noise. The inputs in LVTTL, LVCMOS2, and LVCMOS18 modes have a typical hysteresis of approximately 250 mV to reduce sensitivity to input noise. The PIC contains input circuitry which provides protection against latch-up and electrostatic discharge.

The other features of the PIO inputs relate to the latch/FF structure in the input path. In latch mode, the input signal is fed to a latch that is clocked by either the primary, secondary, or edge clock signal. The clock may be inverted or noninverted. There is also a local set/reset signal to the latch. The senses of these signals are also programmable as well as the capability to enable or disable the global set/reset signal and select the set/reset priority. The same control signals may also be used to control the input latch/FF when it is configured as a FF instead of a latch, with the addition of another control signal used as a clock enable. The PIOs are paired together and have independent CE, Set/reset, and GSRN control signals per PIO pair.

There are two options for zero-hold input capture in the PIO. If input delay mode is selected to delay the signal from the input pin, data can be either registered or latched with guaranteed zero-hold time in the PIO using a global primary system clock. The fast zero-hold mode of the PIO input takes advantage of a latch/FF combination to latch the data quickly for zero-hold using a fast edge clock before passing the data to the FF which is clocked by a global primary system clock.

The combination of input register capability with non-registered inputs provides for input signal demultiplexing without any additional resources. The PIO input signal is sent to both the input register and directly to the unregistered input (INDD). The signal is latched and output to routing at INFF. These signals may then be registered or otherwise processed in the PLCs.

Every PIO input can also perform input double data rate (DDR) functions with no PLC resources required. This type of scheme is necessary for DDR applications which require data to be clocked in from the I/O on both edges of the clock. In this scheme the input of INFF and INSH are captured on the positive and negative edges of the clock.

Table 14. PIO Options

Input	Option
Input Speed	Fast, Delayed, Normal
Float Value	Pull-up, Pull-down, None
Register Mode	Latch, FF, Fast Zero Hold FF, None (direct input)
Clock Sense	Inverted, Noninverted
Keeper Mode	on, off
LVDS Resistor	on, off
Output	**Option**
Output Speed	Fast, Slew
Output Drive Current	12 mA/6 mA, 6 mA/3 mA, or 24 mA/12 mA
Output Function	Normal, Fast Open Drain
Output Sense	Active-high, Active-low
3-State Sense	Active-high, Active-low
Clock Sense	Inverted, Noninverted
Logic Options	See Table 15
I/O Controls	**Option**
Clock Enable	Active-high, Active-low, Always Enabled
Set/Reset Level	Active-high, Active-low, No Local Reset
Set/Reset Type	Synchronous, Asynchronous
Set/Reset Priority	CE over LSR, LSR over CE
GSR Control	Enable GSR, Disable GSR

Programmable Input/Output Cells

(continued)

Outputs

The PIO's output drivers have programmable drive capability and slew rates. Two propagation delays (fast, slewlim) are available on output drivers. There are three combinations of programmable drive currents (24 mA sink/12 mA source, 12 mA sink/6 mA source, and 6 mA sink/3 mA source). At powerup, the output drivers are in slewlim mode with 12mA sink/6 mA source. If an output is not to be driven in the selected configuration mode, it is 3-stated with a pullup resistor.

The output buffer signal can be inverted, and the 3-state control signal can be made active-high, active-low, or always enabled. In addition, this 3-state signal can be registered or nonregistered. Additionally, there is a fast, open-drain output option that directly connects the output signal to the 3-state control, allowing the output buffer to either drive to a logic 0 or 3-state, but never to drive to a logic 1.

Every PIO output can perform output data multiplexing with no PLC resources required. This type of scheme is necessary for DDR applications which require data clocking out of the I/O on both edges of the clock. In this scheme the OUTFF and OUTSH are registered and sent out on both the positive and negative edges of the clock using an output multiplexor. This multiplexor is controlled by either the edge clock or system clock. This multiplexor can also be configured to select between one registered output from OUTFF and one nonregistered output from OUTDD.

The PIC logic block can also generate logic functions based on the signals on the OUTDD and CLK ports of the PIO. The functions are AND, NAND, OR, NOR, XOR, and XNOR. Table 15 is provided as a summary of the PIO logic options.

Table 15. PIO Logic Options

Option	Description
AND	Output logical AND of signals on OUTDD and clock.
NAND	Output logical NAND of signals on OUTDD and clock.
OR	Output logical OR of signals on OUTDD and clock.
NOR	Output logical NOR of signals on OUTDD and clock.
XOR	Output logical XOR of signals on OUTDD and clock.
XNOR	Output logical XNOR of signals on OUTDD and clock.

PIO Register Control Signals

The PIO latches/FFs have various clock, clock enable (CE), local set/reset (LSR), and GSRN controls. Table 16 provides a summary of these control signals and their effect on the PIO latches/FFs. Note that all control signals are optionally invertible.

Table 16. PIO Register Control Signals

Control Signal	Effect/Functionality
Edge Clock (ECLK)	Clocks input fast-capture latch; optionally clocks output FF, or 3-state FF, or PIO shift registers.
System Clock (SCLK)	Clocks input latch/FF; optionally clocks output FF, or 3-state FF, or PIO shift registers.
Clock Enable (CE)	Optionally enables/disables input FF (not available for input latch mode); optionally enables/disables output FF; separate CE inversion capability for input and output.
Local Set/ Reset (LSR)	Option to disable; affects input latch/FF, output FF, and 3-state FF if enabled.
Global Set/ Reset (GSRN)	Option to enable or disable per PIO after initial configuration.
Set/Reset Mode	The input latch/FF, output FF, and 3-state FF are individually set or reset by both the LSR and GSRN inputs.

Programmable Input/Output Cells

(continued)

I/O Banks and Groups

Flexible I/O features allow the user to select the type of I/O needed to meet different high-speed interface requirements and these I/Os require different input references or supply voltages. The perimeter of the device is divided into eight banks of PIO buffers, as shown in Figure 23, and for each bank there is a separate VDDIO that supplies the correct input and output voltage for a particular standard. The user must supply the appropriate power supply to the VDDIO pin. Within a bank, several I/O standards may be mixed as long as they use a common VDDIO. The shaded section of the I/O banks in Figure 23 (banks 2, 3, and 4) are removed for FPSCs, to allow the embedded block to be placed on the side of the FPGA array. Bank 1 and bank 5 are also extended to the corners in FPSCs to incorporate more FPGA I/Os.

Some interface standards require a specified threshold voltage known as VREF. To accommodate various VREF requirements, each bank is further divided into groups. In these modes, where a particular VREF is required, the device is automatically programmed to dedicate a VREF pin for each group of PIOs within a bank. The appropriate VREF voltage must be supplied by the user and connected to the VREF pin for each group. The VREF is dedicated exclusively to the group and cannot be intermixed within the group with other signaling requiring other VREF voltages. However, pins not requiring VREF can be mixed in the same group. When used to supply a reference voltage the VREF pad is no longer available to the user for general use. The VREF inputs should be well isolated to keep the reference voltage at a consistent level.

Table 17. Compatible Mixed I/O Standards

VDDIO Bank Voltage	Compatible Standards
3.3 V	LVTTL, SSTL3-I, SSTL3-II, GTL+, GTL, LVPECL, PECL
2.5 V	LVCMOS2, SSTL2-I, SSTL2-II, LVDS
1.8 V	LVCMOS18
1.5 V	HSTL I, HSTL III, HSTL IV

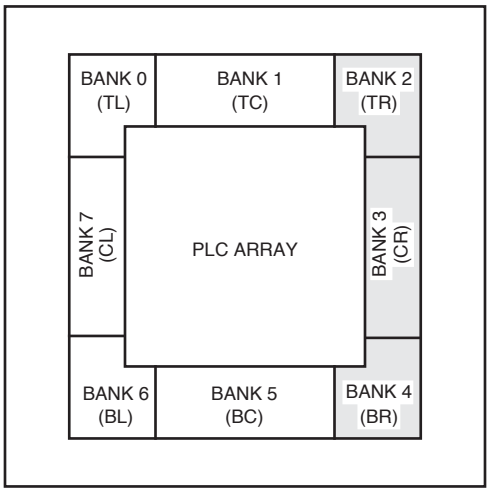

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Figure 23. *ORCA* High-Speed I/O Banks

Differential I/O (LVDS and LVPECL)

Series 4 devices support differential input, output, and input/output capabilities through pairs of PIOs. The two standards supported are LVDS and LVPECL.

The LVDS differential pair I/O standard allows for high-speed, low-voltage swing and low-power interfaces defined by industry standards: *ANSI/TIA/EIA-644* and *IEEE 1596.3 SSI-LVDS*. The general purpose standard is supplied without the need for an input reference supply and uses a low switching voltage which translates to low ac power dissipation.

The *ORCA* LVDS I/O provides an integrated 100 Ω termination resistor used to provide a differential voltage across the inputs of the receiver. The on-chip integration provides termination of the LVDS receiver without the need of discrete external board resistors. The user has the programmable option to enable termination per receiver pair for point-to-point applications or in multi-point interfaces limit the use of termination to bussed pairs. If the user chooses to terminate any differential receiver, a single LVDS_R pin is dedicated to connect a single 100 Ω (± 1%) resistor to VSS which then enables an internal resistor matching circuit to provide a balance 100 Ω (± 10%) termination across all process, voltage, and temperature. Experiments have also shown that enabling this 100 Ω matching resistor for LVDS outputs also improves performance.

Programmable Input/Output Cells

(continued)

High-Speed Memory Interfaces

PIO features allow high-speed interfaces to external SRAM and/or DRAM devices. Series 4 I/O meet 200 MHz *ZBT* requirements when switching between write and read cycles. *ZBT* allows 100% use of bus cycles during back-to-back read/write and write/read cycles. However this maximum utilization of the bus increases probability of bus contention when the interfaced devices attempt to drive the bus to opposite logic values. The LVTTL I/O interfaces directly with commercial *ZBT* SRAMs signalling and allows the versatility to program the FPGA drive strengths from 6 mA to 24 mA.

DDR allows data to be read on both the rising and the falling edge of the clock which delivers twice the bandwidth. DDR doubles the memory speed from SDRAMs or SRAMs without the need to increase clock frequency. The flexibility of the PIO allows at least 156 MHz/312 Mbits per second performance using the SSTL I/O or HSTL I/O features of the Series 4 devices.

High-Speed Networking Interfaces

Series 4 devices support many I/O standards used in networking. Two examples of this are the XGMII standard for 10 GbE (HSTL or SSTL I/Os) and the SPI-4 standard for various 10 Gbits/s network interfaces (LVDS I/Os). Both operate as a point-to-point link between devices that are forward clocked and transmit data on both clock edges (DDR). The XGMII interface is 36-bits wide per data flow direction and the SPI-4 interface is a 16-bit interface. The XGMII specification is 156 MHz/312 Mbits/s and the SPI-4 specification that can be met is 325 MHz/650 Mbits/s. More information about using *ORCA* for these applications can be found in the associated application note.

Bus Hold

Each PIO can be programmed with a KEEPERMODE feature. This element is user programmed for bus hold requirements. This mode retains the last known state of a bus when the bus goes into 3-state. It prevents floating busses and saves system power.

PIO Downlink/Uplink (Shift Registers)

Each group of four PIOs in a PIC have access to an input/output shift register as shown in Figure 24. This feature allows high-speed input data to be divided down by 1/2 or 1/4 and output data can be multiplied by 2x or 4x its internal speed. Both the input and output shift registers can be programmed to operate at the same time and are controlled by the same clock and control signals.

For input shift mode, the data from INDD from the PIO is connected to the input shift register. The input data is divided down and is driven to the routing through the INSH nodes. For output shift mode, the data from the OUTSH nodes are driven from the internal routing and connects to the output shift register. This output data is multiplied up and driven to the OUTDD signal on the PIOs.

In 2x output mode or input mode, two of the four I/Os in a PIC can use the shift registers. While in 4x mode, only one I/O can use the shift registers. This also means that all differential I/Os on a Series 4 device can use 2x shift register mode, but 4x mode is only available for half of the differential I/Os.

In 4x input mode, all the INSH nodes are used, while 2x mode uses INSH4 and INSH3 for one shift register and INSH2 and INSH1 for the second shift register. Similarly, the output shift register in 4x mode uses all the OUTSH signals. OUTSH2 and OUTSH1 are used for 2x output mode for one shift register and OUTSH4 and OUTSH3 are used for the other output shift register.

Programmable Input/Output Cells

(continued)

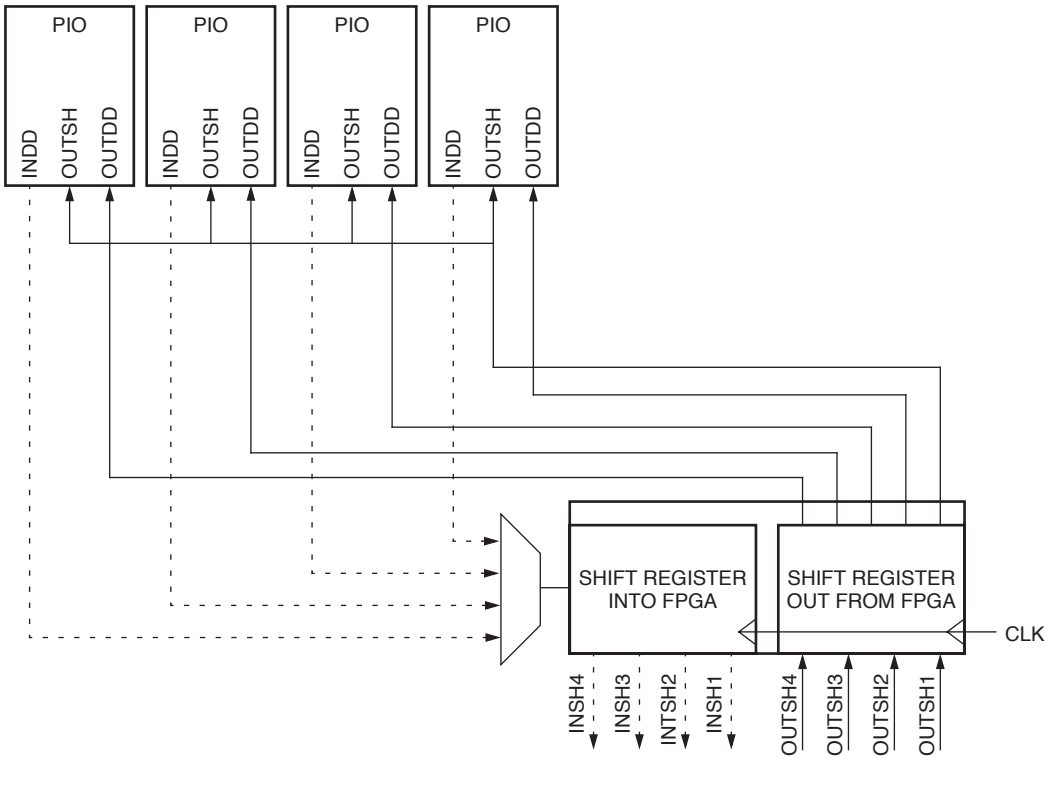


Figure 24. PIO Shift Register

Special Function Blocks

Special function blocks in the Series 4 provide extra capabilities beyond general FPGA operation. These blocks reside in the corners and MIDs (middle inter-quad areas) of the FPGA array.

Internal Oscillator

The internal oscillator resides in the upper left corner of the FPGA array. It has output clock frequencies of 1.25 MHz and 10 MHz. The internal oscillator is the source of the internal CCLK used for configuration. It may also be used after configuration as a general-purpose clock signal.

Global Set/Reset (GSRN)

The GSRN logic resides in the upper-left corner of the FPGA. GSRN is an invertible, default, active-low signal that is used to reset all of the user-accessible latches/FFs on the device. GSRN is automatically asserted at powerup and during configuration of the device.

The timing of the release of GSRN at the end of configuration can be programmed in the start-up logic described below. Following configuration, GSRN may be connected to the $\overline{\text{RESET}}$ pin via dedicated routing, or it may be connected to any signal via normal routing. GSRN can also be controlled via a system bus register command. Within each PFU and PIO, individual FFs and latches can be programmed to either be set or reset when GSRN is asserted. Series 4 allows individual PFUs and PIOs to turn off the GSRN signal to its latches/FFs after configuration.

The $\overline{\text{RESET}}$ input pad has a special relationship to GSRN. During configuration, the $\overline{\text{RESET}}$ input pad always initiates a configuration abort, as described in the FPGA States of Operation section. After configuration, the GSRN can either be disabled (the default), directly connected to the $\overline{\text{RESET}}$ input pad, or sourced by a lower-right corner signal. If the $\overline{\text{RESET}}$ input pad is not used as a global reset after configuration, this pad can be used as a normal input pad.

Special Function Blocks (continued)

Start-Up Logic

The start-up logic block can be configured to coordinate the relative timing of the release of GSRN, the activation of all user I/Os, and the assertion of the DONE signal at the end of configuration. If a start-up clock is used to time these events, the start-up clock can come from CCLK, or it can be routed into the start-up block using upper-left corner routing resources.

Temperature Sensing

The built –in temperature sensing diodes allow junction temperature to be measured during device operation. A physical pin (PTEMP) is dedicated for monitoring device junction temperature. PTEMP works by forcing a 10 µA current in the forward direction, and then measuring the resulting voltage. A 250 kΩ resistor tied to 3.3 V will approximate the needed 10 µA. The voltage decreases with increasing temperature at a rate of approximately –1.44 mV/°C. A typical device with an 85°C device temperature will measure about 640 mV.

Boundary-Scan

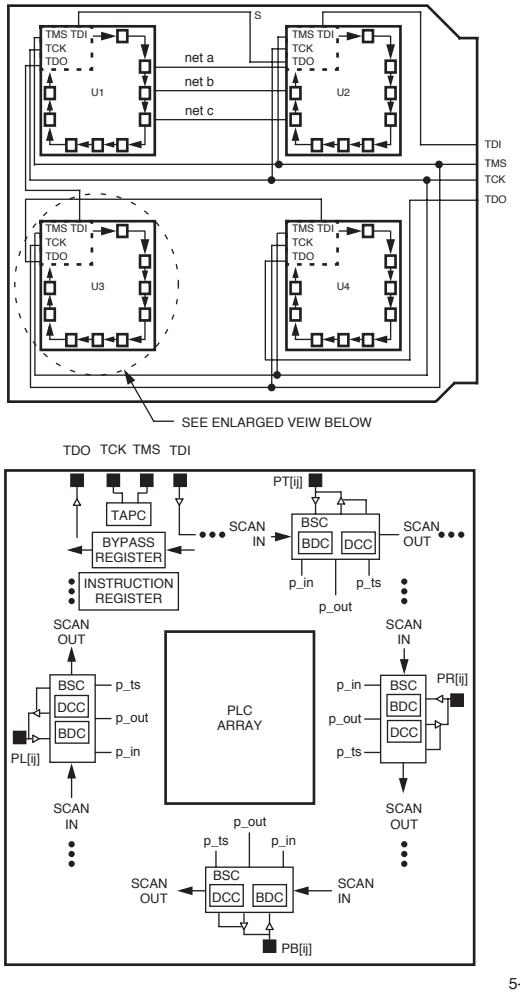
The *IEEE* standards 1149.1 and 1149.2 (*IEEE* Standard test access port and boundary-scan architecture) are implemented in the *ORCA* series of FPGAs. It allows users to efficiently test the interconnection between integrated circuits on a PCB as well as test the integrated circuit itself. The *IEEE* 1149 standard is a well-defined protocol that ensures interoperability among boundary-scan (BSCAN) equipped devices from different vendors.

Series 4 FPGAs are also compliant to *IEEE* standard 1532/D1. This standard for boundary-scan based in-system configuration of programmable devices provides a standardized programming access and methodology for FPGAs. A device, or set of devices, implementing this standard may be programmed, read back, erased verified, singly or concurrently, with a standard set of resources.

The *IEEE* 1149 standards define a test access port (TAP) that consists of a four-pin interface with an optional reset pin for boundary-scan testing of integrated circuits in a system. The *ORCA* Series FPGA provides four interface pins: test data in (TDI), test mode select (TMS), test clock (TCK), and test data out (TDO). The $\overline{\text{PRGM}}$ pin used to reconfigure the device also resets the boundary-scan logic.

The user test host serially loads test commands and test data into the FPGA through these pins to drive outputs and examine inputs. In the configuration shown in Figure 26, where boundary-scan is used to test ICs, test data is transmitted serially into TDI of the first BSCAN device (U1), through TDO/TDI connections between BSCAN devices (U2 and U3), and out TDO of the last BSCAN device (U4). In this configuration, the TMS and TCK signals are routed to all boundary-scan ICs in parallel so that all boundary-scan components operate in the same state. In other configurations, multiple scan paths are used instead of a single ring. When multiple scan paths are used, each ring is independently controlled by its own TMS and TCK signals.

Figure 26 provides a system interface for components used in the boundary-scan testing of PCBs. The three major components shown are the test host, boundary-scan support circuit, and the devices under test (DUTs). The DUTs shown here are *ORCA* Series FPGAs with dedicated boundary-scan circuitry. The test host is normally one of the following: automatic test equipment (ATE), a workstation, a PC, or a microprocessor.



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Key: BSC = boundary-scan cell, BDC = bidirectional data cell, and DCC = data control cell.

Figure 25. Printed-Circuit Board with Boundary-Scan Circuitry

Special Function Blocks (continued)

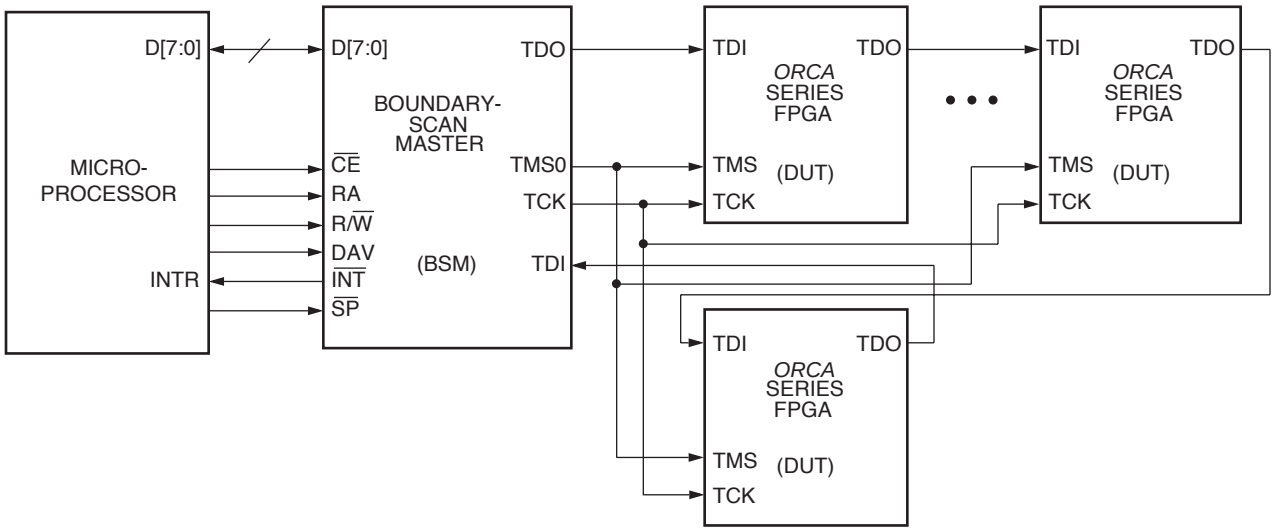

Figure 26. Boundary-Scan Interface

The boundary-scan support circuit shown in Figure 26 is the 497AA boundary-scan master (BSM). The BSM off-loads tasks from the test host to increase test throughput. To interface between the test host and the DUTs, the BSM has a general MPI and provides parallel-to-serial/serial-to-parallel conversion, as well as three 8K data buffers. The BSM also increases test throughput with a dedicated automatic test-pattern generator and with compression of the test response with a signature analysis register. The PC-based boundary-scan test card/software allows a user to quickly prototype a boundary-scan test setup.

Boundary-Scan Instructions

The Series 4 boundary-scan circuitry supports a total of 18 instructions. This includes ten *IEEE* 1149.1, 1149.2, and 1532/D1 instructions, one optional *IEEE* 1149.3 instruction, two *IEEE* 1532/D1 optional instructions, and five *ORCA*-defined instructions. There are also 16 other scan chain instructions that are used only during factory device testing and will not be discussed in this data sheet. A 6-bit wide instruction register supports all the instructions listed in Table 18.

The BYPASS instruction passes data intentionally from TDI to TDO after being clocked by TCK.

Table 18. Boundary-Scan Instructions

Code	Instruction
000000	EXTEST
000001	SAMPLE
000011	PRELOAD
000100	RUNBIST
000101	IDCODE
000110	USERCODE
001000	ISC_ENABLE
001001	ISC_PROGRAM
001010	ISC_NOOP
001011	ISC_DISABLE
001101	ISC_PROGRAM_USERCODE
001110	ISC_READ
010001	PLC_SCAN_RING1
010010	PLC_SCAN_RING2
010011	PLC_SCAN_RING3
010100	RAM_WRITE
010101	RAM_READ
111111	BYPASS

Special Function Blocks (continued)

The external test (EXTEST) instruction allows the interconnections between ICs in a system to be tested for opens and stuck-at faults. If an EXTEST instruction is performed for the system shown in Figure 25, the connections between U1 and U2 (shown by nets a, b, and c) can be tested by driving a value onto the given nets from one device and then determining whether this same value is seen at the other device. This is determined by shifting 3 bits of data for each pin (one for the output value, one for captured input value, and one for the 3-state value) through a boundary scan register (BSR) until each one aligns to the appropriate pin. Then, based upon the value of the 3-state data bit for each pin, either the I/O pad is driven to the value given in the output register of the BSR, or an input signal is applied at the pin. In either case, the BSR input register is updated with the input value from the I/O pad, which allows it to be shifted out TDO. Typically, the user will use the PRELOAD instruction to shift in the first test stimulus for the EXTEST instruction. Note that Series 4 boundary scan includes the ability to perform a self-monitor on each I/O pin by driving out a value from the output register and checking for this value at the input register of the same I/O pad.

The SAMPLE instruction is useful for system debugging and fault diagnosis by allowing the data at the FPGA's I/Os to be observed during normal operation. The data for all of the I/Os is captured simultaneously into the BSR, allowing them to be shifted-out TDO to the test host. Since each I/O buffer in the PIOs is bidirectional, two pieces of data are captured for each I/O pad: the value at the I/O pad and the value of the 3-state control signal.

The PRELOAD instruction is used to allow the scanning of the boundary-scan register without causing interference to the normal operation of the on-chip system logic. In turn it allows an initial data pattern to be placed at the latched parallel outputs of BSR prior to selection of another boundary scan test operation. For example, prior to selection of the EXTEST instruction, data can be loaded onto the latched parallel outputs using PRELOAD. As soon as the EXTEST instruction has been transferred to the parallel output of the instruction register, the preloaded data is driven through the system output pins. This ensures that known data, consistent at the board level, is driven immediately when the EXTEST instruction is entered. Without PRELOAD, indeterminate data would be driven until the first scan sequence had been completed.

There are six *ORCA*-defined instructions. The PLC scan rings 1, 2, and 3 (PSR1, PSR2, PSR3) allow user-defined internal scan paths using the PLC latches/FFs and routing interface. The RAM_Write Enable (RAM_W) instruction allows the user to serially configure the FPGA through TDI. The RAM_Read Enable (RAM_R) allows the user to read back RAM contents on TDO after configuration. The IDCODE instruction allows the user to capture a 32-bit identification code that is unique to each device and serially output it at TDO. The IDCODE format is shown in Table 19.

An optional *IEEE* 1149.3 instruction RUNBIST has been implemented. This instruction is used to invoke the built in self test (BIST) of regular structures like RAMs, ROMs, FIFOs, etc., and the surrounding random logic in the circuit.

The USERCODE instruction shifts out a 32-bit ID serially at TDO. At powerup, a default value of the IDCODE with the manufacturer field (11-bits) set to all zeros is loaded. The user can set this 11-bit value to a user-defined number during device configuration. It may also be changed by the ISC_PROGRAM_USERCODE instruction, described later.

Also implemented in Series 4 devices is the *IEEE* 1532/D1 standards for in-system configuration for programmable logic devices. Included are 4 mandatory and 2 optional instructions defined in the standards. ISC_ENABLE, ISC_PROGRAM, ISC_NOOP, and ISC_DISABLE are the four mandatory instructions. ISC_ENABLE initializes the devices for all subsequent ISC instructions. The ISC_PROGRAM instruction is similar to the RAM_WRITE instruction implemented in all *ORCA* devices where the user must monitor the PINITN pin for a high indicating the end of initialization and a successful configuration can be started. The ISC_PROGRAM instruction is used to program the configuration memory through a dedicated ISC_Pdata register. The ISC_NOOP instruction is user when programming multiple devices in parallel. During this mode TDI and TDO behave like BYPASS. The data shifted through TDI is shifted out through TDO. However the output pins remain in control of the BSR unlike BYPASS where they are driven by the system logic. The ISC_DISABLE is used upon completion of the ISC programming. No new ISC instructions will be operable without another ISC_ENABLE instruction.

Optional 1532/D1 instructions include ISC_PROGRAM_USERCODE. When this instruction is loaded, the user shifts all 32-bits of a user-defined ID (LSB first) through TDI. This overwrites any ID previously loaded into the ID register. This ID can then be read back through the USERCODE instruction defined in *IEEE* 1149.2.

Special Function Blocks (continued)

ISC_READ is similar to the *ORCA* RAM_Read instruction which allows the user to readback the configuration RAM contents serially out on TDO. Both must monitor the PDONE signal to determine weather or not configuration is completed. ISC_READ used a 1-bit register to synchronously readback data coming from the configuration memory. The readback data is clocked into the ISC_READ data register and then clocked out TDO on the falling edge or TCK.

Table 19. Series 4E Boundary-Scan Vendor-ID Codes

Device	Version (4 bit)	Part* (10 bit)	Family (6 bit)	Manufacturer (11 bit)	LSB (1 bit)
OR4E02	0000	0011100000	001000	00000011101	1
OR4E04	0000	0001010000	001000	00000011101	1
OR4E06	0000	0000110000	001000	00000011101	1

* PLC array size of FPGA, reverse bit order.

Note: Table assumes version 0.

ORCA Boundary-Scan Circuitry

The *ORCA* Series boundary-scan circuitry includes a test access port controller (TAPC), instruction register (IR), boundary-scan register (BSR), and bypass register. It also includes circuitry to support the four predefined instructions.

Figure 27 shows a functional diagram of the boundary-scan circuitry that is implemented in the *ORCA* Series. The input pins' (TMS, TCK, and TDI) locations vary depending on the part, and the output pin is the dedicated TDO/RD_DATA output pad. Test data in (TDI) is the serial input data. Test mode select (TMS) controls the boundary-scan test access port controller (TAPC). Test clock (TCK) is the test clock on the board.

The BSR is a series connection of boundary-scan cells (BSCs) around the periphery of the IC. Each I/O pad on the FPGA, except for CCLK, DONE, and the boundary-scan pins (TCK, TDI, TMS, and TDO), is included in the BSR. The first BSC in the BSR (connected to TDI) is located in the first PIO I/O pad on the left of the top side of the FPGA (PTA PIO). The BSR proceeds clockwise around the top, right, bottom, and left sides of the array. The last BSC in the BSR (connected to TDO) is located on the top of the left side of the array (PL1D).

The bypass instruction uses a single FF, which resynchronizes test data that is not part of the current scan operation. In a bypass instruction, test data received on TDI is shifted out of the bypass register to TDO. Since the BSR (which requires a two FF delay for each pad) is bypassed, test throughput is increased when devices that are not part of a test operation are bypassed.

The boundary-scan logic is enabled before and during configuration. After configuration, a configuration option determines whether or not boundary-scan logic is used.

The 32-bit boundary-scan identification register contains the manufacturer's ID number, unique part number, and version (as described earlier). The identification register is the default source for data on TDO after RESET if the TAP controller selects the shift-data-register (SHIFT-DR) instruction. If boundary scan is not used, TMS, TDI, and TCK become user I/Os, and TDO is 3-stated or used in the readback operation.

Special Function Blocks (continued)

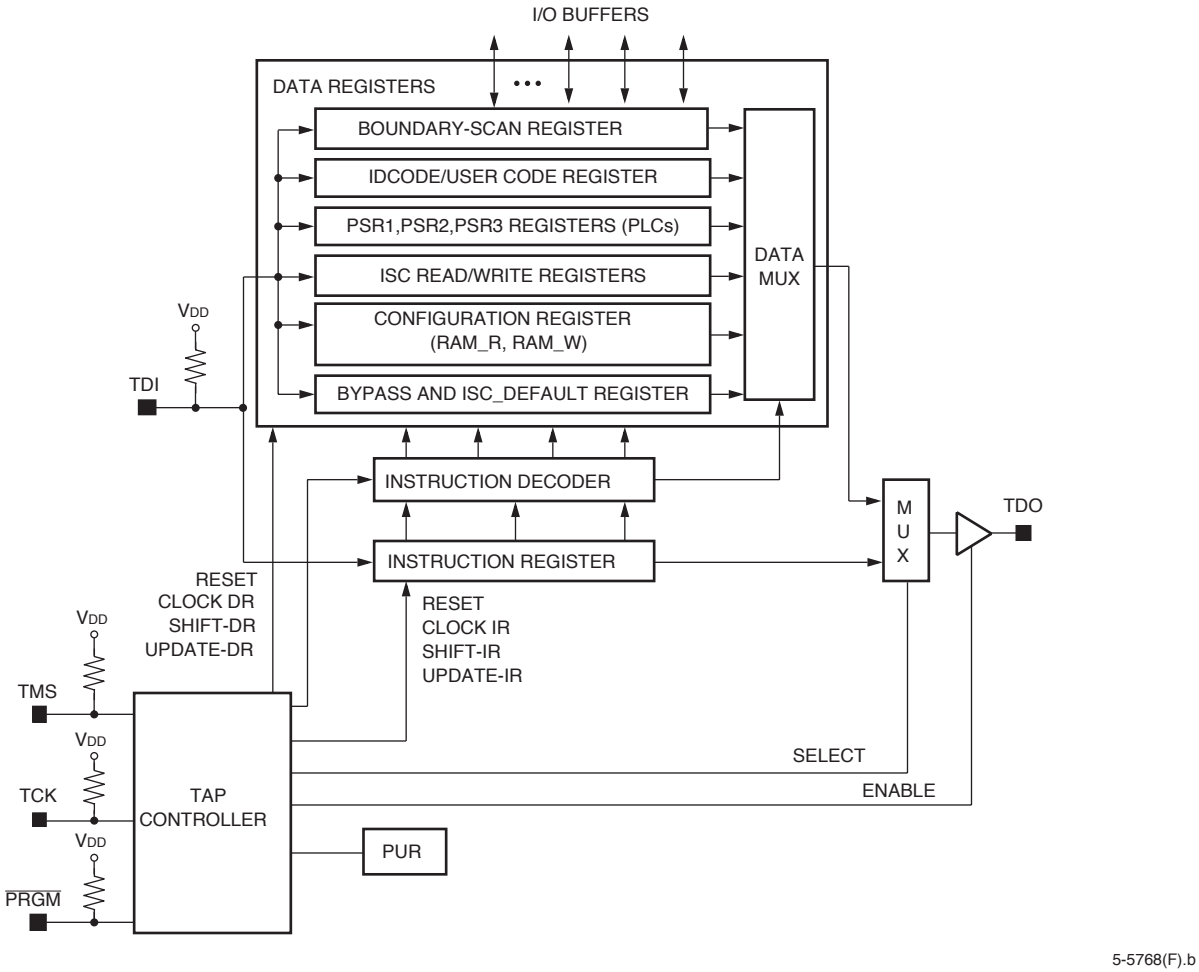

Figure 27. *ORCA* Series Boundary-Scan Circuitry Functional Diagram

ORCA Series TAP Controller (TAPC)

The *ORCA* Series TAP controller (TAPC) is a 1149 compatible test access port controller. The 16 JTAG state assignments from the *IEEE* 1149 specification are used. The TAPC is controlled by TCK and TMS. The TAPC states are used for loading the IR to allow three basic functions in testing: providing test stimuli (Update-DR), test execution (Run-Test/Idle), and obtaining test responses (Capture-DR). The TAPC allows the test host to shift in and out both instructions and test data/results. The inputs and outputs of the TAPC are provided in the table below. The outputs are primarily the control signals to the instruction register and the data register.

Table 20. TAP Controller Input/Outputs

Symbol	I/O	Function
TMS	I	Test Mode Select
TCK	I	Test Clock
PUR	I	Powerup Reset
$\overline{\text{PRGM}}$	I	BSCAN Reset
TRESET	O	Test Logic Reset
Select	O	Select IR (High); Select-DR (Low)
Enable	O	Test Data Out Enable
Capture-DR	O	Capture/Parallel Load-DR
Capture-IR	O	Capture/Parallel Load-IR
Shift-DR	O	Shift Data Register
Shift-IR	O	Shift Instruction Register
Update-DR	O	Update/Parallel Load-DR
Update-IR	O	Update/Parallel Load-IR

Special Function Blocks (continued)

The TAPC generates control signals that allow capture, shift, and update operations on the instruction and data registers. In the capture operation, data is loaded into the register. In the shift operation, the captured data is shifted out while new data is shifted in. In the update operation, either the instruction register is loaded for instruction decode, or the boundary-scan register is updated for control of outputs.

The test host generates a test by providing input into the *ORCA* Series TMS input synchronous with TCK. This sequences the TAPC through states in order to perform the desired function on the instruction register or a data register. Figure 28 provides a diagram of the state transitions for the TAPC. The next state is determined by the TMS input value.

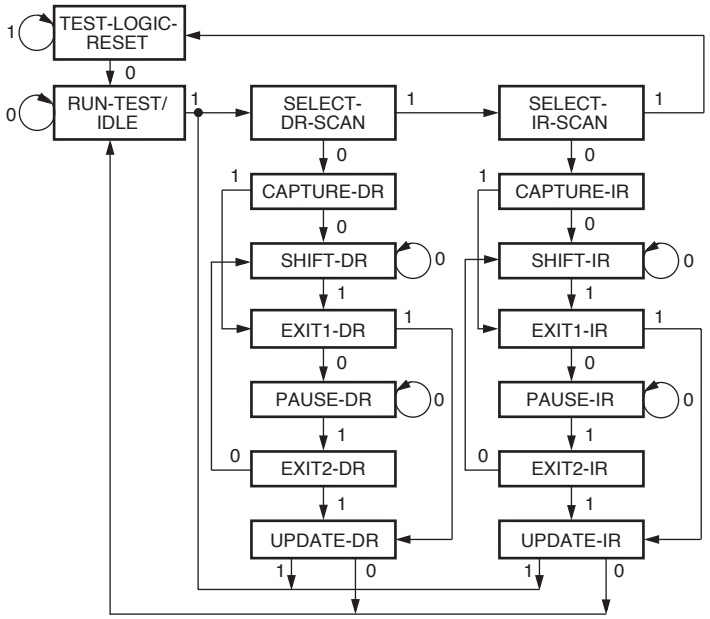

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Figure 28. TAP Controller State Transition Diagram

Boundary-Scan Cells

Figure 29 is a diagram of the boundary-scan cell (BSC) in the *ORCA* series PIOs. There are four BSCs in each PIC: one for each pad, except as noted above. The BSCs are connected serially to form the BSR. The BSC controls the functionality of the in, out, and 3-state signals for each I/O pad.

The BSC allows the I/O to function in either the normal or test mode. Normal mode is defined as when an output buffer receives input from the PLC array and provides output at the pad or when an input buffer provides input from the pad to the PLC array. In the test mode, the BSC executes a boundary-scan operation, such as shifting in scan data from an upstream BSC in the BSR, providing test stimuli to the pad, capturing test data at the pad, etc.

The primary functions of the BSC are shifting scan data serially in the BSR and observing input (p_in), output (p_out), and 3-state (p_ts) signals at the pads. The BSC consists of three circuits: the bidirectional data cell is used to access the input and output data, the capture cell is used to capture the status of the I/O pad, and the direction control cell is used to access the 3-state value. All three cells consist of a FF used to shift scan data which feeds a FF to control the I/O buffer. The capture cell is connected serially to the bidirectional data cell, which is connected serially to the direction control cell to form a boundary-scan shift register.

The TAPC signals (capture, update, shiftn, treset, and TCK) and the MODE signal control the operation of the BSC. The bidirectional data cell is also controlled by the high out/low in (HOLI) signal generated by the direction control cell. When HOLI is low, the bidirectional data cell receives input buffer data into the BSC. When HOLI is high, the BSC is loaded with functional data from the PLC.

Special Function Blocks (continued)

The MODE signal is generated from the decode of the instruction register. When the MODE signal is high (EXTEST), the scan data is propagated to the output buffer. When the MODE signal is low (BYPASS or SAMPLE), functional data from the FPGA's internal logic is propagated to the output buffer.

The boundary-scan description language (BSDL) is provided for each device in the *ORCA* Series of FPGAs on the ispLEVER CD. The BSDL is generated from a device profile, pinout, and other boundary-scan information.

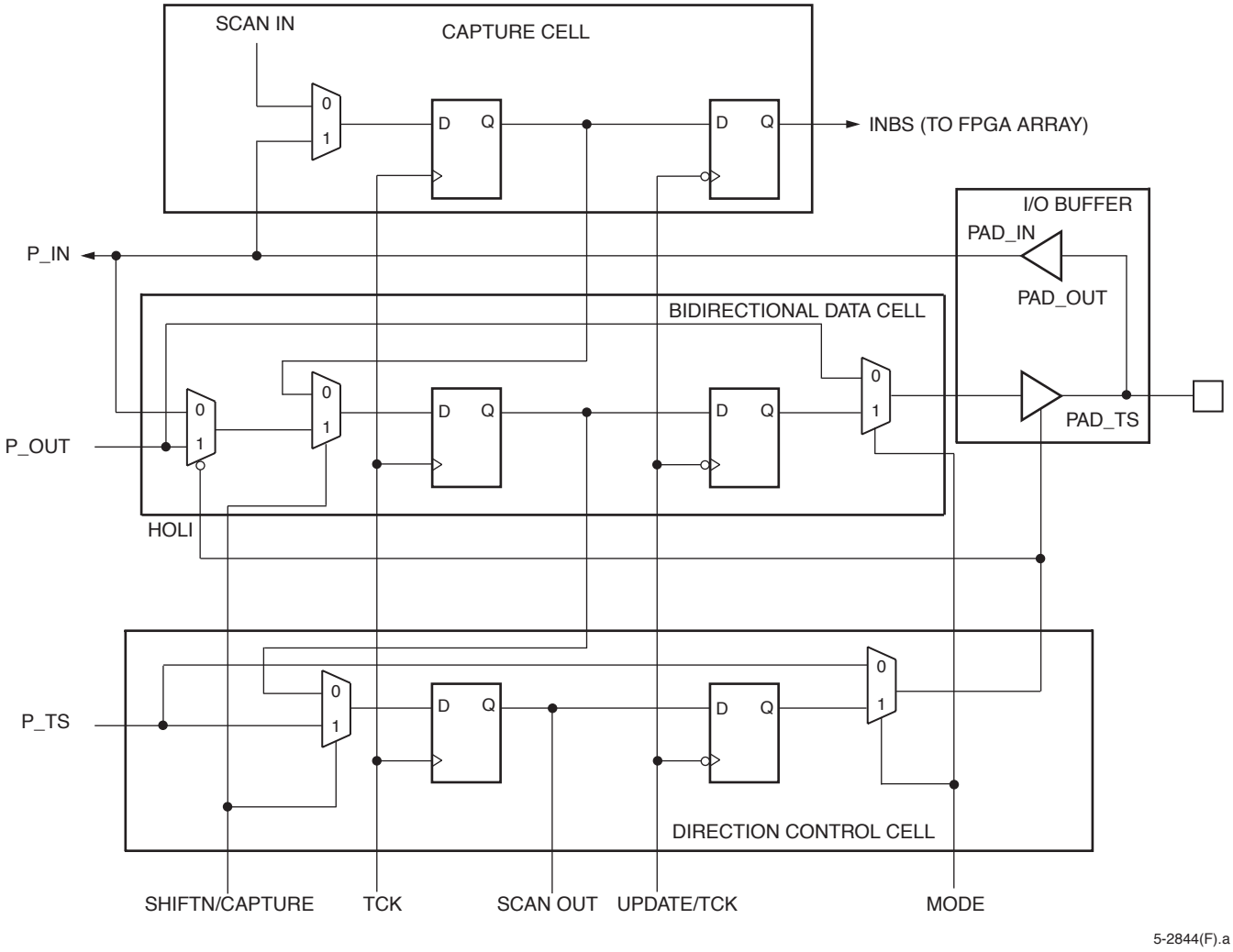

Figure 29. Boundary-Scan Cell

Boundary-Scan Timing

To ensure race-free operation, data changes on specific clock edges. The TMS and TDI inputs are clocked in on the rising edge of TCK, while changes on TDO occur on the falling edge of TCK. In the execution of an EXTEST instruction, parallel data is output from the BSR to the FPGA pads on the falling edge of TCK. The maximum frequency allowed for TCK is 20 MHz.

Figure 30 shows timing waveforms for an instruction scan operation. The diagram shows the use of TMS to sequence the TAPC through states. The test host (or BSM) changes data on the falling edge of TCK, and it is clocked into the DUT on the rising edge.

Special Function Blocks (continued)

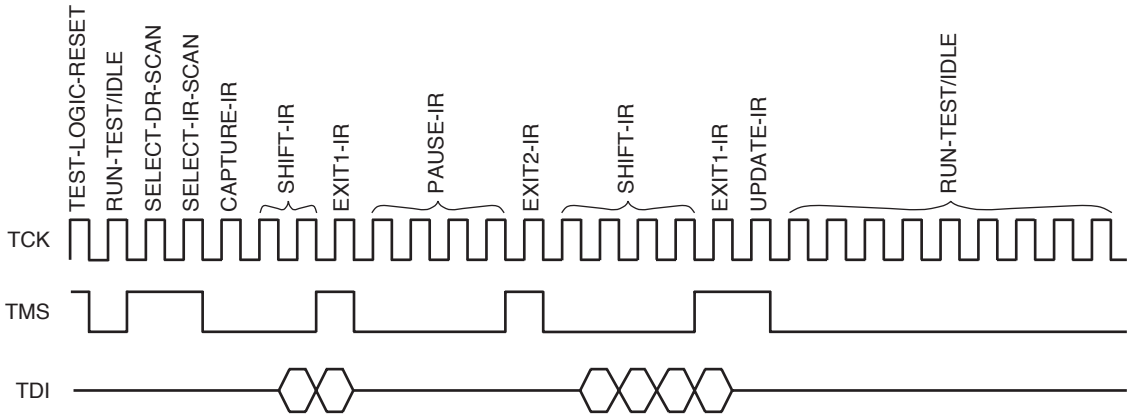

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Figure 30. Instruction Register Scan Timing Diagram

Single Function Blocks

Most of the special function blocks perform a specific dedicated function. These functions are data/configuration readback control, global 3-state control (TS_ALL), internal oscillator generation, GSRN, and start-up logic.

