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Includes
FLEX 10KA

FLEX 10K

Embedded Programmable Logic Device Family

January 2003, ver. 4.2

Data Sheet

Features...

- The industry's first embedded programmable logic device (PLD) family, providing System-on-a-Programmable-Chip (SOPC) integration
 - Embedded array for implementing megafunctions, such as efficient memory and specialized logic functions
 - Logic array for general logic functions
- High density
 - 10,000 to 250,000 typical gates (see [Tables 1](#) and [2](#))
 - Up to 40,960 RAM bits; 2,048 bits per embedded array block (EAB), all of which can be used without reducing logic capacity
- System-level features
 - MultiVolt™ I/O interface support
 - 5.0-V tolerant input pins in FLEX® 10KA devices
 - Low power consumption (typical specification less than 0.5 mA in standby mode for most devices)
 - FLEX 10K and FLEX 10KA devices support peripheral component interconnect Special Interest Group (PCI SIG) *PCI Local Bus Specification, Revision 2.2*
 - FLEX 10KA devices include pull-up clamping diode, selectable on a pin-by-pin basis for 3.3-V PCI compliance
 - Select FLEX 10KA devices support 5.0-V PCI buses with eight or fewer loads
 - Built-in Joint Test Action Group (JTAG) boundary-scan test (BST) circuitry compliant with IEEE Std. 1149.1-1990, available without consuming any device logic

Table 1. FLEX 10K Device Features

| Feature | EPF10K10 EPF10K10A | EPF10K20 | EPF10K30 EPF10K30A | EPF10K40 | EPF10K50 EPF10K50V |
|-----------------------------------|-----------------------|----------|-----------------------|----------|-----------------------|
| Typical gates (logic and RAM) (1) | 10,000 | 20,000 | 30,000 | 40,000 | 50,000 |
| Maximum system gates | 31,000 | 63,000 | 69,000 | 93,000 | 116,000 |
| Logic elements (LEs) | 576 | 1,152 | 1,728 | 2,304 | 2,880 |
| Logic array blocks (LABs) | 72 | 144 | 216 | 288 | 360 |
| Embedded array blocks (EABs) | 3 | 6 | 6 | 8 | 10 |
| Total RAM bits | 6,144 | 12,288 | 12,288 | 16,384 | 20,480 |
| Maximum user I/O pins | 150 | 189 | 246 | 189 | 310 |

Table 2. FLEX 10K Device Features

| Feature | EPF10K70 | EPF10K100 EPF10K100A | EPF10K130V | EPF10K250A |
|-----------------------------------|----------|-------------------------|------------|------------|
| Typical gates (logic and RAM) (1) | 70,000 | 100,000 | 130,000 | 250,000 |
| Maximum system gates | 118,000 | 158,000 | 211,000 | 310,000 |
| LEs | 3,744 | 4,992 | 6,656 | 12,160 |
| LABs | 468 | 624 | 832 | 1,520 |
| EABs | 9 | 12 | 16 | 20 |
| Total RAM bits | 18,432 | 24,576 | 32,768 | 40,960 |
| Maximum user I/O pins | 358 | 406 | 470 | 470 |

Note to tables:

(1) The embedded IEEE Std. 1149.1 JTAG circuitry adds up to 31,250 gates in addition to the listed typical or maximum system gates.

...and More Features

- Devices are fabricated on advanced processes and operate with a 3.3-V or 5.0-V supply voltage (see [Table 3](#))
- In-circuit reconfigurability (ICR) via external configuration device, intelligent controller, or JTAG port
- ClockLock™ and ClockBoost™ options for reduced clock delay/skew and clock multiplication
- Built-in low-skew clock distribution trees
- 100% functional testing of all devices; test vectors or scan chains are not required

Table 3. Supply Voltages for FLEX 10K & FLEX 10KA Devices

| 5.0-V Devices | 3.3-V Devices |
|---------------|---------------|
| EPF10K10 | EPF10K10A |
| EPF10K20 | EPF10K30A |
| EPF10K30 | EPF10K50V |
| EPF10K40 | EPF10K100A |
| EPF10K50 | EPF10K130V |
| EPF10K70 | EPF10K250A |
| EPF10K100 | |

- Flexible interconnect
 - FastTrack[®] Interconnect continuous routing structure for fast, predictable interconnect delays
 - Dedicated carry chain that implements arithmetic functions such as fast adders, counters, and comparators (automatically used by software tools and megafunctions)
 - Dedicated cascade chain that implements high-speed, high-fan-in logic functions (automatically used by software tools and megafunctions)
 - Tri-state emulation that implements internal tri-state buses
 - Up to six global clock signals and four global clear signals
- Powerful I/O pins
 - Individual tri-state output enable control for each pin
 - Open-drain option on each I/O pin
 - Programmable output slew-rate control to reduce switching noise
 - FLEX 10KA devices support hot-socketing
- Peripheral register for fast setup and clock-to-output delay
- Flexible package options
 - Available in a variety of packages with 84 to 600 pins (see [Tables 4 and 5](#))
 - Pin-compatibility with other FLEX 10K devices in the same package
 - FineLine BGA[™] packages maximize board space efficiency
- Software design support and automatic place-and-route provided by Altera development systems for Windows-based PCs and Sun SPARCstation, HP 9000 Series 700/800 workstations
- Additional design entry and simulation support provided by EDIF 2.0.0 and 3.0.0 netlist files, library of parameterized modules (LPM), DesignWare components, Verilog HDL, VHDL, and other interfaces to popular EDA tools from manufacturers such as Cadence, Exemplar Logic, Mentor Graphics, OrCAD, Synopsys, Synplicity, VeriBest, and Viewlogic

Table 4. FLEX 10K Package Options & I/O Pin Count *Note (1)*

| Device | 84-Pin PLCC | 100-Pin TQFP | 144-Pin TQFP | 208-Pin PQFP RQFP | 240-Pin PQFP RQFP |
|------------|----------------|-----------------|--------------|-------------------------|-------------------------|
| EPF10K10 | 59 | | 102 | 134 | |
| EPF10K10A | | 66 | 102 | 134 | |
| EPF10K20 | | | 102 | 147 | 189 |
| EPF10K30 | | | | 147 | 189 |
| EPF10K30A | | | 102 | 147 | 189 |
| EPF10K40 | | | | 147 | 189 |
| EPF10K50 | | | | | 189 |
| EPF10K50V | | | | | 189 |
| EPF10K70 | | | | | 189 |
| EPF10K100 | | | | | |
| EPF10K100A | | | | | 189 |
| EPF10K130V | | | | | |
| EPF10K250A | | | | | |

