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Understanding Embedded - FPGAs (Field Programmable Gate Array)

Embedded - FPGAs, or Field Programmable Gate Arrays, are advanced integrated circuits that offer unparalleled flexibility and performance for digital systems. Unlike traditional fixed-function logic devices, FPGAs can be programmed and reprogrammed to execute a wide array of logical operations, enabling customized functionality tailored to specific applications. This reprogrammability allows developers to iterate designs quickly and implement complex functions without the need for custom hardware.

Applications of Embedded - FPGAs

The versatility of Embedded - FPGAs makes them indispensable in numerous fields. In telecommunications.

Details

Product Status	Obsolete
Number of LABs/CLBs	132
Number of Logic Elements/Cells	1320
Total RAM Bits	-
Number of I/O	117
Number of Gates	16000
Voltage - Supply	4.5V ~ 5.5V
Mounting Type	Surface Mount
Operating Temperature	-40°C ~ 100°C (TJ)
Package / Case	144-LQFP
Supplier Device Package	144-TQFP (20x20)
Purchase URL	https://www.e-xfl.com/product-detail/intel/epf6016ti144-2n

Table 4 shows FLEX 6000 performance for more complex designs.

Table 4. FLEX 6000 Device Performance for Complex Designs <i>Note (1)</i>					
Application	LEs Used	Performance			Units
		-1 Speed Grade	-2 Speed Grade	-3 Speed Grade	
8-bit, 16-tap parallel finite impulse response (FIR) filter	599	94	80	72	MSPS
8-bit, 512-point fast Fourier transform (FFT) function	1,182	75 63	89 53	109 43	μS MHz
16450 universal asynchronous receiver/transmitter (UART)	487	36	30	25	MHz
PCI bus target with zero wait states	609	56	49	42	MHz

Note:

(1) The applications in this table were created using Altera MegaCore™ functions.

FLEX 6000 devices are supported by Altera development systems; a single, integrated package that offers 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 2.0.0 and 3.0.0, 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 6000 architecture.

The Altera development system runs on Windows-based PCs, Sun SPARCstations, and HP 9000 Series 700/800.

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

Functional Description

The FLEX 6000 OptiFLEX architecture consists of logic elements (LEs). Each LE includes a 4-input look-up table (LUT), which can implement any 4-input function, a register, and dedicated paths for carry and cascade chain functions. Because each LE contains a register, a design can be easily pipelined without consuming more LEs. The specified gate count for FLEX 6000 devices includes all LUTs and registers.

LEs are combined into groups called logic array blocks (LABs); each LAB contains 10 LEs. The Altera software automatically places related LEs into the same LAB, minimizing the number of required interconnects. Each LAB can implement a medium-sized block of logic, such as a counter or multiplexer.

Signal interconnections within FLEX 6000 devices—and to and from device pins—are provided via the routing structure of the FastTrack Interconnect. The routing structure is a series of fast, continuous row and column channels that run the entire length and width of the device. Any LE or pin can feed or be fed by any other LE or pin via the FastTrack Interconnect. See “FastTrack Interconnect” on [page 17](#) of this data sheet for more information.

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. Each IOE is placed next to an LAB, where it can be driven by the local interconnect of that LAB. This feature allows fast clock-to-output times of less than 8 ns when a pin is driven by any of the 10 LEs in the adjacent LAB. Also, any LE can drive any pin via the row and column interconnect. I/O pins can drive the LE registers via the row and column interconnect, providing setup times as low as 2 ns and hold times of 0 ns. IOEs provide a variety of features, such as JTAG BST support, slew-rate control, and tri-state buffers.

[Figure 1](#) shows a block diagram of the FLEX 6000 OptiFLEX architecture. Each group of ten LEs is combined into an LAB, and the LABs are arranged into rows and columns. The LABs are interconnected by the FastTrack Interconnect. IOEs are located at the end of each FastTrack Interconnect row and column.

Cascade Chain

The cascade chain enables the FLEX 6000 architecture to implement very wide fan-in functions. Adjacent LUTs can be used to implement 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 gate (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 0.5 ns per LE. Cascade chain logic can be created automatically by the Altera software during design processing, or manually by the designer during design entry. Parameterized functions such as LPM and DesignWare functions automatically take advantage of cascade chains for the appropriate functions.

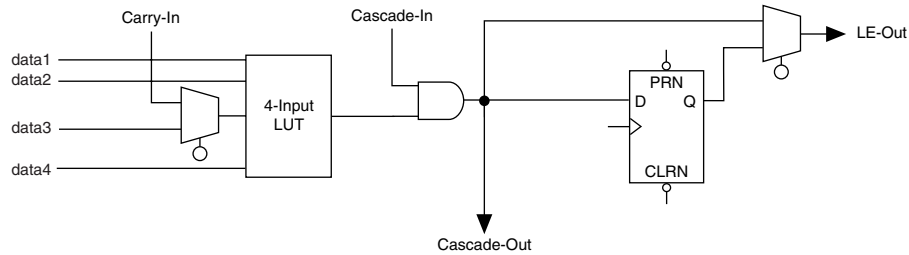
A cascade chain implementing an AND gate can use the register in the last LE; a cascade chain implementing an OR gate cannot use this register because of the inversion required to implement the OR gate.