Readback Logic

The readback logic can be enabled via a bit stream option or by instantiation of a library readback component.

Readback is used to read back the configuration data and, optionally, the state of the PFU outputs. A readback operation can be done while the FPGA is in normal system operation. The readback operation cannot be daisy-chained. To use readback, the user selects options in the bit stream generator in the ispLEVER development system.

Table 21 provides readback options selected in the bit stream generator tool. The table provides the number of times that the configuration data can be read back. This is intended primarily to give the user control over the security of the FPGA's configuration program. The user can prohibit readback (0), allow a single readback (1), or allow unrestricted readback (U).

Table 21. Readback Options

Option	Function
0	Prohibit Readback
1	Allow One Readback Only
U	Allow Unrestricted Number of Readbacks

Readback can be performed via the Series 4 MPI or by using dedicated FPGA readback controls. If the MPI is enabled, readback via the dedicated FPGA readback logic is disabled. Readback using the MPI is discussed in the MPI section.

The pins used for dedicated readback are readback data (RD_DATA), read configuration ($\overline{\text{RD\_CFG}}$), and configuration clock (CCLK). A readback operation is initiated by a high-to-low transition on $\overline{\text{RD\_CFG}}$. The $\overline{\text{RD\_CFG}}$ input must remain low during the readback operation. The readback operation can be restarted at frame 0 by driving the $\overline{\text{RD\_CFG}}$ pin high, applying at least two rising edges of CCLK, and then driving $\overline{\text{RD\_CFG}}$ low again. One bit of data is shifted out on RD_DATA at the rising edge of CCLK. The first start bit of the readback frame is transmitted out several cycles after the first rising edge of CCLK after $\overline{\text{RD\_CFG}}$ is input low (see the readback timing characteristics table in the timing characteristics section). To be certain of the start of the readback frame, the data can be monitored for the 01 frame start bit pair.

Special Function Blocks (continued)

Readback can be initiated at an address other than frame 0 via the new MPI control registers (see the MPI section for more information). In all cases, readback is performed at sequential addresses from the start address.

It should be noted that the RD_DATA output pin is also used as the dedicated boundary-scan output pin, TDO. If this pin is being used as TDO, the RD_DATA output from readback can be routed internally to any other pin desired. The $\overline{\text{RD\_CFG}}$ input pin is also used to control the global 3-state (TS_ALL) function. Before and during configuration, the TS_ALL signal is always driven by the $\overline{\text{RD\_CFG}}$ input and readback is disabled. After configuration, the selection as to whether this input drives the readback or global 3-state function is determined by a set of bit stream options. If used as the $\overline{\text{RD\_CFG}}$ input for readback, the internal TS_ALL input can be routed internally to be driven by any input pin.

The readback frame contains the configuration data and the state of the internal logic. During readback, the value of all registered PFU and PIO outputs can be captured. The following options are allowed when doing a capture of the PFU outputs.

- Do not capture data (the data written to the RAMs, usually 0, will be read back).
- Capture data upon entering readback.
- Capture data based upon a configurable signal internal to the FPGA. If this signal is tied to logic 0, capture RAMs are written continuously.
- Capture data on either options two or three above.

The readback frame has an identical format to that of the configuration data frame, which is discussed later in the Configuration Data Format section. If LUT memory is not used as RAM and there is no data capture, the readback data (not just the format) will be identical to the configuration data for the same frame. This eases a bitwise comparison between the configuration and readback data. The configuration header, including the length count field, is not part of the readback frame. The readback frame contains bits in locations not used in the configuration. These locations need to be masked out when comparing the configuration and readback frames. The development system optionally provides a readback bit stream to compare to readback data from the FPGA. Also note that if any of the LUTs are used as RAM and new data is written to them, these bits will not have the same values as the original configuration data frame either.

Global 3-State Control (TS_ALL)

To increase the testability of the *ORCA* Series FPGAs, the global 3-state function (TS_ALL) disables the device. The TS_ALL signal is driven from either an external pin or an internal signal. Before and during configuration, the TS_ALL signal is driven by the input pad $\overline{\text{RD\_CFG}}$. After configuration, the TS_ALL signal can be disabled, driven from the $\overline{\text{RD\_CFG}}$ input pad, or driven by a general routing signal in the upper right corner. Before configuration, TS_ALL is active-low; after configuration, the sense of TS_ALL can be inverted.

The following occur when TS_ALL is activated:

- All of the user I/O output buffers are 3-stated, the user I/O input buffers are pulled up (with the pull-down disabled), and the input buffers are configured with TTL input thresholds.
- The TDO/RD_DATA output buffer is 3-stated.
- The $\overline{\text{RD\_CFG}}$, $\overline{\text{RESET}}$, and $\overline{\text{PRGM}}$ input buffers remain active with a pull-up.
- The DONE output buffer is 3-stated, and the input buffer is pulled up.

Microprocessor Interface (MPI)

The Series 4 FPGAs have a dedicated synchronous MPI function block. The MPI is programmable to operate with *PowerPC*/PowerQUICC MPC860/MPC8260 series microprocessors. The MPI implements an 8-, 16-, or 32-bit interface with 1-bit, 2-bit, or 4-bit parity to the host processor (*PowerPC*) that can be used for configuration and readback of the FPGA as well as for user-defined data processing and general monitoring of FPGA functions. In addition to dedicated-function registers, the MPI bridges to the *AMBA* embedded system bus through which the *PowerPC* bus master can access the FPGA configuration logic, EBR and other user logic. There is also capability to interrupt the host processor either by a hard interrupt or by having the host processor poll the MPI and the embedded system bus.

The control portion of the MPI is available following powerup of the FPGA if the mode pins specify MPI mode, even if the FPGA is not yet configured. The width of the data port is selectable among 8-, 16-, or 32-bit and the parity bus can be 1-, 2-, or 4-bit. In configuration mode the data and parity bus width are related to the state of the M[0:3] mode pins. For post-configuration use, the MPI must be included in the configuration bit stream by using an MPI library element in your design from the *ORCA* macro library, or by setting the bit of the MPI configuration control register prior to the start of configuration. The user can also enable and disable the parity bus through the configuration bit stream. These pads can be used as general I/O when they are not needed for MPI use.

Table 22 shows the interface signals that are used to interface Series 4 devices to a *PowerPC* MPC860/MPC8260 device. More information is available in the Series 4 MPI and System Bus application note.

The *ORCA* FPGA is a memory-mapped peripheral to the *PowerPC* processor. The MPI interfaces to the user-programmable FPGA logic using the *AMBA* embedded system bus.The MPI has access to a series of addressable registers made accessible by the *AMBA* system bus that provide MPI control and status, configuration and readback data transfer, FPGA device identification, and a dedicated user scratchpad register. All registers are 8 bits wide. The address map for these registers and the user-logic address space utilize the same registers as the *AMBA* embedded system bus.

Embedded System Bus (ESB)

Implemented using the open standard, on-chip *AMBA*-AHB 2.0 specification bus, the Series 4 devices connects all the FPGA elements together with a standardized bus framework. The ESB facilitates communication among MPI, configuration, EBRs, and user logic in all the generic FPGA devices. AHB serves the need for high-performance system-on-chip (SoC) as well as aligning with current synthesis design flows. Multiple bus masters optimizes system performance by sharing resources between different bus masters such as the MPI and configuration logic. The wide data bus configuration of 32-bits with 4-bit parity supports the high-bandwidth of data-intensive applications of using the wide on-chip memory. *AMBA* enhances a reusable design methodology by defining a common backbone for IP modules.

The ESB is a synchronous bus that is driven by either the MPI clock, internal oscillator, CCLK (slave configuration modes), TCK (JTAG configuration modes), or by a user clock from routing. In FPSCs, a clock from the embedded block can also drive the MPI clock. During initial configuration and reconfiguration the bus clock is defaulted to the configuration clock. The post configuration clock source is set during configuration. The user has the ability to program several slaves through the user logic interface. Embedded block RAM also interfaces seamlessly to the system bus.

A single bus arbiter controls the traffic on the bus by ensuring only one master has access to the bus at any time. The arbiter monitors a number of different requests to use the bus and decides which request is currently the highest priority. The configuration modes have the highest priority and overrides all normal user modes. Priority can be programmed between MPI and user logic at configuration in generic FPGAs. If no priority is set a round-robin approach is used by granting the next requesting master in a rotating fixed order.

Several interfaces exist between the ESB and other FPGA elements. The MPI interface acts as a bridge between the external microprocessor bus and ESB. The MPI may work in an independent clock domain from the ESB if the ESB clock is not sourced from the external microprocessor clock. Pipelined operation allows high-speed memory interface to the EBR and peripheral access without the requirement for additional cycles on the bus. Burst transfers allow optimal use of the memory interface by giving advance information of the nature of the transfers.

Table 23 is a listing of the ESB register file and brief descriptions. Table 24 shows the system interrupt registers and Table 25 and Table 26 show the FPGA status and command registers, all with brief descriptions. More information is available in the Series 4 MPI and System Bus application note.

Microprocessor Interface (continued)

Table 22. MPC 860 to *ORCA* MPI Interconnection

PowerPC Signal	*ORCA* Pin Name	MPI I/O	Function
D[0:*n*]	D[0:*n*]	I/O	8, 16, 32-bit data bus.
DP[0:*m*]	DP[0:*m*]	I/O	Selectable parity bus width from1, 2, and 4-bit.
A[14:31]	PPC_A[14:31]	I	32-bit MPI address bus.
$\overline{TS}$	$\overline{MPI\_STRB}$	I	Transfer start signal.
$\overline{BURST}$	$\overline{MPI\_BURST}$	I	Active-low indicates burst transfer in-progress. High indicates current transfer not a burst.
—	$\overline{CS0}$	I	Active-low MPI select.
—	CS1	I	Active-high MPI select.
CLKOUT	MPI_CLK	I	*PowerPC* interface clock.
RD/$\overline{WR}$	MPI_RW	I	Read (high)/write (low) signal.
$\overline{TA}$	$\overline{MPI\_ACK}$	O	Active-low transfer acknowledge signal.
$\overline{BDIP}$	$\overline{MPI\_BDIP}$	I	Active-low burst transfer in progress signal indicates that the second beat in front of the current one is requested by the master. Negated before the burst transfer ends to abort the burst data phase.
Any of $\overline{IRQ}$[7:0]	$\overline{MPI\_IRQ}$	O	Active-low interrupt request signal.
$\overline{TEA}$	$\overline{MPI\_TEA}$	O	Active-low indicates MPI detects a bus error on the internal system bus for current transaction.
$\overline{RETRY}$	$\overline{MPI\_RTRY}$	O	Requests the MPC860/MPC8260 to relinquish the bus and retry the cycle.
TSZ[0:1]	MPI_TSZ[0:1]	I	Driven to indicate the data transfer size for the transaction (byte, half-word, word).

Microprocessor Interface (continued)

Table 23. Embedded System Bus/MPI Registers

Register	Byte	Read/Write	Initial Value	Description
00	03-00	RO	—	32-bit device ID
01	07-04	R/W	—	Scratchpad register
02	0B-08	R/W	—	Command register
03	0F-0C	RO	—	Status register
04	13	R/W	—	Interrupt enable register – MPI
	12	R/W	—	Interrupt enable register – USER
	11	R/W	—	Interrupt enable register – FPSC (unused for FPGAs)
	10	RO	—	Interrupt cause register
05	17-14	R/W	—	Readback address register (14 bits)
06	1B-18	RO	—	Readback data register
07	1F-1C	R/W	—	Configuration data register
08	23-20	RO	—	Trap address register
09	27-24	RO	—	Bus error address register
0A	2B-28	RO	—	Interrupt vector 1 predefined by configuration bit stream
0B	2F-2C	RO	—	Interrupt vector 2 predefined by configuration bit stream
0C	33-30	RO	—	Interrupt vector 3 predefined by configuration bit stream
0D	37-34	RO	—	Interrupt vector 4 predefined by configuration bit stream
0E	3B-38	RO	—	Interrupt vector 5 predefined by configuration bit stream
0F	3F-3C	RO	—	Interrupt vector 6 predefined by configuration bit stream
10	43—40	—	—	Top-left PPLL
11	47—44	—	—	Top-left HPLL
14	53—50	—	—	Top-right PPLL
18	63—60	—	—	Bottom-left PPLL
19	67—64	—	—	Bottom-left HPLL
1C	73—70	—	—	Bottom-right PPLL

Note: RO = Read Only, R/W = Read/Write

Table 24. Interrupt Register Space Assignments

Byte	bit	Read/Write	Description
13	7-0	R/W	Interrupt Enable Register – MPI
12	7-0	R/W	Interrupt Enable Register – USER
11	7-0	R/W	Interrupt Enable Register – FPSC
10	Interrupt Cause Registers		
	7	RO	USER_IRQ_GENERAL;
	6	RO	USER_IRQ_SLAVE;
	5	RO	USER_IRQ_MASTER;
	4	RO	CFG_IRQ_DATA;
	3	RO	ERR_FLAG 1
	2	RO	MPI_IRQ
	1	RO	FPSC_IRQ_SLAVE;
	0	RO	FPSC_IRQ_MASTER

Note: RO = Read Only, R/W = Read/Write.
For internal system bus, bit 7 is most significant bit, for MPI bit 0 is most significant bit.

Microprocessor Interface (continued)

Table 25. Status Register Space Assignments

Byte	bit	Read/Write	Description
0F	7:0	—	Reserved
0E	7:0	—	Reserved
OD	7	RO	Configuration Write Data Acknowledge
	6	RO	Readback Data Ready
	5	RO	Unassigned (Zero)
	4	RO	Unassigned (Zero)
	3	RO	FPSC_BIT_ERR
	2	RO	RAM_BIT_ERR
	1	RO	Configuration Write Data Size (1, 2, or 4 bytes)
	0	RO	Use with above for HSIZE[1:0] (byte, half-word, word)
0C	7	RO	Readback Addresses Out of Range
	6	RO	Error Response Received by CFG From System Bus
	5	RO	Error Responses Received by CFG From System Bus
	4	RO	CFG_DATA_LOST
	3	RO	DONE
	2	RO	INIT_N
	1	RO	ERR_FLAG 1
	0	RO	ERR_FLAG 0

Notes: RO = Read Only. For internal system bus, bit 7 is most significant bit, for MPI bit 0 is most significant bit.

Table 26. Command Register Space Assignments

Byte	bit	Read/Write	Description
0B	7:0	—	Reserved
0A	7:0	—	Reserved
09	7	R/W	SYS_GSR (GSR Input)
	6	R/W	SYS_RD_CFG (similar to FPGA pin RD_CFGN, but active high)
	5	R/W	PRGM from MPI > (similar to FPGA pin, but active high)
	4	R/W	PRGM from USER > (similar to FPGA pin, but active high)
	3	R/W	PRGM from FPSC > (similar to FPGA pin, but active high)
	2	R/W	LOCK from MPI
	1	R/W	LOCK from USER
	0	R/W	LOCK from FPSC
08	7	R/W	Bus Reset from MPI (resets system bus and registers)
	6	R/W	Bus Reset from USER (resets system bus and registers)
	5	R/W	Bus Reset from FPSC (resets system bus and registers)
	4	R/W	SYS_DAISY
	3	R/W	REPEAT_RDBK (don't increment readback address)
	2	R/W	MPI_USR_ENABLE
	1	R/W	Readback Data Size (1, 2, or 4 bytes)
	0	R/W	Use with above for HSIZE[1:0]

Note: R/W = Read/Write. For internal system bus; bit 7 is most significant bit, for MPI bit 0 is most significant bit.

Phase-Locked Loops (PLLs)

There are eight PLLs available to perform many clock modification and clock conditioning functions on the Series 4 FPGAs. Six of the PLLs are programmable allowing the user the flexibility to configure the PLL to manipulate the frequency, phase, and duty cycle of a clock signal. Four of the programmable PLLs (PPLLs) are capable of manipulating and conditioning clocks from 15 MHz to 200 MHz and two others (HPPLLs) are capable of manipulating and conditioning clocks from 60 MHz to 420 MHz. Frequencies can be adjusted from 1/64x to 64x the input clock frequency. Each programmable PLL provides two outputs that have different multiplication factors with the same phase relationships. Duty cycles and phase delays can be adjusted in 12.5% of the clock period increments. An automatic delay compensation mode is available for phase delay. Each PPLL and HPPLL provides two outputs that can have programmable (45 degree increments) phase differences.

The PPLLs and HPPLLs can be utilized to eliminate skew between the clock input pad and the internal clock inputs across the entire device. Both the PPLLS or the HPPLLs can drive onto the primary and secondary clock networks inside the FPGA. Each can take a clock input from the dedicated pad or differential pair of pads in its corner or from general routing resources.

Functionality of the PPLLs and HPPLLs is programmed during operation through a control register internal to the FPGA array or via the configuration bit stream. The embedded system bus enables access to these registers (see Table 23). There is also a PLL output signal, LOCK, that indicates a stable output clock state.

Table 27. PPLL Specifications

Parameter		Min	Nom	Max	Unit
$V_{DD}15$		1.425	1.5	1.575	V
$V_{DD}33$		3.0	3.3	3.6	V
Operating Temp		–40	—	125	C
Input Clock Frequency (No division)	PPLL	2.0	—	200	MHz
	HPPLL	7.5	—	420	
Output Clock Frequency	PPLL	15	—	200	MHz
	HPPLL	60	—	420	
Input Duty Cycle		30	—	70	%
Output Duty Cycle		45	50	55	%
Lock Time		—	<50	—	µs
Frequency Multiplication		Up to 64x			—
Frequency Division		Down to 1/64x			—
Duty Cycle Adjust of Output Clock		12.5, 25, 37.5, 50, 62.5, 75, 87.5			%
Delay Adjust of Output Clock		0, 45, 90, 135, 180, 225, 270, 315			degrees
Phase Shift Between MCLK and NCLK		0, 45, 90, 135, 180, 225, 270, 315			degrees

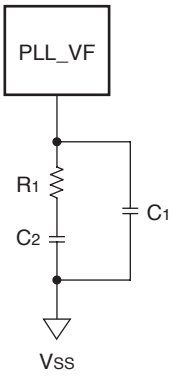
Additional highly tuned and characterized dedicated phase-locked loops (DPLLs) are included to ease system designs. These DPLLs meet ITU-T G.811 primary clocking specifications and enable system designers to target very tightly specified clock conditioning not available in the programmable PPLLs. They also provide enhanced jitter filtering to reduce the amount of input jitter that is transferred to the PLL output when used in any application. DPLLs are targeted to low-speed DS1 and E1 networking systems (PLL1) and high-speed SONET/SDH networking STS-3 and STM-1 networking systems (PLL2).

Phase-Locked Loops (continued)

Table 28. DS-1/E-1 PLL1 Specifications

Parameter	Min	Nom	Max	Unit
$V_{DD}15$	1.425	1.5	1.575	V
$V_{DD}33$	3.0	3.3	3.6	V
Operating Temp	–40	—	125	C
Input Clock Frequency	1.0	—	2.5	MHz
Output Clock Frequency	1.0	—	2.5	MHz
Input Duty Cycle	30	—	70	%
Output Duty Cycle	47	50	53	%
Lock Time	—	<1200	—	μs

A dedicated pin PLL_VF is needed for externally connecting a low pass filter circuit. This provides the specified DS–1/E–1 PLL operating condition.



R_1 = 6 kΩ ± 1%
C_1 = 100 pF ± 5%
C_2 = 0.01 μF ± 5%

0203(F).

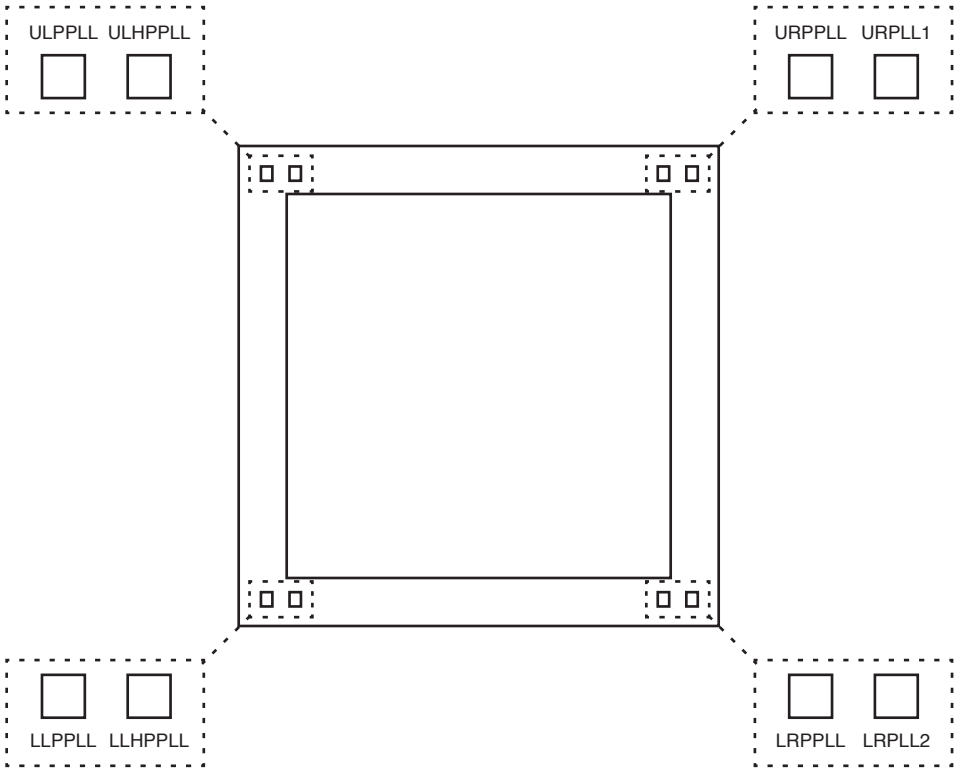
Figure 31. PLL_VF External Requirements

Phase-Locked Loops (continued)

Table 29. STS-3/STM-1 PLL2 Specifications

Parameter	Min	Nom	Max	Unit
VDD15	1.425	1.5	1.575	V
VDD33	3.0	3.3	3.6	V
Operating Temp	–40	—	125	C
Input Clock Frequency	140	155.52	170	MHz
Output Clock Frequency	140	155.52	170	MHz
Input Duty Cycle Tolerance	30	—	70	%
Output Duty Cycle	47	50	53	%
Lock Time	—	<50	—	µs

All Series 4 PLLs operate from the VDD33 power supply. Care needs to be taken during board layout to properly isolate and filter this power supply. More information about the PLLs is available in the *Series 4 FPGA PLL Elements* application note. The location of all eight PLLs on Series 4 FPGAs is shown in Figure 32 and Table 30.



0045(F)

Figure 32. PLL Naming Scheme

Table 30. Phase-lock Loops Index

Name	Description
[UL][LL][UR][LR]PPLL	Universal user programmable PLL (15—200 MHz)
[UL][LL]HPPLL	Universal user programmable PLL (60—420 MHz)
URPLL1	DS-1/E-1 dedicated PLL
LRPLL2	STS-1/STM-1 dedicated PLL

FPGA States of Operation

Prior to becoming operational, the FPGA goes through a sequence of states, including initialization, configuration, and start-up. Figure 33 outlines these three states.

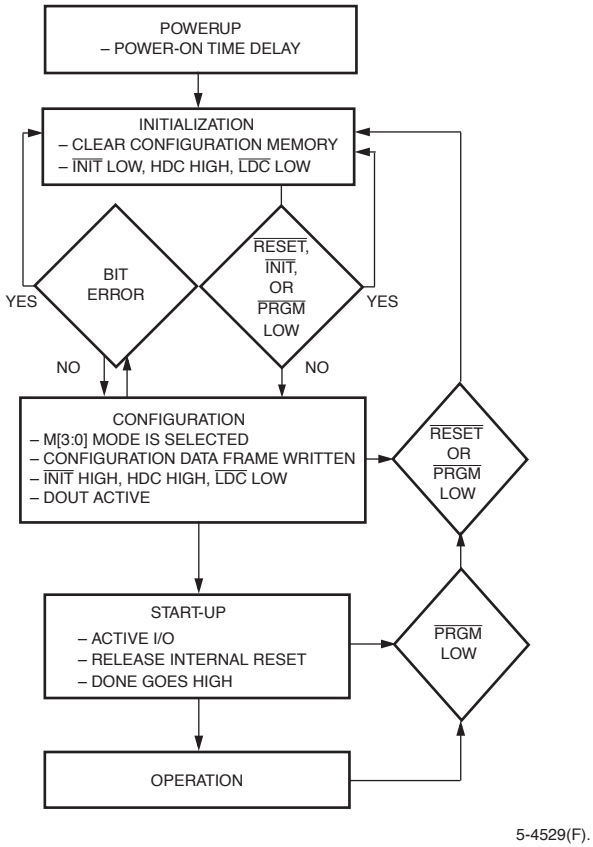


Figure 33. FPGA States of Operation

Initialization

Upon powerup, the device goes through an initialization process. First, an internal power-on-reset circuit is triggered when power is applied. When $V_{DD}15$ and $V_{DD}33$ reach the voltage at which portions of the FPGA begin to operate, the I/Os are configured based on the configuration mode, as determined by the mode select inputs M[3:0]. A time-out delay is then initiated to allow the power supply voltage to stabilize. The $\overline{INIT}$ and DONE outputs are low.

At the end of initialization, the default configuration option is that the configuration RAM is written to a low state. This prevents internal shorts prior to configuration. As a configuration option, after the first configuration (i.e., at reconfiguration), the user can reconfigure without clearing the internal configuration RAM first. The active-low, open-drain initialization signal $\overline{INIT}$ is released and must be pulled high by an external resistor when initialization is complete. To synchronize the configuration of multiple FPGAs, one or more $\overline{INIT}$ pins should be wire-ANDed. If $\overline{INIT}$ is held low by one or more FPGAs or an external device, the FPGA remains in the initialization state. $\overline{INIT}$ can be used to signal that the FPGAs are not yet initialized. After $\overline{INIT}$ goes high for two internal clock cycles, the mode lines (M[3:0]) are sampled, and the FPGA enters the configuration state.

The high during configuration (HDC), low during configuration ($\overline{LDC}$), and DONE signals are active outputs in the FPGA's initialization and configuration states. HDC, $\overline{LDC}$, and DONE can be used to provide control of external logic signals such as reset, bus enable, or PROM enable during configuration. For parallel master configuration modes, these signals provide PROM enable control and allow the data pins to be shared with user logic signals.

If configuration has begun, an assertion of $\overline{RESET}$ or $\overline{PRGM}$ initiates an abort, returning the FPGA to the initialization state. The $\overline{PRGM}$ and $\overline{RESET}$ pins must be pulled back high before the FPGA will enter the configuration state. During the start-up and operating states, only the assertion of $\overline{PRGM}$ causes a reconfiguration.

In the master configuration modes, the FPGA is the source of configuration clock (CCLK). In this mode, the initialization state is extended to ensure that, in daisy-chain operation, all daisy-chained slave devices are ready. Independent of differences in clock rates, master mode devices remain in the initialization state an additional six internal clock cycles after $\overline{INIT}$ goes high.

When configuration is initiated, a counter in the FPGA is set to 0 and begins to count configuration clock cycles applied to the FPGA. As each configuration data frame is supplied to the FPGA, it is internally assembled into data words. Each data word is loaded into the internal configuration memory. The configuration loading process is complete when the internal length count equals the loaded length count in the length count field, and the required end of configuration frame is written.

During configuration, the PIO and PLC latches/FFs are held set/reset and the internal SLIC buffers are 3-stated. The combinatorial logic begins to function as the FPGA is configured. Figure 34 shows the general waveform of the initialization, configuration, and start-up states.

FPGA States of Operation (continued)

Power Supply Sequencing

FPGAs are CMOS static RAM (SRAM) based programmable logic devices. The circuitry that the user designs for the FPGA is implemented within the FPGA by setting multiple SRAM configuration memory cells. This unique structure as compared with typical CMOS circuits lends to having certain powerup voltage and current requirements. This section describes these related power issues for the *ORCA* Series 4 FPGAs and FPSCs.

The flexibility of Series 4 FPGAs lends itself to more power up considerations as it mixes many power supplies to meet today's versatile system standards. The board designer must account for the relationship of the supplies early in board development. The proper sequence of supplies insures that the board will not be troubled with power up issues.

The Series 4 devices have many new design improvements to prevent short-circuit contention. This contention is typically caused by configuration RAM cells in the device not all powering up to a Q = 0 RAM state. In order for this to occur, a minimum current was needed to push the internal circuitry beyond the initial short-circuit-like condition to become a full CMOS circuit. Series 4 has overcome this requirement through many improvements which have dramatically decreased the adverse effects of internal power up memory contention.

At power up, the internal V_{DD} ramp and the duration of the ramp will depend on the amount of dynamic current available from the power supply. If a large amount of current is available, the voltage ramp seen by the device will be very fast. When final voltage has been reached, this high quiescent current is no longer required. If the available current is limited, the time for the device power to rise will be longer. The voltage ramp should be monotonic with very little or no flattening as the supply ramps up. It is also recommended that the supply should not rise and fall as it is powering up as this will cause improper power up behavior.

In Series 4 devices, it is required that the $V_{DD}15$ supply pass through its operational threshold voltage of approximately 1 V before the $V_{DD}33$ supply reaches its operational threshold of 2.3 V. The current required by both $V_{DD}15$ and $V_{DD}33$ supplies while it passes through their operational thresholds is approximately between 1 and 2 amperes each. The powering of the $V_{DD}IO$ supplies should be after the $V_{DD}15$ and $V_{DD}33$ supplies reach operational levels. This sequence and supply currents can guarantee that the device will properly power up without any adverse effects.

In cases where the power up ramps are greater than 50 mS, it is recommended that $\overline{PRGM}$ pin be held low during power up. However, this work around is only valid if the power supplies meet the above mentioned current and voltage requirements. The assertion of the $\overline{PRGM}$ will hold off the device from configuration while the device stabilizes and will not counter act any internal power up requirements.

Configuration

The *ORCA* Series FPGA functionality is determined by the state of internal configuration RAM. This configuration RAM can be loaded in a number of different modes. In these configuration modes, the FPGA can act as a master or a slave of other devices in the system. The decision as to which configuration mode to use is a system design issue. Configuration is discussed in detail, including the configuration data format and the configuration modes used to load the configuration data in the FPGA, following a description of the start-up state.

Start-Up

After configuration, the FPGA enters the start-up phase. This phase is the transition between the configuration and operational states and begins when the number of CCLKs received after $\overline{INIT}$ goes high is equal to the value of the length count field in the configuration frame and when the end of configuration frame has been written. The system design issue in the start-up phase is to ensure the user I/Os become active without inadvertently activating devices in the system or causing bus contention. A second system design concern is the timing of the release of global set/reset of the PLC latches/FFs.

FPGA States of Operation (continued)

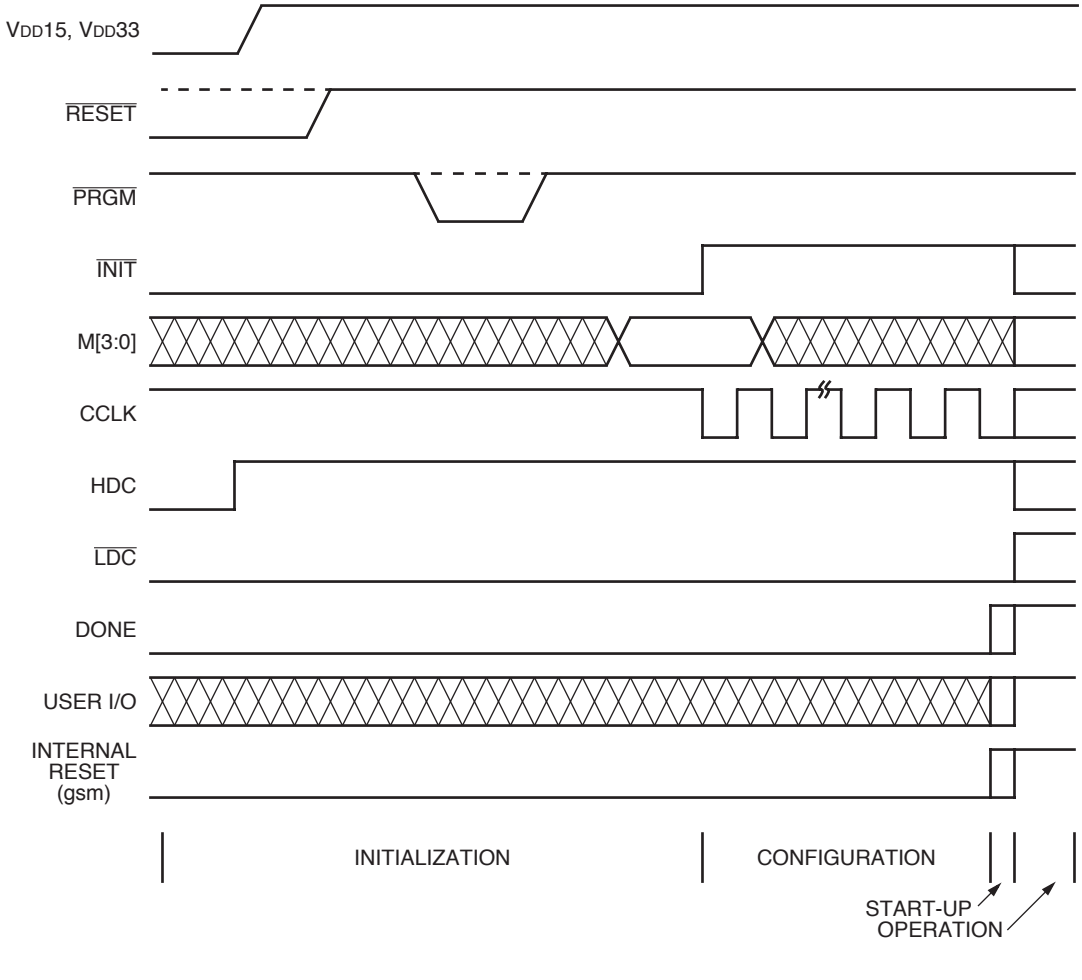


Figure 34. Initialization/Configuration/Start-Up Waveforms

FPGA States of Operation (continued)

There are configuration options that control the relative timing of three events: DONE going high, release of the set/reset of internal FFs, and user I/Os becoming active. Figure 35 shows the start-up timing for *ORCA* FPGAs. The system designer determines the relative timing of the I/Os becoming active, DONE going high, and the release of the set/reset of internal FFs. In the *ORCA* Series FPGA, the three events can occur in any arbitrary sequence. This means that they can occur before or after each other, or they can occur simultaneously.

There are four main start-up modes: CCLK_NOSYNC, CCLK_SYNC, UCLK_NOSYNC, and UCLK_SYNC. The only difference between the modes starting with CCLK and those starting with UCLK is that for the UCLK modes, a user clock must be supplied to the start-up logic. The timing of start-up events is then based upon this user clock, rather than CCLK. The difference between the SYNC and NOSYNC modes is that for SYNC mode, the timing of two of the start-up events, release of the set/reset of internal FFs, and the I/Os becoming active is triggered by the rise of the external DONE pin followed by a variable number of rising clock edges (either CCLK or UCLK). For the NOSYNC mode, the timing of these two events is based only on either CCLK or UCLK.

DONE is an open-drain bidirectional pin that may include an optional (enabled by default) pull-up resistor to accommodate wired ANDing. The open-drain DONE signals from multiple FPGAs can be tied together (ANDed) with a pull-up (internal or external) and used as an active-high ready signal, an active-low PROM enable, or a reset to other portions of the system. When used in SYNC mode, these ANDed DONE pins can be used to synchronize the other two start-up events, since they can all be synchronized to the same external signal. This signal will not rise until all FPGAs release their DONE pins, allowing the signal to be pulled high.

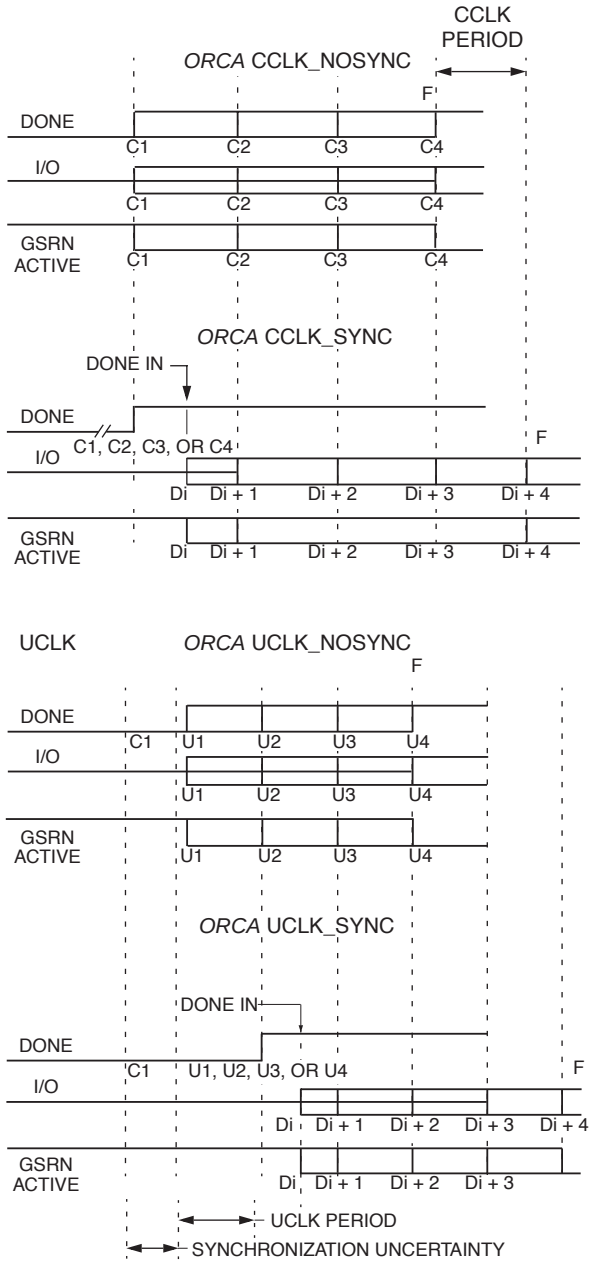
An example of using the synchronized modes are the CCLK_SYNC synchronized start-up mode where DONE is released on the first CCLK rising edge, C1 (see Figure 35).

Since this is a synchronized start-up mode, the open-drain DONE signal can be held low externally to stop the occurrence of the other two start-up events. Once the DONE pin has been released and pulled up to a high level, the other two start-up events can be programmed individually to either happen immediately or after up to four rising edges of CCLK (Di, Di + 1, Di + 2, Di + 3, Di + 4). The default is for both events to happen immediately after DONE is released and pulled high.

A commonly used design technique is to release DONE one or more clock cycles before allowing the I/O to become active. This allows other configuration devices, such as PROMs, to be disconnected using the DONE signal so that there is no bus contention when the I/Os become active. In addition to controlling the FPGA during start-up, other start-up techniques that avoid contention include using isolation devices between the FPGA and other circuits in the system, reassigning I/O locations, and maintaining I/Os as 3-stated outputs until contentions are resolved.

Each of these start-up options can be selected during bit stream generation in ispLEVER, using Advanced Options. For more information, please see the ispLEVER documentation.

FPGA States of Operation (continued)



F = FINISHED, NO MORE CLKS REQUIRED.

5-2761(F)

Figure 35. Start-Up Waveforms

FPGA States of Operation (continued)

Reconfiguration

To reconfigure the FPGA when the device is operating in the system, a low pulse is input into $\overline{\text{PRGM}}$ or one of the program bits in the embedded system bus control register must be set. The configuration data in the FPGA is cleared, and the I/Os not used for configuration are 3-stated with a pullup. The FPGA then samples the mode select inputs and begins reconfiguration. When reconfiguration is complete, DONE is released, allowing it to be pulled high.

Partial Reconfiguration

All *ORCA* device families have been designed to allow a partial reconfiguration of the FPGA at any time. This is done by setting a bit stream option in the previous configuration sequence that tells the FPGA to not reset all of the configuration RAM during a reconfiguration. Then only the configuration frames that are to be modified need to be rewritten, thereby reducing the configuration time.

Other bit stream options are also available that allow one portion of the FPGA to remain in operation while a partial reconfiguration is being done. If this is done, the user must be careful to not cause contention between the two configurations (the bit stream resident in the FPGA and the partial reconfiguration bit stream) as the second reconfiguration bit stream is being loaded.

During a partial re-configuration where the configuration option is set to have the internal logic remain active during configuration the internal SLJC BIDI signals will always be 3-stated. Previous families of ORCA FPGAs would allow the BIDIs to continue to be under user logic control during a partial re-configuration.

Other Configuration Options

There are many other configuration options available to the user that can be set during bit stream generation in ispLEVER. These include options to enable boundary-scan and/or the MPI and/or the programmable PLL blocks, readback options, and options to control and use the internal oscillator after configuration.

Other useful options that affect the next configuration (not the current configuration process) include options to disable the global set/reset during configuration, disable the 3-state of I/Os during configuration, and disable the reset of internal RAMs during configuration to allow for partial configurations (see above). For more information on how to set these and other configuration options, please see the ispLEVER documentation.

Configuration Data Format

The ispLEVER Development System interfaces with front-end design entry tools and provides tools to produce a fully configured FPGA. This section discusses using the ispLEVER Development System to generate configuration RAM data and then provides the details of the configuration frame format.

Using ispLEVER to Generate Configuration RAM Data

The configuration data bit stream defines the I/O functionality, logic, and interconnections within the FPGA. The bit stream is generated by the development system. The bit stream created by the bit stream generation tool is a series of 1s and 0s used to write the FPGA configuration RAM. It can be loaded into the FPGA using one of the configuration modes discussed later.

In bit stream generator, the designer selects options that affect the FPGA's functionality. Using the output of the bit stream generator, **circuit_name.bit**, the development system's download tool can load the configuration data into the *ORCA* series FPGA evaluation board from a PC or workstation.

A download cable that can be used to download from any PC or workstation supported by ispLEVER is available. This cable allows download to an FPGA that can be programmed via the serial configuration interface (requiring the mode pins to be set) or the JTAG boundary scan interface (not requiring the setting of mode pins). The lead device can then program other FPGAs or FPSCs on the board via daisy-chaining.

Alternatively, a user can program a PROM (such as a Serial ROM or a standard EPROM) and load the FPGA from the PROM. The development system's PROM programming tool produces a file in .mcs, .tek or .exo format.

Configuration Data Format (continued)

Configuration Data Frame

Configuration data can be presented to the FPGA in two frame formats: autoincrement and explicit. A detailed description of the frame formats is shown in Figure 36, Figure 37, and Tables Table 31 and Table 31A. The two modes are similar except that autoincrement mode uses assumed address incrementation to reduce the bit stream size, and explicit mode uses an optional address frame. In both cases, the header frame begins with a series of 1s and a preamble of 0010, followed by a 24-bit length count field representing the total number of configuration clocks needed to complete the loading of the FPGAs. If only Series 4 devices are used, a second preamble value of 0100 is supported. If this preamble is found, the Series 4 device will expect an expanded length count field of 32-bits. This allows more larger Series 4 FPGAs to be configured through daisy-chaining.

Following the header frame is a mandatory ID frame. The ID frame contains data used to determine if the bit stream is being loaded to the correct type of *ORCA* FPGA (i.e., a bit stream generated for an OR4E06 is being sent to an OR4E06). Error checking is always enabled for Series 4 devices through the use of an 8-bit checksum. Following the ID frame is a 16-bit header to select the portion of the device to be configured with the following data. the options are an FPGA header (shown in Table 32), an embedded RAM header (shown in Table 32A), and an FPSC embedded block header (not shown).

A configuration data frame follows the header frame. A data frame starts with a 01-start bit pair and ends with enough 1-stop bit to reach a byte boundary. If subsequent data frames follow the frame address is auto-incremented. If using explicit mode, an address frame can follow a data frame, telling the FPGA at what address to update the auto-increment counter to for the next data frame. Address frame starts with 00.

Following all data and address frames is the postamble. The format of the postamble is the same as an address frame with the highest possible address value with the checksum set to all ones, if no other sections of configuration data follow. If another section is to follow, the header starts with 10.