Table 5. FLEX 10K Package Options & I/O Pin Count (Continued) *Note (1)*

| Device | 503-Pin PGA | 599-Pin PGA | 256-Pin FineLine BGA | 356-Pin BGA | 484-Pin FineLine BGA | 600-Pin BGA | 403-Pin PGA |
|------------|----------------|----------------|-------------------------|----------------|-------------------------|----------------|----------------|
| EPF10K10 | | | | | | | |
| EPF10K10A | | | 150 | | 150 (2) | | |
| EPF10K20 | | | | | | | |
| EPF10K30 | | | | 246 | | | |
| EPF10K30A | | | 191 | 246 | 246 | | |
| EPF10K40 | | | | | | | |
| EPF10K50 | | | | 274 | | | 310 |
| EPF10K50V | | | | 274 | | | |
| EPF10K70 | 358 | | | | | | |
| EPF10K100 | 406 | | | | | | |
| EPF10K100A | | | | 274 | 369 | 406 | |
| EPF10K130V | | 470 | | | | 470 | |
| EPF10K250A | | 470 | | | | 470 | |

Notes to tables:

- (1) FLEX 10K and FLEX 10KA device package types include plastic J-lead chip carrier (PLCC), thin quad flat pack (TQFP), plastic quad flat pack (PQFP), power quad flat pack (RQFP), ball-grid array (BGA), pin-grid array (PGA), and FineLine BGA™ packages.
- (2) This option is supported with a 256-pin FineLine BGA package. By using SameFrame pin migration, all FineLine BGA packages are pin compatible. For example, a board can be designed to support both 256-pin and 484-pin FineLine BGA packages. The Altera software automatically avoids conflicting pins when future migration is set.

General Description

Altera’s FLEX 10K devices are the industry’s first embedded PLDs. Based on reconfigurable CMOS SRAM elements, the Flexible Logic Element MatriX (FLEX) architecture incorporates all features necessary to implement common gate array megafunctions. With up to 250,000 gates, the FLEX 10K family provides the density, speed, and features to integrate entire systems, including multiple 32-bit buses, into a single device.

FLEX 10K devices are reconfigurable, which allows 100% testing prior to shipment. As a result, the designer is not required to generate test vectors for fault coverage purposes. Additionally, the designer does not need to manage inventories of different ASIC designs; FLEX 10K devices can be configured on the board for the specific functionality required.

Table 6 shows FLEX 10K performance for some common designs. All performance values were obtained with Synopsys DesignWare or LPM functions. No special design technique was required to implement the applications; the designer simply inferred or instantiated a function in a Verilog HDL, VHDL, Altera Hardware Description Language (AHDL), or schematic design file.

Table 6. FLEX 10K & FLEX 10KA Performance

| Application | Resources Used | | Performance | | | | Units |
|-----------------------------------|----------------|------|----------------|----------------|----------------|----------------|-------|
| | LEs | EABs | -1 Speed Grade | -2 Speed Grade | -3 Speed Grade | -4 Speed Grade | |
| 16-bit loadable counter (1) | 16 | 0 | 204 | 166 | 125 | 95 | MHz |
| 16-bit accumulator (1) | 16 | 0 | 204 | 166 | 125 | 95 | MHz |
| 16-to-1 multiplexer (2) | 10 | 0 | 4.2 | 5.8 | 6.0 | 7.0 | ns |
| 256 × 8 RAM read cycle speed (3) | 0 | 1 | 172 | 145 | 108 | 84 | MHz |
| 256 × 8 RAM write cycle speed (3) | 0 | 1 | 106 | 89 | 68 | 63 | MHz |

Notes:

- (1) The speed grade of this application is limited because of clock high and low specifications.
- (2) This application uses combinatorial inputs and outputs.
- (3) This application uses registered inputs and outputs.

The FLEX 10K architecture is similar to that of embedded gate arrays, the fastest-growing segment of the gate array market. As with standard gate arrays, embedded gate arrays implement general logic in a conventional “sea-of-gates” architecture. In addition, embedded gate arrays have dedicated die areas for implementing large, specialized functions. By embedding functions in silicon, embedded gate arrays provide reduced die area and increased speed compared to standard gate arrays. However, embedded megafunctions typically cannot be customized, limiting the designer’s options. In contrast, FLEX 10K devices are programmable, providing the designer with full control over embedded megafunctions and general logic while facilitating iterative design changes during debugging.

Each FLEX 10K device contains an embedded array and a logic array. The embedded array is used to implement a variety of memory functions or complex logic functions, such as digital signal processing (DSP), microcontroller, wide-data-path manipulation, and data-transformation functions. The logic array performs the same function as the sea-of-gates in the gate array: it is used to implement general logic, such as counters, adders, state machines, and multiplexers. The combination of embedded and logic arrays provides the high performance and high density of embedded gate arrays, enabling designers to implement an entire system on a single device.

FLEX 10K devices are configured at system power-up with data stored in an Altera serial configuration device or provided by a system controller. Altera offers the EPC1, EPC2, EPC16, and EPC1441 configuration devices, which configure FLEX 10K devices via a serial data stream. Configuration data can also be downloaded from system RAM or from Altera’s BitBlaster™ serial download cable or ByteBlasterMV™ parallel port download cable. After a FLEX 10K device has been configured, it can be reconfigured in-circuit by resetting the device and loading new data. Because reconfiguration requires less than 320 ms, real-time changes can be made during system operation.

FLEX 10K devices contain an optimized interface that permits microprocessors to configure FLEX 10K devices serially or in parallel, and synchronously or asynchronously. The interface also enables microprocessors to treat a FLEX 10K device as memory and configure the device by writing to a virtual memory location, making it very easy for the designer to reconfigure the device.



For more information, see the following documents:

- *Configuration Devices for APEX & FLEX Devices Data Sheet*
- *BitBlaster Serial Download Cable Data Sheet*
- *ByteBlasterMV Parallel Port Download Cable Data Sheet*
- *Application Note 116 (Configuring APEX 20K, FLEX 10K & FLEX 6000 Devices)*

FLEX 10K devices are supported by Altera development systems; single, integrated packages that offer schematic, text (including AHDL), and waveform design entry, compilation and logic synthesis, full simulation and worst-case timing analysis, and device configuration. The Altera software provides EDIF 2.0 and 3.0, LPM, VHDL, Verilog HDL, and other interfaces for additional design entry and simulation support from other industry-standard PC- and UNIX workstation-based EDA tools.

The Altera software works easily with common gate array EDA tools for synthesis and simulation. For example, the Altera software can generate Verilog HDL files for simulation with tools such as Cadence Verilog-XL. Additionally, the Altera software contains EDA libraries that use device-specific features such as carry chains which are used for fast counter and arithmetic functions. For instance, the Synopsys Design Compiler library supplied with the Altera development systems include DesignWare functions that are optimized for the FLEX 10K architecture.

The Altera development systems run on Windows-based PCs and Sun SPARCstation, and HP 9000 Series 700/800 workstations.



See the *MAX+PLUS II Programmable Logic Development System & Software Data Sheet* for more information.

Functional Description

Each FLEX 10K device contains an embedded array to implement memory and specialized logic functions, and a logic array to implement general logic.

The embedded array consists of a series of EABs. When implementing memory functions, each EAB provides 2,048 bits, which can be used to create RAM, ROM, dual-port RAM, or first-in first-out (FIFO) functions. When implementing logic, each EAB can contribute 100 to 600 gates towards complex logic functions, such as multipliers, microcontrollers, state machines, and DSP functions. EABs can be used independently, or multiple EABs can be combined to implement larger functions.