Because the first LE of an LAB can generate control signals for that LAB, the first LE in each LAB is not included in cascade chains. Moreover, cascade chains longer than nine bits are automatically implemented 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 an even-numbered LAB to another even-numbered LAB, or from an odd-numbered LAB to another odd-numbered LAB. For example, the last LE of the first LAB in a row cascades to the second LE of the third LAB. The cascade chain does not cross the center of the row. For example, in an EPF6016 device, the cascade chain stops at the 11th LAB in a row and a new cascade chain begins at the 12th LAB.

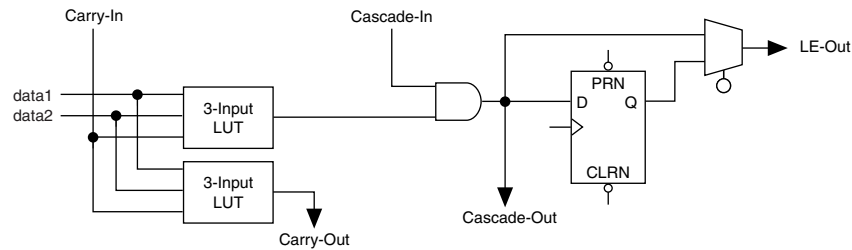
Figure 6 shows how the cascade function can connect adjacent LEs to form functions with a wide fan-in. In this example, functions of $4n$ variables are implemented with n LEs. The cascade chain requires 3.4 ns to decode a 16-bit address.

Figure 7. LE Operating Modes

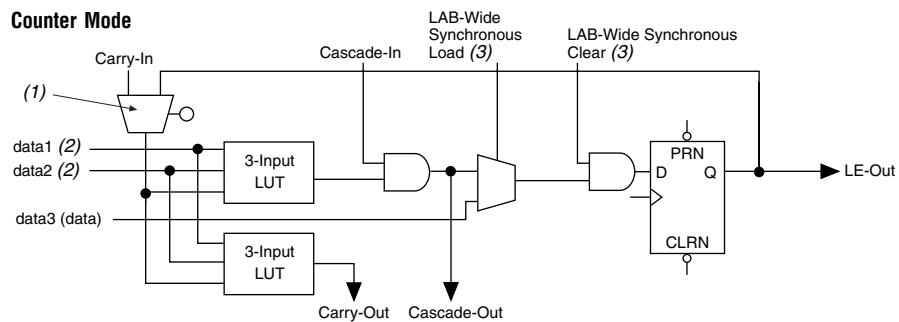
Normal Mode



Arithmetic Mode



Counter Mode



Notes:

- (1) The register feedback multiplexer is available on LE 2 of each LAB.
- (2) The data1 and data2 input signals can supply a clock enable, up or down control, or register feedback signals for all LEs other than the second LE in an LAB.
- (3) The LAB-wide synchronous clear and LAB-wide synchronous load affect all registers in an LAB.