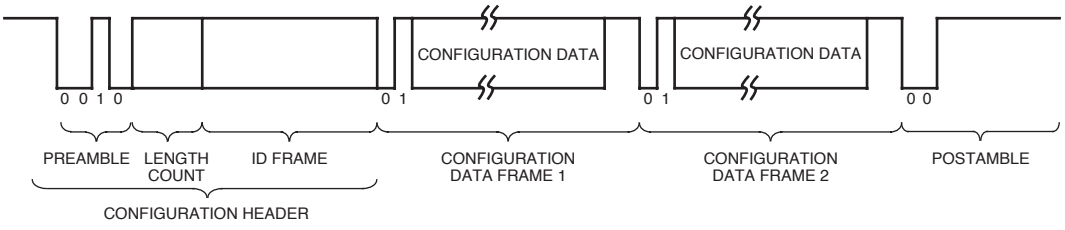


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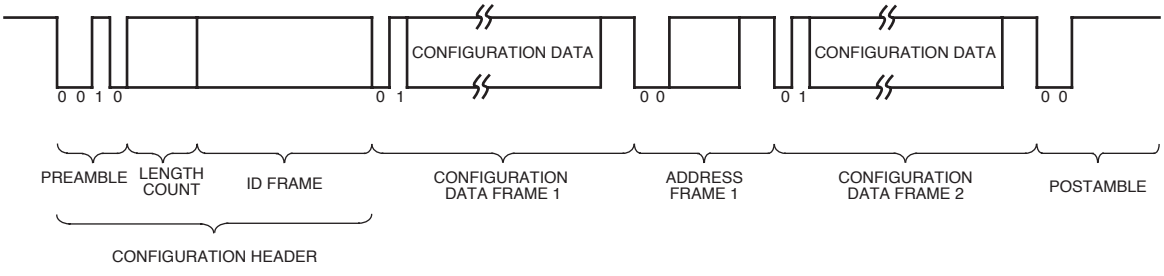
Figure 36. Serial Configuration Data Format—Autoincrement Mode



5-5760(F).a

Figure 37. Serial Configuration Data Format—Explicit Mode

Configuration Data Format (continued)

Table 31. Configuration Frame Format and Contents

Frame	Contents	Description
Header	11110010	Preamble for generic FPGA.
	24-bit length count	Configuration bitstream length.
	11111111	8-bit trailing header.
ID Frame	0101 1111 1111 1111	ID frame header.
	44 reserved bits	Reserved bits set to 0.
	Part ID	20-bit part ID.
	Checksum	8-bit checksum.
	11111111	8 stop bits (high) to separate frames.
FPGA Header	1111 0010	This is a new mandatory header for generic portion.
	11111111	8 stop bits (high) to separate frames.
FPGA Address Frame	00	Address frame header.
	14-bit address	14-bit address of generic FPGA.
	Checksum	8-bit checksum.
	11111111	Eight stop bits (high) to separate frames.
FPGA Data Frame	01	Data frame header. same as generic.
	Alignment bits	String of 0 bits added to frame to reach a byte boundary.
	Data bits	Number of data bits depends upon device.
	Checksum	8-bit checksum.
	11111111	Eight stop bits (high) to separate frames.
Postamble for Generic FPGA	00 or 10	Postamble header, 00 = finish, 10 = more bits coming.
	11111111 111111	Dummy address.
	11111111 11111111	16 stop bits (high).

Table 31A. Configuration Frame Format and Contents for Embedded Block RAM

Frame	Contents	Description
RAM Header	11110001	A mandatory header for RAM bitstream portion.
	11111111	8 stop bits (high) to separate frames.
RAM Address Frame	00	Address frame header. same as generic.
	6-bit address	6-bit address of RAM blocks.
	Checksum	8-bit checksum.
	11111111	Eight stop bits (high) to separate frames.
RAM Data Frame	01	Data frame header. same as generic.
	000000	Six of 0 bits added to reach a byte boundary.
	512x18 data bits	Exact number of bits in a RAM block.
	Checksum	8-bit checksum.
	11111111	Eight stop bits (high) to separate frames.
Postamble for RAM	00 or 10	Postamble header. 00 = finish, 10 = more bits coming.
	111111	Dummy address.
	11111111 11111111	16 stop bits (high).

Configuration Data Format (continued)

The number of frames, number of bits/frame, total number of bits and the required PROM size for each Series 4 device is shown in Table 32

Table 32. Configuration Frame Size

Devices	OR4E02	OR4E04	OR4E06
Number of Frames	1796	2436	3076
Data Bits/Frame	900	1284	1540
Maximum Configuration Data (Number of bits/frame x Number of frames)	1,616,400	3,127,824	4,737,040
Maximum PROM Size (bits) (add configuration header and postamble)	1,616,648	3,128,072	4,737,288

Bit Stream Error Checking

There are three different types of bit stream error checking performed in the *ORCA* Series 4 FPGAs: ID frame, frame alignment, and CRC checking.

The ID data frame is sent to a dedicated location in the FPGA. This ID frame contains a unique code for the device for which it was generated. This device code is compared to the internal code of the FPGA. Any differences are flagged as an ID error. This frame is automatically created by the bit stream generation program in ispLEVER.

Each data and address frame in the FPGA begins with a frame start pair of bits and ends with eight stop bits set to 1. If any of the previous stop bits were a 0 when a frame start pair is encountered, it is flagged as a frame alignment error.

Error checking is also done on the FPGA for each frame by means of a checksum byte. If an error is found on evaluation of the checksum byte, then a checksum/parity error is flagged. The checksum is the XOR of all the data bytes, from the start of frame up to and including the bytes before the checksum. It applies to the ID, address, and data frames.

When any of the three possible errors occur, the FPGA is forced into an idle state, forcing $\overline{\text{INIT}}$ low. The FPGA will remain in this state until either the $\overline{\text{RESET}}$ or $\overline{\text{PRGM}}$ pins are asserted The $\overline{\text{PGRM}}$ bits of the MPI control register can also be used to reset out of the error condition and restart configuration.

If using any of the MPI modes to configure the FPGA, the specific type of bit stream error is written to one of the MPI registers by the FPGA configuration logic. This same information can also be read from the data register when in asynchronous peripheral mode.

FPGA Configuration Modes

There are twelve methods for configuring the FPGA as show in Table 33. Eleven of the configuration modes are selected on the M0, M1, M2, and M3 inputs. The twelfth configuration mode is accessed through the boundary-scan interface. Some modes are used to select the frequency of the internal oscillator, which is the source for CCLK in some configuration modes. The nominal frequencies of the internal oscillator are 1.25 MHz and 10 MHz.

There are three basic FPGA configuration modes: master, slave, and peripheral which includes MPI mode. The configuration data can be transmitted to the FPGA serially or in parallel bytes. As a master, the FPGA provides the control signals out to strobe data in. As a slave device, a clock is generated externally and provided into the CCLK input. In the five peripheral modes, the FPGA acts as a microprocessor peripheral. Table 33 lists the functions of the configuration mode pins.

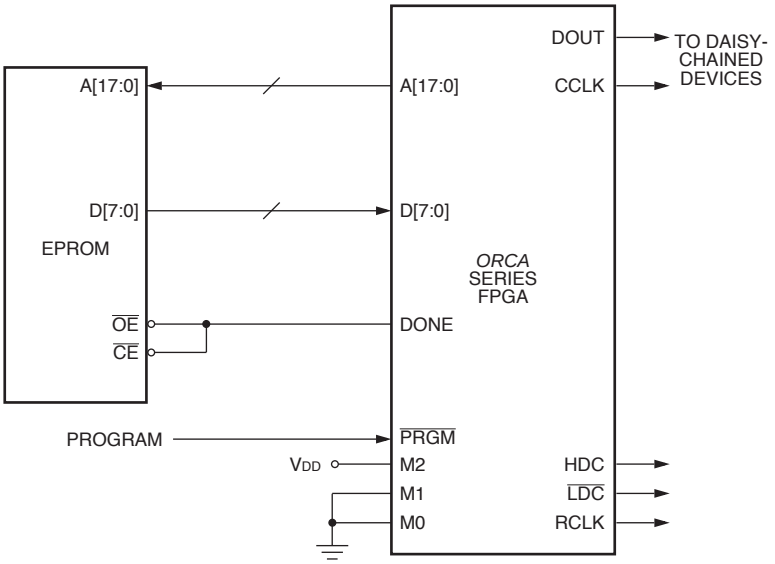
FPGA Configuration Modes (continued)

Table 33. Configuration Modes

M3	M2	M1	M0	CCLK	Configuration Mode	Data
0	0	0	0	Output. High-frequency.	Master Serial	Serial
0	1	0	0	Output. High-frequency.	Master Parallel	8-bit
0	1	0	1	Output. High-frequency.	Asynchronous Peripheral	8-bit
0	1	1	1	NA	Reserved	NA
1	0	0	0	Output. Low-frequency.	Master Serial	Serial
1	0	0	1	Input.	Slave Parallel	8-bit
1	0	1	0	Output.	MPC860 MPI	8-bit
1	0	1	1	Output.	MPC860 MPI	16-bit
1	1	0	0	Output. Low-frequency.	Master Parallel	8-bit
1	1	0	1	Output. Low-frequency.	Asynchronous Peripheral	8-bit
1	1	1	0	Output.	MPC860 MPI	32-bit
1	1	1	1	Input.	Slave Serial	Serial

Master Parallel Mode

The master parallel configuration mode is generally used to interface to industry-standard, byte-wide memory. Figure 38 provides the connections for master parallel mode. The FPGA outputs an 22-bit address on A[21:0] to memory and reads 1 byte of configuration data on the rising edge of RCLK. The parallel bytes are internally serialized starting with the least significant bit, D0. D[7:0] of the FPGA can be connected to D[7:0] of the microprocessor only if a standard prom file format is used. If a .bit or .rbt file is used from ispLEVER, then the user must mirror the bytes in the .bit or .rbt file OR leave the .bit or .rbt file unchanged and connect D[7:0] of the FPGA to D[0:7] of the microprocessor.



Note: M3 = GND for high-speed CCLK; M3 = V_{DD} for low-frequency CCLK.

5-9738(F).a

Figure 38. Master Parallel Configuration Schematic

In master parallel mode, the starting memory address is 00000 hex, and the FPGA increments the address for each byte loaded.

FPGA Configuration Modes (continued)

One master mode FPGA can interface to the memory and provide configuration data on DOUT to additional FPGAs in a daisy-chain. The configuration data on DOUT is provided synchronously with the rising edge of CCLK. The frequency of the CCLK output is eight times that of RCLK.

Master Serial Mode

In the master serial mode, the FPGA loads the configuration data from an external serial ROM. The configuration data is either loaded automatically at start-up or on a $\overline{\text{PRGM}}$ command to reconfigure. Serial PROMs can be used to configure the FPGA in the master serial mode.

Configuration in the master serial mode can be done at powerup and/or upon a configure command. The system or the FPGA must activate the serial ROM's $\overline{\text{RESET}}$/OE and $\overline{\text{CE}}$ inputs. At powerup, the FPGA and serial ROM each contain internal power-on reset circuitry that allows the FPGA to be configured without the system providing an external signal. The power-on reset circuitry causes the serial ROM's internal address pointer to be reset. After powerup, the FPGA automatically enters its initialization phase.

The serial ROM/FPGA interface used depends on such factors as the availability of a system reset pulse, availability of an intelligent host to generate a configure command, whether a single serial ROM is used or multiple serial ROMs are cascaded, whether the serial ROM contains a single or multiple configuration programs, etc. Because of differing system requirements and capabilities, a single FPGA/serial ROM interface is generally not appropriate for all applications.

Data is read in the FPGA sequentially from the serial ROM. The DATA output from the serial ROM is connected directly into the DIN input of the FPGA. The CCLK output from the FPGA is connected to the CLK input of the serial ROM. During the configuration process, CCLK clocks one data bit on each rising edge.

Since the data and clock are direct connects, the FPGA/serial ROM design task is to use the system or FPGA to enable the $\overline{\text{RESET}}$/OE and $\overline{\text{CE}}$ of the serial ROM(s). There are several methods for enabling the serial ROM's $\overline{\text{RESET}}$/OE and $\overline{\text{CE}}$ inputs. The serial ROM's $\overline{\text{RESET}}$/OE is programmable to function with RESET active-high and $\overline{\text{OE}}$ active-low or $\overline{\text{RESET}}$ active-low and OE active-high.

In Figure 39, serial ROMs are cascaded to configure multiple daisy-chained FPGAs. The host generates a 500 ns low pulse into the FPGA's $\overline{\text{PRGM}}$ input. The FPGA's $\overline{\text{INIT}}$ input is connected to the serial ROMs' $\overline{\text{RESET}}$/OE input, which has been programmed to function with $\overline{\text{RESET}}$ active-low and OE active-high. The FPGA DONE is routed to the $\overline{\text{CE}}$ pin. The low on DONE enables the serial ROMs. At the completion of configuration, the high on the FPGAs DONE disables the serial ROM.

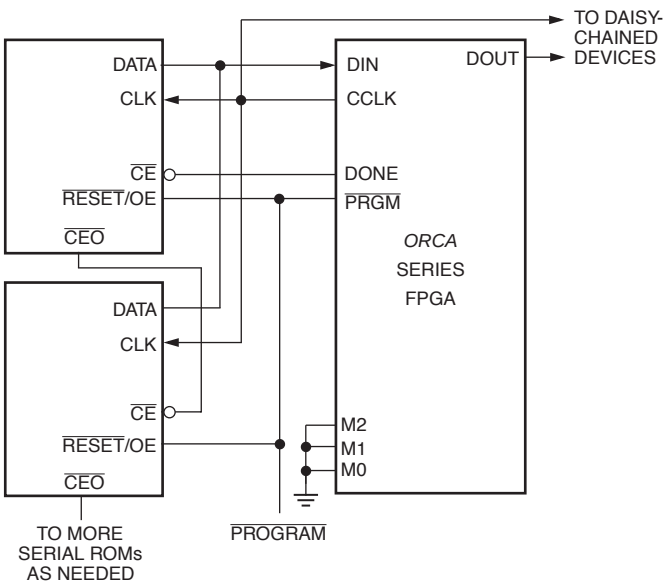
Serial ROMs can also be cascaded to support the configuration of multiple FPGAs or to load a single FPGA when configuration data requirements exceed the capacity of a single serial ROM. After the last bit from the first serial ROM is read, the serial ROM outputs $\overline{\text{CEO}}$ low and 3-states the DATA output. The next serial ROM recognizes the low on $\overline{\text{CE}}$ input and outputs configuration data on the DATA output. After configuration is complete, the FPGA's DONE output into $\overline{\text{CE}}$ disables the serial ROMs.

This FPGA/serial ROM interface is not used in applications in which a serial ROM stores multiple configuration programs. In these applications, the next configuration program to be loaded is stored at the ROM location that follows the last address for the previous configuration program. The reason the interface in Figure 39 will not work in this application is that the low output on the $\overline{\text{INIT}}$ signal would reset the serial ROM address pointer, causing the first configuration to be reloaded.

In some applications, there can be contention on the FPGA's DIN pin. During configuration, DIN receives configuration data, and after configuration, it is a user I/O. If there is contention, an early DONE at start-up (selected in ispLEVER) may correct the problem. An alternative is to use $\overline{\text{LDC}}$ to drive the serial ROM's $\overline{\text{CE}}$ pin. In order to reduce noise, it is generally better to run the master serial configuration at 1.25 MHz (M3 pin tied high), rather than 10 MHz, if possible.

One FPGA in master serial mode can provide configuration data out on DOUT to additional FPGAs in a daisy-chain configuration. The configuration data on DOUT is provided synchronously with the rising edge of CCLK.

FPGA Configuration Modes (continued)



Note: M3 = GND for high-speed CCLK; M3 = VDD for low-frequency CCLK.

5-4456(F).a

Figure 39. Master Serial Configuration Schematic

Asynchronous Peripheral Mode

Figure 40 shows the connections needed for the asynchronous peripheral mode. In this mode, the FPGA system interface is similar to that of a microprocessor-peripheral interface. The microprocessor generates the control signals to write an 8-bit byte into the FPGA. The FPGA control inputs include active-low $\overline{CS0}$ and active-high CS1 chip selects and $\overline{WR}$ and $\overline{RD}$ inputs. The chip selects can be cycled or maintained at a static level during the configuration cycle. Each byte of data is written into the FPGA's D[7:0] input pins. D[7:0] of the FPGA can be connected to D[7:0] of the microprocessor only if a standard prom file format is used. If a .bit or .rbt file is used from ispLEVER, then the user must mirror the bytes in the .bit or .rbt file OR leave the .bit or .rbt file unchanged and connect D[7:0] of the FPGA to D[0:7] of the microprocessor.

The FPGA provides an RDY/$\overline{BUSY}$ status output to indicate that another byte can be loaded. A low on RDY/$\overline{BUSY}$ indicates that the double-buffered hold/shift registers are not ready to receive data, and this pin must be monitored to go high before another byte of data can be written. The shortest time RDY/$\overline{BUSY}$ is low occurs when a byte is loaded into the hold register and the shift register is empty, in which case the byte is immediately transferred to the shift register. The longest time for RDY/$\overline{BUSY}$ to remain low occurs when a byte is loaded into the holding register and the shift register has just started shifting configuration data into configuration RAM.

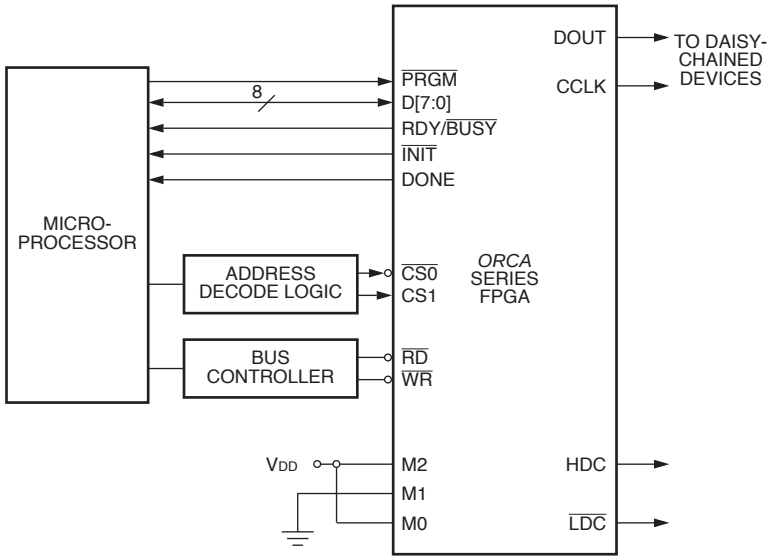
The RDY/$\overline{BUSY}$ status is also available on the D7 pin by enabling the chip selects, setting $\overline{WR}$ high, and applying $\overline{RD}$ low, where the $\overline{RD}$ input provides an output enable for the D[7:3] when $\overline{RD}$ is low. The D[2:0] pins are not enabled to drive when $\overline{RD}$ is low and, therefore, only act as input pins in asynchronous peripheral mode. Optionally, the user can ignore the RDY/$\overline{BUSY}$ status and simply wait until the maximum time it would take for the RDY/$\overline{BUSY}$ line to go high, indicating the FPGA is ready for more data, before writing the next data byte.

The following signals are also available on D[6:3] when $\overline{WR}$ is high and $\overline{RD}$ is low:

- D[6:5] is a 2-bit configuration bitstream error description flag: 00= no error, 01 = ID error, 10 = checksum error, 11 = stop bit/frame alignment error.
- D[4:3] is a 2-bit system bus error flag: 00 = no error, 01 = one error occurred, 11 = multiple errors occurred.

One FPGA in asynchronous peripheral mode can provide configuration data out on DOUT to additional FPGAs in a daisy-chain configuration. The configuration data on DOUT is provided synchronously with the rising edge of CCLK.

FPGA Configuration Modes (continued)



Note: M3 = GND for high-speed CCLK; M3 = V_{DD} for low-frequency CCLK.

5-9739(F).a

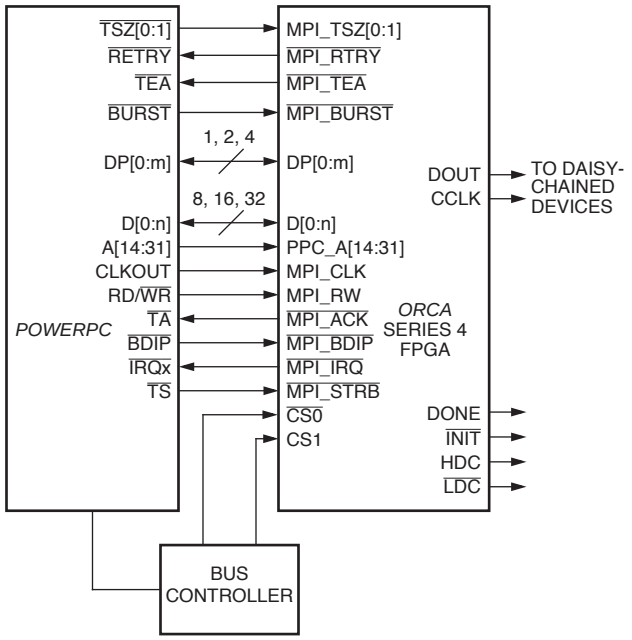
Figure 40. Asynchronous Peripheral Configuration

Microprocessor Interface Mode

The built-in MPI in Series 4 FPGAs is designed for use in configuring the FPGA. Figure 41 show the glueless interface for FPGA configuration and readback from the *PowerPC* processor. When enabled by the mode pins, the MPI handles all configuration/readback control and handshaking with the host processor. For single FPGA configuration, the host sets the configuration control register MPI_PRGM to one then back to zero and, after reading that the configuration write data acknowledge register is high, transfers data 8, 16, or 32 bits at a time to the FPGA's D[#:0] input pins. If configuring multiple FPGAs through daisy-chain operation is desired, the SYS_DAISY bit must be set in the configuration control register of the MPI.

The configuration control register offers control bits to enable the interrupt on a bit stream error. The MPI status register may be used in conjunction with, or in place of, the interrupt request option. The status register contains a 2-bit field to indicate the bit stream error status. A flow chart of the MPI configuration process is shown in Figure 42.

FPGA Configuration Modes (continued)

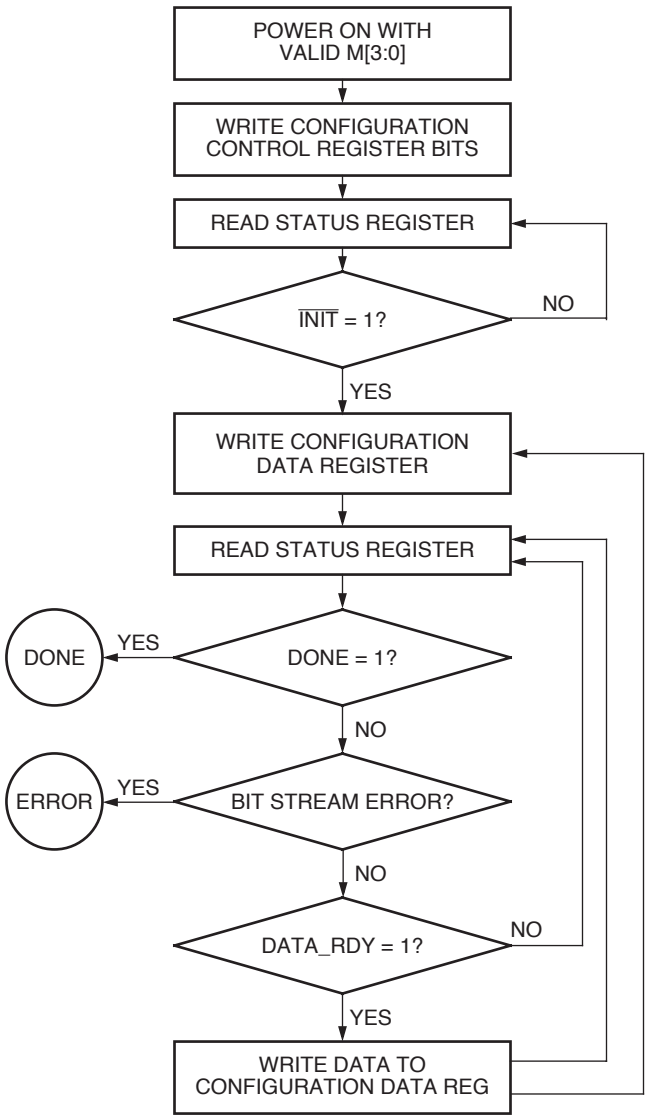


5-9738(F).b

Figure 41. *PowerPC*/MPI Configuration Schematic

Configuration readback can also be performed via the MPI when it is in user mode. The MPI is enabled in user mode by setting the MP_USER_ENABLE bit to 1 in the configuration control register prior to the start of configuration or through a configuration option. To perform readback, the host processor writes the 14-bit readback start address to the readback address registers and sets the SYS_RD_CFG bit to one, then back to zero in the configuration control register. Readback data is returned 8 bits at a time to the readback data register and is valid when the DATA_RDY bit of the status register is 1. There is no error checking during readback. A flow chart of the MPI readback operation is shown in Figure 43. The RD_DATA pin used for dedicated FPGA readback is invalid during MPI readback.

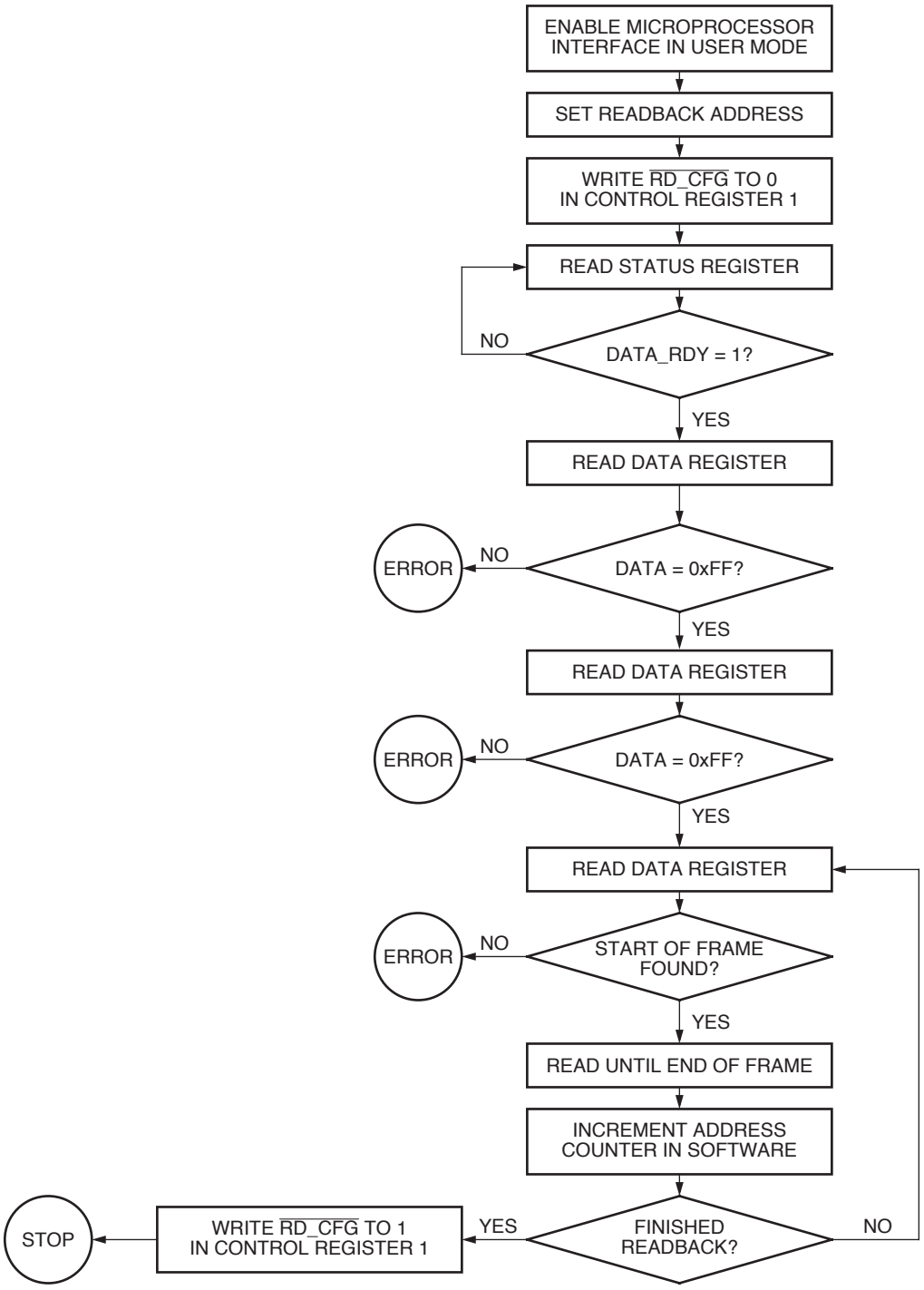
FPGA Configuration Modes (continued)



5-5763(F)

Figure 42. Configuration Through MPI

FPGA Configuration Modes (continued)



5-5764(F)

Figure 43. Readback Through MPI

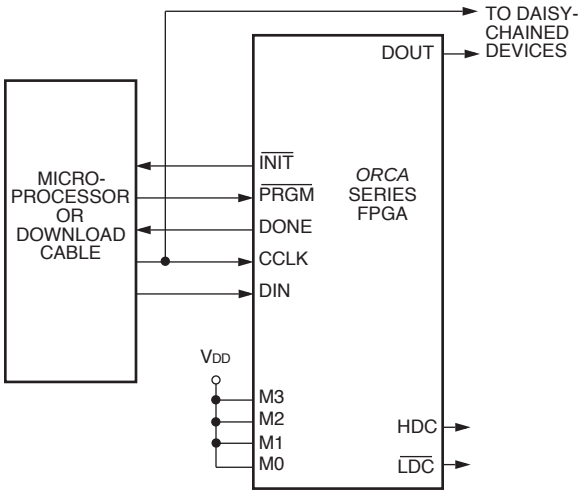
FPGA Configuration Modes (continued)

Slave Serial Mode

The slave serial mode is primarily used when multiple FPGAs are configured in a daisy-chain (see the Daisy-Chaining section). It is also used on the FPGA evaluation board that interfaces to the download cable. A device in the slave serial mode can be used as the lead device in a daisy-chain. Figure 44 shows the connections for the slave serial configuration mode.

The configuration data is provided into the FPGA's DIN input synchronous with the configuration clock CCLK input. After the FPGA has loaded its configuration data, it retransmits the incoming configuration data on DOUT at the rising edge of CCLK. CCLK is routed into all slave serial mode devices in parallel.

Multiple slave FPGAs can be loaded with identical configurations simultaneously. This is done by loading the configuration data into the DIN inputs in parallel.



5-4485(F).a

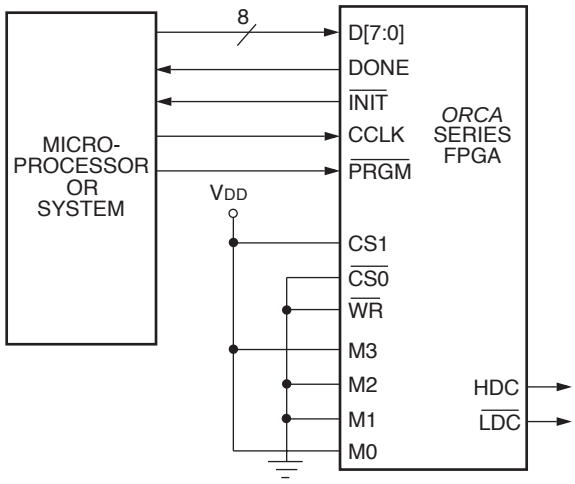
Figure 44. Slave Serial Configuration Schematic

Slave Parallel Mode

The slave parallel mode is essentially the same as the slave serial mode except that 8 bits of data are input on pins D[7:0] for each CCLK cycle. Due to 8 bits of data being input per CCLK cycle, the DOUT pin does not contain a valid bit stream for slave parallel mode. As a result, the lead device cannot be used in the slave parallel mode in a daisy-chain configuration.

Figure 45 is a schematic of the connections for the slave parallel configuration mode. $\overline{WR}$ and $\overline{CS0}$ are active-low chip select signals, and CS1 is an active-high chip select signal. These chip selects allow the user to configure multiple FPGAs in slave parallel mode using an 8-bit data bus common to all of the FPGAs. These chip selects can then be used to select the FPGAs to be configured with a given bit stream. The chip selects must be active for each valid CCLK cycle until the device has been completely programmed. They can be inactive between cycles but must meet the setup and hold times for each valid positive CCLK. D[7:0] of the FPGA can be connected to D[7:0] of the microprocessor only if a standard prom file format is used. If a .bit or .rbt file is used from ispLEVER, then the user must mirror the bytes in the .bit or .rbt file OR leave the .bit or .rbt file unchanged and connect D[7:0] of the FPGA to D[0:7] of the microprocessor.

FPGA Configuration Modes (continued)



5-4487(F).a

Figure 45. Slave Parallel Configuration Schematic

Daisy-Chaining

Multiple FPGAs can be configured by using a daisy-chain of the FPGAs. Daisy-chaining uses a lead FPGA and one or more FPGAs configured in slave serial mode. The lead FPGA can be configured in any mode except slave parallel mode.

All daisy-chained FPGAs are connected in series. Each FPGA reads and shifts the preamble and length count in on positive CCLK and out on positive CCLK edges.

An upstream FPGA that has received the preamble and length count outputs a high on DOUT until it has received the appropriate number of data frames so that downstream FPGAs do not receive frame start indications. After loading and retransmitting the preamble and length count to a daisy-chain of slave devices, the lead device loads its configuration data frames. The loading of configuration data continues after the lead device has received its configuration data if its internal frame bit counter has not reached the length count. When the configuration RAM is full and the number of bits received is less than the length count field, the FPGA shifts any additional data out on DOUT.

The configuration data is read into DIN of slave devices on the positive edge of CCLK, and shifted out DOUT on the positive edge of CCLK. Figure 46 shows the connections for loading multiple FPGAs in a daisy-chain configuration.

The generation of CCLK for the daisy-chained devices that are in slave serial mode differs depending on the configuration mode of the lead device. A master parallel mode device uses its internal timing generator to produce an internal CCLK at eight times its memory address rate (RCLK). The asynchronous peripheral mode and MPI mode device outputs eight CCLKs for each write cycle. If the lead device is configured in slave mode, CCLK must be routed to the lead device and to all of the daisy-chained devices.

FPGA Configuration Modes (continued)

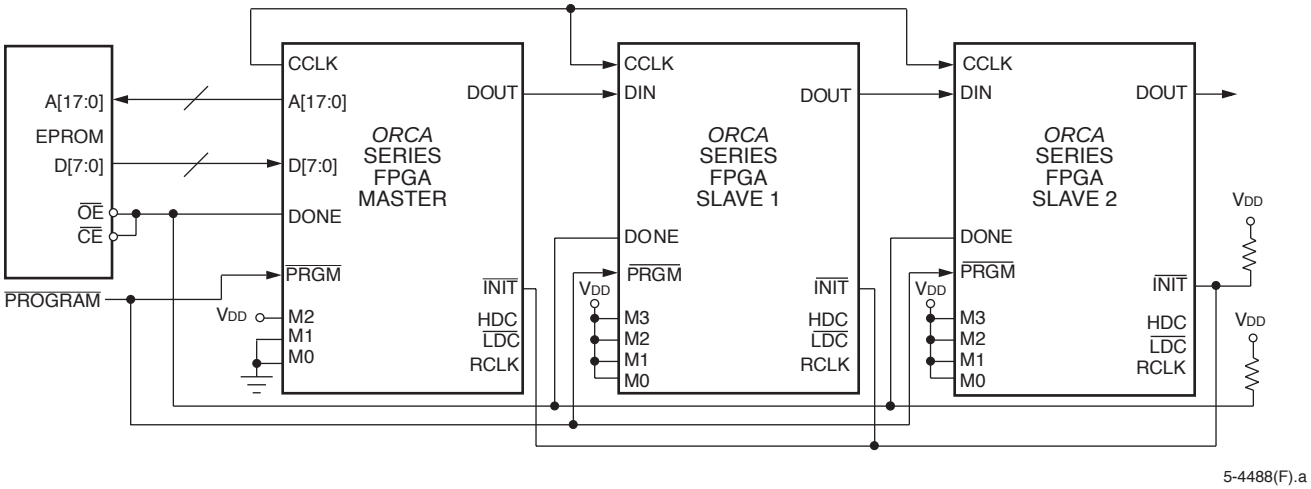


Figure 46. Daisy-Chain Configuration Schematic

As seen in Figure 46, the $\overline{\text{INIT}}$ pins for all of the FPGAs are connected together. This is required to guarantee that powerup and initialization will work correctly. In general, the DONE pins for all of the FPGAs are also connected together as shown to guarantee that all of the FPGAs enter the start-up state simultaneously. This may not be required, depending upon the start-up sequence desired.

Daisy-Chaining with Boundary-Scan

Multiple FPGAs can be configured through the JTAG ports by using a daisy-chain of the FPGAs. This daisy-chaining operation is available upon initial configuration after powerup, after a power-on reset, after pulling the program pin to reset the chip, or during a reconfiguration if the EN_JTAG RAM has been set.

All daisy-chained FPGAs are connected in series. Each FPGA reads and shifts the preamble and length count in on the positive TCK and out on the negative TCK edges.

An upstream FPGA that has received the preamble and length count outputs a high on TDO until it has received the appropriate number of data frames so that downstream FPGAs do not receive frame start bit pairs. After loading and retransmitting the preamble and length count to a daisy-chain of downstream devices, the lead device loads its configuration data frames.

The loading of configuration data continues after the lead device had received its configuration read into TDI of downstream devices on the positive edge of TCK, and shifted out TDO on the negative edge of TCK.

Absolute Maximum Ratings

Stresses in excess of the absolute maximum ratings can cause permanent damage to the device. These are absolute stress ratings only. Functional operation of the device is not implied at these or any other conditions in excess of those given in the operations sections of this data sheet. Exposure to absolute maximum ratings for extended periods can adversely affect device reliability.

The *ORCA* Series FPGAs include circuitry designed to protect the chips from damaging substrate injection currents and to prevent accumulations of static charge. Nevertheless, conventional precautions should be observed during storage, handling, and use to avoid exposure to excessive electrical stress.

Table 34. Absolute Maximum Ratings

Parameter	Symbol	Min	Max	Unit
Storage Temperature	T_{stg}	–65	150	°C
Power Supply Voltage with Respect to Ground	$V_{DD}33$	–0.3	4.2	V
	$V_{DD}IO$	–0.3	4.2	V
	$V_{DD}15$	–0.3	2.0	V
Input Signal with Respect to Ground	V_{IN}	– 0.3	$V_{DD}IO$ + 0.3	V
Signal Applied to High-impedance Output	—	– 0.3	$V_{DD}IO$ + 0.3	V
Maximum Package Body (Soldering) Temperature	—	—	220	°C

Note: Overshoot and undershoot of -2V to (V_{IHMAX} +2) volts is permitted for a duration of <20ns.

Recommended Operating Conditions

Table 35. Recommended Operating Conditions

Parameter	Symbol	Min	Max	Unit
Power Supply Voltage with Respect to Ground	$V_{DD}33$	3.0	3.6	V
	$V_{DD}IO$	1.4	3.6	V
	$V_{DD}15$	1.425	1.575	V
Input Signal with Respect to Ground	V_{IN}	– 0.3	$V_{DD}IO$ + 0.3	V
Junction Temperature	T_J	–40	125	°C

Note:
1. The maximum recommended junction temperature (T_J) during operation is 125 °C.
2. Timing parameters in this data sheet an ispLEVER are characterized under higher voltage and temperature conditions than the recommended operating conditions in this table.
3. The internal PLLs operate from the $V_{DD}33$ power supply. This power supply should be well isolated from all other power supplies on the board for proper operation.

Electrical Characteristics

Table 36. Electrical Characteristics

OR4Exx Industrial: $V_{DD}15$ = 1.4 V to 1.6 V, $V_{DD}33$ = 3.0 V to 3.6 V, $V_{DD}IO$ = 3.0 V to 3.6 V, –40 °C < T_A < +125 °C; C_L = 30 pF.

Parameter	Symbol	Test Conditions	OR4Exx			Unit
			Min	Typ	Max	
Input Leakage Current	I_L	$V_{DD}IO$ = max, V_{IN} = V_{SS} or $V_{DD}IO$	– 10	—	10	µA
Standby Current ($V_{DD}15$):	$I_{DD}SB15$	T_A = 25 °C, $V_{DD}15$ = 1.6 V,				
OR4E02		$V_{DD}33$ = 3.6 V, $V_{DD}IO$ = 3.6 V,	—	5	200	mA
OR4E04		internal oscillator running, no output loads,	—	10	200	mA
OR4E06		inputs $V_{DD}IO$ or V_{SS} (after configuration)	—	15	200	mA
		Same conditions except T_A = 85 °C	—	—	500	mA
Standby Current ($V_{DD}33$):	$I_{DD}SB33$	T_A = 25 °C, $V_{DD}15$ = 1.6 V,				
OR4E02		$V_{DD}33$ = 3.6 V, $V_{DD}IO$ = 3.6 V,	—	4	100	mA
OR4E04		internal oscillator stopped, no output loads,	—	7	100	mA
OR4E06		inputs $V_{DD}IO$ or GND (after configuration)	—	10	100	mA
		Same conditions except T_A = 85 °C	—	—	300	mA
Data Retention Voltage ($V_{DD}33$)	$V_{DR}33$	T_J = –40 °C to 125 °C	2.3	—	—	V
Data Retention Voltage ($V_{DD}15$)	$V_{DR}15$	T_J = –40 °C to 125 °C	1.1	—	—	V
DC Input Levels	V_{IL} V_{IH}	Input levels vary per input standard. See the Series 4 IO Application Note for details	Various	—	Various	V
DC Output Levels	V_{OL} V_{OH}	Output levels vary per output standard. See the Series 4 IO Application Note for details	Various	—	Various	V
Output Drive Currents	I_{OL} I_{OH}	Output currents vary per output standard. See the Series 4 IO Application Note for details	Various	—	Various	mA
Input Capacitance	C_{IN}	T_A = 25 °C, $V_{DD}IO$ = 3.6 V, Test frequency = 1 MHz	—	—	5	pF
Output Capacitance	C_{OUT}	T_A = 25 °C, $V_{DD}IO$ = 3.6 V, Test frequency = 1 MHz	—	—	5	pF
DONE Pull-up Resistor*	R_{DONE}	$V_{DD}IO$ = 3.0 V to 3.6 V, V_{IN} = V_{SS}, T_J = –40 °C to 125 °C	100	—	—	kΩ
M[3:0] Pull-up Resistors*	R_M	$V_{DD}IO$ = 3.0 V to 3.6 V, V_{IN} = V_{SS}, T_J = –40 °C to 125 °C	100	—	—	kΩ
I/O Pad Static Pull-up Current*	I_{PU}	$V_{DD}IO$ = 3.0 V to 3.6 V, V_{IN} = V_{SS}, T_J = –40 °C to 125 °C	14.4	—	50.9	µA
I/O Pad Static Pull-down Current	I_{PD}	$V_{DD}IO$ = 3.0 V to 3.6 V, V_{IN} = V_{SS}, T_J = –40 °C to 125 °C	26	—	103	µA
I/O Pad Pull-up Resistor*	R_{PU}	$V_{DD}IO$ = 3.0 V to 3.6 V, V_{IN} = V_{SS}, T_J = –40 °C to 125 °C	100	—	—	kΩ
I/O Pad Pull-down Resistor	R_{PD}	$V_{DD}IO$ = 3.0 V to 3.6 V, V_{IN} = V_{DD}, T_J = –40 °C to 125 °C	50	—	—	kΩ

* The pull-up resistor will externally pull the pin to a level 1.0 V below $V_{DD}IO$.

Note: 1. The Standby Current for $V_{DD}IO$ is variable depending upon I/O types. For LVTTL I/O held at $V_{DD}IO$ or GND, this value is typically less than 1 mA.

Power Estimation

A spreadsheet is available in ispLEVER for detailed power estimates based on circuit implementation details from ispLEVER and user inputs. A quick estimate of power dissipation for a Series 4 device is now presented.

Estimating Power Dissipation

The total operating power dissipated is estimated by adding the standby ($I_{DD}SB$), internal, and external power dissipated. The internal and external power is the power consumed in the PLCs and PICs, respectively. In general, the standby power is small and may be neglected. The total operating power is as follows:

$$P_T = \Sigma P_{INT} + \Sigma P_{IO} + P_{CLK}$$

The internal operating power is made up of two parts: clock generation and PFU/EBR/PIO power. The PFU/EBR/PIO power can be estimated per output based upon the number of PFU/EBR/PIO outputs switching when driving a typical fanout (three X6 lines and nine X1 lines).

$$P_{INT} = 0.015 \text{ mW/MHz}$$

For each PFU/EBR/PIO output that switches, 0.015 mW/MHz needs to be multiplied times the frequency (in MHz) that the output switches. Generally, this can be estimated by using the clock rate multiplied by some activity factor; for example, 20%.

The power dissipated by clocks is due to either global primary clock networks or secondary/edge clock networks. Their power has a fixed component and a variable component based on the number of PFUs, PIOs, or EBRs that use that clock as follows:

- Primary: 0.143 mW/MHz + (0.0033mW/MHz x number of blocks driven)
- Secondary: 0.06 mW/MHz + (0.0029mW/MHz x number of blocks driven)

Clock power is calculated from these equations by multiplying times the clock frequency in MHz. Note that an activity factor (i.e., 100% activity) is not used to calculate clock power.

The device I/O power dissipated is the sum of the power dissipated in the four PIOs in the PIC. This consists of power dissipated by inputs and ac power dissipated by outputs. The power dissipated in each PIO depends on whether it is configured as an input, output, or input/output. If a PIO is operating as an output, then there is a power dissipation component for P_{IN}, as well as P_{OUT}. This is because the output feeds back to the input.

The power dissipated by a LVCMOS2 input buffer is ($V_{IH} = V_{DD} – 0.3$ V or higher) estimated as:

$$P_{IN} = 0.09 \text{ mW/MHz}$$

The ac power dissipation from a LVCMOS2 output or bidirectional is estimated by the following:

$$P_{OUT} = (C_L + 5.0 \text{ pF}) \times V_{DD}^2 \times F \text{ Watts}$$

where the unit for C_L (the output capacitive load) is Farads, and the unit for F is Hz.

For all other I/O buffer types other than LVCMOS2, see the detailed power estimation spreadsheet available in ispLEVER.

Timing Characteristics

To define speed grades, the *ORCA* series part number designation (see Ordering Information) uses a single-digit number to designate a speed grade. This number is not related to any single ac parameter. Higher numbers indicate a faster set of timing parameters. The actual speed sorting is based on testing the delay in a path consisting of an input buffer, combinatorial delay through all PLCs in a row, and an output buffer. Other tests are then done to verify other delay parameters, such as routing delays, setup times to FFs, etc.

The most accurate timing characteristics are reported by the timing analyzer in ispLEVER™ design software. A timing report provided by the development system after layout divides path delays into logic and routing delays. The timing analyzer can also provide logic delays prior to layout. While this allows routing budget estimates, there is wide variance in routing delays associated with different layouts.

The logic timing parameters noted in the Electrical Characteristics section of this data sheet are the same as those in ispLEVER. In the timing tables that follow, symbol names are generally a concatenation of the PFU operating mode (as defined in Table 3) and the parameter type. The setup, hold, and propagation delay parameters, defined below, are designated in the symbol name by the SET, HLD, and DEL characters, respectively. The values given for the parameters are the same as those used during production testing and speed binning of the devices. The junction temperature and supply voltage used to characterize the devices are listed in the delay tables and the delay values in this data sheet are from ispLEVER. Actual delays at nominal temperature and voltage for best-case processes can be much better than the values given.