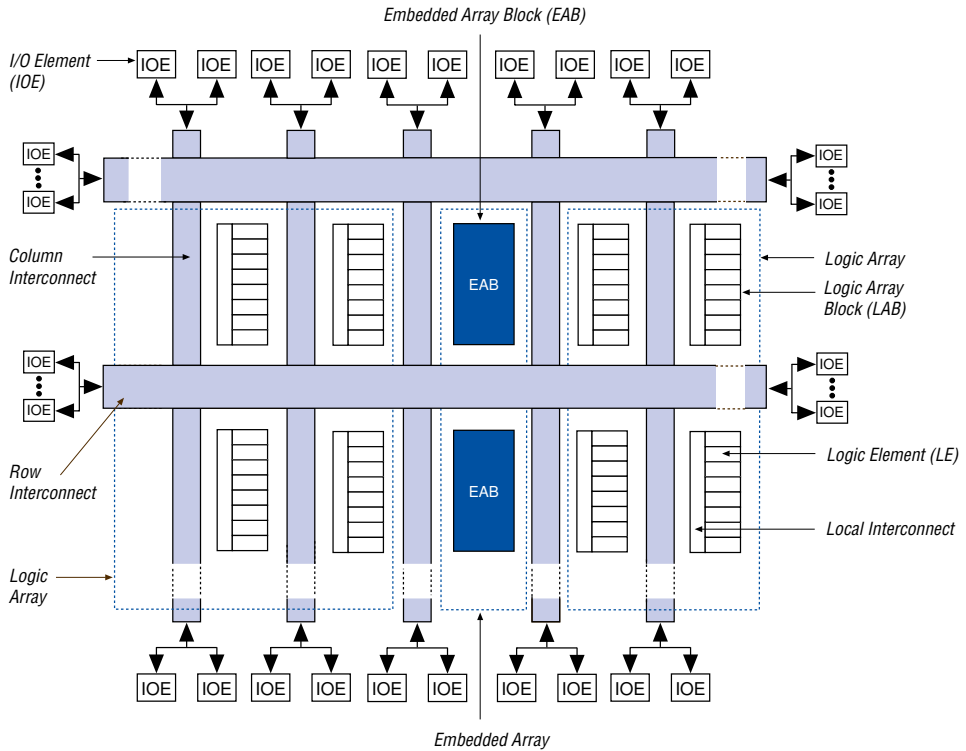
The logic array consists of logic array blocks (LABs). Each LAB contains eight LEs and a local interconnect. An LE consists of a 4-input look-up table (LUT), a programmable flipflop, and dedicated signal paths for carry and cascade functions. The eight LEs can be used to create medium-sized blocks of logic—8-bit counters, address decoders, or state machines—or combined across LABs to create larger logic blocks. Each LAB represents about 96 usable gates of logic.

Signal interconnections within FLEX 10K devices and to and from device pins are provided by the FastTrack Interconnect, a series of fast, continuous row and column channels that run the entire length and width of the device.

Each I/O pin is fed by an I/O element (IOE) located at the end of each row and column of the FastTrack Interconnect. Each IOE contains a bidirectional I/O buffer and a flipflop that can be used as either an output or input register to feed input, output, or bidirectional signals. When used with a dedicated clock pin, these registers provide exceptional performance. As inputs, they provide setup times as low as 1.6 ns and hold times of 0 ns; as outputs, these registers provide clock-to-output times as low as 5.3 ns. IOEs provide a variety of features, such as JTAG BST support, slew-rate control, tri-state buffers, and open-drain outputs.

Figure 1 shows a block diagram of the FLEX 10K architecture. Each group of LEs is combined into an LAB; LABs are arranged into rows and columns. Each row also contains a single EAB. The LABs and EABs are interconnected by the FastTrack Interconnect. IOEs are located at the end of each row and column of the FastTrack Interconnect.

Figure 1. FLEX 10K Device Block Diagram



FLEX 10K devices provide six dedicated inputs that drive the flipflops' control inputs to ensure the efficient distribution of high-speed, low-skew (less than 1.5 ns) control signals. These signals use dedicated routing channels that provide shorter delays and lower skews than the FastTrack Interconnect. Four of the dedicated inputs drive four global signals. These four global signals can also be driven by internal logic, providing an ideal solution for a clock divider or an internally generated asynchronous clear signal that clears many registers in the device.

Embedded Array Block

The EAB is a flexible block of RAM with registers on the input and output ports, and is used to implement common gate array megafunctions. The EAB is also suitable for functions such as multipliers, vector scalars, and error correction circuits, because it is large and flexible. These functions can be combined in applications such as digital filters and microcontrollers.

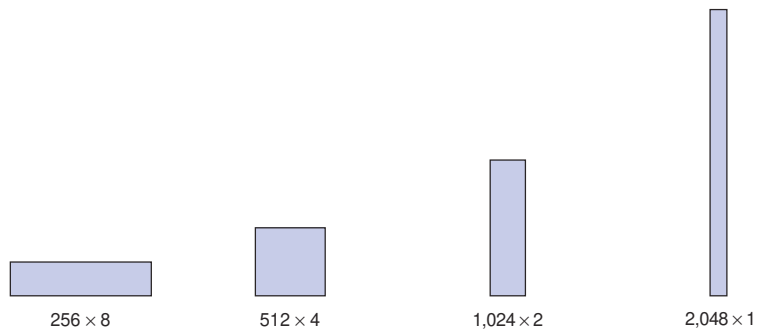
Logic functions are implemented by programming the EAB with a read-only pattern during configuration, creating a large LUT. With LUTs, combinatorial functions are implemented by looking up the results, rather than by computing them. This implementation of combinatorial functions can be faster than using algorithms implemented in general logic, a performance advantage that is further enhanced by the fast access times of EABs. The large capacity of EABs enables designers to implement complex functions in one logic level without the routing delays associated with linked LEs or field-programmable gate array (FPGA) RAM blocks. For example, a single EAB can implement a 4×4 multiplier with eight inputs and eight outputs. Parameterized functions such as LPM functions can automatically take advantage of the EAB.

The EAB provides advantages over FPGAs, which implement on-board RAM as arrays of small, distributed RAM blocks. These FPGA RAM blocks contain delays that are less predictable as the size of the RAM increases. In addition, FPGA RAM blocks are prone to routing problems because small blocks of RAM must be connected together to make larger blocks. In contrast, EABs can be used to implement large, dedicated blocks of RAM that eliminate these timing and routing concerns.

EABs can be used to implement synchronous RAM, which is easier to use than asynchronous RAM. A circuit using asynchronous RAM must generate the RAM write enable (\overline{WE}) signal, while ensuring that its data and address signals meet setup and hold time specifications relative to the \overline{WE} signal. In contrast, the EAB's synchronous RAM generates its own \overline{WE} signal and is self-timed with respect to the global clock. A circuit using the EAB's self-timed RAM need only meet the setup and hold time specifications of the global clock.

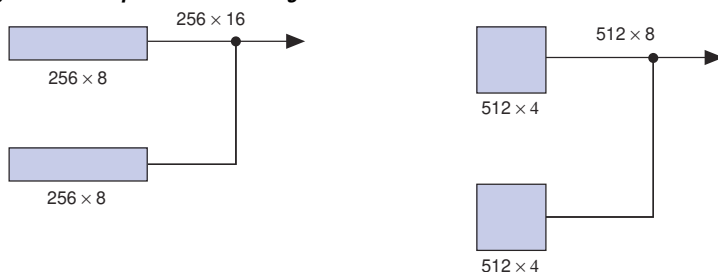
When used as RAM, each EAB can be configured in any of the following sizes: 256×8 , 512×4 , $1,024 \times 2$, or $2,048 \times 1$. See [Figure 2](#).

Figure 2. EAB Memory Configurations



Larger blocks of RAM are created by combining multiple EABs. For example, two 256×8 RAM blocks can be combined to form a 256×16 RAM block; two 512×4 blocks of RAM can be combined to form a 512×8 RAM block. See [Figure 3](#).

Figure 3. Examples of Combining EABs

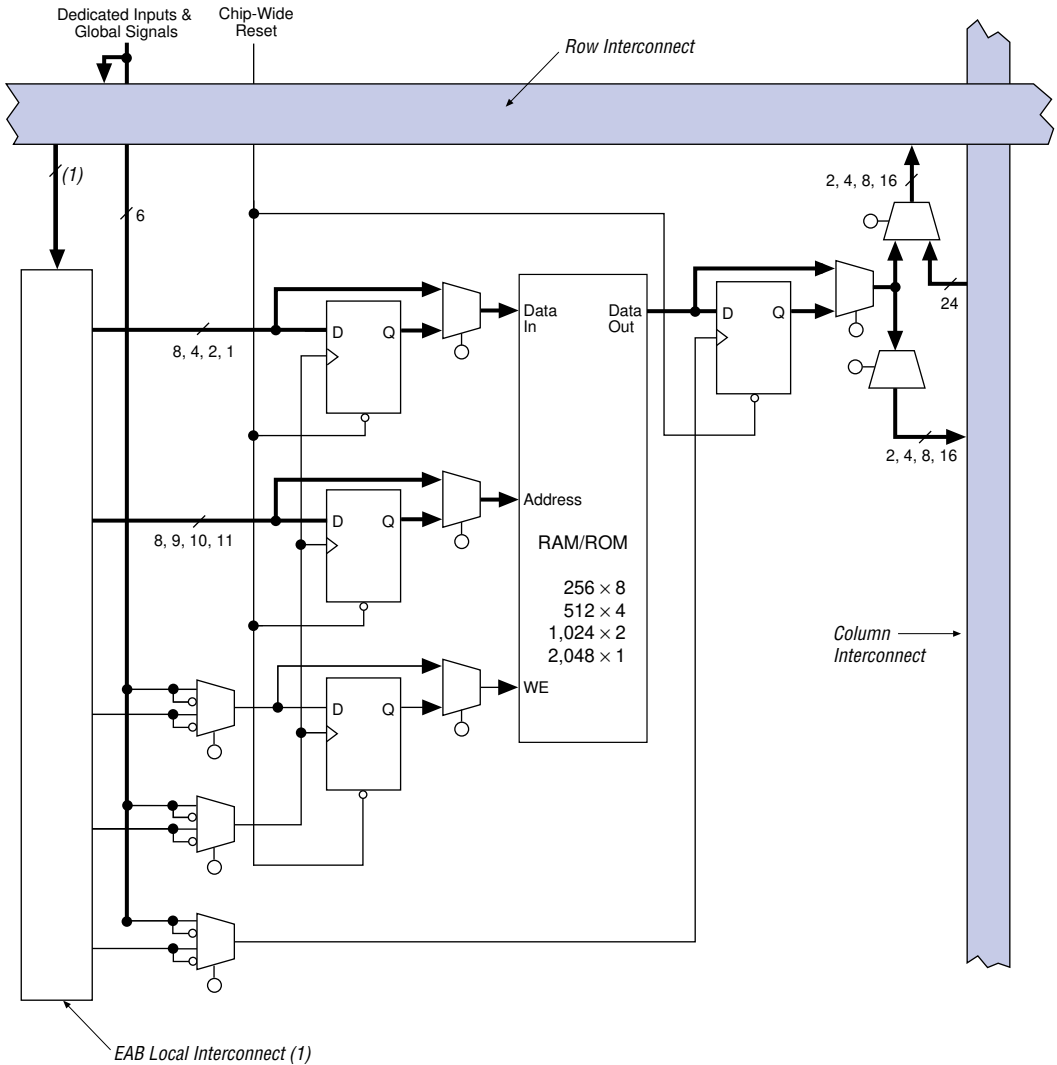


If necessary, all EABs in a device can be cascaded to form a single RAM block. EABs can be cascaded to form RAM blocks of up to 2,048 words without impacting timing. Altera's software automatically combines EABs to meet a designer's RAM specifications.

EABs provide flexible options for driving and controlling clock signals. Different clocks can be used for the EAB inputs and outputs. Registers can be independently inserted on the data input, EAB output, or the address and WE inputs. The global signals and the EAB local interconnect can drive the WE signal. The global signals, dedicated clock pins, and EAB local interconnect can drive the EAB clock signals. Because the LEs drive the EAB local interconnect, the LEs can control the WE signal or the EAB clock signals.

Each EAB is fed by a row interconnect and can drive out to row and column interconnects. Each EAB output can drive up to two row channels and up to two column channels; the unused row channel can be driven by other LEs. This feature increases the routing resources available for EAB outputs. See [Figure 4](#).