It should be noted that the junction temperature used in the tables is generally 85 °C or 100 °C, based on the temperature grade of the device. The junction temperature for the FPGA depends on the power dissipated by the device, the package thermal characteristics (Θ_{JA}), and the ambient temperature, as calculated in the following equation and as discussed further in the Package Thermal Characteristics section:

$$T_{Jmax} = T_{Amax} + (P \bullet \Theta_{JA})\ ^\circ C$$

Note: The user must determine this junction temperature to see if the delays from ispLEVER should be derated based on the following derating tables.

Table 37—Table 38 provide approximate power supply and junction temperature derating for Series 4 commercial and industrial devices. The delay values in this data sheet and reported by ispLEVER are shown as **1.00** in the tables. The method for determining the maximum junction temperature is defined in the Package Thermal Characteristics section. Taken cumulatively, the range of parameter values for best-case vs. worst-case processing, supply voltage, and junction temperature can approach 3 to 1.

The typical timing path in Series 4 is made up of both 3.3 V ($V_{DD}IO$ and/or $V_{DD}33$) components and 1.5 V ($V_{DD}15$) components. For example, all I/O circuits use $V_{DD}IO$ at the device interface but all internal routing and I/O register logic use $V_{DD}15$. Thus actual voltage derating needs to be done based on multiple parameters. A simple approximation is that 50% of the delay path is due to each of these parameters. All internal paths use $V_{DD}15$ for logic and $V_{DD}33$ for routing, but if $V_{DD}33$ remains above 3.0 V the internal delays can be assumed to be dependent on $V_{DD}15$ derating values only. Note however that temperature derating is approximately the same percentage for all three supply voltages thus allowing one temperature derating value to be used. For the most accurate results, voltage and temperature derating capabilities to be released in ispLEVER should be used.

Timing Characteristics (continued)

Table 37. I/O Derating for 3.3 V I/Os (V_{DDIO})—Only valid for TTL/CMOS I/Os

T_J (°C) Commercial	T_J (°C) Industrial	Power Supply Voltage				
		3.0 V	3.15 V	3.3 V	3.45 V	3.6 V
–	–40	0.82	0.80	0.77	0.75	0.74
–40	–25	0.83	0.81	0.78	0.76	0.75
0	15	0.87	0.84	0.81	0.80	0.78
25	40	0.91	0.88	0.85	0.82	0.81
85	100	**1.00**	0.97	0.93	0.91	0.88
100	115	1.02	0.99	0.96	0.93	0.90
110	125	1.05	1.01	0.97	0.95	0.92
125	–	1.07	1.03	0.99	0.97	0.94

Table 38. Internal Derating for 1.5V ($V_{DD}15$)

T_J (°C) Commercial	T_J (°C) Industrial	Power Supply Voltage				
		1.40 V	1.425 V	1.500 V	1.575 V	1.6 V
–	–40	0.87	0.85	0.82	0.79	0.78
–40	–25	0.89	0.87	0.83	0.80	0.79
0	15	0.93	0.91	0.87	0.82	0.81
25	40	0.96	0.94	0.89	0.85	0.84
85	100	1.02	**1.00**	0.95	0.91	0.90
100	115	1.04	1.02	0.97	0.93	0.92
110	125	1.05	1.03	0.98	0.94	0.93
125	–	1.06	1.05	1.00	0.96	0.95

In addition to supply voltage, process variation, and operating temperature, circuit and process improvements of the *ORCA* Series FPGAs over time will result in significant improvement of the actual performance over those listed for a speed grade. Even though lower speed grades may still be available, the distribution of yield to timing parameters may be several speed grades higher than that designated on a product brand. Design practices need to consider best-case timing parameters (e.g., delays = 0), as well as worst-case timing.

The routing delays are a function of fan-out and the capacitance associated with the CIPs and metal interconnect in the path. The number of logic elements that can be driven (fan-out) by PFUs is unlimited, although the delay to reach a valid logic level can exceed timing requirements. It is difficult to make accurate routing delay estimates prior to design compilation based on fan-out. This is because the CAE software may delete redundant logic inserted by the designer to reduce fan-out, and/or it may also automatically reduce fan-out by net splitting.

The waveform test points are given in the Input/Output Buffer Measurement Conditions section of this data sheet. The timing parameters given in the electrical characteristics tables in this data sheet follow industry practices, and the values they reflect are described below.

Timing Characteristics (continued)

Propagation Delay—The time between the specified reference points. The delays provided are the worst case of the tphh and tpll delays for noninverting functions, tplh and tphl for inverting functions, and tphz and tplz for 3-state enable.

Setup Time—The interval immediately preceding the transition of a clock or latch enable signal, during which the data must be stable to ensure it is recognized as the intended value.

Hold Time—The interval immediately following the transition of a clock or latch enable signal, during which the data must be held stable to ensure it is recognized as the intended value.

3-State Enable—The time from when a 3-state control signal becomes active and the output pad reaches the high-impedance state.

Table 39. PFU Timing Parameters

OR4Exx commercial: VDD15 = 1.425 V, VDD33 = 3.0 V, TJ = +85 ˚C
OR4Exx industrial: VDD15 = 1.425 V, VDD33 = 3.0 V, TJ = +100 ˚C

Parameter	Symbol	Speed						Unit
		–1		–2		–3		
		Min	Max	Min	Max	Min	Max	
Combinatorial Delays:								
Four-input Variables to LUT out	F4_DEL	—	0.66	—	0.55	—	0.50	ns
Five-input Variables to LUT out	F5_DEL	—	0.77	—	0.64	—	0.58	ns
Six-input Variables to LUT out	F6_DEL	—	1.10	—	0.81	—	0.74	ns
Sequential Delays:								
CLK Low Time	CLKL_MPW	0.36	—	0.35	—	0.32	—	ns
CLK High Time	CLKH_MPW	0.40	—	0.38	—	0.35	—	ns
Four-input Variables to Register CLK setup	F4_SET	0.28	—	0.23	—	0.21	—	ns
Five-input Variables to Register CLK setup	F5_SET	0.38	—	0.28	—	0.25	—	ns
Six-input Variables to Register CLK setup	F6_SET	0.71	—	0.63	—	0.57	—	ns
Data In to Register CLK setup	DIN_SET	0.00	—	0.00	—	0.00	—	ns
Four-input Variables from Register CLK hold	F4_HLD	0.00	—	0.00	—	0.00	—	ns
Five-input Variables from Register CLK hold	F5_HLD	0.10	—	0.16	—	0.15	—	ns
Six-input Variables from Register CLK hold	F6_HLD	0.00	—	0.10	—	0.09	—	ns
Data In from Register CLK hold	DIN-HLD	0.25	—	0.24	—	0.22	—	ns
Register CLK to Out	REG_DEL	1.03	—	0.92	—	0.84	—	ns
PFU CLK to Out (REG_DEL) Delay Adjustments from Cycle Stealing:								
One Delay Cell	CYCDEL1	0.89	—	0.70	—	0.64	—	ns
Two Delay Cells	CYCDEL2	1.64	—	1.29	—	1.18	—	ns
Three Delay Cells	CYCDEL3	2.43	—	1.98	—	1.80	—	ns

Note:
A complete listing of PFU Timing Parameters can be displayed in ispLEVER. This is a sampling of the key timing parameters.

Timing Characteristics (continued)

Table 40. PFU used as Dual-Port RAM: Sync. Write and Sync. or Async. Read Timing Characteristics

OR4Exx commercial: VDD15 = 1.425 V, VDD33 = 3.0 V, TJ = +85 ˚C
OR4Exx industrial: VDD15 = 1.425 V, VDD33 = 3.0 V, TJ = +100 ˚C

Parameter	Symbol	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
Write Operation for RAM Mode:								
Maximum Write Clock Frequency	SMWCLK_FRQ	—	300.00	—	382.00	—	422.00	MHz
Write Data to CLK Setup Time	WD_SET	0.00	—	0.00	—	0.00	—	ns
Write CLK to Data Out	MEM_DEL	—	2.21	—	1.89	—	1.71	ns
Async Read Operation for RAM Mode:								
Data Out Valid After Address	RA_DEL	—	0.66	—	0.55	—	0.50	ns
Sync Read Operation for RAM Mode:								
Maximum Read Clock Frequency	SMRCLK_FRQ	—	300.00	—	382.00	—	422.00	MHz
Read CLK to Data Out	REG_DEL	—	1.03	—	0.92	—	0.84	ns

Note: A complete listing of PFU timing parameters can be displayed in ispLEVER. This is a sampling of the key timing parameters.

Timing Characteristics (continued)

Table 41. Embedded Block RAM (EBR) Timing Characteristics (512 x 18) Quad-Port RAM Mode

OR4Exx commercial: VDD15 = 1.425 V, VDD33 = 3.0 V, TJ = +85 ˚C
OR4Exx industrial: VDD15 = 1.425 V, VDD33 = 3.0 V, TJ = +100 ˚C

Parameter	Symbol	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
Write Operation for RAM Mode:								
Maximum Write Clock Frequency	EBRWCLK_FRQ	—	200.0	—	217.0	—	225.0	MHz
Write Data to Write Clock Setup Time	D*_CKW*_SET	0.39	—	0.37	—	0.34	—	ns
Write Address to Write Clock Setup Time	A*_CKW*_SET	0.60	—	0.58	—	0.52	—	ns
Async Read Operation for RAM Mode:								
Data Out Valid After Read Address	EBR_RA_DEL	—	4.72	—	4.48	—	4.06	ns
Sync Read Operation for RAM Mode:								
Maximum Read Clock Frequency	EBRRCLK_FRQ	—	200.0	—	217.0	—	225.0	MHz
Read Address to Read Clock Setup Time (OUTREG Mode)	AR*_CKR*_SET	0.59	—	0.56	—	0.51	—	ns
Read Clock to Data Out (IOREG or OUTREG modes)	CKR*_Q*_DEL	—	2.39	—	2.27	—	2.06	ns

Note: A complete listing of EBR Timing Parameters can be displayed in ispLEVER. This is a sampling of the key timing parameters.

Table 42. Supplemental Logic and Interconnect Cell (SLIC) Timing Characteristics

OR4Exx commercial: VDD15 = 1.425 V, VDD33 = 3.0 V, TJ = +85 ˚C
OR4Exx industrial: VDD15 = 1.425 V, VDD33 = 3.0 V, TJ = +100 ˚C

Parameter	Symbol	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
3-Statable BIDIs								
BIDI Buffer Delay	BUF_DEL	—	0.35	—	0.35	—	0.32	ns
BIDI 3-state Enable/Disable Delay	TRI_DEL	—	0.39	—	0.35	—	0.32	ns
Decoder								
Decoder Delay (BR[9:8], BL[9:8] to DEC)	DEC_DEL	—	0.89	—	0.81	—	0.73	—

Note: A complete listing of SLIC Timing Parameters can be displayed in ispLEVER. This is a sampling of the key timing parameters.

Timing Characteristics (continued)

Table 43. PIO Input Buffer Timing Characteristics

OR4Exx commercial: VDD15 = 1.425 V, VDD33 = 3.0 V, VDDIO = Min, TJ = +85 ˚C
OR4Exx industrial: VDD15 = 1.425 V, VDD33 = 3.0 V, VDDIO = Min, TJ = +100 ˚C

Parameter	Symbol	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
Input Delays								
Input Rise Time	IN_RIS	—	100	—	100	—	100	ns
Input Fall Time	IN_FAL	—	100	—	100	—	100	ns
Input Delay Adjustments from LVTTL:								
LVCMOS2 (2.5 V)	IN_LVCMOS25	—	0.54	—	0.44	—	0.40	ns
LVCMOS18 (1.8 V)	IN_LVCMOS15	—	1.91	—	1.50	—	1.36	ns
LVDS	IN_LVDS	—	–0.04	—	0.10	—	0.09	ns
LVDSE	IN_LVDSE	—	0.30	—	0.32	—	0.29	ns
LVPECL	IN_LVPECL	—	–0.31	—	–0.21	—	–0.19	ns
PCI_33 (3.3 V)	IN_PCI_33	—	0.59	—	0.50	—	0.45	ns
PCI_66 (3.3 V)	IN_PCI_66	—	0.59	—	0.50	—	0.45	ns
GTL	IN_GTL	—	5.32	—	4.68	—	4.26	ns
GTLP (GTL+)	IN_GTLP	—	1.87	—	2.04	—	1.86	ns
HSTL_I	IN_HSTL_I	—	–0.05	—	–0.06	—	–0.06	ns
HSTL_II	IN_HSTL_II	—	–0.05	—	–0.06	—	–0.06	ns
HSTL_III	IN_HSTL_III	—	–0.20	—	–0.13	—	–0.12	ns
HSTL_IV	IN_HSTL_IV	—	–0.20	—	–0.13	—	–0.12	ns
SSTL2_I	IN_SSTL2_I	—	2.28	—	1.66	—	1.51	ns
SSTL2_II	IN_SSTL2_II	—	2.28	—	1.66	—	1.51	ns
SSTL3_I	IN_SSTL3_I	—	0.78	—	0.69	—	0.63	ns
SSTL3_II	IN_SSTL3_II	—	0.78	—	0.69	—	0.63	ns
PECL	IN_PECL	—	0.83	—	0.72	—	0.65	ns

Notes:
The delays for all input buffers assume an input rise/fall time of <1 V/ns.
The values in the above table should be used to modify the information in Table 46 through Table 52, which are all based on LVTTL input timing.

Timing Characteristics (continued)

Table 44. PIO Output Buffer Timing Characteristics

OR4Exx commercial: VDD15 = 1.425 V, VDD33 = 3.0 V, VDDIO = Min, TJ = +85 ˚C
OR4Exx industrial: VDD15 = 1.425 V, VDD33 = 3.0 V, VDDIO = Min, TJ = +100 ˚C

Parameter	Symbol	Speed						Unit	Output Load (pF)
		-1		-2		-3			
		Min	Max	Min	Max	Min	Max		
Output Delays									
Output Delay Adjustments from OLVTTL_F12:									
LVTTL_S6 (Slew Limited, 6 mA)	OUT_LVTTL_S6	—	2.01	—	1.72	—	1.56	ns	30 pF
LVTTL_S12 (Slew Limited, 12 mA)	OUT_LVTTL_S12	—	1.25	—	1.06	—	0.97	ns	30 pF
LVTTL_S24 (Slew Limited, 24 mA)	OUT_LVTTL_S24	—	0.76	—	0.60	—	0.55	ns	30 pF
LVTTL_F6 (Fast, 6 mA)	OUT_LVTTL_F6	—	0.72	—	0.68	—	0.61	ns	30 pF
LVTTL_F24 (Fast, 24 mA)	OUT_LVTTL_F24	—	–0.35	—	–0.32	—	–0.29	ns	30 pF
LVCMOS18_S6 (Slew Limited, 6 mA)	OUT_CMOS18_S6	—	6.91	—	5.36	—	4.87	ns	30 pF
LVCMOS18_S12 (Slew Limited, 12 mA)	OUT_CMOS18_S12	—	6.23	—	3.90	—	3.55	ns	30 pF
LVCMOS18_S24 (Slew Limited, 24 mA)	OUT_CMOS18_S24	—	4.50	—	3.29	—	2.99	ns	30 pF
LVCMOS18_F6 (Fast, 6 mA)	OUT_CMOS18_F6	—	4.75	—	3.83	—	3.48	ns	30 pF
LVCMOS18_F12 (Fast, 12 mA)	OUT_CMOS18_F12	—	2.38	—	1.86	—	1.69	ns	30 pF
LVCMOS18_F24 (Fast, 24 mA)	OUT_CMOS18_F24	—	1.23	—	0.90	—	0.82	ns	30 pF
LVCMOS2_S6 (Slew Limited, 6 mA)	OUT_CMOS18_S6	—	3.26	—	2.66	—	2.42	ns	30 pF
LVCMOS2_S12 (Slew Limited, 12 mA)	OUT_CMOS18_S12	—	2.09	—	1.69	—	1.54	ns	30 pF
LVCMOS2_S24(Slew Limited, 24 mA)	OUT_CMOS18_S24	—	1.58	—	1.23	—	1.12	ns	30 pF
LVCMOS2_F6 (Fast, 6 mA)	OUT_CMOS18_F6	—	1.80	—	1.59	—	1.44	ns	30 pF
LVCMOS2_F12 (Fast, 12 mA)	OUT_CMOS18_F12	—	0.61	—	0.50	—	0.45	ns	30 pF
LVCMOS2_F24 (Fast, 24 mA)	OUT_CMOS18_F24	—	0.03	—	–0.03	—	–0.03	ns	30 pF
LVDS	OUT_LVDS	—	0.07	—	0.00	—	0.00	ns	*
LVDSE	OUT_LVDSE	—	-0.09	—	0.02	—	0.02	ns	*
LVPECL	OUT_LVPECL	—	–0.57	—	–0.55	—	–0.50	ns	*
PCI_33 (3.3V)	OUT_PCI_33	—	4.84	—	3.42	—	3.11	ns	10 pF
PCI_66 (3.3V)	OUT_PCI_66	—	4.84	—	3.42	—	3.11	ns	10 pF
GTL	OUT_GTL	—	3.22	—	2.45	—	2.23	ns	*
GTLP (GTL+)	OUT_GTLP	—	3.60	—	2.76	—	2.51	ns	*
HSTL_I	OUT_HSTL_I	—	1.89	—	1.30	—	1.18	ns	20 pF
HSTL_II	OUT_HSTL_II	—	1.89	—	1.30	—	1.18	ns	20 pF
HSTL_III	OUT_HSTL_III	—	2.78	—	1.78	—	1.62	ns	20 pF
HSTL_IV	OUT_HSTL_IV	—	2.78	—	1.78	—	1.62	ns	20 pF
SSTL2_I	OUT_SSTL2_I	—	–0.15	—	–0.18	—	–0.16	ns	30 pF
SSTL2_II	OUT_SSTL2_II	—	–0.15	—	–0.18	—	–0.16	ns	30 pF
SSTL3_I	OUT_SSTL3_I	—	–0.50	—	–0.41	—	–0.37	ns	30 pF
SSTL3_II	OUT_SSTL3_II	—	–0.50	—	–0.41	—	–0.37	ns	30 pF
PECL	OUT_PECL	—	0.12	—	0.16	—	0.15	ns	25 pF
Output Delay Adjustments from Cycle Stealing (typically used to adjust setup vs. clk->out):									
One Delay Cell	OCYCDEL1	0.89	—	0.70	—	0.64	—	ns	—
Two Delay Cells	OCYCDEL2	1.64	—	1.29	—	1.18	—	ns	—
Three Delay Cells	OCYCDEL3	2.43	—	1.98	—	1.80	—	ns	—

* See the Series 4 PIO Application note for output load conditions on these output buffer types.

Note: The values in the above table should be used to modify the information in Table 46 through Table 48, which are all based on OLVTTL_F12 outputs.

Timing Characteristics (continued)

Table 45. Primary Clock Skew to any PFU or PIO Register

OR4Exx commercial/industrial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, –40 °C < TJ < +125 °C.

Description	Device	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
Primary Clock Skew Information (pos edge to pos edge or neg edge to neg edge)	OR4E02	—	85	—	75	—	70	ps
	OR4E04	—	110	—	95	—	90	ps
	OR4E06	—	120	—	105	—	100	ps
Primary Clock Skew Information (pos edge to pos edge, neg edge to neg edge, pos edge to neg edge or neg edge to pos edge)	OR4E02	—	265	—	190	—	180	ps
	OR4E04	—	285	—	210	—	200	ps
	OR4E06	—	300	—	220	—	210	ps

Table 46. Secondary Clock to Output Delay without on-chip PLLs (Pin-to-Pin)

OR4Exx commercial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +85 °C.; CL = 30 pF
OR4Exx industrial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +100 °C.; CL = 30 pF.

Description	Device	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
SCLK → OUTPUT Pin (LVTTL-12 mA Fast, Output within 6 PICs of SCLK input)	All	—	7.22	—	6.70	—	6.06	ns
Additional Delay per each extra 6 PICs per clock route direction.	All	—	0.36	—	0.38	—	0.34	ns

Notes:
1. Timing is without the use of the phase-locked loops (PLLs).
2. This clock delay is for a fully routed clock tree that uses the secondary clock network. It includes the LVTTL (3.3 V) input clock buffer, the clock routing to the PIO CLK input, the clock→Q of the FF, and the delay through the LVTTL (3.3 V) data output buffer. An SCLK input clock can be at any input pin.
3. For timing improvements using other I/O buffer types for the input clock buffer or output data buffer, see Table 53 and Table 55.

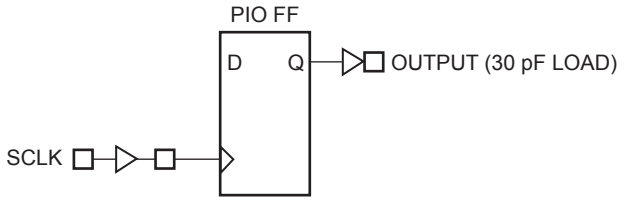


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Figure 47. Secondary CLK to Output Delay

Timing Characteristics (continued)

Table 47. Primary CLK (PCLK) to Output Delay without on-chip PLLs (Pin-to-Pin)

OR4Exx commercial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +85 °C; CL = 30 p.
OR4Exx industrial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +100 °C; CL = 30 p.

Description	Device	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
PCLK Input Pin →OUTPUT Pin (LVTTL-12 mA Fast)	OR4E02	—	9.00	—	8.03	—	7.28	ns
	OR4E04	—	9.24	—	8.23	—	7.46	ns
	OR4E06	—	9.42	—	8.41	—	7.62	ns

Notes:
1. Timing is without the use of the phase-locked loops (PLLs).
2. This clock delay is for a fully routed clock tree that uses the primary clock network. It includes both the LVTTL (3.3 V) input clock buffer delay, the clock routing to the PIO CLK input, the clock→Q of the FF, and the delay through the LVTTL (3.3 V) data output buffer. The PCLK input clock is connected at the semi-dedicated primary clock input pins.
3. For timing improvements using other I/O buffer types for the input clock buffer or output data buffer, see Table 53 and Table 55.

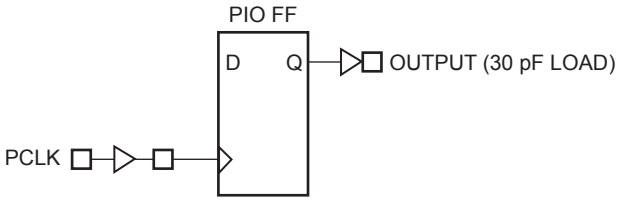

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Figure 48. Primary Clock to Output Delay

Table 48. Primary CLK (PCLK) to Output Delay using on-chip PLLs (Pin-to-Pin)

OR4Exx commercial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +85 °C; CL = 30 p.
OR4Exx industrial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +100 °C; CL = 30 p.

Description	Device	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
PCLK Input Pin →OUTPUT Pin (LVTTL-12 mA Fast)	OR4E02	—	5.53	—	5.00	—	4.54	ns
	OR4E04	—	5.54	—	5.00	—	4.55	ns
	OR4E06	—	5.53	—	5.00	—	4.54	ns
PLL Delay Adjustments from Cycle Stealing (used to reduce clk->out by the min delay value shown):								
One Delay Cell	All	—	0.89	—	0.70	—	0.64	ns
Two Delay Cells	All	—	1.64	—	1.29	—	1.18	ns
Three Delay Cells	All	—	2.43	—	1.98	—	1.80	ns

Notes:
1. Timing uses the automatic delay compensation mode of the PLLs. The feedback to the PLL is provided by the global system clock routing. Other delay values are possible by using the phase modifications mode of the PLL instead.
2. This clock delay is for a fully routed clock tree that uses the primary clock network. It includes both the LVTTL (3.3 V) input clock buffer delay, a PLL block, the clock routing to the PIO CLK input, the clock→Q of the FF, and the delay through the LVTTL (3.3 V) data output buffer. The PCLK input clock is connected at the semi-dedicated PLL input pin.
3. For timing improvements using other I/O buffer types for the input clock buffer or output data buffer, see Table 53 and Table 55.

Timing Characteristics (continued)

Table 49. Secondary CLK (SCLK) Setup/Hold Time without on-chip PLLs (Pin-to-Pin)

OR4Exx commercial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +85 °C
OR4Exx industrial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +100 °C

Description	Device	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
Input to SCLK Setup Time (Input within 6 PICs of SCLK input), Fast Capture Enabled	All	5.99	—	5.60	—	5.11	—	ns
Input to SCLK Setup Time (Input within 6 PICs of SCLK input), No Input Data Delay	All	0.00	—	0.00	—	0.00	—	ns
Reduced Setup Time per each extra 6 PICs per clock route direction.	All	0.36	—	0.38	—	0.34	—	ns
Input to SCLK Hold Time (Input within 6 PICs of SCLK input), Fast Capture Enabled	All	0.00	—	0.00	—	0.00	—	ns
Input to SCLK Hold Time (Input within 6 PICs of SCLK input), No Input Data Delay	All	3.12	—	3.09	—	2.79	—	ns
Additional Hold Time per each extra 6 PICs per clock route direction.	All	0.36	—	0.38	—	0.34	—	ns
Input Delay Adjustments from PIO Cycle Stealing (typically used to reduce setup time by the min value shown):								
One Delay Cell	All	—	0.89	—	0.70	—	0.64	ns
Two Delay Cells	All	—	1.64	—	1.29	—	1.18	ns
Three Delay Cells	All	—	2.43	—	1.98	—	1.80	ns

Notes:
1. The pin-to-pin timing parameters in this table will match ispLEVER if the clock delay multiplier in the setup preference is set to 0.95 for setup time and 1.05 for hold time.
2. Timing is without the use of the phase-locked loops (PLLs) or PIO input FF cycle stealing delays (which can provide reductions in setup time at the expense of hold time).
3. This setup/hold time is for a fully routed clock tree that uses the secondary clock network. It includes both the LVTTL (3.3 V) input clock buffer delay, the clock routing to the PIO CLK input, the setup/hold time of the PIO FF (with the data input delay disabled) and the LVTTL (3.3 V) input data buffer to PIO FF delay. An SCLK input clock can be at any input pin.
4. For timing improvements using other I/O buffer types for the input clock buffer or input data buffer, see Table 53.
5. The ORT8850H FPSC has slightly reduced performance from the values in this table. ispLEVER will report the actual delay values for all devices, including the ORT8850H in this arrangement.

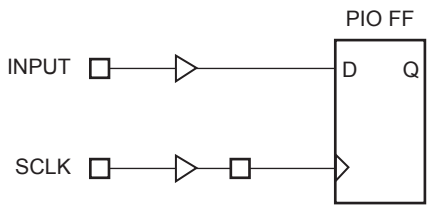

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Figure 49. Input to Secondary CLK Setup/Hold Time

Timing Characteristics (continued)

Table 50. Edge CLK (ECLK) Setup/Hold Time without on-chip PLLs (Pin-to-Pin)

OR4Exx commercial: $V_{DD}15$ = 1.425 V to 1.575 V, $V_{DD}33$ = 3.0 V to 3.6 V, $V_{DD}IO$ = 3.0 V to 3.6 V, –40 °C < T_J < +85 °C

OR4Exx industrial: $V_{DD}15$ = 1.425 V to 1.575 V, $V_{DD}33$ = 3.0 V to 3.6 V, $V_{DD}IO$ = 3.0 V to 3.6 V, –40 °C < T_J < +100 °C

Description	Device	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
Input to ECLK Setup Time (Input within 6 PICs of ECLK input), Fast Capture Enabled	All	1.13	—	1.17	—	1.08	—	ns
Input to ECLK Setup Time (Input within 6 PICs of ECLK input), Fast Input Enabled	All	0.00	—	0.00	—	0.00	—	ns
Reduced Setup Time per each extra 6 PICs per clock route direction.	All	0.36	—	0.38	—	0.34	—	ns
Input to ECLK Hold Time (Input within 6 PICs of ECLK input), Fast Capture Enabled	All	0.00	—	0.00	—	0.00	—	ns
Input to ECLK Hold Time (Input within 6 PICs of ECLK input), Fast Input Enabled	All	1.68	—	1.65	—	1.40	—	ns
Additional Hold Time per each extra 6 PICs per clock route direction.	All	0.36	—	0.38	—	0.34	—	ns
Input Delay Adjustments from PIO Cycle Stealing (typically used to reduce setup time by the min value shown):								
One Delay Cell	All	—	0.89	—	0.70	—	0.64	ns
Two Delay Cells	All	—	1.64	—	1.29	—	1.18	ns
Three Delay Cells	All	—	2.43	—	1.98	—	1.80	ns

Notes:
1. The pin-to-pin timing parameters in this table will match ispLEVER if the clock delay multiplier in the setup preference is set to 0.95 for setup time and 1.05 for hold time.
2. Timing is without the use of the phase-locked loops (PLLs) or PIO input FF cycle stealing delays (which can provide reductions in setup time at the expense of hold time).
3. This setup/hold time is for a fully routed clock tree that uses the Edge Clock network. It includes both the LVTTL (3.3 V) input clock buffer delay, the clock routing to the PIO CLK input, the setup/hold time of the PIO FF (with the data input delay disabled) and the LVTTL (3.3 V) input data buffer to PIO FF delay. Edge clocks can only be connected to one pin or pin-pair per PIC, those ending in the letter C for singled-ended and those ending in C and D for differential inputs. See the pinout section for more details.
4. For timing improvements using other I/O buffer types for the input clock buffer or input data buffer, see Table 53.
5. The ORT8850H FPSC has slightly reduced performance from the values in this table. ispLEVER will report the actual delay values for all devices, including the ORT8850H in this arrangement.

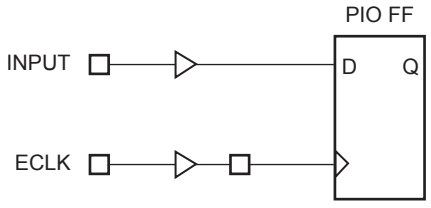

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Figure 50. Input to Edge CLK Setup/Hold Time

Timing Characteristics (continued)

Table 51. Primary CLK (PCLK) Setup/Hold Time without on-chip PLLs (Pin-to-Pin)

OR4Exx commercial: $V_{DD}15$ = 1.425 V to 1.575 V, $V_{DD}33$ = 3.0 V to 3.6 V, $V_{DD}IO$ = 3.0 V to 3.6 V, –40 °C < T_J < +85 °C
OR4Exx industrial: $V_{DD}15$ = 1.425 V to 1.575 V, $V_{DD}33$ = 3.0 V to 3.6 V, $V_{DD}IO$ = 3.0 V to 3.6 V, –40 °C < T_J < +100 °C

Description	Device	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
Input to PCLK Setup Time, Input Data Delay Enabled	OR4E02	4.42	—	4.41	—	4.04	—	ns
	OR4E04	4.24	—	4.26	—	3.90	—	ns
	OR4E06	4.11	—	4.14	—	3.80	—	ns
Input to PCLK Setup Time, No Input Data Delay	OR4E02	0.00	—	0.00	—	0.00	—	ns
	OR4E04	0.00	—	0.00	—	0.00	—	ns
	OR4E06	0.00	—	0.00	—	0.00	—	ns
Input to PCLK Hold Time, Input Data Delay Enabled	OR4E02	0.00	—	0.00	—	0.00	—	ns
	OR4E04	0.00	—	0.00	—	0.00	—	ns
	OR4E06	0.00	—	0.00	—	0.00	—	ns
Input to PCLK Hold Time, No Input Data Delay	OR4E02	4.98	—	4.50	—	4.07	—	ns
	OR4E04	5.22	—	4.71	—	4.26	—	ns
	OR4E06	5.43	—	4.89	—	4.42	—	ns
Input Delay Adjustments from PIO Cycle Stealing (used to reduce setup time by the min value shown):								
One Delay Cell	All	—	0.89	—	0.70	—	0.64	ns
Two Delay Cells	All	—	1.64	—	1.29	—	1.18	ns
Three Delay Cells	All	—	2.43	—	1.98	—	1.80	ns

Notes:
1. The pin-to-pin timing parameters in this table will match ispLEVER if the clock delay multiplier in the setup preference is set to 0.95 for setup time and 1.05 for hold time.
2. Timing is without the use of the phase-locked loops (PLLs) or PIO input FF cycle stealing delays (which can provide reductions in setup time at the expense of hold time).
3. This setup/hold time is for a fully routed clock tree that uses the primary clock network. It includes both the LVTTL (3.3 V) input clock buffer delay, the clock routing to the PIO CLK input, the setup/hold time of the PIO FF (with the data input delay disabled) and the LVTTL (3.3 V) input data buffer to PIO FF delay. The PCLK input clock is connected at the semi-dedicated primary clock input pins.
4. For timing improvements using other I/O buffer types for the input clock buffer or input data buffer, see Table 53.

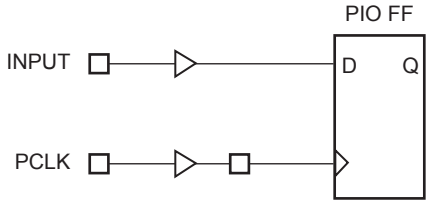

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Figure 51. Input to Primary Clock Setup/Hold Time

Timing Characteristics (continued)

Table 52. Primary CLK (PCLK) Setup/Hold Time using on-chip PLLs (Pin-to-Pin)

OR4Exx commercial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +85 °C
OR4Exx industrial: VDD15 = 1.425 V to 1.575 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +100 °C

Description	Device	Speed						Unit
		-1		-2		-3		
		Min	Max	Min	Max	Min	Max	
Input to PCLK Setup Time, Input Data Delay Enabled	OR4E02	7.92	—	7.48	—	6.81	—	ns
	OR4E04	8.01	—	7.56	—	6.88	—	ns
	OR4E06	8.08	—	7.62	—	6.94	—	ns
Input to PCLK Setup Time, No Input Data Delay	OR4E02	0.00	—	0.00	—	0.00	—	ns
	OR4E04	0.00	—	0.00	—	0.00	—	ns
	OR4E06	0.00	—	0.00	—	0.00	—	ns
Input to PCLK Hold Time, Input Data Delay Enabled	OR4E02	0.00	—	0.00	—	0.00	—	ns
	OR4E04	0.00	—	0.00	—	0.00	—	ns
	OR4E06	0.00	—	0.00	—	0.00	—	ns
Input to PCLK Hold Time, No Input Data Delay	OR4E02	1.55	—	1.50	—	1.36	—	ns
	OR4E04	1.56	—	1.51	—	1.37	—	ns
	OR4E06	1.57	—	1.52	—	1.38	—	ns
Input Delay Adjustments from PIO Cycle Stealing (typically used to reduce setup time by the min value shown):								
One Delay Cell	All	—	0.89	—	0.70	—	0.64	ns
Two Delay Cells	All	—	1.64	—	1.29	—	1.18	ns
Three Delay Cells	All	—	2.43	—	1.98	—	1.80	ns
PLL Delay Adjustments from Cycle Stealing (used to reduce hold by the min delay value shown):								
One Delay Cell	All	—	0.89	—	0.70	—	0.64	ns
Two Delay Cells	All	—	1.64	—	1.29	—	1.18	ns
Three Delay Cells	All	—	2.43	—	1.98	—	1.80	ns

Notes:
1. The pin-to-pin timing parameters in this table will match ispLEVER if the clock delay multiplier in the setup preference is set to 0.95 for setup time and 1.05 for hold time.
2. Timing uses the automatic delay compensation mode of the PLLs. The feedback to the PLL is provided by the global system clock routing. Other delay values are possible by using the phase modifications mode of the PLL instead.
3. This setup/hold time is for a fully routed clock tree that uses the primary clock network. It includes both the LVTTL (3.3 V) input clock buffer delay, PLL block, the clock routing to the PIO CLK input, the setup/hold time of the PIO FF (with the data input delay disabled) and the LVTTL (3.3 V) input data buffer to PIO FF delay. The PCLK input clock is connected at the semi-dedicated PLL input pin.
4. Note that the PIO cycle stealing delay adjustments and the PLL cycle stealing delay adjustments are each attempting to pull the same clock in both directions. If both are being used, then the difference between them will provide the basis for PIO setup and hold times.
5. For timing improvements using other I/O buffer types for the input clock buffer or input data buffer, see Table 53.

Timing Characteristics (continued)

Table 53. Microprocessor Interface (MPI) Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO= 3.0 V to 3.6 V, –40 °C < TJ < + 125 °C

Parameter	Symbol	Min	Max	Unit
MPI Control (STRB, WR, etc.) to MPI_CLK Setup Time	MPICTRL_SET	7.7	—	ns
MPI Address to MPI_CLK Setup Time	MPIADR_SET	3.5	—	ns
MPI Write Data to MPI_CLK Setup Time	MPIDAT_SET	3.4	—	ns
All Hold Times	MPI_HLD	0.0	—	ns
MPI_CLK to MPI Control (TA, TEA, RETRY)	MPICTRL_DEL	—	8.3	ns
MPI_CLK to MPI Data (8-bit)	MPIDAT8_DEL	—	9.2	ns
MPI_CLK to MPI Data (16-bit)	MPIDAT16_DEL	—	10.0	ns
MPI_CLK to MPI Data (32-bit)	MPIDAT32_DEL	—	10.6	ns
MPI_CLK Frequency	MPI_CLK_FRQ	—	66	MHz

Table 54. Embedded System Bus (ESB) Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO= 3.0 V to 3.6 V, –40 °C < TJ < + 125 °C

Parameter	Symbol	Min	Max	Unit
ESB_CLK Frequency (no wait states)	ESB_CLK_FRQ	—	66	MHz
ESB_CLK Frequency (with wait states)	ESB_CLK_FRQ	—	100	MHz

Table 55. Phase-Locked Loop (PLL) Timing Characteristics

See the section on PLLs in this data sheet and in the PLL application note for timing information.

Table 56. Boundary-Scan Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO= 3.0 V to 3.6 V, –40 °C < TJ < +125 °C; CL = 30 pF.

Parameter	Symbol	Min	Max	Unit
TDI/TMS to TCK Setup Time	T_S	10.0	—	ns
TDI/TMS Hold Time from TCK	T_H	0.0	—	ns
TCK Low Time	T_{CL}	25.0	—	ns
TCK High Time	T_{CH}	25.0	—	ns
TCK to TDO Delay	T_D	—	10.0	ns
TCK Frequency	T_{TCK}	—	20.0	MHz

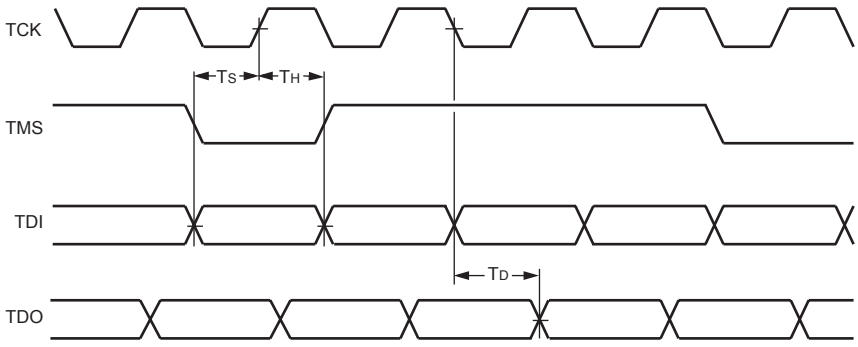

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Figure 52. Boundary-Scan Timing Diagram

Timing Characteristics (continued)

Configuration Timing

Table 57. General Configuration Mode Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +125 °C; CL = 30 pF

Parameter	Symbol	Min	Max	Unit
All Configuration Modes				
M[3:0] Setup Time to $\overline{\text{INIT}}$ High	TSMODE	0.00	—	ns
M[3:0] Hold Time from $\overline{\text{INIT}}$ High	THMODE	600.00	—	ns
$\overline{\text{RESET}}$ Pulse Width Low to Start Reconfiguration	TRW	50.00	—	ns
$\overline{\text{PRGM}}$ Pulse Width Low to Start Reconfiguration	TPGW	50.00	—	ns
Master and Asynchronous Peripheral Modes				
Power-on Reset Delay	TPO	15.70	52.40	ms
CCLK Period (M3 = 0)	TCCLK	60.00	200.00	ns
(M3 = 1)		480.00	1,600.00	ns
Configuration Latency (autoincrement mode, no EBR initialization):	TCL			
OR4E02 (M3 = 0)		69.7	232.3	ms
(M3 = 1)		557.6	1,858.6	ms
OR4E04 (M3 = 0)		187.7	625.6	ms
(M3 = 1)		1,501.5	5,004.9	ms
OR4E06 (M3 = 0)		284.2	947.5	ms
(M3 = 1)		2,273.9	7,579.7	ms
Microprocessor (**MPI**) Mode†				
Power-on Reset Delay	TPO	15.70	52.40	ms
MPI Clock Period	TCL	15.00	—	
Configuration Latency (autoincrement mode, no EBR initialization):				
OR4E02		290,412	—	MPI clk cycles
OR4E04		782,018	—	MPI clk cycles
OR4E06		1,184,322	—	MPI clk cycles
Partial Reconfiguration (per data frame):	TPR			
OR4E02		225	—	MPI clk cycles
OR4E04		321	—	MPI clk cycles
OR4E06		385	—	MPI clk cycles
Slave Serial Mode				
Power-on Reset Delay	TPO	3.90	13.10	ms
CCLK Period	TCCLK	10.00	—	ns
Configuration Latency (autoincrement mode, no EBR initialization):	TCL			
OR4E02		11.6	—	ms
OR4E04		31.3	—	ms
OR4E06		47.4	—	ms
Partial Reconfiguration (per data frame):	TPR			
OR4E02		9.0	—	µs
OR4E04		12.8	—	µs
OR4E06		15.4	—	µs

* Not applicable to asynchronous peripheral mode.
† Values are shown for the MPI in 32-bit mode with daisy-chaining through the DOUT pin disabled.

Timing Characteristics (continued)

Table 58. General Configuration Mode Timing Characteristics (continued)

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +125 ° C; CL = 30 pF.

Parameter	Symbol	Min	Max	Unit
Slave Parallel Mode				
Power-on Reset Delay	TPO	3.90	13.10	ms
CCLK Period:	TCCLK	10.00	—	ns
Configuration Latency (normal mode):	TCL			
OR4E02		1.5	—	ms
OR4E04		3.9	—	ms
OR4E06		5.9	—	ms
Partial Reconfiguration (per data frame):	TPR			
OR4E02		1.1	—	µs
OR4E04		1.6	—	µs
OR4E06		1.9	—	µs
$\overline{\text{INIT}}$ **Timing**				
$\overline{\text{INIT}}$ High to CCLK Delay:	TINIT_CCLK			
Slave Parallel		0.50	1.60	µs
Slave Serial		0.50	1.60	µs
Master Serial		0.50	1.60	µs
Master Parallel		0.50	1.60	µs
Initialization Latency ($\overline{\text{PRGM}}$ high to $\overline{\text{INIT}}$ high):	TIL			
OR4E02		0.43	1.44	ms
OR4E04		0.58	1.95	ms
OR4E06		0.74	2.46	ms
$\overline{\text{INIT}}$ High to $\overline{\text{WR}}$, Asynchronous Peripheral	TINIT_WR	2.00	—	µs

Note: TPO is triggered when VDD33 reaches between 2.7 V and 3.0 V.

Timing Characteristics (continued)

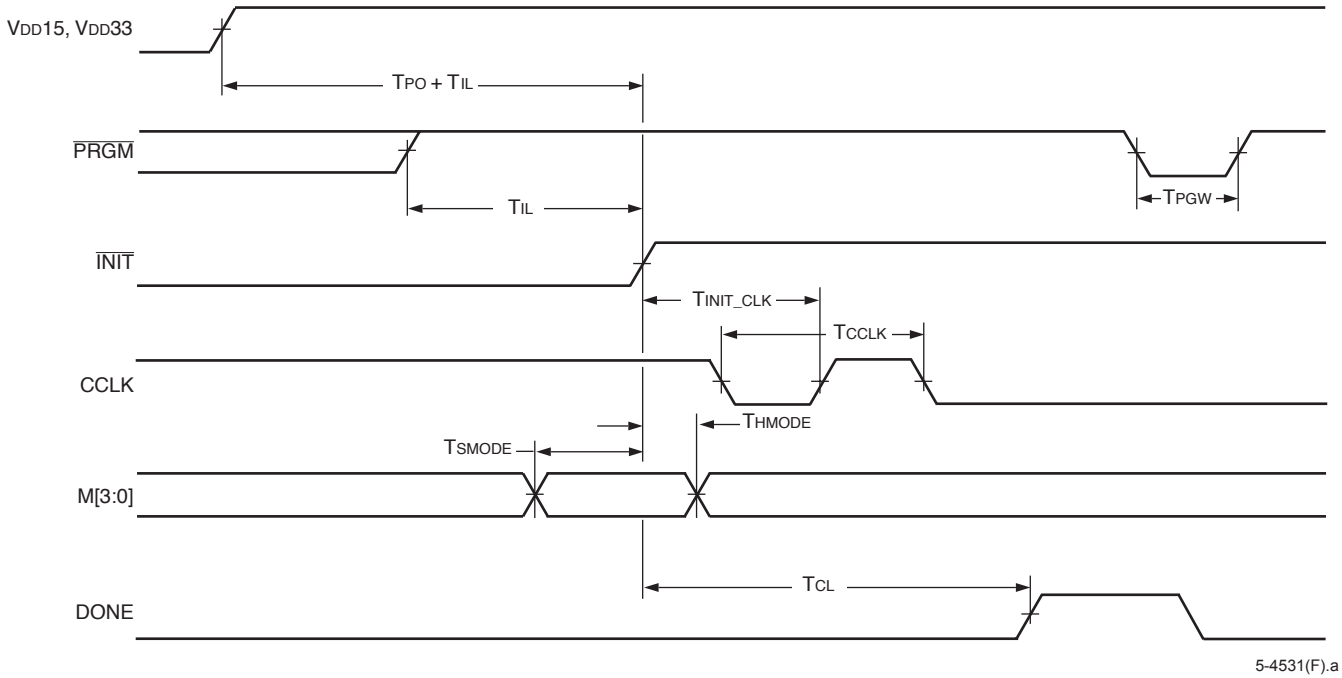


Figure 53. General Configuration Mode Timing Diagram

Timing Characteristics (continued)

Table 59. Master Serial Configuration Mode Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +125 °C; CL = 30 pF.

Parameter	Symbol	Min	Max	Unit
DIN Setup Time*	T_S	10.00	—	ns
DIN Hold Time	T_H	0.00	—	ns
CCLK Frequency (M3 = 0)	F_C	5.00	16.67	MHz
CCLK Frequency (M3 = 1)	F_C	0.63	2.08	MHz
CCLK to DOUT Delay	T_D	—	5.00	ns

Note: Serial configuration data is transmitted out on DOUT on the rising edge of CCLK after it is input on DIN.

* Data gets clocked out from an external serial ROM. The clock to data delay of the serial ROM must be less than the CCLK frequency since the data available out of the serial ROM must be setup and waiting to be clocked into the FPGA before the next CCLK rising edge.

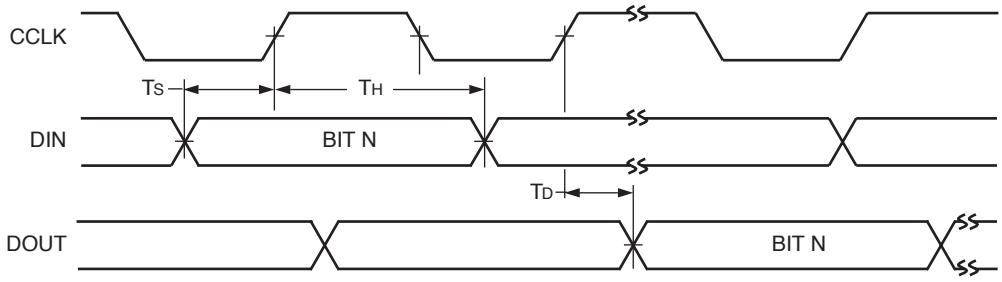


Figure 54. Master Serial Configuration Mode Timing Diagram

Timing Characteristics (continued)

Table 60. Master Parallel Configuration Mode Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +125 °C; CL = 30 pF.

Parameter	Symbol	Min	Max	Unit
RCLK to Address Valid	T_{AV}	—	10.00	ns
D[7:0] Setup Time to RCLK High	T_S	10.00	—	ns
D[7:0] Hold Time to RCLK High	T_H	0.00	—	ns
RCLK Low Time	T_{CL}	7.00	7.00	CCLK cycles
RCLK High Time	T_{CH}	1.00	1.00	CCLK cycles
CCLK to DOUT	T_D	—	5.00	ns

Note:
The RCLK period consists of seven CCLKs for RCLK low and one CCLK for RCLK high.
Serial data is transmitted out on DOUT two CCLK cycles after the byte is input on D[7:0].

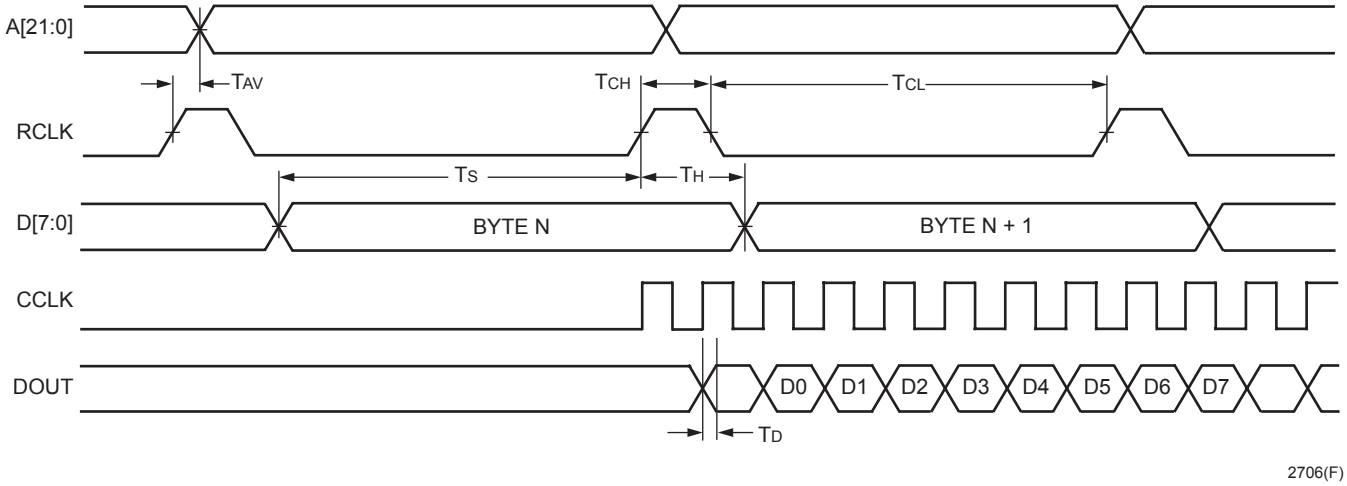


Figure 55. Master Parallel Configuration Mode Timing Diagram

Timing Characteristics (continued)

Table 61. Asynchronous Peripheral Configuration Mode Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +125 °C; CL = 30 pF.

Parameter	Symbol	Min	Max	Unit
WR, CS0, and CS1 Pulse Width	TWR	10.00	60.00 / 500.00*	ns
D[7:0] Setup Time:	TS	0.00	—	ns
RDY Delay	TRDY	—	10.00	ns
RDY Low	TB	1.00	8.00	CCLK Periods
Earliest WR After RDY Goes High†	TWR2	0.00	—	ns
RD to D[7:0] Enable/Disable	TDEN	—	10.00	ns
CCLK to DOUT	TD	—	5.00	ns

* The smaller delay is for fast asynchronous peripheral mode (mode pins M[3:0]=”0101”) and the larger delay is for slow asynchronous peripheral mode (mode pins M[3:0]=”1101”).

† This parameter is valid whether the end of not RDY is determined from the RDY pin or from the D7 pin.

Note: Serial data is transmitted out on DOUT on the rising edge of CCLK after the byte is input on D[7:0]. D[2:0] timing is the same as the write data portion of the D[7:3] waveform because D[2:0] are not enabled by RD.

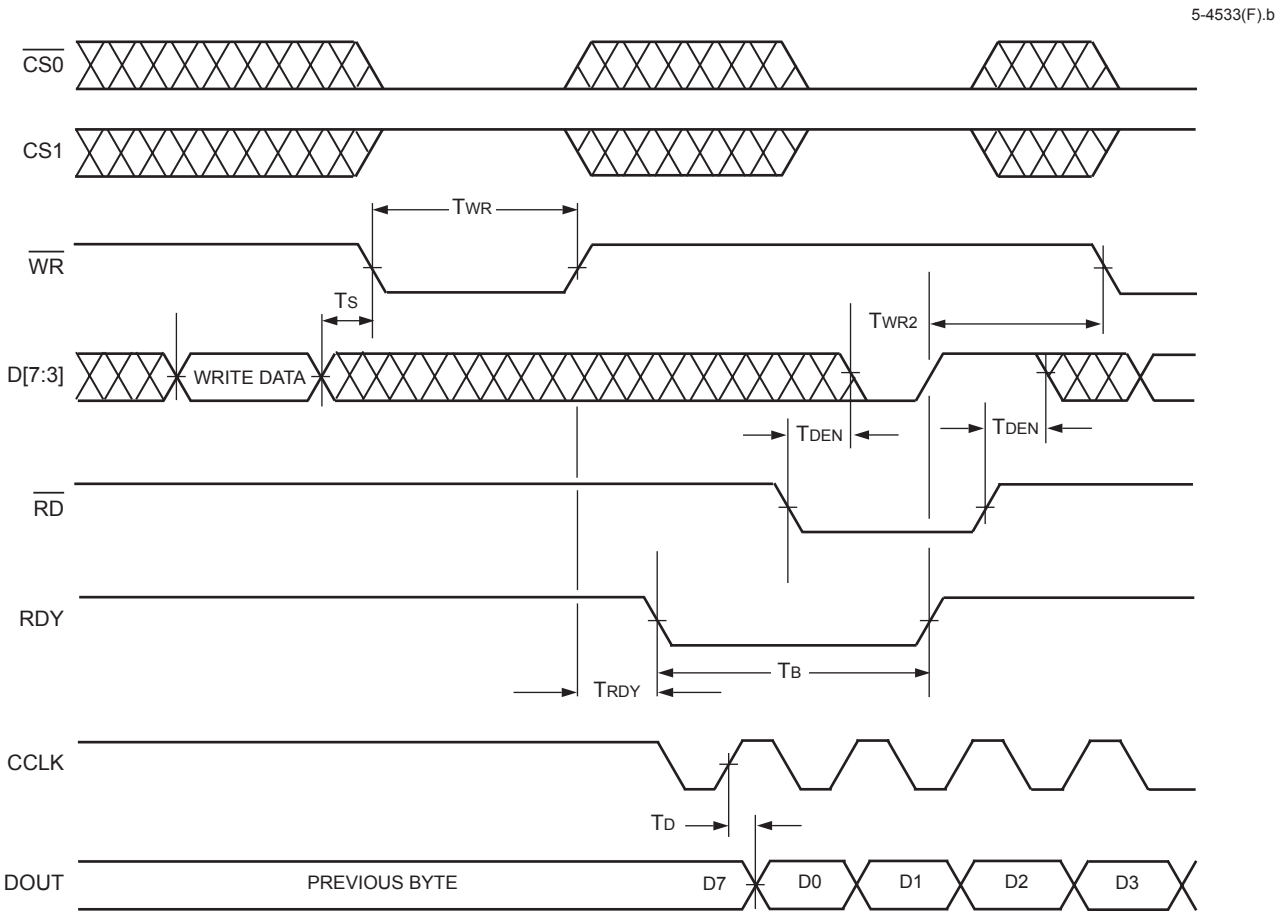


Figure 56. Asynchronous Peripheral Configuration Mode Timing Diagram

Timing Characteristics (continued)

Table 62. Slave Serial Configuration Mode Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +125 °C; CL = 30 pF.

Parameter	Symbol	Min	Max	Unit
DIN Setup Time	T_S	5.00	—	ns
DIN Hold Time	T_H	0.00	—	ns
CCLK High Time	T_{CH}	5.00	—	ns
CCLK Low Time	T_{CL}	5.00	—	ns
CCLK Frequency	F_C	—	100.00	MHz
CCLK to DOUT	T_D	—	5.00	ns

Note: Serial configuration data is transmitted out on DOUT on the rising edge of CCLK after it is input on DIN.

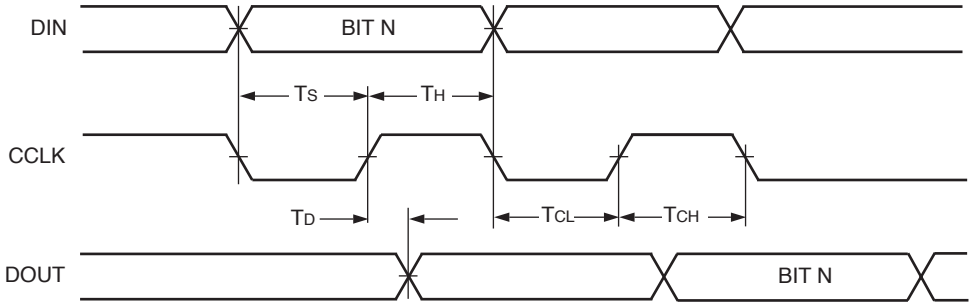


Figure 57. Slave Serial Configuration Mode Timing Diagram

Timing Characteristics (continued)

Table 63. Slave Parallel Configuration Mode Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +125 °C; CL = 30 pF.

Parameter	Symbol	Min	Max	Unit
$\overline{CS0}$, CS1, $\overline{WR}$ Setup Time	TS1	5.00	—	ns
$\overline{CS0}$, CS1, $\overline{WR}$ Hold Time	TH1	2.00	—	ns
D[7:0] Setup Time	TS2	5.00	—	ns
D[7:0] Hold Time	TH2	0.00	—	ns
CCLK High Time	TCH	5.00	—	ns
CCLK Low Time	TCL	5.00	—	ns
CCLK Frequency	FC	—	100.00	MHz

Note: Daisy-chaining of FPGAs is not supported in this mode.

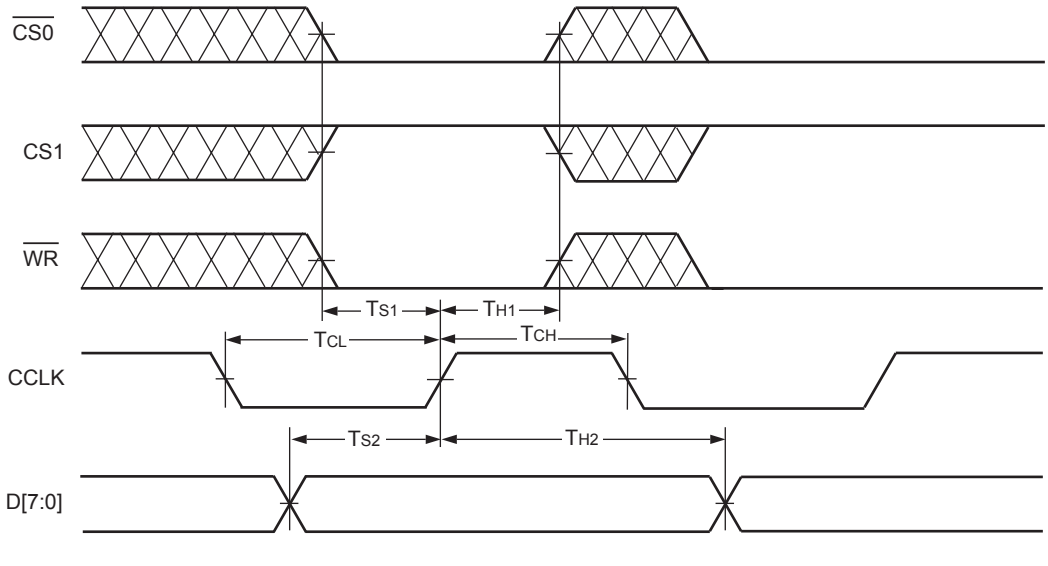


Figure 58. Slave Parallel Configuration Mode Timing Diagram

Timing Characteristics (continued)

Readback Timing

Table 64. Readback Timing Characteristics

OR4Exx commercial/industrial: VDD15 = 1.4 V to 1.6 V, VDD33 = 3.0 V to 3.6 V, VDDIO = 3.0 V to 3.6 V, –40 °C < TJ < +125 °C; CL = 30 pF.

Parameter	Symbol	Min	Max	Unit
$\overline{\text{RD\_CFG}}$ to CCLK Setup Time	T_S	5.00	—	ns
$\overline{\text{RD\_CFG}}$ High Width to Abort Readback	T_{RBA}	2	—	CCLK cycles
CCLK Low Time	T_{CL}	5.00	—	ns
CCLK High Time	T_{CH}	5.00	—	ns
CCLK Frequency	F_C	—	100.00	MHz
CCLK to RD_DATA Delay	T_D	—	5.00	ns

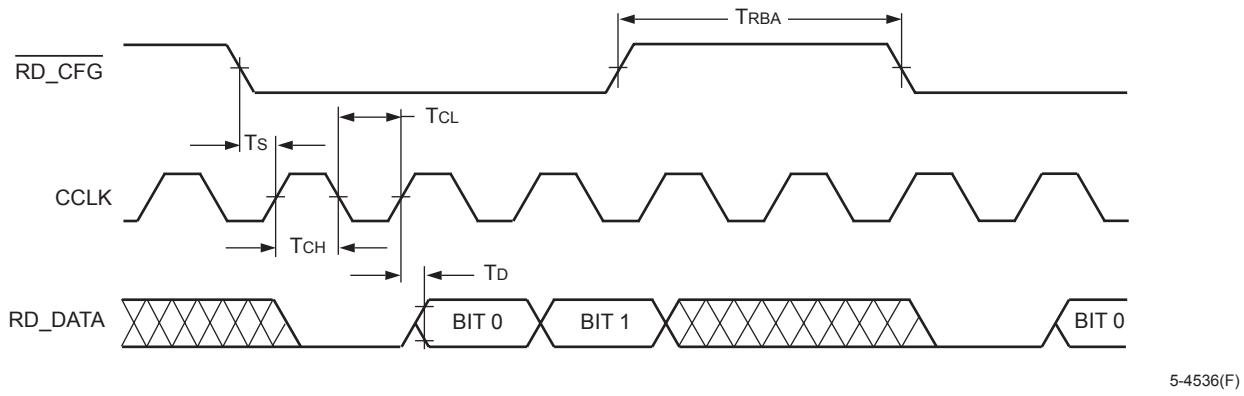


Figure 59. Readback Timing Diagram

Pin Information

Pin Descriptions

This section describes the pins found on the Series 4 FPGAs. Any pin not described in this table is a user-programmable I/O. During configuration, the user-programmable I/Os are 3-stated with an internal pull-up resistor enabled. If any pin is not used (or not bonded to a package pin), it is also 3-stated with an internal pull-up resistor enabled after configuration. The pin descriptions in Table 65 and throughout this data sheet show active-low signals with an overscore. The package pinout tables that follow, show this as a signal ending with _N, for $\overline{\text{LDC}}$ and LDC_N are equivalent.

Table 65. Pin Descriptions

Symbol	I/O	Description
Dedicated Pins		
$V_{DD}33$	—	3.3 V positive power supply. This power supply is used for 3.3 V configuration RAMs and internal PLLs. When using PLLs, this power supply should be well isolated from all other power supplies on the board for proper operation.
$V_{DD}15$	—	1.5 V positive power supply for internal logic.
$V_{DD}IO$	—	Positive power supply used by I/O banks.
V_{SS}	—	Ground.
PTEMP	I	Temperature sensing diode pin. Dedicated input.
$\overline{\text{RESET}}$	I	During configuration, $\overline{\text{RESET}}$ forces the restart of configuration and a pull-up is enabled. After configuration, $\overline{\text{RESET}}$ can be used as a general FPGA input or as a direct input, which causes all PLC latches/FFs to be asynchronously set/reset.
CCLK	O	In the master and asynchronous peripheral modes, CCLK is an output which strobes configuration data in.
	I	In the slave or readback after configuration, CCLK is input synchronous with the data on DIN or D[7:0]. CCLK is an output for daisy-chain operation when the lead device is in master, peripheral, or system bus modes.
DONE	I	As an input, a low level on DONE delays FPGA start-up after configuration.*
	O	As an active-high, open-drain output, a high level on this signal indicates that configuration is complete. DONE has an optional pull-up resistor.
$\overline{\text{PRGM}}$	I	$\overline{\text{PRGM}}$ is an active-low input that forces the restart of configuration and resets the boundary-scan circuitry. This pin always has an active pull-up.
$\overline{\text{RD\_CFG}}$	I	This pin must be held high during device initialization until the $\overline{\text{INIT}}$ pin goes high. This pin always has an active pull-up. During configuration, $\overline{\text{RD\_CFG}}$ is an active-low input that activates the TS_ALL function and 3-states all of the I/O. After configuration, $\overline{\text{RD\_CFG}}$ can be selected (via a bit stream option) to activate the TS_ALL function as described above, or, if readback is enabled via a bit stream option, a high-to-low transition on $\overline{\text{RD\_CFG}}$ will initiate readback of the configuration data, including PFU output states, starting with frame address 0.
RD_DATA/TDO	O	RD_DATA/TDO is a dual-function pin. If used for readback, RD_DATA provides configuration data out. If used in boundary-scan, TDO is test data out.
$\overline{\text{CFG\_IRQ}}$/MPI_IRQ	O	During JTAG, slave, master, and asynchronous peripheral configuration assertion on this $\overline{\text{CFG\_IRQ}}$ (active-low) indicates an error or errors for block RAM or FPSC initialization. MPI active-low interrupt request output, when the MPI is used.

* The FPGA States of Operation section contains more information on how to control these signals during start-up. The timing of DONE release is controlled by one set of bit stream options, and the timing of the simultaneous release of all other configuration pins (and the activation of all user I/Os) is controlled by a second set of options.

Pin Information (continued)

Table 65. Pin Descriptions (continued)

Symbol	I/O	Description
Special-Purpose Pins		
M[3:0]	I	During powerup and initialization, M0—M3 are used to select the configuration mode with their values latched on the rising edge of $\overline{\text{INIT}}$. During configuration, a pull-up is enabled.
	I/O	After configuration, these pins are user-programmable I/O.*
PLL_CK[0:7][TC]	I	Semi-dedicated PLL clock pins. During configuration they are 3-stated with a pull up.
	I/O	These pins are user-programmable I/O pins if not used by PLLs after configuration.
P[TBLR]CLK[1:0][TC]	I	Pins dedicated for the primary clock. Input pins on the middle of each side with differential pairing.
	I/O	After configuration these pins are user programmable I/O, if not used for clock inputs.
TDI, TCK, TMS	I	Before configuration these pins are test data in, test clock, and test mode select inputs. If boundary-scan is enabled after configuration, these pins remain test data in, test clock, and test mode select inputs. If boundary-scan is not enabled after configuration, all boundery-scan functions are inhibited once configuration is complete. During configuration, either TCK or TMS must be held at a logic 1. Each pin has a pull-up enabled during configuration. To enable boundary-scan after configuration, a BNDSCAN library element must be instantiated in the user's design and the appropriate bitgen setting must be enabled in the ispLEVER software.
	I/O	After configuration, these pins are user-programmable I/O in boundary scan is not used.*
RDY/$\overline{\text{BUSY}}$/RCLK	O	During configuration in asynchronous peripheral mode, RDY/RCLK indicates another byte can be written to the FPGA. If a read operation is done when the device is selected, the same status is also available on D7 in asynchronous peripheral mode. During the master parallel configuration mode, RCLK is a read output signal to an external memory. This output is not normally used.
	I/O	After configuration this pin is a user-programmable I/O pin.*
HDC	O	High during configuration is output high until configuration is complete. It is used as a control output, indicating that configuration is not complete.
	I/O	After configuration, this pin is a user-programmable I/O pin.*
$\overline{\text{LDC}}$	O	$\overline{\text{Low during configuration}}$ is output low until configuration is complete. It is used as a control output, indicating that configuration is not complete.
	I/O	After configuration, this pin is a user-programmable I/O pin.*
$\overline{\text{INIT}}$	I/O	$\overline{\text{INIT}}$ is a bidirectional signal before and during configuration. During configuration, a pull-up is enabled, but an external pull-up resistor is recommended. As an active-low open-drain output, $\overline{\text{INIT}}$ is held low during power stabilization and internal clearing of memory. As an active-low input, $\overline{\text{INIT}}$ holds the FPGA in the wait-state before the start of configuration. After configuration, this pin is a user-programmable I/O pin.*
$\overline{\text{CS0}}$, CS1	I	$\overline{\text{CS0}}$ and CS1 are used in the asynchronous peripheral, slave parallel, and microprocessor configuration modes. The FPGA is selected when $\overline{\text{CS0}}$ is low and CS1 is high. During configuration, a pull-up is enabled.
	I/O	After configuration, if MPI is not used, these pins are user-programmable I/O pins.*
$\overline{\text{RD}}$/$\overline{\text{MPI\_STRB}}$	I	$\overline{\text{RD}}$ is used in the asynchronous peripheral configuration mode. A low on $\overline{\text{RD}}$ changes D[7:3] into a status output. $\overline{\text{WR}}$ and $\overline{\text{RD}}$ should not be used simultaneously. If they are, the write strobe overrides. This pin is also used as the MPI data transfer strobe. As a status indication, a high indicates ready, and a low indicates busy.
	I/O	After configuration, if the MPI is not used, this pin is a user-programmable I/O pin.*

* The FPGA States of Operation section contains more information on how to control these signals during start-up. The timing of DONE release is controlled by one set of bit stream options, and the timing of the simultaneous release of all other configuration pins (and the activation of all user I/Os) is controlled by a second set of options.

Pin Information (continued)

Table 65. Pin Descriptions (continued)

Symbol	I/O	Description
Special-Purpose Pins (continued)		
$\overline{WR}$/MPI_RW	I	$\overline{WR}$ is used in asynchronous peripheral mode. A low on $\overline{WR}$ transfers data on D[7:0] to the FPGA. In MPI mode, a high on MPI_RW allows a read from the data bus, while a low causes a write transfer to the FPGA.
	I/O	After configuration, if the MPI is not used, $\overline{WR}$/MPI_RW is a user-programmable I/O pin.*
PPC_A[14:31]	I	During MPI mode the PPC_A[14:31] are used as the address bus driven by the *PowerPC* bus master utilizing the least-significant bits of the *PowerPC* 32-bit address.
$\overline{MPI\_BURST}$	I	$\overline{MPI\_BURST}$ is driven low to indicate a burst transfer is in progress in MPI mode. Driven high indicates that the current transfer is not a burst.
$\overline{MPI\_BDIP}$	I	$\overline{MPI\_BDIP}$ is driven by the *PowerPC* processor in MPI mode. Assertion of this pin indicates that the second beat in front of the current one is requested by the master. Negated before the burst transfer ends to abort the burst data phase.
MPI_TSZ[0:1]	I	MPI_TSZ[0:1] signals are driven by the bus master in MPI mode to indicate the data transfer size for the transaction. Set 01 for byte, 10 for half-word, and 00 for word.
A[21:0]	O	During master parallel mode A[21:0] address the configuration EPROMs up to 4M bytes.
	I/O	If not used for MPI these pins are user-programmable I/O pins after configuration.*
$\overline{MPI\_ACK}$	O	In MPI mode this is driven low indicating the MPI received the data on the write cycle or returned data on a read cycle.
	I/O	If not used for MPI these pins are user-programmable I/O pins after configuration.*
MPI_CLK	I	This is the *PowerPC* synchronous, positive-edge bus clock used for the MPI interface. It can be a source of the clock for the embedded system bus. If MPI is used this will be the *AMBA* bus clock.
	I/O	If not used for MPI these pins are user-programmable I/O pins after configuration.*
$\overline{MPI\_TEA}$	O	A low on the MPI transfer error acknowledge indicates that the MPI detects a bus error on the internal system bus for the current transaction.
	I/O	If not used for MPI these pins are user-programmable I/O pins after configuration.*
$\overline{MPI\_RTRY}$	O	This pin requests the MPC860 to relinquish the bus and retry the cycle.
	I/O	If not used for MPI these pins are user-programmable I/O pins after configuration.*
D[0:31]	I/O	Selectable data bus width from 8, 16, 32-bit in MPI mode. Driven by the bus master in a write transaction and driven by MPI in a read transaction.
	I	D[7:0] receive configuration data during master parallel, peripheral, and slave parallel configuration modes when $\overline{WR}$ is low and each pin has a pull-up enabled. During serial configuration modes, D0 is the DIN input.
	O	D[7:3] output internal status for asynchronous peripheral mode when $\overline{RD}$ is low.
	I/O	After configuration, if MPI is not used, the pins are user-programmable I/O pins.*
DP[0:3]	I/O	Selectable parity bus width in MPI mode from 1, 2, 4-bit, DP[0] for D[0:7], DP[1] for D[8:15], DP[2] for D[16:23], and DP[3] for D[24:31]. After configuration, if MPI is not used, the pins are user-programmable I/O pin.*

* The FPGA States of Operation section contains more information on how to control these signals during start-up. The timing of DONE release is controlled by one set of bit stream options, and the timing of the simultaneous release of all other configuration pins (and the activation of all user I/Os) is controlled by a second set of options.

Pin Information (continued)

Table 65. Pin Descriptions (continued)

Symbol	I/O	Description
Special-Purpose Pins (continued)		
DIN	I	During slave serial or master serial configuration modes, DIN accepts serial configuration data synchronous with CCLK. During parallel configuration modes, DIN is the D0 input. During configuration, a pull-up is enabled.
	I/O	After configuration, this pin is a user-programmable I/O pin.*
DOUT	O	During configuration, DOUT is the serial data output that can drive the DIN of daisy-chained slave devices. Data out on DOUT changes on the rising edge of CCLK.
	I/O	After configuration, DOUT is a user-programmable I/O pin.*
TESTCFG	I	During configuration this pin should be held high, to allow configuration to occur. A pull up is enabled during configuration.
	I/O	After configuration, TESTCFG is a user programmable I/O pin.*

* The FPGA States of Operation section contains more information on how to control these signals during start-up. The timing of DONE release is controlled by one set of bit stream options, and the timing of the simultaneous release of all other configuration pins (and the activation of all user I/Os) is controlled by a second set of options.

Pin Information (continued)

Package Compatibility

Table 66 provides the number of user I/Os available for the *ORCA* Series 4 FPGAs for each available package. Each package has six dedicated configuration pins.

Table 67 thru Table 69 provide the package pin and pin function for the Series 4 FPGAs and packages. The bond pad name is identified in the PIO nomeclature used in the ispLEVER design editor. The Bank column provides information as to which output voltage level bank the given pin is in. The Group column provides information as to the group of pins the given pin is in. This is used to show which VREF pin is used to provide the reference voltage for single-ended limited-swing I/Os. If none of these buffer types (such as SSTL, GTL, HSTL) are used in a given group, then the VREF pin is available as an I/O pin.

When the number of FPGA bond pads exceeds the number of package pins, bond pads are unused. When the number of package pins exceeds the number of bond pads, package pins are left unconnected (no connects). When a package pin is to be left as a no connect for a specific die, it is indicated as a note in the device column for the FPGA. The tables provide no information on unused pads.

In order to allow pin-for-pin compatible board layouts that can accommodate both devices, some key compatibility issues include the following.:

- **Shared Control Signals on I/O Registers.** The *ORCA* Series 4 architecture shares clock and control signals between two adjacent I/O pads. If I/O registers are used, incompatibilities may arise between devices when different clock or control signals are needed on adjacent package pins. This is because one device may allow independent clock or control signals on these adjacent pins, while the other may force them to be the same. There are two ways to avoid this issue.
  - — Always keep an open bonded pin (non-bonded pins do not count) between pins that require different clock or control signals. Note that this open pin can be used to connect signals that do not require the use of I/O registers to meet timing.
  - — Place and route the design in all target devices to verify they produce valid designs. Note that this method guarantees the current design, but does not necessarily guard against issues that can occur when design changes are made that affect I/O registers.
  - — **2X/4X I/O Shift Registers.** If 2X I/O shift registers or 4X I/O shift registers are used in the design, this may cause incompatibilities between the devices because only the A and C I/Os in a PIC support 2X I/O shift registers and only A I/Os supports 4X I/O shift register mode. A and C I/Os are shown in the following pinout tables under the I/O pad columns as those ending in A or C.
- **Edge Clock Input Pins.** The input buffers for fast edge clocks are only available at the C I/O pad. The C I/Os are shown in the following pinout tables under the I/O pad columns as those ending in C.
- **680 PBGAM Differential I/O Pairs.** Note that the OR4E02 device in the 680 PBGAM package has two less differential I/O pairs available than the OR4E04 or OR4E06, even though the total number of user I/Os are the same for all three devices.

Pin Information (continued)

Table 66. *ORCA* Series 4 I/Os Summary

Device	352 PBGA	416 PBGAM	680 PBGAM
OR4E02/OR4E04/OR4E06			
User I/O Single Ended	262	290	466 (4E4, 4E6) 405 (4E2)
User I/O Differential Pairs (LVDS, LVPECL)	128	139	197 (4E4, 4E6) 195 (4E2)
Configuration	7	7	7
Dedicated Function	3	3	3
$V_{DD}15$	16	28	48
$V_{DD}33$	8	8	8
$V_{DD}IO$	24	32	60
V_{SS}	68	48	88
Single-ended/Differential I/O per Bank			
Bank 0	39/19	46/22	68/32
Bank 1	26/13	28/14	47/20
Bank 2	32/16	35/17	54/24 (23 for 4E2)
Bank 3	33/16	37/18	63/22 (21 for 4E2)
Bank 4	34/16	38/17	52/22
Bank 5	24/12	24/12	44/18
Bank 6	40/19	45/21	76/32
Bank 7	34/17	37/18	62/27

Note: Each VREF pin required reduces the available user I/Os.

As shown in the Pair column, differential pairs and physical locations are numbered within each bank (e.g., L19C_A0 is the nineteenth pair in an associated bank). The C indicates complementary differential whereas a T indicates true differential. The _A0 indicates the physical location of adjacent balls in either the horizontal or vertical direction. Other physical indicators are as follows:

- _A1 indicates one ball between pairs.
- _A2 indicates two balls between pairs.
- _D0 indicates balls are diagonally adjacent.
- _D1 indicates diagonally adjacent separated by one physical ball.

V_{REF} pins, shown in the Additional Function column, are associated to the bank and group (e.g., V_{REF}_TL_01 is the V_{REF} for group one of the top left (TL) bank).

352-Pin PBGA Pinout

Table 67. 352-Pin PBGA Pinout

BA352	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
A1	—	—	Vss	Vss	Vss	Vss	—	—
B1	—	—	VDD33	VDD33	VDD33	VDD33	—	—
C2	—	—	O	PRD_DATA	PRD_DATA	PRD_DATA	RD_DATA/TDO	—
AA23	—	—	VDD15	VDD15	VDD15	VDD15	—	—
C1	—	—	I	PRESET_N	PRESET_N	PRESET_N	RESET_N	—
D2	—	—	I	PRD_CFG_N	PRD_CFG_N	PRD_CFG_N	RD_CFG_N	—
D3	—	—	I	PPRGRM_N	PPRGRM_N	PPRGRM_N	PRGRM_N	—
D1	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	VDDIO0	—	—
E2	0 (TL)	7	IO	PL2D	PL2D	PL2D	PLL_CK0C/HPPLL	L12C_A1
E4	0 (TL)	7	IO	PL2C	PL2C	PL2C	PLL_CK0T/HPPLL	L12T_A1
A2	—	—	Vss	Vss	Vss	Vss	—	—
E3	0 (TL)	7	IO	PL3D	PL4D	PL4D	D5	L13C_A1
E1	0 (TL)	7	IO	PL3C	PL4C	PL4C	D6	L13T_A1
F2	0 (TL)	8	IO	PL4D	PL5D	PL6D	HDC	L14C_D1
G4	0 (TL)	8	IO	PL4C	PL5C	PL6C	LDC_N	L14T_D1
A26	—	—	Vss	Vss	Vss	Vss	—	—
F3	0 (TL)	9	IO	PL5D	PL6D	PL8D	TESTCFG	L15C_A1
F1	0 (TL)	9	IO	PL5C	PL6C	PL8C	D7	L15T_A1
G2	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	VDDIO0	—	—
G1	0 (TL)	9	IO	PL5B	PL7D	PL9D	VREF_0_09	L16C_A1
G3	0 (TL)	9	IO	PL5A	PL7C	PL9C	A17/PPC_A31	L16T_A1
H2	0 (TL)	9	IO	PL6D	PL8D	PL10D	CS0_N	L17C_D1
J4	0 (TL)	9	IO	PL6C	PL8C	PL10C	CS1	L17T_D1
AC13	—	—	Vss	Vss	Vss	Vss	—	—
H1	0 (TL)	10	IO	PL7D	PL10D	PL12D	INIT_N	L18C_A1
H3	0 (TL)	10	IO	PL7C	PL10C	PL12C	DOUT	L18T_A1
AA4	—	—	VDD15	VDD15	VDD15	VDD15	—	—
J2	0 (TL)	10	IO	PL7B	PL11D	PL13D	VREF_0_10	L19C_A0
J1	0 (TL)	10	IO	PL7A	PL11C	PL13C	A16/PPC_A30	L19T_A0
K2	7 (CL)	1	IO	PL8D	PL12D	PL14D	A15/PPC_A29	L1C_D0
J3	7 (CL)	1	IO	PL8C	PL12C	PL14C	A14/PPC_A28	L1T_D0
K1	7 (CL)	1	IO	PL9D	PL13D	PL16D	VREF_7_01	L2C_A2
K4	7 (CL)	1	IO	PL9C	PL13C	PL16C	D4	L2T_A2
AD3	—	—	Vss	Vss	Vss	Vss	—	—
L2	7 (CL)	2	IO	PL10D	PL14D	PL18D	RDY/BUSY_N/RCLK	L3C_D0
K3	7 (CL)	2	IO	PL10C	PL14C	PL18C	VREF_7_02	L3T_D0
L1	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
M2	7 (CL)	2	IO	PL10B	PL15D	PL19D	A13/PPC_A27	L4C_A0
M1	7 (CL)	2	IO	PL10A	PL15C	PL19C	A12/PPC_A26	L4T_A0

Table 67. 352-Pin PBGA Pinout

BA352	$V_{DD}IO$ Bank	V_{REF} Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AE1	—	—	Vss	Vss	Vss	Vss	—	—
L3	7 (CL)	3	IO	PL11B	PL17D	PL21D	A11/PPC_A25	L5C_D1
N2	7 (CL)	3	IO	PL11A	PL17C	PL21C	VREF_7_03	L5T_D1
AC11	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
M4	7 (CL)	4	IO	PL13D	PL19D	PL23D	RD_N/MPI_STRB_N	L6C_D2
N1	7 (CL)	4	IO	PL13C	PL19C	PL23C	VREF_7_04	L6T_D2
AE2	—	—	Vss	Vss	Vss	Vss	—	—
M3	7 (CL)	4	IO	PL14D	PL20D	PL24D	PLCK0C	L7C_D1
P2	7 (CL)	4	IO	PL14C	PL20C	PL24C	PLCK0T	L7T_D1
P4	7 (CL)	—	$V_{DD}IO7$	$V_{DD}IO7$	$V_{DD}IO7$	$V_{DD}IO7$	—	—
AC16	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
AE25	—	—	Vss	Vss	Vss	Vss	—	—
P1	7 (CL)	5	IO	PL15D	PL21D	PL25D	A10/PPC_A24	L8C_D1
N3	7 (CL)	5	IO	PL15C	PL21C	PL25C	A9/PPC_A23	L8T_D1
AF1	—	—	Vss	Vss	Vss	Vss	—	—
R2	7 (CL)	5	IO	PL16D	PL22D	PL26D	A8/PPC_A22	L9C_D0
P3	7 (CL)	5	IO	PL16C	PL22C	PL26C	VREF_7_05	L9T_D0
R1	7 (CL)	6	IO	PL17D	PL24D	PL28D	PLCK1C	L10C_D0
T2	7 (CL)	6	IO	PL17C	PL24C	PL28C	PLCK1T	L10T_D0
AF25	—	—	Vss	Vss	Vss	Vss	—	—
R3	7 (CL)	6	IO	PL17B	PL25D	PL29D	VREF_7_06	L11C_D1
T1	7 (CL)	6	IO	PL17A	PL25C	PL29C	A7/PPC_A21	L11T_D1
R4	7 (CL)	6	IO	PL18D	PL26D	PL30D	A6/PPC_A20	L12C_D1
U2	7 (CL)	6	IO	PL18C	PL26C	PL30C	A5/PPC_A19	L12T_D1
T3	7 (CL)	—	$V_{DD}IO7$	$V_{DD}IO7$	$V_{DD}IO7$	$V_{DD}IO7$	—	—
U1	7 (CL)	7	IO	PL19D	PL27D	PL32D	WR_N/MPI_RW	L13C_A2
U4	7 (CL)	7	IO	PL19C	PL27C	PL32C	VREF_7_07	L13T_A2
V2	7 (CL)	8	IO	PL20D	PL28D	PL34D	A4/PPC_A18	L14C_D1
U3	7 (CL)	8	IO	PL20C	PL28C	PL34C	VREF_7_08	L14T_D1
V1	7 (CL)	8	IO	PL20B	PL29D	PL35D	A3/PPC_A17	L15C_D0
W2	7 (CL)	8	IO	PL20A	PL29C	PL35C	A2/PPC_A16	L15T_D0
W1	7 (CL)	8	IO	PL21D	PL30D	PL36D	A1/PPC_A15	L16C_D1
V3	7 (CL)	8	IO	PL21C	PL30C	PL36C	A0/PPC_A14	L16T_D1
Y2	7 (CL)	8	IO	PL21B	PL31D	PL37D	DP0	L17C_D1
W4	7 (CL)	8	IO	PL21A	PL31C	PL37C	DP1	L17T_D1
Y1	6 (BL)	1	IO	PL22D	PL32D	PL38D	D8	L1C_D1
W3	6 (BL)	1	IO	PL22C	PL32C	PL38C	VREF_6_01	L1T_D1
B25	—	—	Vss	Vss	Vss	Vss	—	—
AA2	6 (BL)	1	IO	PL22B	PL33D	PL39D	D9	L2C_D1
Y4	6 (BL)	1	IO	PL22A	PL33C	PL39C	D10	L2T_D1
AA1	6 (BL)	2	IO	PL23C	PL34C	PL40C	VREF_6_02	—
Y3	6 (BL)	—	$V_{DD}IO6$	$V_{DD}IO6$	$V_{DD}IO6$	$V_{DD}IO6$	—	—
AB2	6 (BL)	3	IO	PL24D	PL35B	PL42D	D11	L3C_A0
AB1	6 (BL)	3	IO	PL24C	PL35A	PL42C	D12	L3T_A0

Table 67. 352-Pin PBGA Pinout

BA352	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
B26	—	—	Vss	Vss	Vss	Vss	—	—
AA3	6 (BL)	3	IO	PL25D	PL36B	PL44D	VREF_6_03	L4C_D1
AC2	6 (BL)	3	IO	PL25C	PL36A	PL44C	D13	L4T_D1
C24	—	—	Vss	Vss	Vss	Vss	—	—
AB4	6 (BL)	4	IO	PL27D	PL39D	PL47D	PLL_CK7C/HPPLL	L5C_D2
AC1	6 (BL)	4	IO	PL27C	PL39C	PL47C	PLL_CK7T/HPPLL	L5T_D2
C3	—	—	Vss	Vss	Vss	Vss	—	—
D14	—	—	Vss	Vss	Vss	Vss	—	—
AB3	—	—	I	PTEMP	PTEMP	PTEMP	PTEMP	—
AD2	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—
AC21	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AC3	—	—	IO	LVDS_R	LVDS_R	LVDS_R	LVDS_R	—
AD1	—	—	VDD33	VDD33	VDD33	VDD33	—	—
D19	—	—	Vss	Vss	Vss	Vss	—	—
AF2	—	—	VDD33	VDD33	VDD33	VDD33	—	—
AC6	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AE3	6 (BL)	5	IO	PB2A	PB2A	PB2A	DP2	—
AF3	6 (BL)	5	IO	PB2C	PB2C	PB2C	PLL_CK6T/PPLL	L6T_A0
AE4	6 (BL)	5	IO	PB2D	PB2D	PB2D	PLL_CK6C/PPLL	L6C_A0
AD4	6 (BL)	5	IO	PB3C	PB4A	PB4C	VREF_6_05	L7T_A1
AF4	6 (BL)	5	IO	PB3D	PB4B	PB4D	DP3	L7C_A1
D23	—	—	Vss	Vss	Vss	Vss	—	—
AE5	6 (BL)	6	IO	PB4C	PB5C	PB6C	VREF_6_06	L8T_A1
AC5	6 (BL)	6	IO	PB4D	PB5D	PB6D	D14	L8C_A1
AD5	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—
AF5	6 (BL)	7	IO	PB5C	PB6C	PB8C	D15	L9T_D0
AE6	6 (BL)	7	IO	PB5D	PB6D	PB8D	D16	L9C_D0
AC7	6 (BL)	7	IO	PB6A	PB7C	PB9C	D17	L10T_D0
AD6	6 (BL)	7	IO	PB6B	PB7D	PB9D	D18	L10C_D0
D4	—	—	Vss	Vss	Vss	Vss	—	—
AF6	6 (BL)	7	IO	PB6C	PB8C	PB10C	VREF_6_07	L11T_D0
AE7	6 (BL)	7	IO	PB6D	PB8D	PB10D	D19	L11C_D0
AF7	6 (BL)	8	IO	PB7A	PB9C	PB11C	D20	L12T_A1
AD7	6 (BL)	8	IO	PB7B	PB9D	PB11D	D21	L12C_A1
AE8	6 (BL)	8	IO	PB7C	PB10C	PB12C	VREF_6_08	L13T_D1
AC9	6 (BL)	8	IO	PB7D	PB10D	PB12D	D22	L13C_D1
D9	—	—	Vss	Vss	Vss	Vss	—	—
AF8	6 (BL)	9	IO	PB8C	PB11C	PB13C	D23	L14T_A1
AD8	6 (BL)	9	IO	PB8D	PB11D	PB13D	D24	L14C_A1
AE9	6 (BL)	9	IO	PB9C	PB12C	PB14C	VREF_6_09	L15T_A0
AF9	6 (BL)	9	IO	PB9D	PB12D	PB14D	D25	L15C_A0
AE10	6 (BL)	10	IO	PB10C	PB13C	PB16C	D26	L16T_D0
AD9	6 (BL)	10	IO	PB10D	PB13D	PB16D	D27	L16C_D0
AF10	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—