Figure 4. FLEX 10K Embedded Array Block



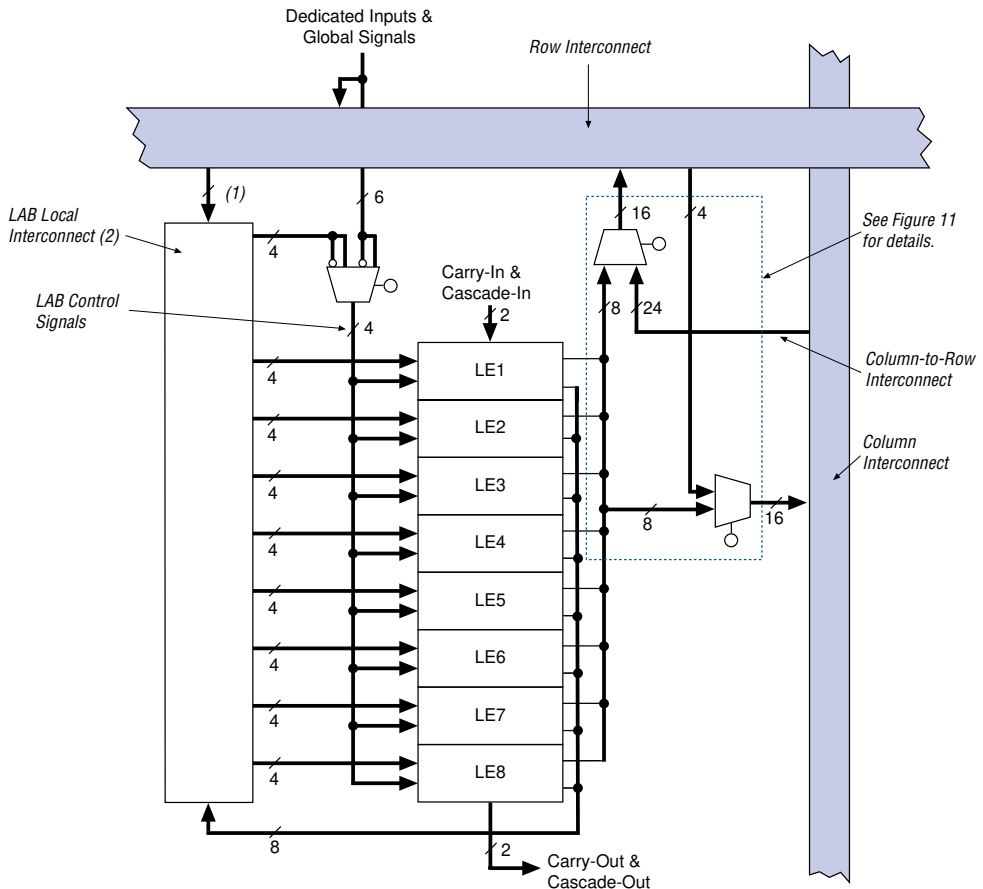
Note:

- (1) EPF10K10, EPF10K10A, EPF10K20, EPF10K30, EPF10K30A, EPF10K40, EPF10K50, and EPF10K50V devices have 22 EAB local interconnect channels; EPF10K70, EPF10K100, EPF10K100A, EPF10K130V, and EPF10K250A devices have 26.

Logic Array Block

Each LAB consists of eight LEs, their associated carry and cascade chains, LAB control signals, and the LAB local interconnect. The LAB provides the coarse-grained structure to the FLEX 10K architecture, facilitating efficient routing with optimum device utilization and high performance. See [Figure 5](#).

Figure 5. FLEX 10K LAB



Notes:

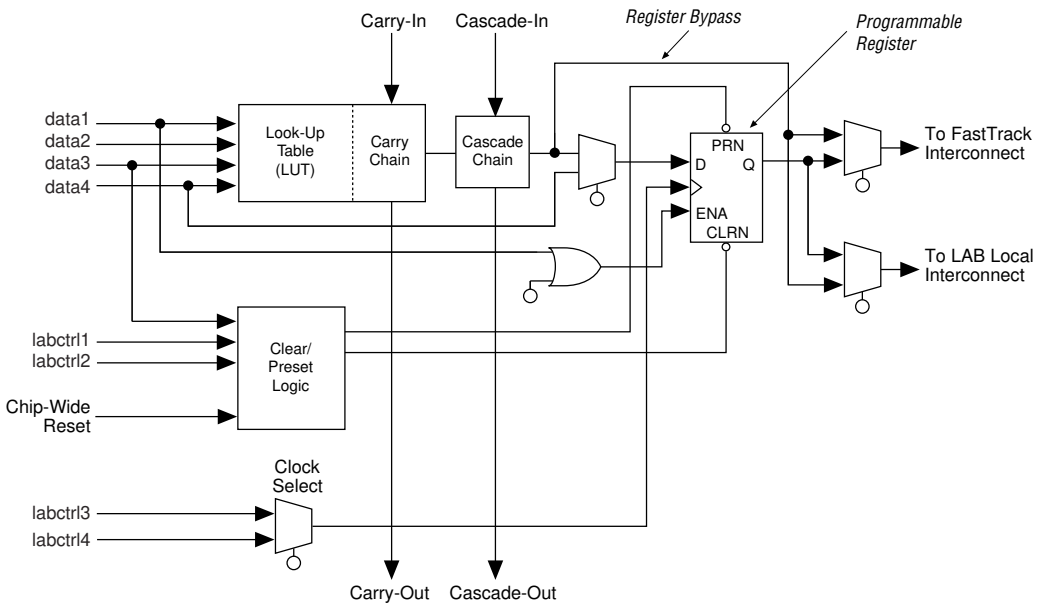
- (1) EPF10K10, EPF10K10A, EPF10K20, EPF10K30, EPF10K30A, EPF10K40, EPF10K50, and EPF10K50V devices have 22 inputs to the LAB local interconnect channel from the row; EPF10K70, EPF10K100, EPF10K100A, EPF10K130V, and EPF10K250A devices have 26.
- (2) EPF10K10, EPF10K10A, EPF10K20, EPF10K30, EPF10K30A, EPF10K40, EPF10K50, and EPF10K50V devices have 30 LAB local interconnect channels; EPF10K70, EPF10K100, EPF10K100A, EPF10K130V, and EPF10K250A devices have 34 LABs.

Each LAB provides four control signals with programmable inversion that can be used in all eight LEs. Two of these signals can be used as clocks; the other two can be used for clear/preset control. The LAB clocks can be driven by the dedicated clock input pins, global signals, I/O signals, or internal signals via the LAB local interconnect. The LAB preset and clear control signals can be driven by the global signals, I/O signals, or internal signals via the LAB local interconnect. The global control signals are typically used for global clock, clear, or preset signals because they provide asynchronous control with very low skew across the device. If logic is required on a control signal, it can be generated in one or more LEs in any LAB and driven into the local interconnect of the target LAB. In addition, the global control signals can be generated from LE outputs.

Logic Element

The LE, the smallest unit of logic in the FLEX 10K architecture, has a compact size that provides efficient logic utilization. Each LE contains a four-input LUT, which is a function generator that can quickly compute any function of four variables. In addition, each LE contains a programmable flipflop with a synchronous enable, a carry chain, and a cascade chain. Each LE drives both the local and the FastTrack Interconnect. See [Figure 6](#).

Figure 6. FLEX 10K Logic Element



The programmable flipflop in the LE can be configured for D, T, JK, or SR operation. The clock, clear, and preset control signals on the flipflop can be driven by global signals, general-purpose I/O pins, or any internal logic. For combinatorial functions, the flipflop is bypassed and the output of the LUT drives the output of the LE.

The LE has two outputs that drive the interconnect; one drives the local interconnect and the other drives either the row or column FastTrack Interconnect. The two outputs can be controlled independently. For example, the LUT can drive one output while the register drives the other output. This feature, called register packing, can improve LE utilization because the register and the LUT can be used for unrelated functions.

The FLEX 10K architecture provides two types of dedicated high-speed data paths that connect adjacent LEs without using local interconnect paths: carry chains and cascade chains. The carry chain supports high-speed counters and adders; the cascade chain implements wide-input functions with minimum delay. Carry and cascade chains connect all LEs in an LAB and all LABs in the same row. Intensive use of carry and cascade chains can reduce routing flexibility. Therefore, the use of these chains should be limited to speed-critical portions of a design.