Table 67. 352-Pin PBGA Pinout

BA352	$V_{DD}IO$ Bank	V_{REF} Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AC10	6 (BL)	10	IO	PB11C	PB14C	PB18C	VREF_6_10	L17T_D1
AE11	6 (BL)	10	IO	PB11D	PB14D	PB18D	D28	L17C_D1
AD10	6 (BL)	11	IO	PB12A	PB15C	PB19C	D29	L18T_D1
AF11	6 (BL)	11	IO	PB12B	PB15D	PB19D	D30	L18C_D1
AE12	6 (BL)	11	IO	PB12C	PB16C	PB20C	VREF_6_11	L19T_A0
AF12	6 (BL)	11	IO	PB12D	PB16D	PB20D	D31	L19C_A0
AD11	5 (BC)	1	IO	PB13A	PB17C	PB21C	—	L1T_D1
AE13	5 (BC)	1	IO	PB13B	PB17D	PB21D	—	L1C_D1
D11	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
AC12	5 (BC)	1	IO	PB13C	PB18C	PB22C	VREF_5_01	L2T_D2
AF13	5 (BC)	1	IO	PB13D	PB18D	PB22D	—	L2C_D2
H4	—	—	Vss	Vss	Vss	Vss	—	—
AD12	5 (BC)	2	IO	PB14C	PB19C	PB23C	PBCK0T	L3T_D1
AE14	5 (BC)	2	IO	PB14D	PB19D	PB23D	PBCK0C	L3C_D1
AC14	5 (BC)	—	$V_{DD}IO5$	$V_{DD}IO5$	$V_{DD}IO5$	$V_{DD}IO5$	—	—
AF14	5 (BC)	2	IO	PB15C	PB20C	PB24C	VREF_5_02	L4T_D1
AD13	5 (BC)	2	IO	PB15D	PB20D	PB24D	—	L4C_D1
D16	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
AE15	5 (BC)	3	IO	PB16C	PB21C	PB26C	—	L5T_D0
AD14	5 (BC)	3	IO	PB16D	PB21D	PB26D	VREF_5_03	L5C_D0
AF15	5 (BC)	3	IO	PB17A	PB22C	PB27C	—	L6T_D0
AE16	5 (BC)	3	IO	PB17B	PB22D	PB27D	—	L6C_D0
J23	—	—	Vss	Vss	Vss	Vss	—	—
AD15	5 (BC)	3	IO	PB17C	PB23C	PB28C	PBCK1T	L7T_D1
AF16	5 (BC)	3	IO	PB17D	PB23D	PB28D	PBCK1C	L7C_D1
AC15	5 (BC)	4	IO	PB18A	PB24C	PB29C	—	L8T_D1
AE17	5 (BC)	4	IO	PB18B	PB24D	PB29D	—	L8C_D1
AD16	5 (BC)	—	$V_{DD}IO5$	$V_{DD}IO5$	$V_{DD}IO5$	$V_{DD}IO5$	—	—
AF17	5 (BC)	4	IO	PB18C	PB25C	PB30C	—	L9T_A2
AC17	5 (BC)	4	IO	PB18D	PB25D	PB30D	VREF_5_04	L9C_A2
N4	—	—	Vss	Vss	Vss	Vss	—	—
P23	—	—	Vss	Vss	Vss	Vss	—	—
AE18	5 (BC)	5	IO	PB19C	PB26C	PB32C	—	L10T_D0
AD17	5 (BC)	5	IO	PB19D	PB26D	PB32D	VREF_5_05	L10C_D0
AF18	5 (BC)	5	IO	PB20C	PB27C	PB34C	—	L11T_D0
AE19	5 (BC)	5	IO	PB20D	PB27D	PB34D	—	L11C_D0
AF19	5 (BC)	6	IO	PB21A	PB28C	PB35C	—	L12T_D1
AD18	5 (BC)	6	IO	PB21B	PB28D	PB35D	VREF_5_06	L12C_D1
AE20	4 (BR)	1	IO	PB22A	PB30C	PB37C	—	L1T_D1
AC19	4 (BR)	1	IO	PB22B	PB30D	PB37D	—	L1C_D1
L13	—	—	Vss	Vss	Vss	Vss	—	—
AF20	4 (BR)	1	IO	PB22C	PB31C	PB38C	VREF_4_01	L2T_D1
AD19	4 (BR)	1	IO	PB22D	PB31D	PB38D	—	L2C_D1
AE21	4 (BR)	1	IO	PB23A	PB32C	PB39C	—	L3T_D1

Table 67. 352-Pin PBGA Pinout

BA352	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AC20	4 (BR)	1	IO	PB23B	PB32D	PB39D	—	L3C_D1
AF21	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
AD20	4 (BR)	2	IO	PB23C	PB33C	PB40C	—	L4T_D1
AE22	4 (BR)	2	IO	PB23D	PB33D	PB40D	VREF_4_02	L4C_D1
L14	—	—	Vss	Vss	Vss	Vss	—	—
AF22	4 (BR)	2	IO	PB24C	PB34C	PB42C	—	—
AD21	4 (BR)	3	IO	PB25A	PB35A	PB43A	—	—
AE23	4 (BR)	3	IO	PB25C	PB35C	PB44C	—	L5T_D1
AC22	4 (BR)	3	IO	PB25D	PB35D	PB44D	VREF_4_03	L5C_D1
L15	—	—	Vss	Vss	Vss	Vss	—	—
AF23	4 (BR)	3	IO	PB26C	PB36C	PB45C	—	L6T_D1
AD22	4 (BR)	3	IO	PB26D	PB36D	PB45D	—	L6C_D1
L16	—	—	Vss	Vss	Vss	Vss	—	—
AE24	4 (BR)	4	IO	PB27C	PB37C	PB47C	PLL_CK5T/PPLL	L7T_D0
AD23	4 (BR)	4	IO	PB27D	PB37D	PB47D	PLL_CK5C/PPLL	L7C_D0
D21	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AF24	—	—	VDD33	VDD33	VDD33	VDD33	—	—
M11	—	—	Vss	Vss	Vss	Vss	—	—
M12	—	—	Vss	Vss	Vss	Vss	—	—
D6	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AE26	—	—	VDD33	VDD33	VDD33	VDD33	—	—
AD25	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
AD26	4 (BR)	5	IO	PR26A	PR38A	PR46C	PLL_CK4T/PLL2	L8T_D0
AC25	4 (BR)	5	IO	PR26B	PR38B	PR46D	PLL_CK4C/PLL2	L8C_D0
M13	—	—	Vss	Vss	Vss	Vss	—	—
AC24	4 (BR)	5	IO	PR25A	PR37A	PR44C	VREF_4_05	L9T_A1
AC26	4 (BR)	5	IO	PR25B	PR37B	PR44D	—	L9C_A1
M14	—	—	Vss	Vss	Vss	Vss	—	—
AB25	4 (BR)	6	IO	PR25C	PR36A	PR43C	—	L10T_A1
AB23	4 (BR)	6	IO	PR25D	PR36B	PR43D	—	L10C_A1
AB24	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
AB26	4 (BR)	6	IO	PR24C	PR35C	PR41C	VREF_4_06	L11T_D0
AA25	4 (BR)	6	IO	PR24D	PR35D	PR41D	—	L11C_D0
Y23	4 (BR)	7	IO	PR23A	PR34C	PR40C	—	L12T_D0
AA24	4 (BR)	7	IO	PR23B	PR34D	PR40D	—	L12C_D0
M15	—	—	Vss	Vss	Vss	Vss	—	—
AA26	4 (BR)	7	IO	PR23C	PR33C	PR39C	—	L13T_D0
Y25	4 (BR)	7	IO	PR23D	PR33D	PR39D	VREF_4_07	L13C_D0
Y26	4 (BR)	7	IO	PR22A	PR32C	PR38C	—	L14T_A1
Y24	4 (BR)	7	IO	PR22B	PR32D	PR38D	—	L14C_A1
W25	4 (BR)	8	IO	PR22C	PR31C	PR37C	—	L15T_D1
V23	4 (BR)	8	IO	PR22D	PR31D	PR37D	VREF_4_08	L15C_D1
W26	4 (BR)	8	IO	PR21C	PR30C	PR36C	—	L16T_A1
W24	4 (BR)	8	IO	PR21D	PR30D	PR36D	—	L16C_A1

Table 67. 352-Pin PBGA Pinout

BA352	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
V25	3 (CR)	1	IO	PR20C	PR29C	PR35C	—	L1T_A0
V26	3 (CR)	1	IO	PR20D	PR29D	PR35D	—	L1C_A0
M16	—	—	Vss	Vss	Vss	Vss	—	—
U25	3 (CR)	1	IO	PR19C	PR28C	PR33C	VREF_3_01	L2T_D0
V24	3 (CR)	1	IO	PR19D	PR28D	PR33D	—	L2C_D0
U26	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
U23	3 (CR)	2	IO	PR18C	PR26A	PR31C	—	L3T_D1
T25	3 (CR)	2	IO	PR18D	PR26B	PR31D	VREF_3_02	L3C_D1
U24	3 (CR)	2	IO	PR17A	PR25A	PR30C	—	L4T_D1
T26	3 (CR)	2	IO	PR17B	PR25B	PR30D	—	L4C_D1
N11	—	—	Vss	Vss	Vss	Vss	—	—
R25	3 (CR)	3	IO	PR17C	PR25C	PR29C	—	L5T_A0
R26	3 (CR)	3	IO	PR17D	PR25D	PR29D	VREF_3_03	L5C_A0
F23	—	—	VDD15	VDD15	VDD15	VDD15	—	—
T24	3 (CR)	4	IO	PR16C	PR23C	PR27C	PRCK1T	L6T_D1
P25	3 (CR)	4	IO	PR16D	PR23D	PR27D	PRCK1C	L6C_D1
R23	3 (CR)	4	IO	PR15A	PR22C	PR26C	—	L7T_D2
P26	3 (CR)	4	IO	PR15B	PR22D	PR26D	VREF_3_04	L7C_D2
R24	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
N25	3 (CR)	5	IO	PR15C	PR21C	PR25C	—	L8T_A1
N23	3 (CR)	5	IO	PR15D	PR21D	PR25D	—	L8C_A1
N12	—	—	Vss	Vss	Vss	Vss	—	—
F4	—	—	VDD15	VDD15	VDD15	VDD15	—	—
N26	3 (CR)	5	IO	PR14A	PR20C	PR24C	PRCK0T	L9T_D1
P24	3 (CR)	5	IO	PR14B	PR20D	PR24D	PRCK0C	L9C_D1
M25	3 (CR)	5	IO	PR14C	PR19C	PR23C	VREF_3_05	L10T_D0
N24	3 (CR)	5	IO	PR14D	PR19D	PR23D	—	L10C_D0
N13	—	—	Vss	Vss	Vss	Vss	—	—
M26	3 (CR)	6	IO	PR13C	PR17C	PR21C	—	L11T_D0
L25	3 (CR)	6	IO	PR13D	PR17D	PR21D	VREF_3_06	L11C_D0
M24	3 (CR)	6	IO	PR12A	PR16C	PR20C	—	L12T_D1
L26	3 (CR)	6	IO	PR12B	PR16D	PR20D	—	L12C_D1
M23	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
K25	3 (CR)	7	IO	PR12C	PR15A	PR19C	—	L13T_D0
L24	3 (CR)	7	IO	PR12D	PR15B	PR19D	—	L13C_D0
K26	3 (CR)	7	IO	PR11B	PR14B	PR18D	—	—
N14	—	—	Vss	Vss	Vss	Vss	—	—
K23	3 (CR)	7	IO	PR11C	PR14C	PR17C	VREF_3_07	L14T_D1
J25	3 (CR)	7	IO	PR11D	PR14D	PR17D	—	L14C_D1
K24	3 (CR)	8	IO	PR10C	PR13C	PR15C	—	L15T_D1
J26	3 (CR)	8	IO	PR10D	PR13D	PR15D	—	L15C_D1
N15	—	—	Vss	Vss	Vss	Vss	—	—
H25	3 (CR)	8	IO	PR9C	PR12C	PR14C	VREF_3_08	L16T_A0
H26	3 (CR)	8	IO	PR9D	PR12D	PR14D	—	L16C_A0

Table 67. 352-Pin PBGA Pinout

BA352	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
L23	—	—	VDD15	VDD15	VDD15	VDD15	—	—
J24	2 (TR)	1	IO	PR8C	PR11C	PR13C	—	L1T_D1
G25	2 (TR)	1	IO	PR8D	PR11D	PR13D	VREF_2_01	L1C_D1
H23	2 (TR)	1	IO	PR7A	PR10C	PR12C	—	L2T_D2
G26	2 (TR)	1	IO	PR7B	PR10D	PR12D	—	L2C_D2
P12	—	—	Vss	Vss	Vss	Vss	—	—
H24	2 (TR)	1	IO	PR7C	PR9C	PR11C	—	L3T_D1
F25	2 (TR)	1	IO	PR7D	PR9D	PR11D	—	L3C_D1
G23	2 (TR)	2	IO	PR6A	PR7A	PR10C	—	L4T_D2
F26	2 (TR)	2	IO	PR6B	PR7B	PR10D	—	L4C_D2
G24	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
E25	2 (TR)	2	IO	PR6C	PR6A	PR9C	VREF_2_02	L5T_A0
E26	2 (TR)	2	IO	PR6D	PR6B	PR9D	—	L5C_A0
P13	—	—	Vss	Vss	Vss	Vss	—	—
F24	2 (TR)	3	IO	PR5C	PR5A	PR7C	—	L6T_D1
D25	2 (TR)	3	IO	PR5D	PR5B	PR7D	VREF_2_03	L6C_D1
E23	2 (TR)	3	IO	PR4C	PR4C	PR5C	—	L7T_D2
D26	2 (TR)	3	IO	PR4D	PR4D	PR5D	—	L7C_D2
P14	—	—	Vss	Vss	Vss	Vss	—	—
E24	2 (TR)	4	IO	PR3C	PR3C	PR3C	PLL_CK3T/PLL1	L8T_D1
C25	2 (TR)	4	IO	PR3D	PR3D	PR3D	PLL_CK3C/PLL1	L8C_D1
D24	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
C26	—	—	VDD33	VDD33	VDD33	VDD33	—	—
L4	—	—	VDD15	VDD15	VDD15	VDD15	—	—
P15	—	—	Vss	Vss	Vss	Vss	—	—
P16	—	—	Vss	Vss	Vss	Vss	—	—
A25	—	—	VDD33	VDD33	VDD33	VDD33	—	—
B24	—	—	IO	PLL_VF	PLL_VF	PLL_VF	PLL_VF	—
A24	2 (TR)	5	IO	PT27D	PT37D	PT47D	PLL_CK2C/PPLL	L9C_A0
B23	2 (TR)	5	IO	PT27C	PT37C	PT47C	PLL_CK2T/PPLL	L9T_A0
R11	—	—	Vss	Vss	Vss	Vss	—	—
C23	2 (TR)	5	IO	PT26D	PT36D	PT45D	VREF_2_05	L10C_A1
A23	2 (TR)	5	IO	PT26C	PT36C	PT45C	—	L10T_A1
B22	2 (TR)	6	IO	PT26B	PT35B	PT43D	—	L11C_A1
D22	2 (TR)	6	IO	PT26A	PT35A	PT43C	—	L11T_A1
C22	2 (TR)	6	IO	PT25D	PT34D	PT42D	VREF_2_06	L12C_A1
A22	2 (TR)	6	IO	PT25C	PT34C	PT42C	—	L12T_A1
R12	—	—	Vss	Vss	Vss	Vss	—	—
B21	2 (TR)	7	IO	PT24D	PT33D	PT40D	—	L13C_D1
D20	2 (TR)	7	IO	PT24C	PT33C	PT40C	VREF_2_07	L13T_D1
C21	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
A21	2 (TR)	7	IO	PT24B	PT32D	PT39D	—	L14C_D0
B20	2 (TR)	7	IO	PT24A	PT32C	PT39C	—	L14T_D0
A20	2 (TR)	8	IO	PT23D	PT31D	PT38D	—	L15C_A1

Table 67. 352-Pin PBGA Pinout

BA352	$V_{DD}IO$ Bank	V_{REF} Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
C20	2 (TR)	8	IO	PT23C	PT31C	PT38C	VREF_2_08	L15T_A1
R13	—	—	Vss	Vss	Vss	Vss	—	—
B19	2 (TR)	8	IO	PT22D	PT29D	PT36D	—	L16C_D1
D18	2 (TR)	8	IO	PT22C	PT29C	PT36C	—	L16T_D1
A19	1 (TC)	1	IO	PT21D	PT28D	PT35D	—	L1C_A1
C19	1 (TC)	1	IO	PT21C	PT28C	PT35C	—	L1T_A1
R15	—	—	Vss	Vss	Vss	Vss	—	—
B18	1 (TC)	1	IO	PT20D	PT27D	PT34D	VREF_1_01	L2C_A0
A18	1 (TC)	1	IO	PT20C	PT27C	PT34C	—	L2T_A0
B17	1 (TC)	1	IO	PT20B	PT27B	PT33D	—	L3C_D0
C18	1 (TC)	1	IO	PT20A	PT27A	PT33C	—	L3T_D0
A17	1 (TC)	2	IO	PT19D	PT26D	PT32D	—	L4C_A2
D17	1 (TC)	2	IO	PT19C	PT26C	PT32C	VREF_1_02	L4T_A2
R16	—	—	Vss	Vss	Vss	Vss	—	—
T11	—	—	Vss	Vss	Vss	Vss	—	—
T23	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
B16	1 (TC)	2	IO	PT18D	PT25D	PT30D	—	L5C_D0
C17	1 (TC)	2	IO	PT18C	PT25C	PT30C	—	L5T_D0
A16	1 (TC)	—	$V_{DD}IO1$	$V_{DD}IO1$	$V_{DD}IO1$	$V_{DD}IO1$	—	—
B15	1 (TC)	3	IO	PT18B	PT24D	PT29D	—	L6C_A0
A15	1 (TC)	3	IO	PT18A	PT24C	PT29C	VREF_1_03	L6T_A0
C16	1 (TC)	3	IO	PT17D	PT23D	PT28D	—	L7C_D1
B14	1 (TC)	3	IO	PT17C	PT23C	PT28C	—	L7T_D1
T12	—	—	Vss	Vss	Vss	Vss	—	—
D15	1 (TC)	4	IO	PT16D	PT21D	PT26D	—	L8C_D2
A14	1 (TC)	4	IO	PT16C	PT21C	PT26C	—	L8T_D2
T4	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
C15	1 (TC)	4	IO	PT15D	PT19D	PT24D	—	L9C_D1
B13	1 (TC)	4	IO	PT15C	PT19C	PT24C	VREF_1_04	L9T_D1
D13	1 (TC)	—	$V_{DD}IO1$	$V_{DD}IO1$	$V_{DD}IO1$	$V_{DD}IO1$	—	—
A13	1 (TC)	5	IO	PT14D	PT18D	PT23D	PTCK1C	L10C_D1
C14	1 (TC)	5	IO	PT14C	PT18C	PT23C	PTCK1T	L10T_D1
T13	—	—	Vss	Vss	Vss	Vss	—	—
B12	1 (TC)	5	IO	PT13D	PT17D	PT22D	PTCK0C	L11C_D0
C13	1 (TC)	5	IO	PT13C	PT17C	PT22C	PTCK0T	L11T_D0
A12	1 (TC)	5	IO	PT13B	PT16D	PT21D	VREF_1_05	L12C_D0
B11	1 (TC)	5	IO	PT13A	PT16C	PT21C	—	L12T_D0
T14	—	—	Vss	Vss	Vss	Vss	—	—
C12	1 (TC)	6	IO	PT12B	PT14D	PT19D	—	L13C_D1
A11	1 (TC)	6	IO	PT12A	PT14C	PT19C	VREF_1_06	L13T_D1
D12	0 (TL)	1	IO	PT11D	PT13D	PT18D	MPI_RTRY_N	L1C_D2
B10	0 (TL)	1	IO	PT11C	PT13C	PT18C	MPI_ACK_N	L1C_D2
C11	0 (TL)	—	$V_{DD}IO0$	$V_{DD}IO0$	$V_{DD}IO0$	$V_{DD}IO0$	—	—
A10	0 (TL)	1	IO	PT10D	PT12D	PT16D	M0	L2C_A2

Table 67. 352-Pin PBGA Pinout

BA352	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
D10	0 (TL)	1	IO	PT10C	PT12C	PT16C	M1	L2T_A2
AC18	—	—	Vss	Vss	Vss	Vss	—	—
B9	0 (TL)	2	IO	PT10B	PT12B	PT15D	MPI_CLK	L3C_D0
C10	0 (TL)	2	IO	PT10A	PT12A	PT15C	A21/MPI_BURST_N	L3C_D0
A9	0 (TL)	2	IO	PT9D	PT11D	PT14D	M2	L4C_D0
B8	0 (TL)	2	IO	PT9C	PT11C	PT14C	M3	L4T_D0
A8	0 (TL)	2	IO	PT9B	PT11B	PT13D	VREF_0_02	L5C_D1
C9	0 (TL)	2	IO	PT9A	PT11A	PT13C	MPI_TEA_N	L5T_D1
B7	0 (TL)	3	IO	PT8B	PT9D	PT11D	VREF_0_03	—
D8	0 (TL)	3	IO	PT7D	PT8D	PT10D	D0	L6C_D2
A7	0 (TL)	3	IO	PT7C	PT8C	PT10C	TMS	L6T_D2
AC23	—	—	Vss	Vss	Vss	Vss	—	—
C8	0 (TL)	4	IO	PT7B	PT7D	PT9D	A20/MPI_BDIP_N	L7C_D2
B6	0 (TL)	4	IO	PT7A	PT7C	PT9C	A19/MPI_TSZ1	L7T_D2
D7	0 (TL)	4	IO	PT6D	PT6D	PT8D	A18/MPI_TSZ0	L8C_D2
A6	0 (TL)	4	IO	PT6C	PT6C	PT8C	D3	L8T_D2
C7	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	VDDIO0	—	—
B5	0 (TL)	5	IO	PT5D	PT5D	PT6D	D1	L9C_A0
A5	0 (TL)	5	IO	PT5C	PT5C	PT6C	D2	L9T_A0
AC4	—	—	Vss	Vss	Vss	Vss	—	—
C6	0 (TL)	5	IO	PT4D	PT4D	PT4D	TDI	L10C_D2
B4	0 (TL)	5	IO	PT4C	PT4C	PT4C	TCK	L10T_D2
AC8	—	—	Vss	Vss	Vss	Vss	—	—
D5	0 (TL)	6	IO	PT2D	PT2D	PT2D	PLL_CK1C/PPLL	L11C_D2
A4	0 (TL)	6	IO	PT2C	PT2C	PT2C	PLL_CK1T/PPLL	L11T_D2
C5	—	—	O	PCFG_ MPI_IRQ	PCFG_ MPI_IRQ	PCFG_ MPI_IRQ	CFG_IRQ_N/ MPI_IRQ_N	—
B3	—	—	IO	PCCLK	PCCLK	PCCLK	CCLK	—
C4	—	—	IO	PDONE	PDONE	PDONE	DONE	—
A3	—	—	VDD33	VDD33	VDD33	VDD33	—	—
AD24	—	—	Vss	Vss	Vss	Vss	—	—
AF26	—	—	Vss	Vss	Vss	Vss	—	—
B2	—	—	Vss	Vss	Vss	Vss	—	—
V4	—	—	Vss	Vss	Vss	Vss	—	—
W23	—	—	Vss	Vss	Vss	Vss	—	—
L11	—	—	Vss	Vss	Vss	Vss	—	—
L12	—	—	Vss	Vss	Vss	Vss	—	—
N16	—	—	Vss	Vss	Vss	Vss	—	—
P11	—	—	Vss	Vss	Vss	Vss	—	—
R14	—	—	Vss	Vss	Vss	Vss	—	—
T15	—	—	Vss	Vss	Vss	Vss	—	—
T16	—	—	Vss	Vss	Vss	Vss	—	—

416-Pin BGAM Pinout

Table 68. 416-Pin BGAM Pinout

BM416	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
A2	—	—	Vss	Vss	Vss	—	—
D4	—	—	VDD33	VDD33	VDD33	—	—
D3	—	—	O	PRD_DATA	PRD_DATA	RD_DATA/TDO	—
A1	—	—	VDD15	VDD15	VDD15	—	—
C1	—	—	I	PRESET_N	PRESET_N	RESET_N	—
E4	—	—	I	PRD_CFG_N	PRD_CFG_N	RD_CFG_N	—
F4	—	—	I	PPRGRM_N	PPRGRM_N	PRGRM_N	—
C2	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	—	—
D2	0 (TL)	7	IO	PL2D	PL2D	PLL_CK0C/HPPLL	L14C_D0
E3	0 (TL)	7	IO	PL2C	PL2C	PLL_CK0T/HPPLL	L14T_D0
A25	—	—	Vss	Vss	Vss	—	—
D1	0 (TL)	7	IO	PL2A	PL3C	VREF_0_07	—
E2	0 (TL)	7	IO	PL3D	PL4D	D5	L15C_D0
F3	0 (TL)	7	IO	PL3C	PL4C	D6	L15T_D0
E1	0 (TL)	8	IO	PL4D	PL5D	HDC	L16C_D0
F2	0 (TL)	8	IO	PL4C	PL5C	LDC_N	L16T_D0
B1	—	—	Vss	Vss	Vss	—	—
G4	0 (TL)	9	IO	PL5D	PL6D	TESTCFG	L17C_A0
H4	0 (TL)	9	IO	PL5C	PL6C	D7	L17T_A0
G3	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	—	—
F1	0 (TL)	9	IO	PL5B	PL7D	VREF_0_09	L18C_D0
G2	0 (TL)	9	IO	PL5A	PL7C	A17/PPC_A31	L18T_D0
H2	0 (TL)	9	IO	PL6D	PL8D	CS0_N	L19C_A0
H3	0 (TL)	9	IO	PL6C	PL8C	CS1	L19T_A0
G1	0 (TL)	10	IO	PL6B	PL9D	—	L20C_A0
H1	0 (TL)	10	IO	PL6A	PL9C	—	L20T_A0
J4	0 (TL)	10	IO	PL7D	PL10D	INIT_N	L21C_A0
K4	0 (TL)	10	IO	PL7C	PL10C	DOUT	L21T_A0
A26	—	—	VDD15	VDD15	VDD15	—	—
J3	0 (TL)	10	IO	PL7B	PL11D	VREF_0_10	L22C_A0
J2	0 (TL)	10	IO	PL7A	PL11C	A16/PPC_A30	L22T_A0
J1	7 (CL)	1	IO	PL8D	PL12D	A15/PPC_A29	L1C_D0
K2	7 (CL)	1	IO	PL8C	PL12C	A14/PPC_A28	L1T_D0
K1	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	—	—
K3	7 (CL)	1	IO	PL9D	PL13D	VREF_7_01	L2C_A0
L3	7 (CL)	1	IO	PL9C	PL13C	D4	L2T_A0
U16	—	—	Vss	Vss	Vss	—	—
L4	7 (CL)	2	IO	PL10D	PL14D	RDY/BUSY_N/RCLK	L3C_A0
M4	7 (CL)	2	IO	PL10C	PL14C	VREF_7_02	L3T_A0
L2	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	—	—
L1	7 (CL)	2	IO	PL10B	PL15D	A13/PPC_A27	L4C_A0

Table 68. 416-Pin BGAM Pinout

BM416	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
M1	7 (CL)	2	IO	PL10A	PL15C	A12/PPC_A26	L4T_A0
M3	7 (CL)	3	IO	PL11D	PL16D	—	L5C_A0
M2	7 (CL)	3	IO	PL11C	PL16C	—	L5T_A0
U17	—	—	Vss	Vss	Vss	—	—
N1	7 (CL)	3	IO	PL11B	PL17D	A11/PPC_A25	L6C_A0
N2	7 (CL)	3	IO	PL11A	PL17C	VREF_7_03	L6T_A0
U14	—	—	VDD15	VDD15	VDD15	—	—
N3	7 (CL)	4	IO	PL13D	PL19D	RD_N/ MPI_STRB_N	L7C_A0
N4	7 (CL)	4	IO	PL13C	PL19C	VREF_7_04	L7T_A0
AE1	—	—	Vss	Vss	Vss	—	—
P4	7 (CL)	4	IO	PL14D	PL20D	PLCK0C	L8C_A0
P3	7 (CL)	4	IO	PL14C	PL20C	PLCK0T	L8T_A0
P2	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	—	—
AE26	—	—	Vss	Vss	Vss	—	—
P1	7 (CL)	5	IO	PL15D	PL21D	A10/PPC_A24	L9C_A0
R1	7 (CL)	5	IO	PL15C	PL21C	A9/PPC_A23	L9T_A0
AF2	—	—	Vss	Vss	Vss	—	—
R2	7 (CL)	5	IO	PL16D	PL22D	A8/PPC_A22	L10C_A0
R3	7 (CL)	5	IO	PL16C	PL22C	VREF_7_05	L10T_A0
AF1	—	—	VDD15	VDD15	VDD15	—	—
T1	7 (CL)	6	IO	PL17D	PL24D	PLCK1C	L11C_A0
T2	7 (CL)	6	IO	PL17C	PL24C	PLCK1T	L11T_A0
AF25	—	—	Vss	Vss	Vss	—	—
T4	7 (CL)	6	IO	PL17B	PL25D	VREF_7_06	L12C_A0
R4	7 (CL)	6	IO	PL17A	PL25C	A7/PPC_A21	L12T_A0
U1	7 (CL)	6	IO	PL18D	PL26D	A6/PPC_A20	L13C_A0
U2	7 (CL)	6	IO	PL18C	PL26C	A5/PPC_A19	L13T_A0
T3	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	—	—
V1	7 (CL)	7	IO	PL18B	PL26B	—	—
V2	7 (CL)	7	IO	PL19D	PL27D	WR_N/MPI_RW	L14C_D0
U3	7 (CL)	7	IO	PL19C	PL27C	VREF_7_07	L14T_D0
AF26	—	—	VDD15	VDD15	VDD15	—	—
W1	7 (CL)	8	IO	PL20D	PL28D	A4/PPC_A18	L15C_A0
Y1	7 (CL)	8	IO	PL20C	PL28C	VREF_7_08	L15T_A0
V4	7 (CL)	8	IO	PL20B	PL29D	A3/PPC_A17	L16C_A0
U4	7 (CL)	8	IO	PL20A	PL29C	A2/PPC_A16	L16T_A0
V3	7 (CL)	8	IO	PL21D	PL30D	A1/PPC_A15	L17C_D0
W2	7 (CL)	8	IO	PL21C	PL30C	A0/PPC_A14	L17T_D0
Y2	7 (CL)	8	IO	PL21B	PL31D	DP0	L18C_D0
W3	7 (CL)	8	IO	PL21A	PL31C	DP1	L18T_D0
AA1	6 (BL)	1	IO	PL22D	PL32D	D8	L1C_A0
AA2	6 (BL)	1	IO	PL22C	PL32C	VREF_6_01	L1T_A0
T16	—	—	Vss	Vss	Vss	—	—

Table 68. 416-Pin BGAM Pinout

BM416	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
Y3	6 (BL)	1	IO	PL22B	PL33D	D9	L2C_D0
W4	6 (BL)	1	IO	PL22A	PL33C	D10	L2T_D0
Y4	6 (BL)	2	IO	PL23D	PL34D	—	L3C_D0
AA3	6 (BL)	2	IO	PL23C	PL34C	VREF_6_02	L3T_D0
AB1	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	—	—
AB2	6 (BL)	3	IO	PL24D	PL35B	D11	L4C_D0
AC1	6 (BL)	3	IO	PL24C	PL35A	D12	L4T_D0
T17	—	—	Vss	Vss	Vss	—	—
AC2	6 (BL)	3	IO	PL25D	PL36B	VREF_6_03	L5C_D0
AB3	6 (BL)	3	IO	PL25C	PL36A	D13	L5T_D0
AD1	6 (BL)	4	IO	PL26C	PL37A	VREF_6_04	—
U10	—	—	Vss	Vss	Vss	—	—
AA4	6 (BL)	4	IO	PL27D	PL39D	PLL_CK7C/HPPLL	L6C_A0
AB4	6 (BL)	4	IO	PL27C	PL39C	PLL_CK7T/HPPLL	L6T_A0
U11	—	—	Vss	Vss	Vss	—	—
U12	—	—	Vss	Vss	Vss	—	—
AC3	—	—	I	PTEMP	PTEMP	PTEMP	—
AD2	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	—	—
R14	—	—	VDD15	VDD15	VDD15	—	—
AE2	—	—	IO	LVDS_R	LVDS_R	LVDS_R	—
AD3	—	—	VDD33	VDD33	VDD33	—	—
U15	—	—	Vss	Vss	Vss	—	—
AC4	—	—	VDD33	VDD33	VDD33	—	—
T13	—	—	VDD15	VDD15	VDD15	—	—
AE3	6 (BL)	5	IO	PB2A	PB2A	DP2	—
AC5	6 (BL)	5	IO	PB2C	PB2C	PLL_CK6T/PPLL	L7T_D0
AD4	6 (BL)	5	IO	PB2D	PB2D	PLL_CK6C/PPLL	L7C_D0
AE4	6 (BL)	5	IO	PB3C	PB4A	VREF_6_05	L8T_D0
AF3	6 (BL)	5	IO	PB3D	PB4B	DP3	L8C_D0
AC6	6 (BL)	6	IO	PB4A	PB4C	—	L9T_D0
AD5	6 (BL)	6	IO	PB4B	PB4D	—	L9C_D0
AF4	6 (BL)	6	IO	PB4C	PB5C	VREF_6_06	L10T_D0
AE5	6 (BL)	6	IO	PB4D	PB5D	D14	L10C_D0
AD6	6 (BL)	6	IO	PB5B	PB6B	—	—
AF5	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	—	—
AC7	6 (BL)	7	IO	PB5C	PB6C	D15	L11T_A0
AC8	6 (BL)	7	IO	PB5D	PB6D	D16	L11C_A0
AD7	6 (BL)	7	IO	PB6A	PB7C	D17	L12T_D0
AE6	6 (BL)	7	IO	PB6B	PB7D	D18	L12C_D0
AE7	6 (BL)	7	IO	PB6C	PB8C	VREF_6_07	L13T_D0
AD8	6 (BL)	7	IO	PB6D	PB8D	D19	L13C_D0
AF6	6 (BL)	8	IO	PB7A	PB9C	D20	L14T_A0
AF7	6 (BL)	8	IO	PB7B	PB9D	D21	L14C_A0
T14	—	—	VDD15	VDD15	VDD15	—	—

Table 68. 416-Pin BGAM Pinout

BM416	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
AE8	6 (BL)	8	IO	PB7C	PB10C	VREF_6_08	L15T_D0
AD9	6 (BL)	8	IO	PB7D	PB10D	D22	L15C_D0
AC9	6 (BL)	9	IO	PB8C	PB11C	D23	L16T_A0
AC10	6 (BL)	9	IO	PB8D	PB11D	D24	L16C_A0
AF8	6 (BL)	9	IO	PB9C	PB12C	VREF_6_09	L17T_D0
AE9	6 (BL)	9	IO	PB9D	PB12D	D25	L17C_D0
AD10	6 (BL)	10	IO	PB10C	PB13C	D26	L18T_A0
AE10	6 (BL)	10	IO	PB10D	PB13D	D27	L18C_A0
AF9	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	—	—
AE11	6 (BL)	10	IO	PB11C	PB14C	VREF_6_10	L19T_A0
AD11	6 (BL)	10	IO	PB11D	PB14D	D28	L19C_A0
AC12	6 (BL)	11	IO	PB12A	PB15C	D29	L20T_A0
AC11	6 (BL)	11	IO	PB12B	PB15D	D30	L20C_A0
AF10	6 (BL)	11	IO	PB12C	PB16C	VREF_6_11	L21T_A0
AF11	6 (BL)	11	IO	PB12D	PB16D	D31	L21C_A0
AD12	5 (BC)	1	IO	PB13A	PB17C	—	L1T_A0
AE12	5 (BC)	1	IO	PB13B	PB17D	—	L1C_A0
P16	—	—	VDD15	VDD15	VDD15	—	—
AF12	5 (BC)	1	IO	PB13C	PB18C	VREF_5_01	L2T_A0
AF13	5 (BC)	1	IO	PB13D	PB18D	—	L2C_A0
R16	—	—	Vss	Vss	Vss	—	—
AD13	5 (BC)	2	IO	PB14C	PB19C	PBCK0T	L3T_A0
AE13	5 (BC)	2	IO	PB14D	PB19D	PBCK0C	L3C_A0
AF14	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	—	—
AC14	5 (BC)	2	IO	PB15C	PB20C	VREF_5_02	L4T_A0
AC13	5 (BC)	2	IO	PB15D	PB20D	—	L4C_A0
P17	—	—	VDD15	VDD15	VDD15	—	—
AE14	5 (BC)	3	IO	PB16C	PB21C	—	L5T_A0
AD14	5 (BC)	3	IO	PB16D	PB21D	VREF_5_03	L5C_A0
AF15	5 (BC)	3	IO	PB17A	PB22C	—	L6T_A0
AE15	5 (BC)	3	IO	PB17B	PB22D	—	L6C_A0
R17	—	—	Vss	Vss	Vss	—	—
AD15	5 (BC)	3	IO	PB17C	PB23C	PBCK1T	L7T_D0
AE16	5 (BC)	3	IO	PB17D	PB23D	PBCK1C	L7C_D0
AC15	5 (BC)	4	IO	PB18A	PB24C	—	L8T_A0
AC16	5 (BC)	4	IO	PB18B	PB24D	—	L8C_A0
AF17	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	—	—
AD16	5 (BC)	4	IO	PB18C	PB25C	—	L9T_D0
AE17	5 (BC)	4	IO	PB18D	PB25D	VREF_5_04	L9C_D0
T10	—	—	Vss	Vss	Vss	—	—
T11	—	—	Vss	Vss	Vss	—	—
AF18	5 (BC)	5	IO	PB19C	PB26C	—	L10T_A0
AE18	5 (BC)	5	IO	PB19D	PB26D	VREF_5_05	L10C_A0
AD17	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	—	—

Table 68. 416-Pin BGAM Pinout

BM416	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
AF19	5 (BC)	5	IO	PB20C	PB27C	—	L11T_A0
AF20	5 (BC)	5	IO	PB20D	PB27D	—	L11C_A0
AC18	5 (BC)	6	IO	PB21A	PB28C	—	L12T_A0
AC17	5 (BC)	6	IO	PB21B	PB28D	VREF_5_06	L12C_A0
R13	—	—	VDD15	VDD15	VDD15	—	—
AD18	4 (BR)	1	IO	PB22A	PB30C	—	L1T_D0
AE19	4 (BR)	1	IO	PB22B	PB30D	—	L1C_D0
P13	—	—	Vss	Vss	Vss	—	—
AE20	4 (BR)	1	IO	PB22C	PB31C	VREF_4_01	L2T_D0
AD19	4 (BR)	1	IO	PB22D	PB31D	—	L2C_D0
AF21	4 (BR)	1	IO	PB23A	PB32C	—	L3T_A0
AE21	4 (BR)	1	IO	PB23B	PB32D	—	L3C_A0
AD20	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	—	—
AC19	4 (BR)	2	IO	PB23C	PB33C	—	L4T_A0
AC20	4 (BR)	2	IO	PB23D	PB33D	VREF_4_02	L4C_A0
AF22	4 (BR)	2	IO	PB24A	PB34A	—	—
P14	—	—	Vss	Vss	Vss	—	—
AE22	4 (BR)	2	IO	PB24C	PB34C	—	—
AD21	4 (BR)	3	IO	PB25A	PB35A	—	—
AF23	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	—	—
AE23	4 (BR)	3	IO	PB25C	PB35C	—	L5T_D0
AF24	4 (BR)	3	IO	PB25D	PB35D	VREF_4_03	L5C_D0
R10	—	—	Vss	Vss	Vss	—	—
AC21	4 (BR)	3	IO	PB26C	PB36C	—	L6T_D0
AD22	4 (BR)	3	IO	PB26D	PB36D	—	L6C_D0
AD23	4 (BR)	4	IO	PB27A	PB37A	—	L7T_D0
AE24	4 (BR)	4	IO	PB27B	PB37B	VREF_4_04	L7C_D0
R11	—	—	Vss	Vss	Vss	—	—
AC22	4 (BR)	4	IO	PB27C	PB37C	PLL_CK5T/PPLL	L8T_A0
AC23	4 (BR)	4	IO	PB27D	PB37D	PLL_CK5C/PPLL	L8C_A0
P10	—	—	VDD15	VDD15	VDD15	—	—
AD24	—	—	VDD33	VDD33	VDD33	—	—
R12	—	—	Vss	Vss	Vss	—	—
R15	—	—	Vss	Vss	Vss	—	—
P11	—	—	VDD15	VDD15	VDD15	—	—
AE25	—	—	VDD33	VDD33	VDD33	—	—
AC24	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	—	—
AD25	4 (BR)	5	IO	PR26A	PR38A	PLL_CK4T/PLL2	L9T_A0
AD26	4 (BR)	5	IO	PR26B	PR38B	PLL_CK4C/PLL2	L9C_A0
AB23	4 (BR)	5	IO	PR25A	PR37A	VREF_4_05	L10T_A0
AA23	4 (BR)	5	IO	PR25B	PR37B	—	L10C_A0
AC25	4 (BR)	6	IO	PR25C	PR36A	—	L11T_D0
AB24	4 (BR)	6	IO	PR25D	PR36B	—	L11C_D0
AB25	4 (BR)	6	IO	PR24A	PR36C	—	—

Table 68. 416-Pin BGAM Pinout

BM416	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
AA24	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	—	—
AC26	4 (BR)	6	IO	PR24C	PR35C	VREF_4_06	L12T_A0
AB26	4 (BR)	6	IO	PR24D	PR35D	—	L12C_A0
Y24	4 (BR)	7	IO	PR23A	PR34C	—	L13T_D0
W23	4 (BR)	7	IO	PR23B	PR34D	—	L13C_D0
AA25	4 (BR)	7	IO	PR23C	PR33C	—	L14T_A0
AA26	4 (BR)	7	IO	PR23D	PR33D	VREF_4_07	L14C_A0
Y23	4 (BR)	7	IO	PR22A	PR32C	—	L15T_D0
W24	4 (BR)	7	IO	PR22B	PR32D	—	L15C_D0
P12	—	—	VDD15	VDD15	VDD15	—	—
Y25	4 (BR)	8	IO	PR22C	PR31C	—	L16T_A0
Y26	4 (BR)	8	IO	PR22D	PR31D	VREF_4_08	L16C_A0
W25	4 (BR)	8	IO	PR21C	PR30C	—	L17T_D0
V24	4 (BR)	8	IO	PR21D	PR30D	—	L17C_D0
W26	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	—	—
V23	3 (CR)	1	IO	PR20C	PR29C	—	L1T_A0
U23	3 (CR)	1	IO	PR20D	PR29D	—	L1C_A0
M12	—	—	Vss	Vss	Vss	—	—
V25	3 (CR)	1	IO	PR19C	PR28C	VREF_3_01	L2T_D0
U24	3 (CR)	1	IO	PR19D	PR28D	—	L2C_D0
V26	3 (CR)	2	IO	PR18A	PR27A	—	—
U26	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	—	—
U25	3 (CR)	2	IO	PR18C	PR26A	—	L3T_D0
T24	3 (CR)	2	IO	PR18D	PR26B	VREF_3_02	L3C_D0
R23	3 (CR)	2	IO	PR17A	PR25A	—	L4T_A0
T23	3 (CR)	2	IO	PR17B	PR25B	—	L4C_A0
M15	—	—	Vss	Vss	Vss	—	—
T25	3 (CR)	3	IO	PR17C	PR25C	—	L5T_A0
T26	3 (CR)	3	IO	PR17D	PR25D	VREF_3_03	L5C_A0
N15	—	—	VDD15	VDD15	VDD15	—	—
R24	3 (CR)	4	IO	PR16C	PR23C	PRCK1T	L6T_A0
R25	3 (CR)	4	IO	PR16D	PR23D	PRCK1C	L6C_A0
R26	3 (CR)	4	IO	PR15A	PR22C	—	L7T_D0
P25	3 (CR)	4	IO	PR15B	PR22D	VREF_3_04	L7C_D0
P24	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	—	—
P26	3 (CR)	5	IO	PR15C	PR21C	—	L8T_A0
N26	3 (CR)	5	IO	PR15D	PR21D	—	L8C_A0
M16	—	—	Vss	Vss	Vss	—	—
N23	3 (CR)	5	IO	PR14A	PR20C	PRCK0T	L9T_A0
P23	3 (CR)	5	IO	PR14B	PR20D	PRCK0C	L9C_A0
N16	—	—	VDD15	VDD15	VDD15	—	—
N25	3 (CR)	5	IO	PR14C	PR19C	VREF_3_05	L10T_A0
N24	3 (CR)	5	IO	PR14D	PR19D	—	L10C_A0
M26	3 (CR)	5	IO	PR13A	PR18C	—	L11T_A0

Table 68. 416-Pin BGAM Pinout

BM416	$V_{DD}IO$ Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
M25	3 (CR)	5	IO	PR13B	PR18D	—	L11C_A0
M17	—	—	Vss	Vss	Vss	—	—
M24	3 (CR)	6	IO	PR13C	PR17C	—	L12T_A0
M23	3 (CR)	6	IO	PR13D	PR17D	VREF_3_06	L12C_A0
L26	3 (CR)	6	IO	PR12A	PR16C	—	L13T_A0
L25	3 (CR)	6	IO	PR12B	PR16D	—	L13C_A0
K26	3 (CR)	—	$V_{DD}IO3$	$V_{DD}IO3$	$V_{DD}IO3$	—	—
L23	3 (CR)	7	IO	PR12C	PR15A	—	L14T_A0
L24	3 (CR)	7	IO	PR12D	PR15B	—	L14C_A0
K25	3 (CR)	7	IO	PR11A	PR14A	—	L15T_D0
J26	3 (CR)	7	IO	PR11B	PR14B	—	L15C_D0
N13	—	—	Vss	Vss	Vss	—	—
J25	3 (CR)	7	IO	PR11C	PR14C	VREF_3_07	L16T_D0
K24	3 (CR)	7	IO	PR11D	PR14D	—	L16C_D0
H26	3 (CR)	8	IO	PR10C	PR13C	—	L17T_A0
G26	3 (CR)	8	IO	PR10D	PR13D	—	L17C_A0
N14	—	—	Vss	Vss	Vss	—	—
K23	3 (CR)	8	IO	PR9C	PR12C	VREF_3_08	L18T_A0
J23	3 (CR)	8	IO	PR9D	PR12D	—	L18C_A0
M14	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
J24	2 (TR)	1	IO	PR8C	PR11C	—	L1T_D0
H25	2 (TR)	1	IO	PR8D	PR11D	VREF_2_01	L1C_D0
G25	2 (TR)	1	IO	PR7A	PR10C	—	L2T_D0
H24	2 (TR)	1	IO	PR7B	PR10D	—	L2C_D0
L12	—	—	Vss	Vss	Vss	—	—
F26	2 (TR)	1	IO	PR7C	PR9C	—	L3T_A0
E26	2 (TR)	1	IO	PR7D	PR9D	—	L3C_A0
H23	2 (TR)	2	IO	PR6A	PR7A	—	L4T_D0
G24	2 (TR)	2	IO	PR6B	PR7B	—	L4C_D0
G23	2 (TR)	—	$V_{DD}IO2$	$V_{DD}IO2$	$V_{DD}IO2$	—	—
F25	2 (TR)	2	IO	PR6C	PR6A	VREF_2_02	L5T_A0
E25	2 (TR)	2	IO	PR6D	PR6B	—	L5C_A0
F24	2 (TR)	2	IO	PR5A	PR6C	—	—
L15	—	—	Vss	Vss	Vss	—	—
D26	2 (TR)	3	IO	PR5C	PR5A	—	L6T_A0
D25	2 (TR)	3	IO	PR5D	PR5B	VREF_2_03	L6C_A0
C25	2 (TR)	3	IO	PR4A	PR4A	—	L7T_D0
D24	2 (TR)	3	IO	PR4B	PR4B	—	L7C_D0
F23	2 (TR)	3	IO	PR4C	PR4C	—	L8T_D0
E24	2 (TR)	3	IO	PR4D	PR4D	—	L8C_D0
L16	—	—	Vss	Vss	Vss	—	—
C26	2 (TR)	4	IO	PR3C	PR3C	PLL_CK3T/PLL1	L9T_D0
B25	2 (TR)	4	IO	PR3D	PR3D	PLL_CK3C/PLL1	L9C_D0
E23	2 (TR)	—	$V_{DD}IO2$	$V_{DD}IO2$	$V_{DD}IO2$	—	—