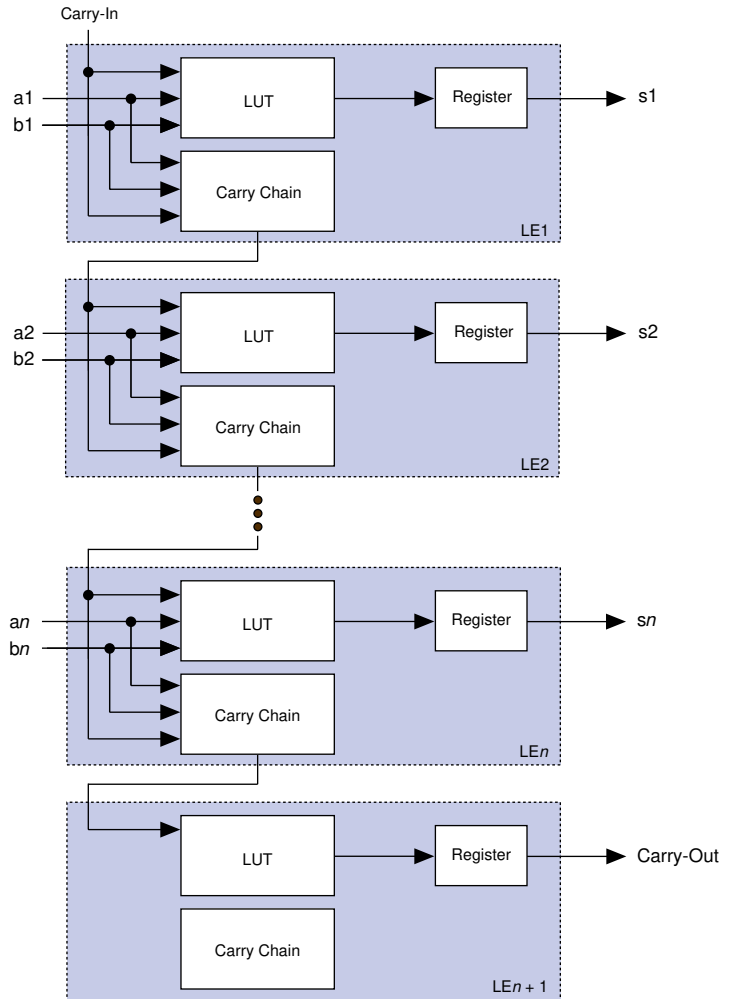
Carry Chain

The carry chain provides a very fast (as low as 0.2 ns) carry-forward function between LEs. The carry-in signal from a lower-order bit drives forward into the higher-order bit via the carry chain, and feeds into both the LUT and the next portion of the carry chain. This feature allows the FLEX 10K architecture to implement high-speed counters, adders, and comparators of arbitrary width efficiently. Carry chain logic can be created automatically by the Compiler during design processing, or manually by the designer during design entry. Parameterized functions such as LPM and DesignWare functions automatically take advantage of carry chains.

Carry chains longer than eight LEs are automatically implemented by linking LABs together. For enhanced fitting, a long carry chain skips alternate LABs in a row. A carry chain longer than one LAB skips either from even-numbered LAB to even-numbered LAB, or from odd-numbered LAB to odd-numbered LAB. For example, the last LE of the first LAB in a row carries to the first LE of the third LAB in the row. The carry chain does not cross the EAB at the middle of the row. For instance, in the EPF10K50 device, the carry chain stops at the eighteenth LAB and a new one begins at the nineteenth LAB.

Figure 7 shows how an n -bit full adder can be implemented in $n + 1$ LEs with the carry chain. One portion of the LUT generates the sum of two bits using the input signals and the carry-in signal; the sum is routed to the output of the LE. The register can either be bypassed for simple adders or be used for an accumulator function. The carry chain logic generates the carry-out signal, which is routed directly to the carry-in signal of the next higher-order bit. The final carry-out signal is routed to an LE, where it can be used as a general-purpose signal.

Figure 7. Carry Chain Operation (n -bit Full Adder)



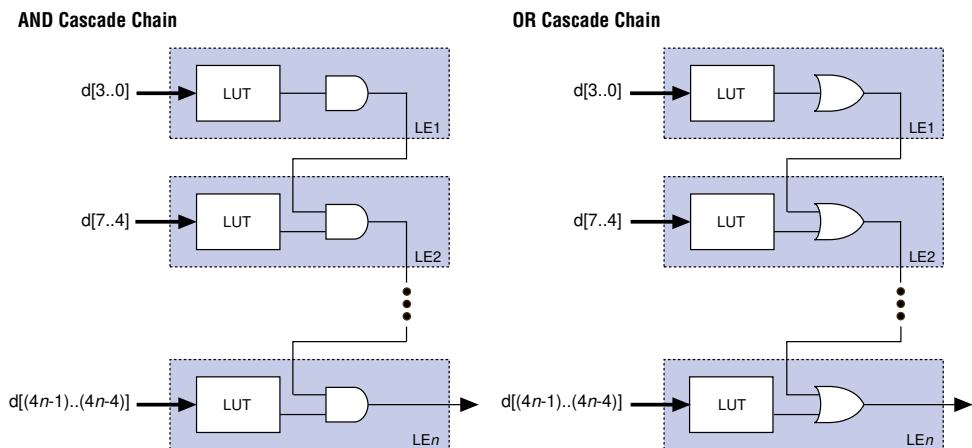
Cascade Chain

With the cascade chain, the FLEX 10K architecture can implement functions that have a very wide fan-in. Adjacent LUTs can be used to compute portions of the function in parallel; the cascade chain serially connects the intermediate values. The cascade chain can use a logical AND or logical OR (via De Morgan's inversion) to connect the outputs of adjacent LEs. Each additional LE provides four more inputs to the effective width of a function, with a delay as low as 0.7 ns per LE. Cascade chain logic can be created automatically by the Compiler during design processing, or manually by the designer during design entry.

Cascade chains longer than eight bits are implemented automatically by linking several LABs together. For easier routing, a long cascade chain skips every other LAB in a row. A cascade chain longer than one LAB skips either from even-numbered LAB to even-numbered LAB, or from odd-numbered LAB to odd-numbered LAB (e.g., the last LE of the first LAB in a row cascades to the first LE of the third LAB). The cascade chain does not cross the center of the row (e.g., in the EPF10K50 device, the cascade chain stops at the eighteenth LAB and a new one begins at the nineteenth LAB). This break is due to the EAB's placement in the middle of the row.

Figure 8 shows how the cascade function can connect adjacent LEs to form functions with a wide fan-in. These examples show functions of $4n$ variables implemented with n LEs. The LE delay is as low as 1.6 ns; the cascade chain delay is as low as 0.7 ns. With the cascade chain, 3.7 ns is needed to decode a 16-bit address.