Table 68. 416-Pin BGAM Pinout

BM416	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
C24	—	—	VDD33	VDD33	VDD33	—	—
N10	—	—	VDD15	VDD15	VDD15	—	—
L17	—	—	Vss	Vss	Vss	—	—
M10	—	—	Vss	Vss	Vss	—	—
D23	—	—	VDD33	VDD33	VDD33	—	—
N11	—	—	VDD15	VDD15	VDD15	—	—
B24	—	—	IO	PLL_VF	PLL_VF	PLL_VF	—
D22	2 (TR)	5	IO	PT27D	PT37D	PLL_CK2C/PPLL	L10C_D0
C23	2 (TR)	5	IO	PT27C	PT37C	PLL_CK2T/PPLL	L10T_D0
M11	—	—	Vss	Vss	Vss	—	—
A24	2 (TR)	5	IO	PT26D	PT36D	VREF_2_05	L11C_D0
B23	2 (TR)	5	IO	PT26C	PT36C	—	L11T_D0
C22	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	—	—
D21	2 (TR)	6	IO	PT26B	PT35B	—	L12C_A0
C21	2 (TR)	6	IO	PT26A	PT35A	—	L12T_A0
A23	2 (TR)	6	IO	PT25D	PT34D	VREF_2_06	L13C_D0
B22	2 (TR)	6	IO	PT25C	PT34C	—	L13T_D0
A22	2 (TR)	7	IO	PT24D	PT33D	—	L14C_D0
B21	2 (TR)	7	IO	PT24C	PT33C	VREF_2_07	L14T_D0
D20	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	—	—
D19	2 (TR)	7	IO	PT24B	PT32D	—	L15C_D0
C20	2 (TR)	7	IO	PT24A	PT32C	—	L15T_D0
B20	2 (TR)	8	IO	PT23D	PT31D	—	L16C_D0
C19	2 (TR)	8	IO	PT23C	PT31C	VREF_2_08	L16T_D0
A21	2 (TR)	8	IO	PT22D	PT29D	—	L17C_A0
A20	2 (TR)	8	IO	PT22C	PT29C	—	L17T_A0
N12	—	—	VDD15	VDD15	VDD15	—	—
B19	1 (TC)	1	IO	PT21D	PT28D	—	L1C_D0
C18	1 (TC)	1	IO	PT21C	PT28C	—	L1T_D0
K12	—	—	Vss	Vss	Vss	—	—
D18	1 (TC)	1	IO	PT20D	PT27D	VREF_1_01	L2C_A0
D17	1 (TC)	1	IO	PT20C	PT27C	—	L2T_A0
A19	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	—	—
B18	1 (TC)	1	IO	PT20B	PT27B	—	L3C_D0
C17	1 (TC)	1	IO	PT20A	PT27A	—	L3T_D0
A18	1 (TC)	2	IO	PT19D	PT26D	—	L4C_D0
B17	1 (TC)	2	IO	PT19C	PT26C	VREF_1_02	L4T_D0
K15	—	—	Vss	Vss	Vss	—	—
K16	—	—	Vss	Vss	Vss	—	—
A17	1 (TC)	2	IO	PT18D	PT25D	—	L5C_D0
B16	1 (TC)	2	IO	PT18C	PT25C	—	L5T_D0
D15	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	—	—
D16	1 (TC)	3	IO	PT18B	PT24D	—	L6C_A0
C16	1 (TC)	3	IO	PT18A	PT24C	VREF_1_03	L6T_A0

Table 68. 416-Pin BGAM Pinout

BM416	$V_{DD}IO$ Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
A16	1 (TC)	3	IO	PT17D	PT23D	—	L7C_A0
A15	1 (TC)	3	IO	PT17C	PT23C	—	L7T_A0
K17	—	—	Vss	Vss	Vss	—	—
C15	1 (TC)	4	IO	PT16D	PT21D	—	L8C_A0
C14	1 (TC)	4	IO	PT16C	PT21C	—	L8T_A0
L13	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
B14	1 (TC)	4	IO	PT15D	PT19D	—	L9C_A0
A14	1 (TC)	4	IO	PT15C	PT19C	VREF_1_04	L9T_A0
D14	1 (TC)	—	$V_{DD}IO1$	$V_{DD}IO1$	$V_{DD}IO1$	—	—
D13	1 (TC)	5	IO	PT14D	PT18D	PTCK1C	L10C_A0
C13	1 (TC)	5	IO	PT14C	PT18C	PTCK1T	L10T_A0
L10	—	—	Vss	Vss	Vss	—	—
B13	1 (TC)	5	IO	PT13D	PT17D	PTCK0C	L11C_A0
A13	1 (TC)	5	IO	PT13C	PT17C	PTCK0T	L11T_A0
L14	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
A12	1 (TC)	5	IO	PT13B	PT16D	VREF_1_05	L12C_A0
B12	1 (TC)	5	IO	PT13A	PT16C	—	L12T_A0
C12	1 (TC)	6	IO	PT12D	PT15D	—	L13C_A0
D12	1 (TC)	6	IO	PT12C	PT15C	—	L13T_A0
L11	—	—	Vss	Vss	Vss	—	—
B11	1 (TC)	6	IO	PT12B	PT14D	—	L14C_A0
A11	1 (TC)	6	IO	PT12A	PT14C	VREF_1_06	L14T_A0
D11	0 (TL)	1	IO	PT11D	PT13D	MPI_RTRY_N	L1C_A0
C11	0 (TL)	1	IO	PT11C	PT13C	MPI_ACK_N	L1T_A0
A10	0 (TL)	—	$V_{DD}IO0$	$V_{DD}IO0$	$V_{DD}IO0$	—	—
C10	0 (TL)	1	IO	PT11A	PT13A	VREF_0_01	—
B10	0 (TL)	1	IO	PT10D	PT12D	M0	L2C_D0
A9	0 (TL)	1	IO	PT10C	PT12C	M1	L2T_D0
B9	0 (TL)	2	IO	PT10B	PT12B	MPI_CLK	L3C_A0
C9	0 (TL)	2	IO	PT10A	PT12A	A21/ MPI_BURST_N	L3T_A0
D10	0 (TL)	2	IO	PT9D	PT11D	M2	L4C_A0
D9	0 (TL)	2	IO	PT9C	PT11C	M3	L4T_A0
A8	0 (TL)	2	IO	PT9B	PT11B	VREF_0_02	L5C_A0
B8	0 (TL)	2	IO	PT9A	PT11A	MPI_TEA_N	L5T_A0
K13	—	—	$V_{DD}15$	$V_{DD}15$	$V_{DD}15$	—	—
A7	0 (TL)	3	IO	PT8B	PT9D	VREF_0_03	L6C_A0
A6	0 (TL)	3	IO	PT8A	PT9C	—	L6T_A0
C8	0 (TL)	3	IO	PT7D	PT8D	D0	L7C_D0
B7	0 (TL)	3	IO	PT7C	PT8C	TMS	L7T_D0
C7	0 (TL)	4	IO	PT7B	PT7D	A20/MPI_BDIP_N	L8C_D0
B6	0 (TL)	4	IO	PT7A	PT7C	A19/MPI_TSZ1	L8T_D0
D7	0 (TL)	4	IO	PT6D	PT6D	A18/MPI_TSZ0	L9C_A0
D8	0 (TL)	4	IO	PT6C	PT6C	D3	L9T_A0

Table 68. 416-Pin BGAM Pinout

BM416	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	Additional Function	Pair
A5	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	—	—
C6	0 (TL)	5	IO	PT5D	PT5D	D1	L10C_D0
B5	0 (TL)	5	IO	PT5C	PT5C	D2	L10T_D0
B26	—	—	Vss	Vss	Vss	—	—
A4	0 (TL)	5	IO	PT4D	PT4D	TDI	L11C_D1
C5	0 (TL)	5	IO	PT4C	PT4C	TCK	L11T_D1
B3	0 (TL)	6	IO	PT3D	PT3D	—	L12C_A0
A3	0 (TL)	6	IO	PT3C	PT3C	VREF_0_06	L12T_A0
K10	—	—	Vss	Vss	Vss	—	—
D5	0 (TL)	6	IO	PT2D	PT2D	PLL_CK1C/PPLL	L13C_A0
D6	0 (TL)	6	IO	PT2C	PT2C	PLL_CK1T/PPLL	L13T_A0
B4	—	—	O	PCFG_MPI_IRQ	PCFG_MPI_IRQ	CFG_IRQ_N/ MPI_IRQ_N	—
B2	—	—	IO	PCCLK	PCCLK	CCLK	—
K14	—	—	VDD15	VDD15	VDD15	—	—
C4	—	—	IO	PDONE	PDONE	DONE	—
C3	—	—	VDD33	VDD33	VDD33	—	—
K11	—	—	Vss	Vss	Vss	—	—
B15	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	—	—
AF16	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	—	—
T12	—	—	Vss	Vss	Vss	—	—
T15	—	—	Vss	Vss	Vss	—	—
U13	—	—	VDD15	VDD15	VDD15	—	—
P15	—	—	VDD15	VDD15	VDD15	—	—
N17	—	—	VDD15	VDD15	VDD15	—	—
M13	—	—	VDD15	VDD15	VDD15	—	—

680-Pin PBGAM Pinout

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
A1	—	—	Vss	Vss	Vss	Vss	—	—
F5	—	—	VDD33	VDD33	VDD33	VDD33	—	—
E4	—	—	O	PRD_DATA	PRD_DATA	PRD_DATA	RD_DATA/TDO	—
E3	—	—	I	PRESET_N	PRESET_N	PRESET_N	RESET_N	—
D2	—	—	I	PRD_CFG_N	PRD_CFG_N	PRD_CFG_N	RD_CFG_N	—
G5	—	—	I	PPRGRM_N	PPRGRM_N	PPRGRM_N	PRGRM_N	—
D3	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	VDDIO0	—	—
D1	0 (TL)	7	IO	PL2D	PL2D	PL2D	PLL_CK0C/HPPLL	L21C_D2
F4	0 (TL)	7	IO	PL2C	PL2C	PL2C	PLL_CK0T/HPPLL	L21T_D2
A2	—	—	Vss	Vss	Vss	Vss	—	—
F3	0 (TL)	7	IO	PL2B	PL3D	PL3D	—	L22C_D0
G4	0 (TL)	7	IO	PL2A	PL3C	PL3C	VREF_0_07	L22T_D0
E2	0 (TL)	7	IO	PL3D	PL4D	PL4D	D5	L23C_D2
H5	0 (TL)	7	IO	PL3C	PL4C	PL4C	D6	L23T_D2
E5	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	VDDIO0	—	—
E1	0 (TL)	8	IO	PL3B	PL4B	PL5D	—	L24C_D0
F2	0 (TL)	8	IO	PL3A	PL4A	PL5C	VREF_0_08	L24T_D0
J5	0 (TL)	8	IO	PL4D	PL5D	PL6D	HDC	L25C_D3
F1	0 (TL)	8	IO	PL4C	PL5C	PL6C	LDC_N	L25T_D3
A18	—	—	Vss	Vss	Vss	Vss	—	—
H4	0 (TL)	8	IO	PL4B	PL5B	PL7D	—	L26C_D0
G3	0 (TL)	8	IO	PL4A	PL5A	PL7C	—	L26T_D0
H3	0 (TL)	9	IO	PL5D	PL6D	PL8D	TESTCFG	L27C_D0
G2	0 (TL)	9	IO	PL5C	PL6C	PL8C	D7	L27T_D0
K5	0 (TL)	9	IO	PL5B	PL7D	PL9D	VREF_0_09	L28C_D3
G1	0 (TL)	9	IO	PL5A	PL7C	PL9C	A17/PPC_A31	L28T_D3
J4	0 (TL)	9	IO	PL6D	PL8D	PL10D	CS0_N	L29C_D1
L5	0 (TL)	9	IO	PL6C	PL8C	PL10C	CS1	L29T_D1
A33	—	—	Vss	Vss	Vss	Vss	—	—
J3	0 (TL)	10	IO	PL6B	PL9D	PL11D	—	L30C_D0
H2	0 (TL)	10	IO	PL6A	PL9C	PL11C	—	L30T_D0
H1	0 (TL)	10	IO	PL7D	PL10D	PL12D	INIT_N	L31C_D0
J2	0 (TL)	10	IO	PL7C	PL10C	PL12C	DOUT	L31T_D0
J1	0 (TL)	10	IO	PL7B	PL11D	PL13D	VREF_0_10	L32C_D1
K3	0 (TL)	10	IO	PL7A	PL11C	PL13C	A16/PPC_A30	L32T_D1
L4	7 (CL)	1	IO	PL8D	PL12D	PL14D	A15/PPC_A29	L1C_D1
K2	7 (CL)	1	IO	PL8C	PL12C	PL14C	A14/PPC_A28	L1T_D1
L1	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
K1	7 (CL)	1	IO	PL8B	PL12B	PL15D	—	L2C_D0
L2	7 (CL)	1	IO	PL8A	PL12A	PL15C	—	L2T_D0
L3	7 (CL)	1	IO	PL9D	PL13D	PL16D	VREF_7_01	L3C_D1
N5	7 (CL)	1	IO	PL9C	PL13C	PL16C	D4	L3T_D1

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AM22	—	—	Vss	Vss	Vss	Vss	—	—
M4	7 (CL)	2	IO	PL9B	PL13B	PL17D	—	L4C_A1
M2	7 (CL)	2	IO	PL9A	PL13A	PL17C	—	L4T_A1
P5	7 (CL)	2	IO	PL10D	PL14D	PL18D	RDY/BUSY_N/RCLK	L5C_D3
M1	7 (CL)	2	IO	PL10C	PL14C	PL18C	VREF_7_02	L5T_D3
M3	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
N1	7 (CL)	2	IO	PL10B	PL15D	PL19D	A13/PPC_A27	L6C_A2
N4	7 (CL)	2	IO	PL10A	PL15C	PL19C	A12/PPC_A26	L6T_A2
N2	7 (CL)	3	IO	PL11D	PL16D	PL20D	—	L7C_D0
P1	7 (CL)	3	IO	PL11C	PL16C	PL20C	—	L7T_D0
AM32	—	—	Vss	Vss	Vss	Vss	—	—
P2	7 (CL)	3	IO	PL11B	PL17D	PL21D	A11/PPC_A25	L8C_A0
P3	7 (CL)	3	IO	PL11A	PL17C	PL21C	VREF_7_03	L8T_A0
P4	7 (CL)	3	IO	PL12D	PL18D	PL22D	—	L9C_D2
R1	7 (CL)	3	IO	PL12C	PL18C	PL22C	—	L9T_D2
R4	7 (CL)	3	IO	PL12B	PL18B	PL22B	—	L10C_A1
R2	7 (CL)	3	IO	PL12A	PL18A	PL22A	—	L10T_A1
U5	7 (CL)	4	IO	PL13D	PL19D	PL23D	RD_N/MPI_STRB_N	L11C_D0
T4	7 (CL)	4	IO	PL13C	PL19C	PL23C	VREF_7_04	L11T_D0
AN1	—	—	Vss	Vss	Vss	Vss	—	—
V5	7 (CL)	4	IO	PL13B	PL19B	PL23B	—	L12C_D3
T1	7 (CL)	4	IO	PL13A	PL19A	PL23A	—	L12T_D3
T2	7 (CL)	4	IO	PL14D	PL20D	PL24D	PLCK0C	L13C_A0
T3	7 (CL)	4	IO	PL14C	PL20C	PL24C	PLCK0T	L13T_A0
R3	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
U4	7 (CL)	4	IO	PL14B	PL20B	PL24B	—	L14C_A0
U3	7 (CL)	4	IO	PL14A	PL20A	PL24A	—	L14T_A0
AN2	—	—	Vss	Vss	Vss	Vss	—	—
U2	7 (CL)	5	IO	PL15D	PL21D	PL25D	A10/PPC_A24	L15C_A0
V2	7 (CL)	5	IO	PL15C	PL21C	PL25C	A9/PPC_A23	L15T_A0
AN33	—	—	Vss	Vss	Vss	Vss	—	—
V3	7 (CL)	5	IO	PL15B	PL21B	PL25B	—	L16C_A0
V4	7 (CL)	5	IO	PL15A	PL21A	PL25A	—	L16T_A0
W5	7 (CL)	5	IO	PL16D	PL22D	PL26D	A8/PPC_A22	L17C_A2
W2	7 (CL)	5	IO	PL16C	PL22C	PL26C	VREF_7_05	L17T_A2
W3	7 (CL)	5	IO	PL16B	PL23D	PL27D	—	L18C_D1
Y1	7 (CL)	5	IO	PL16A	PL23C	PL27C	—	L18T_D1
W4	7 (CL)	6	IO	PL17D	PL24D	PL28D	PLCK1C	L19C_D2
AA1	7 (CL)	6	IO	PL17C	PL24C	PL28C	PLCK1T	L19T_D2
AN34	—	—	Vss	Vss	Vss	Vss	—	—
Y5	7 (CL)	6	IO	PL17B	PL25D	PL29D	VREF_7_06	L20C_A0
Y4	7 (CL)	6	IO	PL17A	PL25C	PL29C	A7/PPC_A21	L20T_A0
AA5	7 (CL)	6	IO	PL18D	PL26D	PL30D	A6/PPC_A20	L21C_D3
AB1	7 (CL)	6	IO	PL18C	PL26C	PL30C	A5/PPC_A19	L21T_D3

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
U1	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
AB2	7 (CL)	7	IO	PL18B	PL26B	PL31D	—	—
AA4	7 (CL)	7	IO	PL19D	PL27D	PL32D	WR_N/MPI_RW	L22C_A0
AB4	7 (CL)	7	IO	PL19C	PL27C	PL32C	VREF_7_07	L22T_A0
AB5	7 (CL)	7	IO	PL19B	PL27B	PL33D	—	L23C_D3
AC1	7 (CL)	7	IO	PL19A	PL27A	PL33C	—	L23T_D3
AC2	7 (CL)	8	IO	PL20D	PL28D	PL34D	A4/PPC_A18	L23C_A2
AC5	7 (CL)	8	IO	PL20C	PL28C	PL34C	VREF_7_08	L23T_A2
W1	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
AD2	7 (CL)	8	IO	PL20B	PL29D	PL35D	A3/PPC_A17	L23C_A0
AD3	7 (CL)	8	IO	PL20A	PL29C	PL35C	A2/PPC_A16	L23T_A0
AE1	7 (CL)	8	IO	PL21D	PL30D	PL36D	A1/PPC_A15	L24C_A0
AE2	7 (CL)	8	IO	PL21C	PL30C	PL36C	A0/PPC_A14	L24T_A0
AD4	7 (CL)	8	IO	PL21B	PL31D	PL37D	DP0	L25C_D0
AE3	7 (CL)	8	IO	PL21A	PL31C	PL37C	DP1	L25T_D0
AF1	6 (BL)	1	IO	PL22D	PL32D	PL38D	D8	L1C_A0
AF2	6 (BL)	1	IO	PL22C	PL32C	PL38C	VREF_6_01	L1T_A0
AB13	—	—	Vss	Vss	Vss	Vss	—	—
AF3	6 (BL)	1	IO	PL22B	PL33D	PL39D	D9	L2C_A0
AF4	6 (BL)	1	IO	PL22A	PL33C	PL39C	D10	L2T_A0
AE5	6 (BL)	2	IO	PL23D	PL34D	PL40D	—	L3C_D3
AG1	6 (BL)	2	IO	PL23C	PL34C	PL40C	VREF_6_02	L3T_D3
AK5	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—
AG2	6 (BL)	2	IO	PL23B	PL34B	PL41D	—	L4C_D2
AF5	6 (BL)	2	IO	PL23A	PL34A	PL41C	—	L4T_D2
AG3	6 (BL)	3	IO	PL24D	PL35B	PL42D	D11	L5C_A0
AG4	6 (BL)	3	IO	PL24C	PL35A	PL42C	D12	L5T_A0
AB14	—	—	Vss	Vss	Vss	Vss	—	—
AH1	6 (BL)	3	IO	PL24B	PL36D	PL43D	—	L6C_A1
AH3	6 (BL)	3	IO	PL24A	PL36C	PL43C	—	L6T_A1
AH4	6 (BL)	3	IO	PL25D	PL36B	PL44D	VREF_6_03	L7C_D0
AG5	6 (BL)	3	IO	PL25C	PL36A	PL44C	D13	L7T_D0
AL3	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—
AH2	6 (BL)	4	IO	PL25B	PL37D	PL44B	—	—
AJ3	6 (BL)	4	IO	PL25A	PL38C	PL45A	—	—
AJ2	6 (BL)	4	IO	PL26D	PL37B	PL45D	—	L8C_D2
AH5	6 (BL)	4	IO	PL26C	PL37A	PL45C	VREF_6_04	L8T_D2
AB15	—	—	Vss	Vss	Vss	Vss	—	—
AJ4	6 (BL)	4	IO	PL26B	PL38B	PL46D	—	—
AJ1	6 (BL)	4	IO	PL26A	PL38A	PL46A	—	—
AK1	6 (BL)	4	IO	PL27D	PL39D	PL47D	PLL_CK7C/HPPLL	L9C_A0
AK2	6 (BL)	4	IO	PL27C	PL39C	PL47C	PLL_CK7T/HPPLL	L9T_A0
AB20	—	—	Vss	Vss	Vss	Vss	—	—
AJ5	6 (BL)	4	IO	PL27B	PL39B	PL47B	—	L10C_D1

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AK3	6 (BL)	4	IO	PL27A	PL39A	PL47A	—	L10T_D1
AB21	—	—	Vss	Vss	Vss	Vss	—	—
AK4	—	—	I	PTEMP	PTEMP	PTEMP	PTEMP	—
AM1	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—
AL1	—	—	IO	LVDS_R	LVDS_R	LVDS_R	LVDS_R	—
AL2	—	—	VDD33	VDD33	VDD33	VDD33	—	—
AB22	—	—	Vss	Vss	Vss	Vss	—	—
AK6	—	—	VDD33	VDD33	VDD33	VDD33	—	—
AL5	6 (BL)	5	IO	PB2A	PB2A	PB2A	DP2	L11T_A0
AM5	6 (BL)	5	IO	PB2B	PB2B	PB2B	—	L11C_A0
AM2	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—
AN4	6 (BL)	5	IO	PB2C	PB2C	PB2C	PLL_CK6T/PPLL	L12T_D2
AK7	6 (BL)	5	IO	PB2D	PB2D	PB2D	PLL_CK6C/PPLL	L12C_D2
AL6	6 (BL)	5	IO	PB3A	PB3C	PB3C	—	L13T_A0
AM6	6 (BL)	5	IO	PB3B	PB3D	PB3D	—	L13C_A0
AL7	6 (BL)	5	IO	PB3C	PB4A	PB4C	VREF_6_05	L14T_D1
AN5	6 (BL)	5	IO	PB3D	PB4B	PB4D	DP3	L14C_D1
AK8	6 (BL)	6	IO	PB4A	PB4C	PB5C	—	L15T_D3
AP5	6 (BL)	6	IO	PB4B	PB4D	PB5D	—	L15C_D3
AB32	—	—	Vss	Vss	Vss	Vss	—	—
AN6	6 (BL)	6	IO	PB4C	PB5C	PB6C	VREF_6_06	L16T_D2
AK9	6 (BL)	6	IO	PB4D	PB5D	PB6D	D14	L16C_D2
AP6	6 (BL)	6	IO	PB5A	PB6A	PB7C	—	L17T_D2
AL8	6 (BL)	6	IO	PB5B	PB6B	PB7D	—	L17C_D2
AM4	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—
AM7	6 (BL)	7	IO	PB5C	PB6C	PB8C	D15	L18T_A0
AM8	6 (BL)	7	IO	PB5D	PB6D	PB8D	D16	L18C_A0
AK10	6 (BL)	7	IO	PB6A	PB7C	PB9C	D17	L19T_D3
AP7	6 (BL)	7	IO	PB6B	PB7D	PB9D	D18	L19C_D3
AL4	—	—	Vss	Vss	Vss	Vss	—	—
AK11	6 (BL)	7	IO	PB6C	PB8C	PB10C	VREF_6_07	L20T_D1
AM9	6 (BL)	7	IO	PB6D	PB8D	PB10D	D19	L20C_D1
AL10	6 (BL)	8	IO	PB7A	PB9C	PB11C	D20	L21T_D2
AP8	6 (BL)	8	IO	PB7B	PB9D	PB11D	D21	L21C_D2
AP9	6 (BL)	8	IO	PB7C	PB10C	PB12C	VREF_6_08	L22T_D1
AM10	6 (BL)	8	IO	PB7D	PB10D	PB12D	D22	L22C_D1
AK12	6 (BL)	9	IO	PB8A	PB11A	PB13A	—	L23T_D0
AL11	6 (BL)	9	IO	PB8B	PB11B	PB13B	—	L23C_D0
AL31	—	—	Vss	Vss	Vss	Vss	—	—
AN10	6 (BL)	9	IO	PB8C	PB11C	PB13C	D23	L24T_A0
AP10	6 (BL)	9	IO	PB8D	PB11D	PB13D	D24	L24C_A0
AN11	6 (BL)	9	IO	PB9A	PB12A	PB14A	—	L25T_A0
AM11	6 (BL)	9	IO	PB9B	PB12B	PB14B	—	L25C_A0
AN3	6 (BL)	—	VDDIO6	VDDIO6	VDDIO6	VDDIO6	—	—

Table 69. 680-Pin PBGAM Pinout

BM680	$V_{DD}IO$ Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AK13	6 (BL)	9	IO	PB9C	PB12C	PB14C	VREF_6_09	L26T_D0
AL12	6 (BL)	9	IO	PB9D	PB12D	PB14D	D25	L26C_D0
AN12	6 (BL)	9	IO	PB10A	PB13A	PB15C	—	L27T_D2
AK14	6 (BL)	9	IO	PB10B	PB13B	PB15D	—	L27C_D2
AM3	—	—	Vss	Vss	Vss	Vss	—	—
AP12	6 (BL)	10	IO	PB10C	PB13C	PB16C	D26	L28T_A0
AP13	6 (BL)	10	IO	PB10D	PB13D	PB16D	D27	L28C_A0
AL13	6 (BL)	10	IO	PB11A	PB14A	PB17C	—	L29T_A1
AN13	6 (BL)	10	IO	PB11B	PB14B	PB17D	—	L29C_A1
AP3	6 (BL)	—	$V_{DD}IO6$	$V_{DD}IO6$	$V_{DD}IO6$	$V_{DD}IO6$	—	—
AP14	6 (BL)	10	IO	PB11C	PB14C	PB18C	VREF_6_10	L30T_D3
AK15	6 (BL)	10	IO	PB11D	PB14D	PB18D	D28	L30C_D3
AM14	6 (BL)	11	IO	PB12A	PB15C	PB19C	D29	L31T_D1
AK16	6 (BL)	11	IO	PB12B	PB15D	PB19D	D30	L31C_D1
AM13	—	—	Vss	Vss	Vss	Vss	—	—
AP15	6 (BL)	11	IO	PB12C	PB16C	PB20C	VREF_6_11	L32T_A2
AL15	6 (BL)	11	IO	PB12D	PB16D	PB20D	D31	L32C_A2
AN16	5 (BC)	1	IO	PB13A	PB17C	PB21C	—	L1T_D2
AK17	5 (BC)	1	IO	PB13B	PB17D	PB21D	—	L1C_D2
AM16	5 (BC)	1	IO	PB13C	PB18C	PB22C	VREF_5_01	L2T_A1
AP16	5 (BC)	1	IO	PB13D	PB18D	PB22D	—	L2C_A1
AN17	5 (BC)	2	IO	PB14A	PB19A	PB23A	—	L3T_A1
AL17	5 (BC)	2	IO	PB14B	PB19B	PB23B	—	L3C_A1
Y15	—	—	Vss	Vss	Vss	Vss	—	—
AM17	5 (BC)	2	IO	PB14C	PB19C	PB23C	PBCK0T	L4T_A0
AM18	5 (BC)	2	IO	PB14D	PB19D	PB23D	PBCK0C	L4C_A0
AL18	5 (BC)	2	IO	PB15A	PB20A	PB24A	—	L5T_A1
AN18	5 (BC)	2	IO	PB15B	PB20B	PB24B	—	L5C_A1
AM12	5 (BC)	—	$V_{DD}IO5$	$V_{DD}IO5$	$V_{DD}IO5$	$V_{DD}IO5$	—	—
AL19	5 (BC)	2	IO	PB15C	PB20C	PB24C	VREF_5_02	L6T_D0
AK18	5 (BC)	2	IO	PB15D	PB20D	PB24D	—	L6C_D0
AM19	5 (BC)	2	IO	PB16A	PB21A	PB25C	—	L7T_A0
AN19	5 (BC)	2	IO	PB16B	PB21B	PB25D	—	L7C_A0
AP20	5 (BC)	3	IO	PB16C	PB21C	PB26C	—	L8T_A0
AN20	5 (BC)	3	IO	PB16D	PB21D	PB26D	VREF_5_03	L8C_A0
AP21	5 (BC)	3	IO	PB17A	PB22C	PB27C	—	L9T_A0
AN21	5 (BC)	3	IO	PB17B	PB22D	PB27D	—	L9C_A0
Y20	—	—	Vss	Vss	Vss	Vss	—	—
AM21	5 (BC)	3	IO	PB17C	PB23C	PB28C	PBCK1T	L10T_A0
AL21	5 (BC)	3	IO	PB17D	PB23D	PB28D	PBCK1C	L10C_A0
AP22	5 (BC)	4	IO	PB18A	PB24C	PB29C	—	L11T_A0
AN22	5 (BC)	4	IO	PB18B	PB24D	PB29D	—	L11C_A0
AM15	5 (BC)	—	$V_{DD}IO5$	$V_{DD}IO5$	$V_{DD}IO5$	$V_{DD}IO5$	—	—
AL22	5 (BC)	4	IO	PB18C	PB25C	PB30C	—	L12T_A0

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AL23	5 (BC)	4	IO	PB18D	PB25D	PB30D	VREF_5_04	L12C_A0
Y21	—	—	Vss	Vss	Vss	Vss	—	—
AK22	5 (BC)	4	IO	PB19A	PB26A	PB31C	—	L13T_D2
AN23	5 (BC)	4	IO	PB19B	PB26B	PB31D	—	L13C_D2
Y22	—	—	Vss	Vss	Vss	Vss	—	—
AP23	5 (BC)	5	IO	PB19C	PB26C	PB32C	—	L14T_A3
AK23	5 (BC)	5	IO	PB19D	PB26D	PB32D	VREF_5_05	L14C_A3
AN24	5 (BC)	5	IO	PB20A	PB27A	PB33C	—	L15T_A0
AM24	5 (BC)	5	IO	PB20B	PB27B	PB33D	—	L15C_A0
AM20	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	VDDIO5	—	—
AL24	5 (BC)	5	IO	PB20C	PB27C	PB34C	—	L16T_D2
AP25	5 (BC)	5	IO	PB20D	PB27D	PB34D	—	L16T_D2
AK24	5 (BC)	6	IO	PB21A	PB28C	PB35C	—	L17T_D3
AP26	5 (BC)	6	IO	PB21B	PB28D	PB35D	VREF_5_06	L17C_D3
AL25	5 (BC)	6	IO	PB21C	PB29C	PB36C	—	L18T_A0
AM25	5 (BC)	6	IO	PB21D	PB29D	PB36D	—	L18C_A0
AP27	4 (BR)	1	IO	PB22A	PB30C	PB37C	—	L1T_A0
AN27	4 (BR)	1	IO	PB22B	PB30D	PB37D	—	L1C_A0
V16	—	—	Vss	Vss	Vss	Vss	—	—
AK25	4 (BR)	1	IO	PB22C	PB31C	PB38C	VREF_4_01	L2T_D0
AL26	4 (BR)	1	IO	PB22D	PB31D	PB38D	—	L2C_D0
AM27	4 (BR)	1	IO	PB23A	PB32C	PB39C	—	L3T_D1
AK26	4 (BR)	1	IO	PB23B	PB32D	PB39D	—	L3C_D1
AK30	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
AP28	4 (BR)	2	IO	PB23C	PB33C	PB40C	—	L4T_A0
AN28	4 (BR)	2	IO	PB23D	PB33D	PB40D	VREF_4_02	L4C_A0
AL27	4 (BR)	2	IO	PB24A	PB34A	PB41C	—	L5T_A0
AL28	4 (BR)	2	IO	PB24B	PB34B	PB41D	—	L5C_A0
V17	—	—	Vss	Vss	Vss	Vss	—	—
AK27	4 (BR)	2	IO	PB24C	PB34C	PB42C	—	—
AM28	4 (BR)	3	IO	PB25A	PB35A	PB43A	—	—
AN29	4 (BR)	3	IO	PB25B	PB35B	PB43D	—	—
AL32	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
AK28	4 (BR)	3	IO	PB25C	PB35C	PB44C	—	L6T_D1
AM29	4 (BR)	3	IO	PB25D	PB35D	PB44D	VREF_4_03	L6C_D1
AL29	4 (BR)	3	IO	PB26A	PB36A	PB45A	—	L7T_A2
AP29	4 (BR)	3	IO	PB26B	PB36B	PB45B	—	L7C_A2
V18	—	—	Vss	Vss	Vss	Vss	—	—
AP30	4 (BR)	3	IO	PB26C	PB36C	PB45C	—	L8T_A0
AN30	4 (BR)	3	IO	PB26D	PB36D	PB45D	—	L8C_A0
AK29	4 (BR)	4	IO	PB27A	PB37A	PB46C	—	L9T_D1
AM30	4 (BR)	4	IO	PB27B	PB37B	PB46D	VREF_4_04	L9C_D1
V19	—	—	Vss	Vss	Vss	Vss	—	—
AL30	4 (BR)	4	IO	PB27C	PB37C	PB47C	PLL_CK5T/PPLL	L10T_D2

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AP31	4 (BR)	4	IO	PB27D	PB37D	PB47D	PLL_CK5C/PPLL	L10C_D2
AN31	—	—	VDD33	VDD33	VDD33	VDD33	—	—
V34	—	—	Vss	Vss	Vss	Vss	—	—
W16	—	—	Vss	Vss	Vss	Vss	—	—
AK31	—	—	VDD33	VDD33	VDD33	VDD33	—	—
AM31	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
AJ30	4 (BR)	5	IO	PR26A	PR38A	PR46C	PLL_CK4T/PLL2	L11T_D1
AK32	4 (BR)	5	IO	PR26B	PR38B	PR46D	PLL_CK4C/PLL2	L11C_D1
W17	—	—	Vss	Vss	Vss	Vss	—	—
AL33	4 (BR)	5	IO	PR26C	PR38C	PR45C	—	L12T_D2
AH30	4 (BR)	5	IO	PR26D	PR38D	PR45D	—	L12C_D2
AL34	4 (BR)	5	IO	PR25A	PR37A	PR44C	VREF_4_05	L13T_D2
AJ31	4 (BR)	5	IO	PR25B	PR37B	PR44D	—	L13C_D2
W18	—	—	Vss	Vss	Vss	Vss	—	—
AJ32	4 (BR)	6	IO	PR25C	PR36A	PR43C	—	L14T_D0
AH31	4 (BR)	6	IO	PR25D	PR36B	PR43D	—	L14C_D0
AK33	4 (BR)	6	IO	PR24A	PR36C	PR42C	—	L15T_D2
AG30	4 (BR)	6	IO	PR24B	PR36D	PR42D	—	L15C_D2
AM34	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
AK34	4 (BR)	6	IO	PR24C	PR35C	PR41C	VREF_4_06	L16T_D0
AJ33	4 (BR)	6	IO	PR24D	PR35D	PR41D	—	L16C_D0
AJ34	4 (BR)	7	IO	PR23A	PR34C	PR40C	—	L17T_D2
AG31	4 (BR)	7	IO	PR23B	PR34D	PR40D	—	L17C_D2
W19	—	—	Vss	Vss	Vss	Vss	—	—
AG32	4 (BR)	7	IO	PR23C	PR33C	PR39C	—	L18T_D0
AH33	4 (BR)	7	IO	PR23D	PR33D	PR39D	VREF_4_07	L18C_D0
AH34	4 (BR)	7	IO	PR22A	PR32C	PR38C	—	L19T_D2
AF31	4 (BR)	7	IO	PR22B	PR32D	PR38D	—	L19C_D2
AG33	4 (BR)	8	IO	PR22C	PR31C	PR37C	—	L20T_D1
AE31	4 (BR)	8	IO	PR22D	PR31D	PR37D	VREF_4_08	L20C_D1
AG34	4 (BR)	8	IO	PR21A	PR30A	PR36A	—	L22T_D0
AF33	4 (BR)	8	IO	PR21B	PR30B	PR36B	—	L22C_D0
Y13	—	—	Vss	Vss	Vss	Vss	—	—
AD30	4 (BR)	8	IO	PR21C	PR30C	PR36C	—	L21T_D3
AF34	4 (BR)	8	IO	PR21D	PR30D	PR36D	—	L21C_D3
AE32	3 (CR)	1	IO	PR20A	PR29A	PR35C	—	L1T_D1
AC30	3 (CR)	1	IO	PR20B	PR29B	PR35D	—	L1C_D1
L34	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
AE33	3 (CR)	1	IO	PR20C	PR29C	PR34C	—	L2T_D1
AC31	3 (CR)	1	IO	PR20D	PR29D	PR34D	—	L2C_D1
AD31	3 (CR)	1	IO	PR19A	PR28A	PR34A	—	—
AE34	3 (CR)	1	IO	PR19B	PR28B	PR33B	—	—
R21	—	—	Vss	Vss	Vss	Vss	—	—
AD32	3 (CR)	1	IO	PR19C	PR28C	PR33C	VREF_3_01	L3T_D1

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AB30	3 (CR)	1	IO	PR19D	PR28D	PR33D	—	L3C_D1
AB31	3 (CR)	2	IO	PR18A	PR27A	PR32C	—	L4T_D0
AA30	3 (CR)	2	IO	PR18B	PR27B	PR32D	—	L4C_D0
M32	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
AC33	3 (CR)	2	IO	PR18C	PR26A	PR31C	—	L5T_A0
AB33	3 (CR)	2	IO	PR18D	PR26B	PR31D	VREF_3_02	L5C_A0
AA32	3 (CR)	2	IO	PR17A	PR25A	PR30C	—	L6T_D1
Y30	3 (CR)	2	IO	PR17B	PR25B	PR30D	—	L6C_D1
R22	—	—	Vss	Vss	Vss	Vss	—	—
AB34	3 (CR)	3	IO	PR17C	PR25C	PR29C	—	L7T_D3
W30	3 (CR)	3	IO	PR17D	PR25D	PR29D	VREF_3_03	L7C_D3
AA33	3 (CR)	3	IO	PR16A	PR24C	PR28C	—	L8T_D1
W31	3 (CR)	3	IO	PR16B	PR24D	PR28D	—	L8C_D1
Y34	3 (CR)	4	IO	PR16C	PR23C	PR27C	PRCK1T	L9T_D0
W33	3 (CR)	4	IO	PR16D	PR23D	PR27D	PRCK1C	L9C_D0
V30	3 (CR)	4	IO	PR15A	PR22C	PR26C	—	L10T_A0
V31	3 (CR)	4	IO	PR15B	PR22D	PR26D	VREF_3_04	L10C_A0
R32	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
V33	3 (CR)	5	IO	PR15C	PR21C	PR25C	—	L11T_A0
V32	3 (CR)	5	IO	PR15D	PR21D	PR25D	—	L11C_A0
T16	—	—	Vss	Vss	Vss	Vss	—	—
T34	3 (CR)	5	IO	PR14A	PR20C	PR24C	PRCK0T	L13T_D2
U31	3 (CR)	5	IO	PR14B	PR20D	PR24D	PRCK0C	L13C_D2
T32	3 (CR)	5	IO	PR14C	PR19C	PR23C	VREF_3_05	L14T_A0
T31	3 (CR)	5	IO	PR14D	PR19D	PR23D	—	L14C_A0
R31	3 (CR)	5	IO	PR13A	PR18C	PR22C	—	L15T_D1
R34	3 (CR)	5	IO	PR13B	PR18D	PR22D	—	L15C_D1
T17	—	—	Vss	Vss	Vss	Vss	—	—
P34	3 (CR)	6	IO	PR13C	PR17C	PR21C	—	L16T_A1
P32	3 (CR)	6	IO	PR13D	PR17D	PR21D	VREF_3_06	L16C_A1
P31	3 (CR)	6	IO	PR12A	PR16C	PR20C	—	L17T_A1
P33	3 (CR)	6	IO	PR12B	PR16D	PR20D	—	L17C_A1
U34	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
N33	3 (CR)	7	IO	PR12C	PR15A	PR19C	—	L18T_A1
N31	3 (CR)	7	IO	PR12D	PR15B	PR19D	—	L18C_A1
M31	3 (CR)	7	IO	PR11A	PR14A	PR18C	—	L19T_A1
M33	3 (CR)	7	IO	PR11B	PR14B	PR18D	—	L19C_A1
T18	—	—	Vss	Vss	Vss	Vss	—	—
M34	3 (CR)	7	IO	PR11C	PR14C	PR17C	VREF_3_07	L20T_D1
L32	3 (CR)	7	IO	PR11D	PR14D	PR17D	—	L20C_D1
L33	3 (CR)	8	IO	PR10A	PR13A	PR15A	—	—
L31	3 (CR)	8	IO	PR10B	PR13B	PR16D	—	—
W34	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
K34	3 (CR)	8	IO	PR10C	PR13C	PR15C	—	L21T_A0

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
K33	3 (CR)	8	IO	PR10D	PR13D	PR15D	—	L21C_A0
K32	3 (CR)	8	IO	PR9A	PR12A	PR14A	—	—
T19	—	—	Vss	Vss	Vss	Vss	—	—
N30	3 (CR)	8	IO	PR9C	PR12C	PR14C	VREF_3_08	L22T_D2
K31	3 (CR)	8	IO	PR9D	PR12D	PR14D	—	L22C_D2
H34	2 (TR)	1	IO	PR8A	PR11A	PR13A	—	L1T_A0
J34	2 (TR)	1	IO	PR8B	PR11B	PR13B	—	L1C_A0
J33	2 (TR)	1	IO	PR8C	PR11C	PR13C	—	L2T_A1
J31	2 (TR)	1	IO	PR8D	PR11D	PR13D	VREF_2_01	L2C_A1
J32	2 (TR)	1	IO	PR7A	PR10C	PR12C	—	L3T_D1
G34	2 (TR)	1	IO	PR7B	PR10D	PR12D	—	L3C_D1
N32	—	—	Vss	Vss	Vss	Vss	—	—
H33	2 (TR)	1	IO	PR7C	PR9C	PR11C	—	L4T_A0
H32	2 (TR)	1	IO	PR7D	PR9D	PR11D	—	L4C_A0
H31	2 (TR)	2	IO	PR6A	PR7A	PR10C	—	L5T_D1
G33	2 (TR)	2	IO	PR6B	PR7B	PR10D	—	L5C_D1
A32	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
F33	2 (TR)	2	IO	PR6C	PR6A	PR9C	VREF_2_02	L6T_D0
G32	2 (TR)	2	IO	PR6D	PR6B	PR9D	—	L6C_D0
K30	2 (TR)	2	IO	PR5A	PR6C	PR8C	—	L7T_D2
G31	2 (TR)	2	IO	PR5B	PR6D	PR8D	—	L7C_D2
P13	—	—	Vss	Vss	Vss	Vss	—	—
E34	2 (TR)	3	IO	PR5C	PR5A	PR7C	—	L8T_D2
J30	2 (TR)	3	IO	PR5D	PR5B	PR7D	VREF_2_03	L8C_D2
F32	2 (TR)	3	IO	PR4A	PR4A	PR6C	—	L9T_A0
F31	2 (TR)	3	IO	PR4B	PR4B	PR6D	—	L9C_A0
B32	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
E33	2 (TR)	3	IO	PR4C	PR4C	PR5C	—	L10T_A0
D33	2 (TR)	3	IO	PR4D	PR4D	PR5D	—	L10C_A0
H30	2 (TR)	4	IO	PR3A	PR3A	PR4C	—	L11T_D2
E32	2 (TR)	4	IO	PR3B	PR3B	PR4D	VREF_2_04	L11C_D2
P14	—	—	Vss	Vss	Vss	Vss	—	—
E31	2 (TR)	4	IO	PR3C	PR3C	PR3C	PLL_CK3T/PLL1	L12T_A0
G30	2 (TR)	4	IO	PR3D	PR3D	PR3D	PLL_CK3C/PLL1	L12C_A0
C31	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
F30	—	—	VDD33	VDD33	VDD33	VDD33	—	—
P15	—	—	Vss	Vss	Vss	Vss	—	—
P20	—	—	Vss	Vss	Vss	Vss	—	—
E29	—	—	VDD33	VDD33	VDD33	VDD33	—	—
D30	—	—	IO	PLL_VF	PLL_VF	PLL_VF	PLL_VF	—
C30	2 (TR)	5	IO	PT27D	PT37D	PT47D	PLL_CK2C/PPLL	L13C_D0
B31	2 (TR)	5	IO	PT27C	PT37C	PT47C	PLL_CK2T/PPLL	L13T_D0
P21	—	—	Vss	Vss	Vss	Vss	—	—
E28	2 (TR)	5	IO	PT27B	PT37B	PT46D	—	L14C_D2