Figure 8. Cascade Chain Operation



LE Operating Modes

The FLEX 10K LE can operate in the following four modes:

- Normal mode
- Arithmetic mode
- Up/down counter mode
- Clearable counter mode

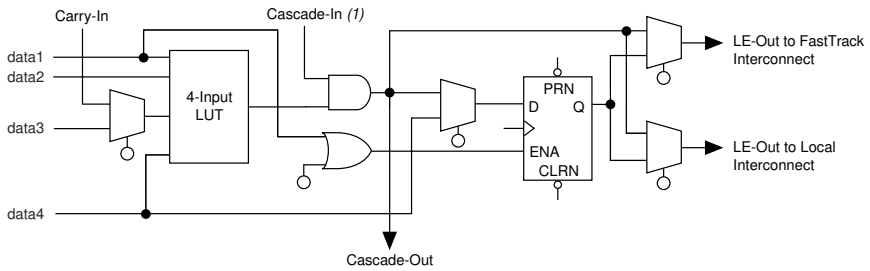
Each of these modes uses LE resources differently. In each mode, seven available inputs to the LE—the four data inputs from the LAB local interconnect, the feedback from the programmable register, and the carry-in and cascade-in from the previous LE—are directed to different destinations to implement the desired logic function. Three inputs to the LE provide clock, clear, and preset control for the register. The Altera software, in conjunction with parameterized functions such as LPM and DesignWare functions, automatically chooses the appropriate mode for common functions such as counters, adders, and multipliers. If required, the designer can also create special-purpose functions which use a specific LE operating mode for optimal performance.

The architecture provides a synchronous clock enable to the register in all four modes. The Altera software can set `DATA1` to enable the register synchronously, providing easy implementation of fully synchronous designs.

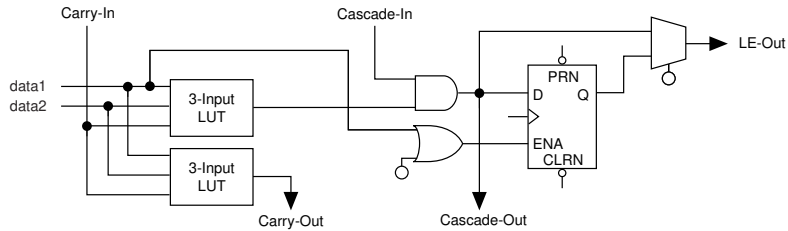
Figure 9 shows the LE operating modes.

Figure 9. FLEX 10K LE Operating Modes

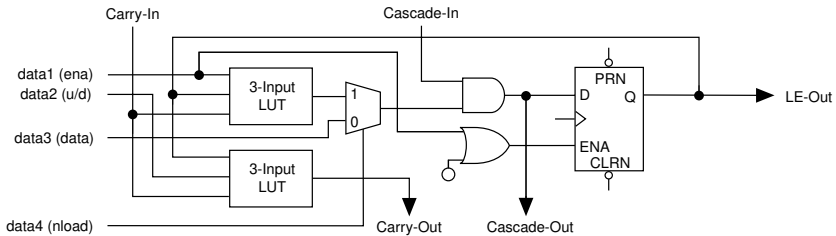
Normal Mode



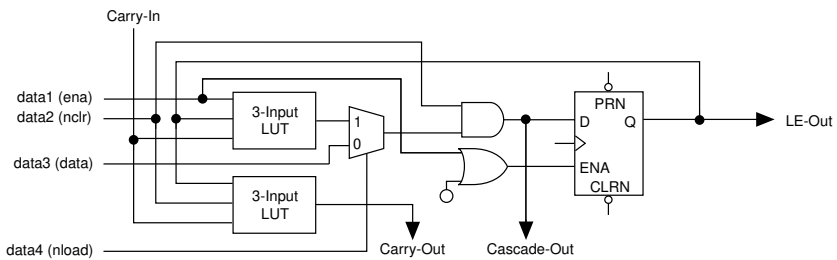
Arithmetic Mode



Up/Down Counter Mode



Clearable Counter Mode



Note:

(1) Packed registers cannot be used with the cascade chain.

Normal Mode

The normal mode is suitable for general logic applications and wide decoding functions that can take advantage of a cascade chain. In normal mode, four data inputs from the LAB local interconnect and the carry-in are inputs to a four-input LUT. The Compiler automatically selects the carry-in or the DATA3 signal as one of the inputs to the LUT. The LUT output can be combined with the cascade-in signal to form a cascade chain through the cascade-out signal. Either the register or the LUT can be used to drive both the local interconnect and the FastTrack Interconnect at the same time.

The LUT and the register in the LE can be used independently; this feature is known as register packing. To support register packing, the LE has two outputs; one drives the local interconnect and the other drives the FastTrack Interconnect. The DATA4 signal can drive the register directly, allowing the LUT to compute a function that is independent of the registered signal; a three-input function can be computed in the LUT, and a fourth independent signal can be registered. Alternatively, a four-input function can be generated, and one of the inputs to this function can be used to drive the register. The register in a packed LE can still use the clock enable, clear, and preset signals in the LE. In a packed LE, the register can drive the FastTrack Interconnect while the LUT drives the local interconnect, or vice versa.

Arithmetic Mode

The arithmetic mode offers 2 three-input LUTs that are ideal for implementing adders, accumulators, and comparators. One LUT computes a three-input function, and the other generates a carry output. As shown in [Figure 9](#) on page 19, the first LUT uses the carry-in signal and two data inputs from the LAB local interconnect to generate a combinatorial or registered output. For example, in an adder, this output is the sum of three signals: a, b, and carry-in. The second LUT uses the same three signals to generate a carry-out signal, thereby creating a carry chain. The arithmetic mode also supports simultaneous use of the cascade chain.

Up/Down Counter Mode

The up/down counter mode offers counter enable, clock enable, synchronous up/down control, and data loading options. These control signals are generated by the data inputs from the LAB local interconnect, the carry-in signal, and output feedback from the programmable register. The Up/down counter mode uses 2 three-input LUTs: one generates the counter data, and the other generates the fast carry bit. A 2-to-1 multiplexer provides synchronous loading. Data can also be loaded asynchronously with the clear and preset register control signals, without using the LUT resources.

Clearable Counter Mode

The clearable counter mode is similar to the up/down counter mode, but supports a synchronous clear instead of the up/down control. The clear function is substituted for the cascade-in signal in the up/down counter mode. Clearable counter mode uses 2 three-input LUTs: one generates the counter data, and the other generates the fast carry bit. Synchronous loading is provided by a 2-to-1 multiplexer. The output of this multiplexer is ANDed with a synchronous clear signal.

Internal Tri-State Emulation

Internal tri-state emulation provides internal tri-stating without the limitations of a physical tri-state bus. In a physical tri-state bus, the tri-state buffers' output enable (OE) signals select which signal drives the bus. However, if multiple OE signals are active, contending signals can be driven onto the bus. Conversely, if no OE signals are active, the bus will float. Internal tri-state emulation resolves contending tri-state buffers to a low value and floating buses to a high value, thereby eliminating these problems. The Altera software automatically implements tri-state bus functionality with a multiplexer.

Clear & Preset Logic Control

Logic for the programmable register's clear and preset functions is controlled by the DATA3, LABCTRL1, and LABCTRL2 inputs to the LE. The clear and preset control structure of the LE asynchronously loads signals into a register. Either LABCTRL1 or LABCTRL2 can control the asynchronous clear. Alternatively, the register can be set up so that LABCTRL1 implements an asynchronous load. The data to be loaded is driven to DATA3; when LABCTRL1 is asserted, DATA3 is loaded into the register.

During compilation, the Compiler automatically selects the best control signal implementation. Because the clear and preset functions are active-low, the Compiler automatically assigns a logic high to an unused clear or preset.

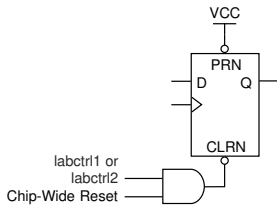
The clear and preset logic is implemented in one of the following six modes chosen during design entry:

- Asynchronous clear
- Asynchronous preset
- Asynchronous clear and preset
- Asynchronous load with clear
- Asynchronous load with preset
- Asynchronous load without clear or preset

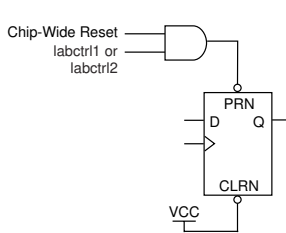
In addition to the six clear and preset modes, FLEX 10K devices provide a chip-wide reset pin that can reset all registers in the device. Use of this feature is set during design entry. In any of the clear and preset modes, the chip-wide reset overrides all other signals. Registers with asynchronous presets may be preset when the chip-wide reset is asserted. Inversion can be used to implement the asynchronous preset. [Figure 10](#) shows examples of how to enter a section of a design for the desired functionality.

Figure 10. LE Clear & Preset Modes

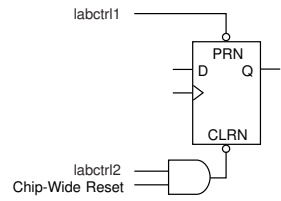
Asynchronous Clear



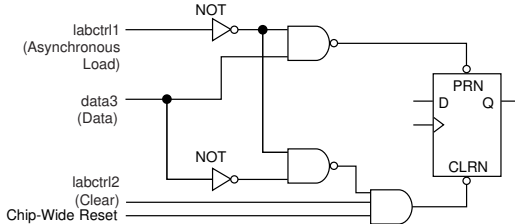
Asynchronous Preset



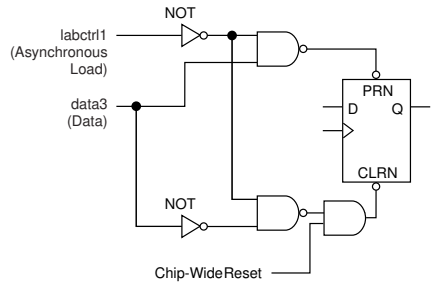
Asynchronous Clear & Preset



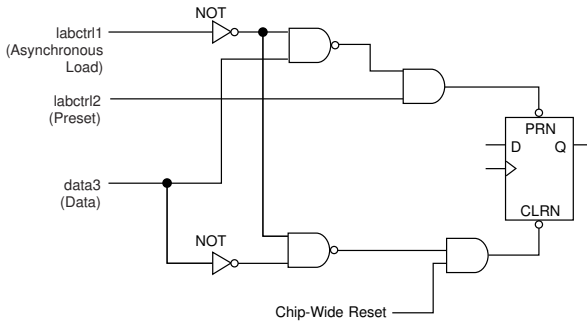
Asynchronous Load with Clear



Asynchronous Load without Clear or Preset



Asynchronous Load with Preset



Asynchronous Clear

The flipflop can be cleared by either LABCTRL1 or LABCTRL2. In this mode, the preset signal is tied to V_{CC} to deactivate it.

Asynchronous Preset

An asynchronous preset is implemented as either an asynchronous load, or with an asynchronous clear. If DATA3 is tied to V_{CC} , asserting LABCTRL1 asynchronously loads a one into the register. Alternatively, the Altera software can provide preset control by using the clear and inverting the input and output of the register. Inversion control is available for the inputs to both LEs and IOEs. Therefore, if a register is preset by only one of the two LABCTRL signals, the DATA3 input is not needed and can be used for one of the LE operating modes.

Asynchronous Preset & Clear

When implementing asynchronous clear and preset, LABCTRL1 controls the preset and LABCTRL2 controls the clear. DATA3 is tied to V_{CC} , therefore, asserting LABCTRL1 asynchronously loads a one into the register, effectively presetting the register. Asserting LABCTRL2 clears the register.

Asynchronous Load with Clear

When implementing an asynchronous load in conjunction with the clear, LABCTRL1 implements the asynchronous load of DATA3 by controlling the register preset and clear. LABCTRL2 implements the clear by controlling the register clear; LABCTRL2 does not have to feed the preset circuits.

Asynchronous Load with Preset

When implementing an asynchronous load in conjunction with preset, the Altera software provides preset control by using the clear and inverting the input and output of the register. Asserting LABCTRL2 presets the register, while asserting LABCTRL1 loads the register. The Altera software inverts the signal that drives DATA3 to account for the inversion of the register's output.

Asynchronous Load without Preset or Clear

When implementing an asynchronous load without preset or clear, LABCTRL1 implements the asynchronous load of DATA3 by controlling the register preset and clear.

FastTrack Interconnect

In the FLEX 10K architecture, connections between LEs and device I/O pins are provided by the FastTrack Interconnect, which is a series of continuous horizontal and vertical routing channels that traverse the device. This global routing structure provides predictable performance, even in complex designs. In contrast, the segmented routing in FPGAs requires switch matrices to connect a variable number of routing paths, increasing the delays between logic resources and reducing performance.

The FastTrack Interconnect consists of row and column interconnect channels that span the entire device. Each row of LABs is served by a dedicated row interconnect. The row interconnect can drive I/O pins and feed other LABs in the device. The column interconnect routes signals between rows and can drive I/O pins.

A row channel can be driven by an LE or by one of three column channels. These four signals feed dual 4-to-1 multiplexers that connect to two specific row channels. These multiplexers, which are connected to each LE, allow column channels to drive row channels even when all eight LEs in an LAB drive the row interconnect.

Each column of LABs is served by a dedicated column interconnect. The column interconnect can then drive I/O pins or another row's interconnect to route the signals to other LABs in the device. A signal from the column interconnect, which can be either the output of an LE or an input from an I/O pin, must be routed to the row interconnect before it can enter an LAB or EAB. Each row channel that is driven by an IOE or EAB can drive one specific column channel.

Access to row and column channels can be switched between LEs in adjacent pairs of LABs. For example, an LE in one LAB can drive the row and column channels normally driven by a particular LE in the adjacent LAB in the same row, and vice versa. This routing flexibility enables routing resources to be used more efficiently. See [Figure 11](#).