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
B30	2 (TR)	5	IO	PT27A	PT37A	PT46C	—	L14T_D2
D29	2 (TR)	5	IO	PT26D	PT36D	PT45D	VREF_2_05	L15C_D2
A31	2 (TR)	5	IO	PT26C	PT36C	PT45C	—	L15T_D2
C33	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
E27	2 (TR)	6	IO	PT26B	PT35B	PT43D	—	L17C_D1
C29	2 (TR)	6	IO	PT26A	PT35A	PT43C	—	L17T_D1
A30	2 (TR)	6	IO	PT25D	PT34D	PT42D	VREF_2_06	L18C_D3
E26	2 (TR)	6	IO	PT25C	PT34C	PT42C	—	L18T_D3
P22	—	—	Vss	Vss	Vss	Vss	—	—
A29	2 (TR)	7	IO	PT25B	PT34B	PT41D	—	L19C_D2
D27	2 (TR)	7	IO	PT25A	PT34A	PT41C	—	L19T_D2
C28	2 (TR)	7	IO	PT24D	PT33D	PT40D	—	L20C_A0
C27	2 (TR)	7	IO	PT24C	PT33C	PT40C	VREF_2_07	L20T_A0
C34	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
B28	2 (TR)	7	IO	PT24B	PT32D	PT39D	—	L21C_D2
E25	2 (TR)	7	IO	PT24A	PT32C	PT39C	—	L21T_D2
A28	2 (TR)	8	IO	PT23D	PT31D	PT38D	—	L22C_D2
D26	2 (TR)	8	IO	PT23C	PT31C	PT38C	VREF_2_08	L22T_D2
R13	—	—	Vss	Vss	Vss	Vss	—	—
C26	2 (TR)	8	IO	PT23B	PT30D	PT37D	—	—
B27	2 (TR)	8	IO	PT23A	PT30A	PT37A	—	—
D25	2 (TR)	8	IO	PT22D	PT29D	PT36D	—	L23C_D2
A27	2 (TR)	8	IO	PT22C	PT29C	PT36C	—	L23T_D2
B26	2 (TR)	8	IO	PT22B	PT29B	PT36B	—	L24C_A0
A26	2 (TR)	8	IO	PT22A	PT29A	PT36A	—	L24T_A0
C25	1 (TC)	1	IO	PT21D	PT28D	PT35D	—	L1C_D1
E24	1 (TC)	1	IO	PT21C	PT28C	PT35C	—	L1T_D1
C22	—	—	Vss	Vss	Vss	Vss	—	—
A25	1 (TC)	1	IO	PT21B	PT28B	PT35B	—	L2C_D2
D24	1 (TC)	1	IO	PT21A	PT28A	PT35A	—	L2T_D2
D23	1 (TC)	1	IO	PT20D	PT27D	PT34D	VREF_1_01	L3C_D1
B25	1 (TC)	1	IO	PT20C	PT27C	PT34C	—	L3T_D1
A11	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	VDDIO1	—	—
C24	1 (TC)	1	IO	PT20B	PT27B	PT33D	—	L4C_D1
E23	1 (TC)	1	IO	PT20A	PT27A	PT33C	—	L4T_D1
B24	1 (TC)	2	IO	PT19D	PT26D	PT32D	—	L5C_D1
D22	1 (TC)	2	IO	PT19C	PT26C	PT32C	VREF_1_02	L5T_D1
C32	—	—	Vss	Vss	Vss	Vss	—	—
E22	1 (TC)	2	IO	PT19B	PT26B	PT31D	—	L6C_D0
D21	1 (TC)	2	IO	PT19A	PT26A	PT31C	—	L6T_D0
D4	—	—	Vss	Vss	Vss	Vss	—	—
B23	1 (TC)	2	IO	PT18D	PT25D	PT30D	—	L7C_A0
B22	1 (TC)	2	IO	PT18C	PT25C	PT30C	—	L7T_A0
A17	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	VDDIO1	—	—

Table 69. 680-Pin PBGAM Pinout

BM680	$V_{DD}IO$ Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
A23	1 (TC)	3	IO	PT18B	PT24D	PT29D	—	L8C_D1
C21	1 (TC)	3	IO	PT18A	PT24C	PT29C	VREF_1_03	L8T_D1
D20	1 (TC)	3	IO	PT17D	PT23D	PT28D	—	L9C_D2
A22	1 (TC)	3	IO	PT17C	PT23C	PT28C	—	L9T_D2
D31	—	—	Vss	Vss	Vss	Vss	—	—
A21	1 (TC)	3	IO	PT17B	PT22D	PT27D	—	L10C_A0
B21	1 (TC)	3	IO	PT17A	PT22C	PT27C	—	L10T_A0
B20	1 (TC)	4	IO	PT16D	PT21D	PT26D	—	L11C_A0
A20	1 (TC)	4	IO	PT16C	PT21C	PT26C	—	L11T_A0
B19	1 (TC)	4	IO	PT16B	PT20D	PT25D	—	L12C_A0
C19	1 (TC)	4	IO	PT16A	PT20C	PT25C	—	L12T_A0
E19	1 (TC)	4	IO	PT15D	PT19D	PT24D	—	L13C_D0
D18	1 (TC)	4	IO	PT15C	PT19C	PT24C	VREF_1_04	L13T_D0
A19	1 (TC)	—	$V_{DD}IO1$	$V_{DD}IO1$	$V_{DD}IO1$	$V_{DD}IO1$	—	—
C18	1 (TC)	4	IO	PT15B	PT19B	PT24B	—	L14C_A0
B18	1 (TC)	4	IO	PT15A	PT19A	PT24A	—	L14T_A0
B17	1 (TC)	5	IO	PT14D	PT18D	PT23D	PTCK1C	L15C_D0
C17	1 (TC)	5	IO	PT14C	PT18C	PT23C	PTCK1T	L15T_D0
N3	—	—	Vss	Vss	Vss	Vss	—	—
A16	1 (TC)	5	IO	PT14B	PT18B	PT23B	—	L16C_D2
D17	1 (TC)	5	IO	PT14A	PT18A	PT23A	—	L16T_D2
B16	1 (TC)	5	IO	PT13D	PT17D	PT22D	PTCK0C	L17C_A0
C16	1 (TC)	5	IO	PT13C	PT17C	PT22C	PTCK0T	L17T_A0
E18	1 (TC)	5	IO	PT13B	PT16D	PT21D	VREF_1_05	L18C_D3
A15	1 (TC)	5	IO	PT13A	PT16C	PT21C	—	L18T_D3
D15	1 (TC)	6	IO	PT12D	PT15D	PT20D	—	L19C_D2
A14	1 (TC)	6	IO	PT12C	PT15C	PT20C	—	L19T_D2
N13	—	—	Vss	Vss	Vss	Vss	—	—
E17	1 (TC)	6	IO	PT12B	PT14D	PT19D	—	L20C_D3
A13	1 (TC)	6	IO	PT12A	PT14C	PT19C	VREF_1_06	L20T_D3
E16	0 (TL)	1	IO	PT11D	PT13D	PT18D	MPI_RTRY_N	L1C_D1
D14	0 (TL)	1	IO	PT11C	PT13C	PT18C	MPI_ACK_N	L1T_D1
A3	0 (TL)	—	$V_{DD}IO0$	$V_{DD}IO0$	$V_{DD}IO0$	$V_{DD}IO0$	—	—
C14	0 (TL)	1	IO	PT11B	PT13B	PT17D	—	L2C_D0
D13	0 (TL)	1	IO	PT11A	PT13A	PT17C	VREF_0_01	L2T_D0
A12	0 (TL)	1	IO	PT10D	PT12D	PT16D	M0	L3C_A0
B12	0 (TL)	1	IO	PT10C	PT12C	PT16C	M1	L3T_A0
A34	—	—	Vss	Vss	Vss	Vss	—	—
E15	0 (TL)	2	IO	PT10B	PT12B	PT15D	MPI_CLK	L4C_D3
B11	0 (TL)	2	IO	PT10A	PT12A	PT15C	A21/MPI_BURST_N	L4T_D3
C11	0 (TL)	2	IO	PT9D	PT11D	PT14D	M2	L5C_D2
E14	0 (TL)	2	IO	PT9C	PT11C	PT14C	M3	L5T_D2
B3	0 (TL)	—	$V_{DD}IO0$	$V_{DD}IO0$	$V_{DD}IO0$	$V_{DD}IO0$	—	—
D12	0 (TL)	2	IO	PT9B	PT11B	PT13D	VREF_0_02	L6C_A0

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
D11	0 (TL)	2	IO	PT9A	PT11A	PT13C	MPI_TEA_N	L6T_A0
A10	0 (TL)	3	IO	PT8D	PT10D	PT12D	—	L7C_A0
B10	0 (TL)	3	IO	PT8C	PT10C	PT12C	—	L7T_A0
C9	0 (TL)	3	IO	PT8B	PT9D	PT11D	VREF_0_03	L8C_D0
D10	0 (TL)	3	IO	PT8A	PT9C	PT11C	—	L8T_D0
B9	0 (TL)	3	IO	PT7D	PT8D	PT10D	D0	L9C_A0
A9	0 (TL)	3	IO	PT7C	PT8C	PT10C	TMS	L9T_A0
B1	—	—	Vss	Vss	Vss	Vss	—	—
D9	0 (TL)	4	IO	PT7B	PT7D	PT9D	A20/MPI_BDIP_N	L10C_D2
A8	0 (TL)	4	IO	PT7A	PT7C	PT9C	A19/MPI_TSZ1	L10T_D2
B8	0 (TL)	4	IO	PT6D	PT6D	PT8D	A18/MPI_TSZ0	L11C_D3
E12	0 (TL)	4	IO	PT6C	PT6C	PT8C	D3	L11T_D3
C1	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	VDDIO0	—	—
C8	0 (TL)	4	IO	PT6B	PT6B	PT7D	VREF_0_04	L12C_A0
D8	0 (TL)	4	IO	PT6A	PT6A	PT7C	—	L12T_A0
E11	0 (TL)	5	IO	PT5D	PT5D	PT6D	D1	L13C_D3
A7	0 (TL)	5	IO	PT5C	PT5C	PT6C	D2	L13T_D3
B2	—	—	Vss	Vss	Vss	Vss	—	—
A6	0 (TL)	5	IO	PT5B	PT5B	PT5D	—	L14C_D0
B7	0 (TL)	5	IO	PT5A	PT5A	PT5C	VREF_0_05	L14T_D0
C7	0 (TL)	5	IO	PT4D	PT4D	PT4D	TDI	L15C_A0
D7	0 (TL)	5	IO	PT4C	PT4C	PT4C	TCK	L15T_A0
C2	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	VDDIO0	—	—
E10	0 (TL)	5	IO	PT4B	PT4B	PT4B	—	L16C_D4
A5	0 (TL)	5	IO	PT4A	PT4A	PT4A	—	L16T_D4
B6	0 (TL)	6	IO	PT3D	PT3D	PT3D	—	L17C_D2
E9	0 (TL)	6	IO	PT3C	PT3C	PT3C	VREF_0_06	L17T_D2
B33	—	—	Vss	Vss	Vss	Vss	—	—
A4	0 (TL)	6	IO	PT3B	PT3B	PT3B	—	L18C_D0
B5	0 (TL)	6	IO	PT3A	PT3A	PT3A	—	L18T_D0
D6	0 (TL)	6	IO	PT2D	PT2D	PT2D	PLL_CK1C/PPLL	L19C_A0
C6	0 (TL)	6	IO	PT2C	PT2C	PT2C	PLL_CK1T/PPLL	L19T_A0
C4	0 (TL)	—	VDDIO0	VDDIO0	VDDIO0	VDDIO0	—	—
C5	0 (TL)	6	IO	PT2B	PT2B	PT2B	—	L20C_D1
E8	0 (TL)	6	IO	PT2A	PT2A	PT2A	—	L20T_D1
E7	—	—	O	PCFG_MPI_IRQ	PCFG_MPI_IRQ	PCFG_MPI_IRQ	CFG_IRQ_N/ MPI_IRQ_N	—
E6	—	—	IO	PCCLK	PCCLK	PCCLK	CCLK	—
B4	—	—	IO	PDONE	PDONE	PDONE	DONE	—
D5	—	—	VDD33	VDD33	VDD33	VDD33	—	—
B34	—	—	Vss	Vss	Vss	Vss	—	—
A24	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	VDDIO1	—	—
AM23	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	VDDIO5	—	—
AP1	—	—	Vss	Vss	Vss	Vss	—	—
K4	0 (TL)	10	IO	Unused	PL9A	PL11A	—	—

Table 69. 680-Pin PBGAM Pinout

BM680	$V_{DD}IO$ Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
M5	0 (TL)	10	IO	Unused	PL11A	PL13A	—	—
R5	7 (CL)	3	IO	Unused	PL16A	PL20A	—	—
T5	7 (CL)	3	IO	Unused	PL17A	PL21A	—	—
Y2	7 (CL)	5	IO	Unused	PL23A	PL27A	—	—
AA2	7 (CL)	6	IO	Unused	PL24A	PL28A	—	—
AA3	7 (CL)	6	IO	Unused	PL25A	PL29A	—	—
AC4	7 (CL)	8	IO	Unused	PL29A	PL35A	—	—
AD5	7 (CL)	8	IO	Unused	PL31A	PL37A	—	—
AE4	6 (BL)	1	IO	Unused	PL32A	PL38A	—	—
AN7	6 (BL)	7	IO	Unused	PB7A	PB9A	—	—
AL9	6 (BL)	7	IO	Unused	PB8A	PB10A	—	—
AN8	6 (BL)	8	IO	Unused	PB9A	PB11A	—	—
AN9	6 (BL)	8	IO	Unused	PB10A	PB12A	—	—
AN14	6 (BL)	11	IO	Unused	PB15A	PB19A	—	—
AL14	6 (BL)	11	IO	Unused	PB16A	PB20A	—	—
AN15	5 (BC)	1	IO	Unused	PB17A	PB21A	—	—
AL16	5 (BC)	1	IO	Unused	PB18A	PB22A	—	—
AL20	5 (BC)	3	IO	Unused	PB22A	PB27A	—	—
AK19	5 (BC)	3	IO	Unused	PB23A	PB28A	—	—
AK20	5 (BC)	3	IO	Unused	PB24A	PB29A	—	—
AK21	5 (BC)	4	IO	Unused	PB25A	PB30A	—	—
AN25	5 (BC)	6	IO	Unused	PB28A	PB35A	—	—
AN26	5 (BC)	6	IO	Unused	PB29A	PB36A	—	—
AM26	4 (BR)	1	IO	Unused	PB30A	PB37A	—	—
D28	2 (TR)	6	IO	Unused	PT35D	PT44D	—	L16C_D1
B29	2 (TR)	6	IO	Unused	PT35C	PT44C	—	L16T_D1
E21	1 (TC)	3	IO	Unused	PT24A	PT29A	—	—
E20	1 (TC)	3	IO	Unused	PT23A	PT28A	—	—
D19	1 (TC)	3	IO	Unused	PT22A	PT27A	—	—
B13	1 (TC)	6	IO	Unused	PT14A	PT19A	—	—
D16	1 (TC)	5	IO	Unused	PT17A	PT22A	—	—
B15	1 (TC)	5	IO	Unused	PT16A	PT21A	—	—
B14	1 (TC)	6	IO	Unused	PT15A	PT20A	—	—
C10	0 (TL)	3	IO	Unused	PT10A	PT12A	—	—
E13	0 (TL)	3	IO	Unused	PT9A	PT11A	—	—
AF30	4 (BR)	7	IO	Unused	PR34A	PR40A	—	—
AH32	4 (BR)	7	IO	Unused	PR33A	PR39A	—	—
AE30	4 (BR)	7	IO	Unused	PR32A	PR38A	—	—
AF32	4 (BR)	8	IO	Unused	PR31A	PR37A	—	—
AA31	3 (CR)	2	IO	Unused	PR27C	PR31A	—	—
AD33	3 (CR)	2	IO	Unused	PR27D	PR32B	—	—
AC34	3 (CR)	2	IO	Unused	PR26C	PR30A	—	—
Y31	3 (CR)	3	IO	Unused	PR24B	PR29B	—	—
AA34	3 (CR)	3	IO	Unused	PR24A	PR28A	—	—

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
Y33	3 (CR)	4	IO	Unused	PR23A	PR27A	—	—
W32	3 (CR)	4	IO	Unused	PR22A	PR26A	—	—
U33	3 (CR)	5	IO	Unused	PR20A	PR24A	—	L12T_A0
U32	3 (CR)	5	IO	Unused	PR20B	PR24B	—	L12C_A0
T33	3 (CR)	5	IO	Unused	PR19A	PR23A	—	—
U30	3 (CR)	5	IO	Unused	PR18A	PR22A	—	—
R33	3 (CR)	5	IO	Unused	PR17A	PR21A	—	—
T30	3 (CR)	6	IO	Unused	PR16A	PR20A	—	—
R30	3 (CR)	6	IO	Unused	PR16B	PR19B	—	—
P30	3 (CR)	7	IO	Unused	PR15C	PR17A	—	—
N34	3 (CR)	7	IO	Unused	PR15D	PR18B	—	—
M30	2 (TR)	1	IO	Unused	PR9A	PR11A	—	—
L30	2 (TR)	1	IO	Unused	PR8A	PR10A	—	—
F34	2 (TR)	2	IO	Unused	PR7C	PR9A	—	—
D34	2 (TR)	3	IO	Unused	PR5C	PR6A	—	—
AP4	6 (BL)	5	IO	Unused	PB3A	PB3A	—	—
Y3	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
AC3	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
AD1	7 (CL)	—	VDDIO7	VDDIO7	VDDIO7	VDDIO7	—	—
AP11	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	VDDIO5	—	—
AP17	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	VDDIO5	—	—
AP19	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	VDDIO5	—	—
AP24	5 (BC)	—	VDDIO5	VDDIO5	VDDIO5	VDDIO5	—	—
AN32	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
AP32	4 (BR)	—	VDDIO4	VDDIO4	VDDIO4	VDDIO4	—	—
Y32	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
AC32	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
AD34	3 (CR)	—	VDDIO3	VDDIO3	VDDIO3	VDDIO3	—	—
D32	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
E30	2 (TR)	—	VDDIO2	VDDIO2	VDDIO2	VDDIO2	—	—
C12	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	VDDIO1	—	—
C15	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	VDDIO1	—	—
C20	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	VDDIO1	—	—
C23	1 (TC)	—	VDDIO1	VDDIO1	VDDIO1	VDDIO1	—	—
N16	—	—	VDD15	VDD15	VDD15	VDD15	—	—
Y16	—	—	VDD15	VDD15	VDD15	VDD15	—	—
Y17	—	—	VDD15	VDD15	VDD15	VDD15	—	—
W13	—	—	VDD15	VDD15	VDD15	VDD15	—	—
V13	—	—	VDD15	VDD15	VDD15	VDD15	—	—
U13	—	—	VDD15	VDD15	VDD15	VDD15	—	—
P18	—	—	VDD15	VDD15	VDD15	VDD15	—	—
P19	—	—	VDD15	VDD15	VDD15	VDD15	—	—
N17	—	—	VDD15	VDD15	VDD15	VDD15	—	—
N18	—	—	VDD15	VDD15	VDD15	VDD15	—	—

Table 69. 680-Pin PBGAM Pinout

BM680	VDDIO Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
N19	—	—	VDD15	VDD15	VDD15	VDD15	—	—
P16	—	—	VDD15	VDD15	VDD15	VDD15	—	—
P17	—	—	VDD15	VDD15	VDD15	VDD15	—	—
R16	—	—	VDD15	VDD15	VDD15	VDD15	—	—
R17	—	—	VDD15	VDD15	VDD15	VDD15	—	—
R18	—	—	VDD15	VDD15	VDD15	VDD15	—	—
R19	—	—	VDD15	VDD15	VDD15	VDD15	—	—
T13	—	—	VDD15	VDD15	VDD15	VDD15	—	—
T14	—	—	VDD15	VDD15	VDD15	VDD15	—	—
T15	—	—	VDD15	VDD15	VDD15	VDD15	—	—
T20	—	—	VDD15	VDD15	VDD15	VDD15	—	—
T21	—	—	VDD15	VDD15	VDD15	VDD15	—	—
T22	—	—	VDD15	VDD15	VDD15	VDD15	—	—
U14	—	—	VDD15	VDD15	VDD15	VDD15	—	—
U15	—	—	VDD15	VDD15	VDD15	VDD15	—	—
U20	—	—	VDD15	VDD15	VDD15	VDD15	—	—
U21	—	—	VDD15	VDD15	VDD15	VDD15	—	—
U22	—	—	VDD15	VDD15	VDD15	VDD15	—	—
V14	—	—	VDD15	VDD15	VDD15	VDD15	—	—
V15	—	—	VDD15	VDD15	VDD15	VDD15	—	—
V20	—	—	VDD15	VDD15	VDD15	VDD15	—	—
V21	—	—	VDD15	VDD15	VDD15	VDD15	—	—
V22	—	—	VDD15	VDD15	VDD15	VDD15	—	—
W14	—	—	VDD15	VDD15	VDD15	VDD15	—	—
W15	—	—	VDD15	VDD15	VDD15	VDD15	—	—
W20	—	—	VDD15	VDD15	VDD15	VDD15	—	—
W21	—	—	VDD15	VDD15	VDD15	VDD15	—	—
W22	—	—	VDD15	VDD15	VDD15	VDD15	—	—
Y18	—	—	VDD15	VDD15	VDD15	VDD15	—	—
Y19	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AA16	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AA17	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AA18	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AA19	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AB16	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AB17	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AB18	—	—	VDD15	VDD15	VDD15	VDD15	—	—
AB19	—	—	VDD15	VDD15	VDD15	VDD15	—	—
C3	—	—	Vss	Vss	Vss	Vss	—	—
C13	—	—	Vss	Vss	Vss	Vss	—	—
AP2	—	—	Vss	Vss	Vss	Vss	—	—
AP18	—	—	Vss	Vss	Vss	Vss	—	—
AP33	—	—	Vss	Vss	Vss	Vss	—	—
AP34	—	—	Vss	Vss	Vss	Vss	—	—

Table 69. 680-Pin PBGAM Pinout

BM680	$V_{DD}IO$ Bank	VREF Group	I/O	OR4E02	OR4E04	OR4E06	Additional Function	Pair
AA13	—	—	Vss	Vss	Vss	Vss	—	—
AA14	—	—	Vss	Vss	Vss	Vss	—	—
AA15	—	—	Vss	Vss	Vss	Vss	—	—
AA20	—	—	Vss	Vss	Vss	Vss	—	—
AA21	—	—	Vss	Vss	Vss	Vss	—	—
AA22	—	—	Vss	Vss	Vss	Vss	—	—
AB3	—	—	Vss	Vss	Vss	Vss	—	—
Y14	—	—	Vss	Vss	Vss	Vss	—	—
U16	—	—	Vss	Vss	Vss	Vss	—	—
U17	—	—	Vss	Vss	Vss	Vss	—	—
U18	—	—	Vss	Vss	Vss	Vss	—	—
U19	—	—	Vss	Vss	Vss	Vss	—	—
V1	—	—	Vss	Vss	Vss	Vss	—	—
R14	—	—	Vss	Vss	Vss	Vss	—	—
R15	—	—	Vss	Vss	Vss	Vss	—	—
R20	—	—	Vss	Vss	Vss	Vss	—	—
N14	—	—	Vss	Vss	Vss	Vss	—	—
N15	—	—	Vss	Vss	Vss	Vss	—	—
N20	—	—	Vss	Vss	Vss	Vss	—	—
N21	—	—	Vss	Vss	Vss	Vss	—	—
N22	—	—	Vss	Vss	Vss	Vss	—	—
AM33	4 (BR)	—	$V_{DD}IO4$	$V_{DD}IO4$	$V_{DD}IO4$	$V_{DD}IO4$	—	—

Package Thermal Characteristics Summary

There are three thermal parameters that are in common use: ΘJA, ψJC, and ΘJC. It should be noted that all the parameters are affected, to varying degrees, by package design (including paddle size) and choice of materials, the amount of copper in the test board or system board, and system airflow.

ΘJA

This is the thermal resistance from junction to ambient (theta-JA, R-theta, etc.):

$$\Theta JA = \frac{TJ - TA}{Q}$$

where T_J is the junction temperature, T_A, is the ambient air temperature, and Q is the chip power.

Experimentally, ΘJA is determined when a special thermal test die is assembled into the package of interest, and the part is mounted on the thermal test board. The diodes on the test chip are separately calibrated in an oven. The package/board is placed either in a JEDEC natural convection box or in the wind tunnel, the latter for forced convection measurements. A controlled amount of power (Q) is dissipated in the test chip's heater resistor, the chip's temperature (T_J) is determined by the forward drop on the diodes, and the ambient temperature (T_A) is noted. Note that ΘJA is expressed in units of °C/watt.

ψJC

This JEDEC designated parameter correlates the junction temperature to the case temperature. It is generally used to infer the junction temperature while the device is operating in the system. It is not considered a true thermal resistance, and it is defined by:

$$\psi JC = \frac{TJ - TC}{Q}$$

where T_C is the case temperature at top dead center, T_J is the junction temperature, and Q is the chip power. During the ΘJA measurements described above, besides the other parameters measured, an additional temperature reading, T_C, is made with a thermocouple attached at top-dead-center of the case. ψJC is also expressed in units of °C/W.

ΘJC

This is the thermal resistance from junction to case. It is most often used when attaching a heat sink to the top of the package. It is defined by:

$$\Theta JC = \frac{TJ - TC}{Q}$$

The parameters in this equation have been defined above. However, the measurements are performed with the case of the part pressed against a water-cooled heat sink to draw most of the heat generated by the chip out the top of the package. It is this difference in the measurement process that differentiates ΘJC from ΨJC. ΘJC is a true thermal resistance and is expressed in units of °C/W.

ΘJB

This is the thermal resistance from junction to board (ΘJL). It is defined by:

$$\Theta JB = \frac{TJ - TB}{Q}$$

where TB is the temperature of the board adjacent to a lead measured with a thermocouple. The other parameters on the right-hand side have been defined above. This is considered a true thermal resistance, and the measurement is made with a water-cooled heat sink pressed against the board to draw most of the heat out of the leads. Note that ΘJB is expressed in units of °C/W, and that this parameter and the way it is measured are still in JEDEC committee.

Package Thermal Characteristics

Table 70. *ORCA* Series 4 Plastic Package Thermal Guidelines

Package	ΘJA (°C/W)			Max Power
	0 fpm	200 fpm	500 fpm	T = 70 °C Max TJ = 125 °C Max 0 fpm (W)
352-Pin PBGA	19.0	16.0	15.0	2.9
416-pin PBGAM	18.0	16.5	13.5	3.1
680-Pin PBGAM	13.4	11.5	10.5	4.1

Note: The 416-pin PBGAM and the 680-pin PBGAM packages include 2 oz. copper plates

Package Coplanarity

The coplanarity limits of packages are as follows:

- PBGA: 8.0 mils
- PBGAM: 8.0 mils

Heat Sink Vendors for BGA Packages

In some cases the power required by the customers application is greater than the package can dissipate. Below, in alphabetical order, is a list of heat sink vendors who advertise heat sinks aimed at the BGA market.

Table 71. Heat Sink Vendors

Vendor	Location	Phone
Aavid Thermalloy	Concord, NH	(603) 224-9988
Chip Coolers (Tyco Electronics)	Harrisburg, PA	(800) 468-2023
IERC (CTS Corp.)	Burbank, CA	(818) 842-7277
R-Theta	Buffalo, NY	(800) 388-5428
Sanyo Denki	Torrance, CA	(310) 783-5400
Wakefield Thermal Solutions	Pelham, NH	(603) 635-2800

Package Parasitics

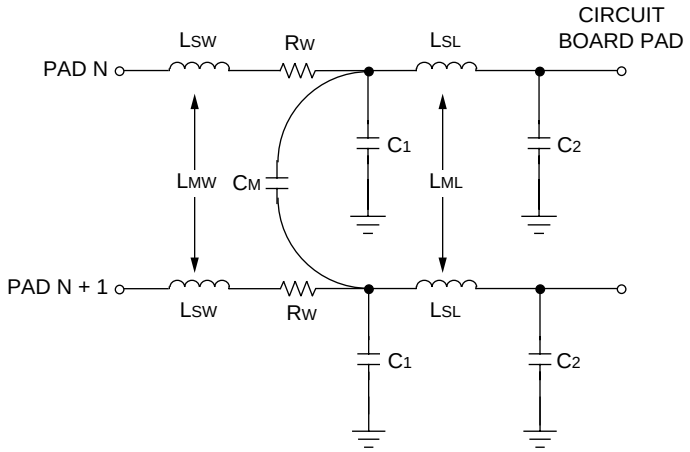
The electrical performance of an IC package, such as signal quality and noise sensitivity, is directly affected by the package parasitics. Table 72 lists eight parasitics associated with the *ORCA* packages. These parasitics represent the contributions of all components of a package, which include the bond wires, all internal package routing, and the external leads.

Four inductances in nH are listed: L_{SW} and L_{SL}, the self-inductance of the lead; and L_{MW} and L_{ML}, the mutual inductance to the nearest neighbor lead. These parameters are important in determining ground bounce noise and inductive crosstalk noise. Three capacitances in pF are listed: C_M, the mutual capacitance of the lead to the nearest neighbor lead; and C_1 and C_2, the total capacitance of the lead to all other leads (all other leads are assumed to be grounded). These parameters are important in determining capacitive crosstalk and the capacitive loading effect of the lead. Resistance values are in mΩ.

The parasitic values in Table 72 are for the circuit model of bond wire and package lead parasitics. If the mutual capacitance value is not used in the designer's model, then the value listed as mutual capacitance should be added to each of the C_1 and C_2 capacitors.

Table 72. *ORCA* Series 4 Package Parasitics

Package Type	L_{SW}	L_{MW}	R_W	C_1	C_2	C_M	L_{SL}	L_{ML}
352-Pin PBGA	5.00	2.00	220	1.50	1.50	1.50	7—12	3—6
416-Pin PBGAM	3.52	0.80	235	0.40	1.00	0.25	1.5—5.0	0.5—1.3
680-Pin PBGAM	3.80	1.30	250	0.50	1.00	0.30	2.8—5	0.5—1.5



5-3862(C)r2

Figure 60. Package Parasitics

Package Outline Diagrams

Terms and Definitions

Basic Size (BSC): The basic size of a dimension is the size from which the limits for that dimension are derived by the application of the allowance and the tolerance.

Design Size: The design size of a dimension is the actual size of the design, including an allowance for fit and tolerance.

Typical (TYP): When specified after a dimension, this indicates the repeated design size if a tolerance is specified or repeated basic size if a tolerance is not specified.

Reference (REF): The reference dimension is an untoleranced dimension used for informational purposes only. It is a repeated dimension or one that can be derived from other values in the drawing.

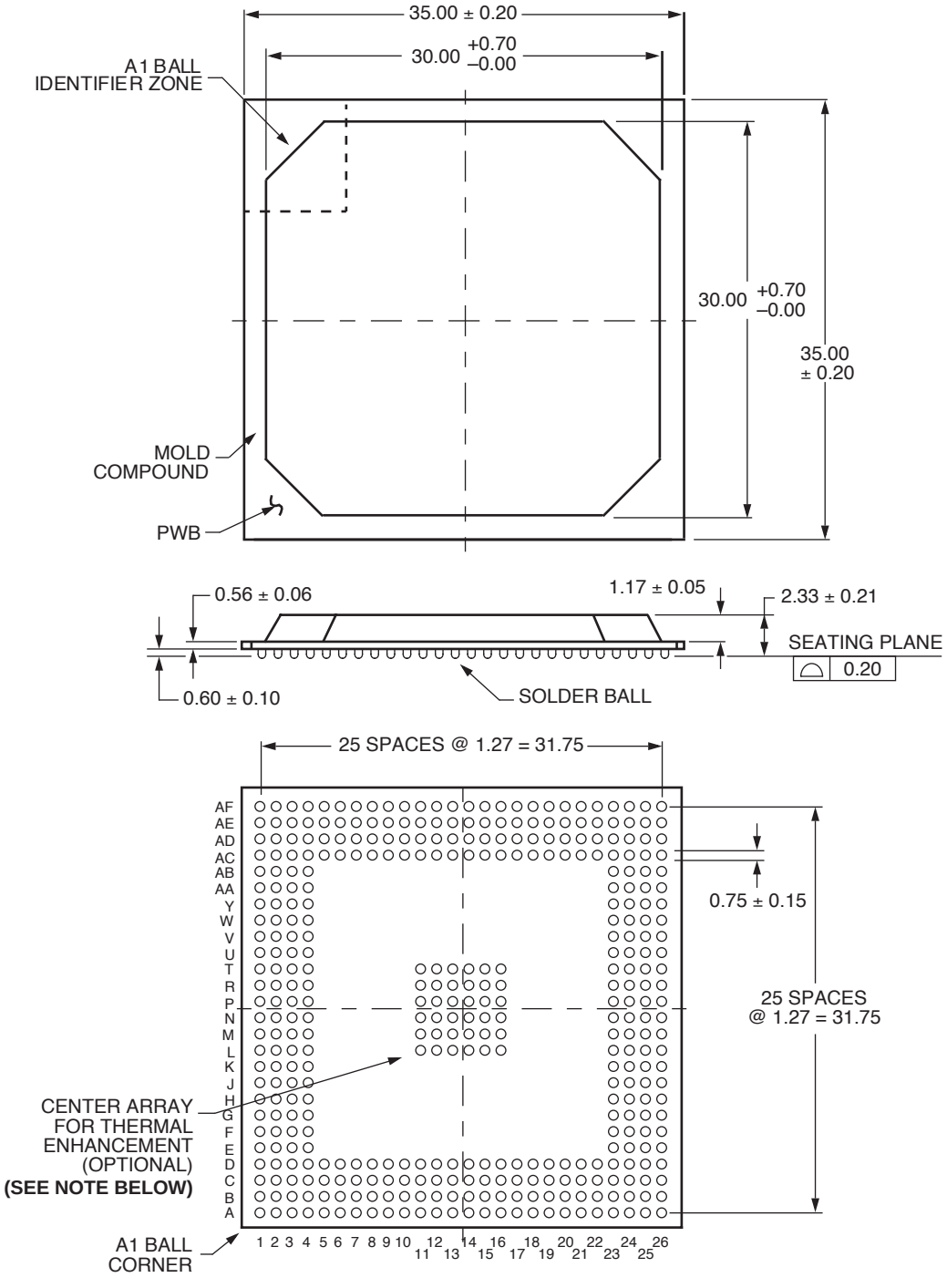
Minimum (MIN) or Maximum (MAX): Indicates the minimum or maximum allowable size of a dimension.

2725(f)

Package Outline Diagrams

352-Pin PBGA

Dimensions are in millimeters.



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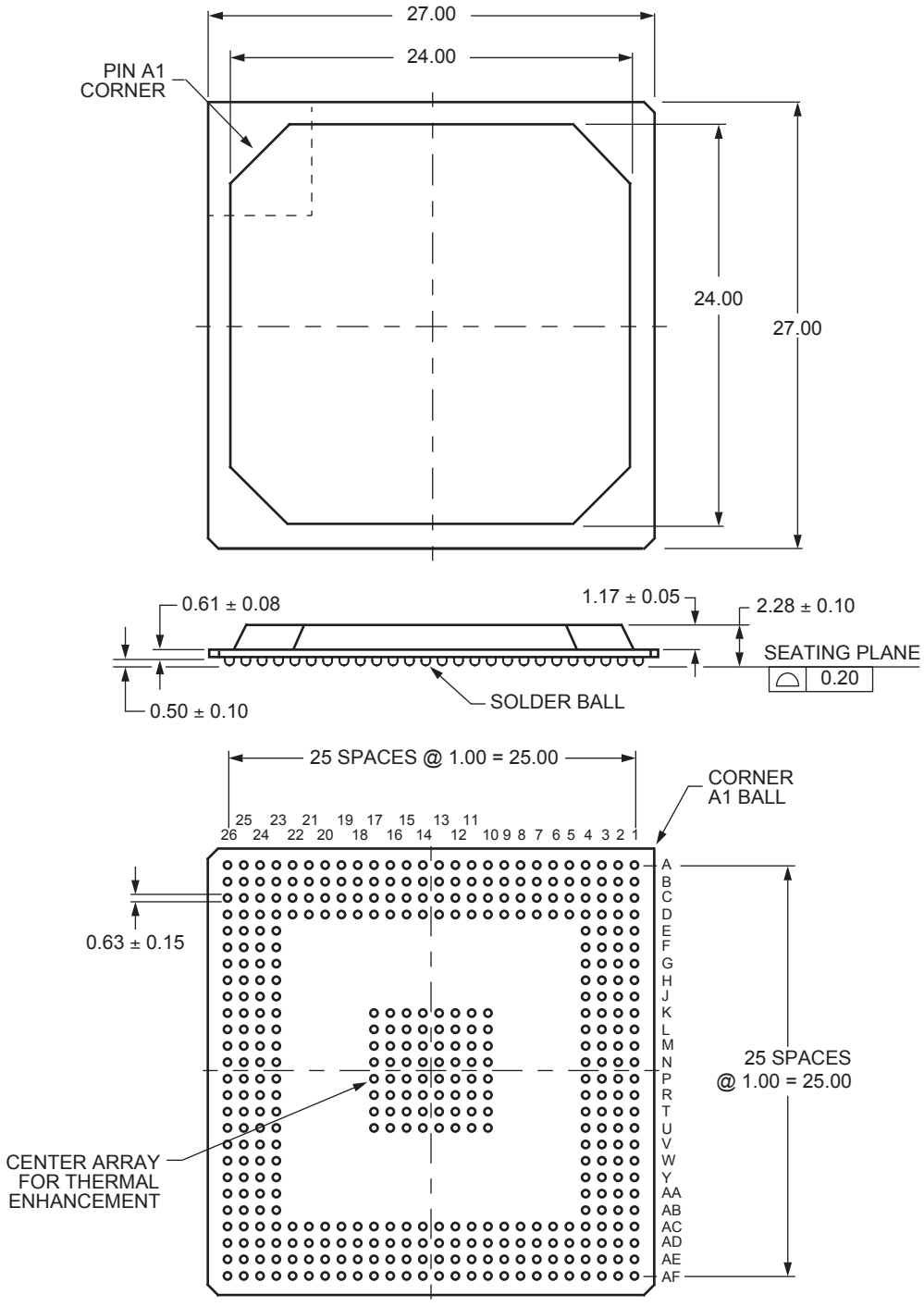
Note: Although the 36 thermal enhancement balls are stated as an option, they are standard on the 352 FPGA package.

Package Outline Diagrams (continued)

416-Pin PBGAM

Dimensions are in millimeters.



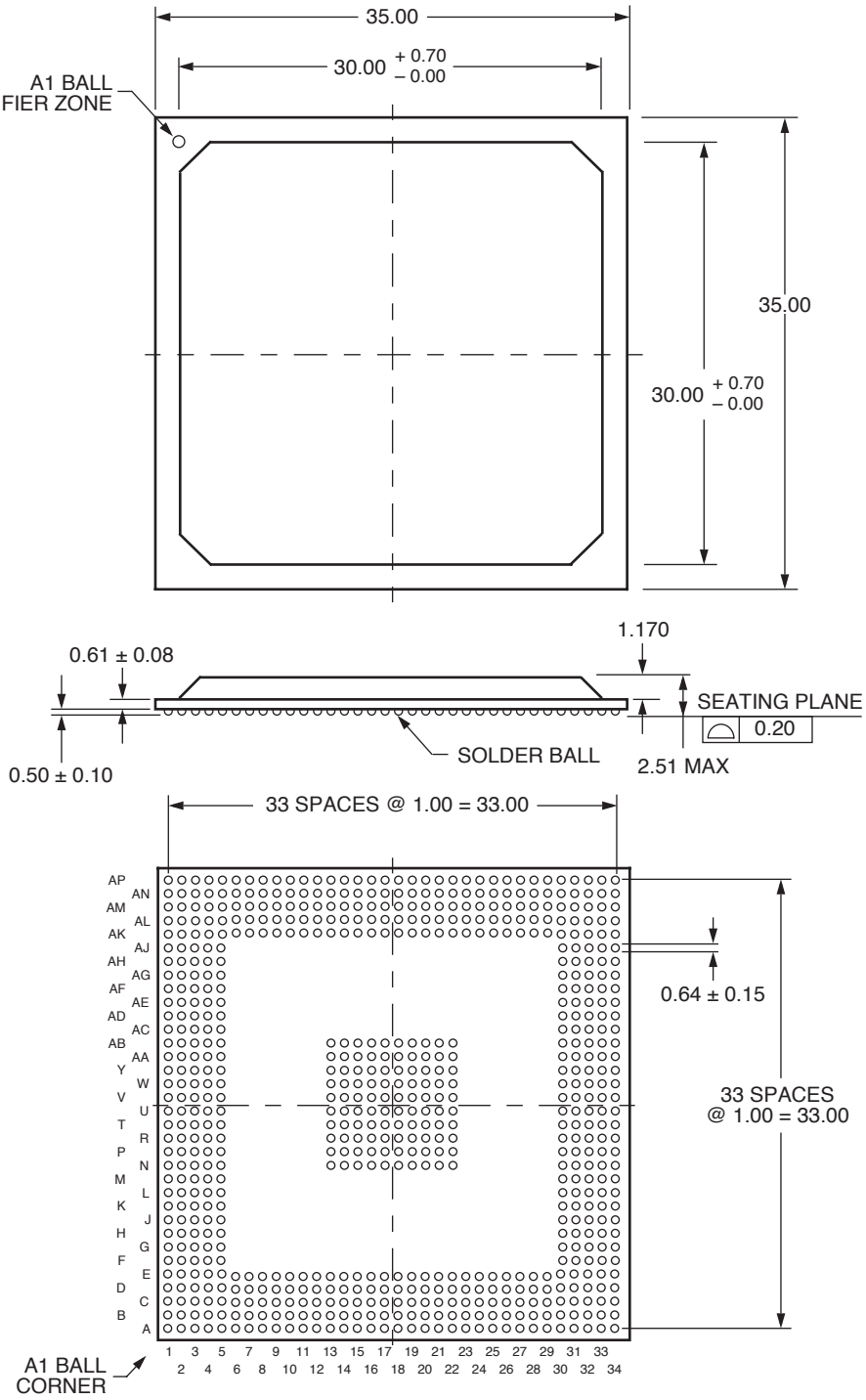
1139(F)

5-4409(F)

Package Outline Drawings (continued)

680-Pin PBGAM

Dimensions are in millimeters.



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Ordering Information

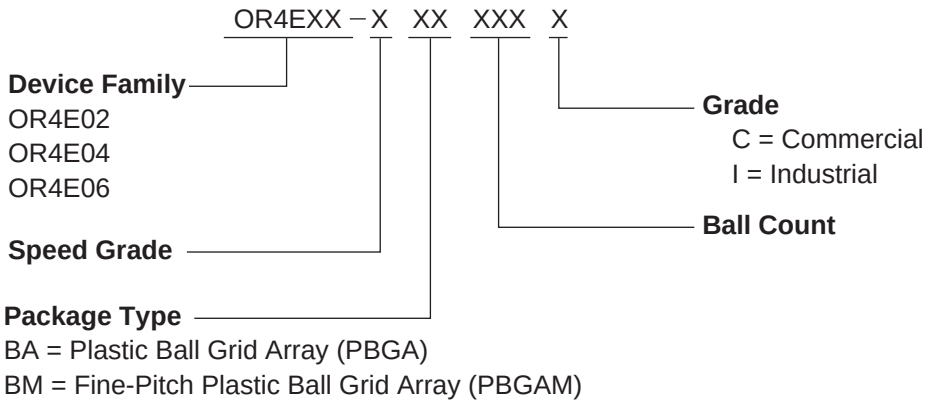

Table 73. Device Type Options

Device	Voltage
OR4Exx	1.5 V internal 3.3 V/2.5 V/1.8 V/1.5 V I/O

Table 74. Recommended Temperature Range

Symbol	Description	Ambient Temperature	Junction Temperature
C	Commercial	0 ˚C to +70 ˚C	0 ˚C to +85 ˚C
I	Industrial	–40 ˚C to +85 ˚C	–40 ˚C to +100 ˚C

Table 75. Commercial Ordering Information

Device Family	Part Number	Speed Grade	Package Type	Ball Count	Grade
OR4E02	OR4E02-3BA352C	3	PBGA	352	C
	OR4E02-3BM416C	3	PBGAM	416	C
	OR4E02-3BM680C	3	PBGAM	680	C
	OR4E02-2BA352C	2	PBGA	352	C
	OR4E02-2BM416C	2	PBGAM	416	C
	OR4E02-2BM680C	2	PBGAM	680	C
	OR4E02-1BA352C	1	PBGA	352	C
	OR4E02-1BM416C	1	PBGAM	416	C
	OR4E02-1BM680C	1	PBGAM	680	C
OR4E04	OR4E04-3BA352C	3	PBGA	352	C
	OR4E04-3BM416C	3	PBGAM	416	C
	OR4E04-3BM680C	3	PBGAM	680	C
	OR4E04-2BA352C	2	PBGA	352	C
	OR4E04-2BM416C	2	PBGAM	416	C
	OR4E04-2BM680C	2	PBGAM	680	C
	OR4E04-1BA352C	1	PBGA	352	C
	OR4E04-1BM416C	1	PBGAM	416	C
	OR4E04-1BM680C	1	PBGAM	680	C
OR4E06	OR4E06-2BA352C	2	PBGA	352	C
	OR4E06-2BM680C	2	PBGAM	680	C
	OR4E06-1BA352C	1	PBGA	352	C
	OR4E06-1BM680C	1	PBGAM	680	C

Note: For all but the slowest commercial speed grade, the speed grades on these devices are dual marked. For example, the commercial speed grade -2XXXXXC is also marked with the industrial grade -1XXXXXI. The commercial grade is always one speed grade faster than the associated dual mark industrial grade. The slowest commercial speed grade is marked as commercial grade only.

Table 76. Industrial Ordering Information

Device Family	Part Number	Speed Grade	Package Type	Ball Count	Grade
OR4E02	OR4E02-2BA352I	2	PBGA	352	I
	OR4E02-2BM416I	2	PBGAM	416	I
	OR4E02-2BM680I	2	PBGAM	680	I
	OR4E02-1BA352I	1	PBGA	352	I
	OR4E02-1BM416I	1	PBGAM	416	I
	OR4E02-1BM680I	1	PBGAM	680	I
OR4E04	OR4E04-2BA352I	2	PBGA	352	I
	OR4E04-2BM416I	2	PBGAM	416	I
	OR4E04-2BM680I	2	PBGAM	680	I
	OR4E04-1BA352I	1	PBGA	352	I
	OR4E04-1BM416I	1	PBGAM	416	I
	OR4E04-1BM680I	1	PBGAM	680	I
OR4E06	OR4E06-1BA352I	1	PBGA	352	I
	OR4E06-1BM680I	1	PBGAM	680	I

Note: For all but the slowest commercial speed grade, the speed grades on these devices are dual marked. For example, the commercial speed grade -2XXXXXC is also marked with the industrial grade -1XXXXXI. The commercial grade is always one speed grade faster than the associated dual mark industrial grade. The slowest commercial speed grade is marked as commercial grade only.

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- Консультации по применению компонента;
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- Техническая поддержка проекта;
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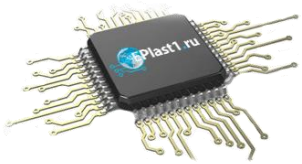

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