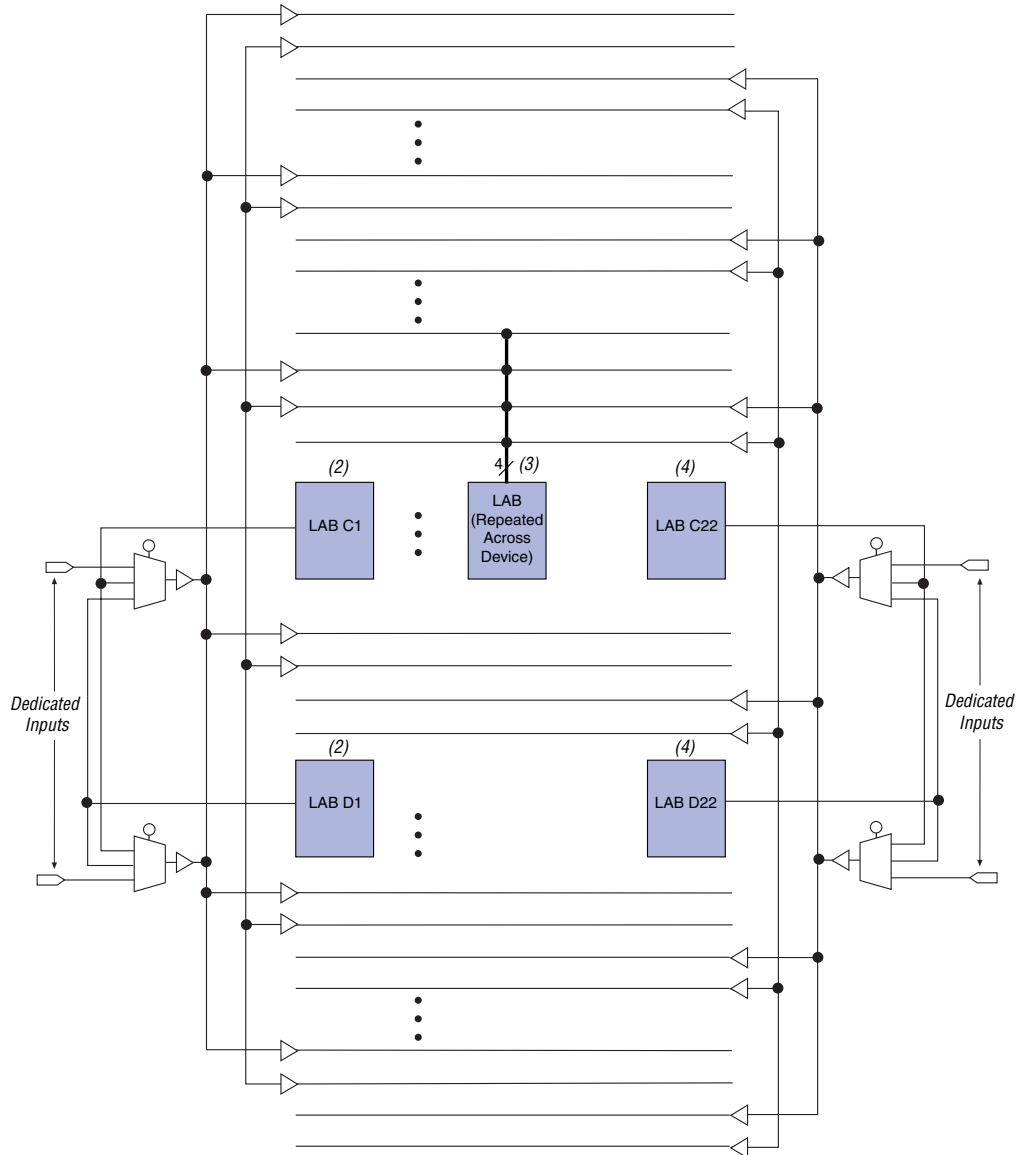
A row channel can be driven by an LE or by one of two column channels. These three signals feed a 3-to-1 multiplexer that connects to six specific row channels. Row channels drive into the local interconnect via multiplexers.

Each column of LABs is served by a dedicated column interconnect. The LEs in an LAB can drive the column interconnect. The LEs in an LAB, a column IOE, or a row interconnect can drive the column interconnect. The column interconnect can then drive another row's interconnect to route the signals to other LABs in the device. A signal from the column interconnect must be routed to the row interconnect before it can enter an LAB.

Each LE has a FastTrack Interconnect output and a local output. The FastTrack interconnect output can drive six row and two column lines directly; the local output drives the local interconnect. Each local interconnect channel driven by an LE can drive four row and two column channels. This feature provides additional flexibility, because each LE can drive any of ten row lines and four column lines.

In addition, LEs can drive global control signals. This feature is useful for distributing internally generated clock, asynchronous clear, and asynchronous preset signals. A pin-driven global signal can also drive data signals, which is useful for high-fan-out data signals.

Each LAB drives two groups of local interconnects, which allows an LE to drive two LABs, or 20 LEs, via the local interconnect. The row-to-local multiplexers are used more efficiently, because the multiplexers can now drive two LABs. [Figure 10](#) shows how an LAB connects to row and column interconnects.

Figure 11. Global Clock & Clear Distribution *Note (1)***Notes:**

- (1) The global clock and clear distribution signals are shown for EPF6016 and EPF6016A devices. In EPF6010A devices, LABs in rows B and C drive global signals. In EPF6024A devices, LABs in rows C and E drive global signals.
- (2) The local interconnect from LABs C1 and D1 can drive two global control signals on the left side.
- (3) Global signals drive into every LAB as clock, asynchronous clear, preset, and data signals.
- (4) The local interconnect from LABs C22 and D22 can drive two global control signals on the right side.

Each IOE drives a row or column interconnect when used as an input or bidirectional pin. A row IOE can drive up to six row lines; a column IOE can drive up to two column lines. The input path from the I/O pad to the FastTrack Interconnect has a programmable delay element that can be used to guarantee a zero hold time. Depending on the placement of the IOE relative to what it is driving, the designer may choose to turn on the programmable delay to ensure a zero hold time. Figure 13 shows how an IOE connects to a row interconnect, and Figure 14 shows how an IOE connects to a column interconnect.

Figure 13. IOE Connection to Row Interconnect

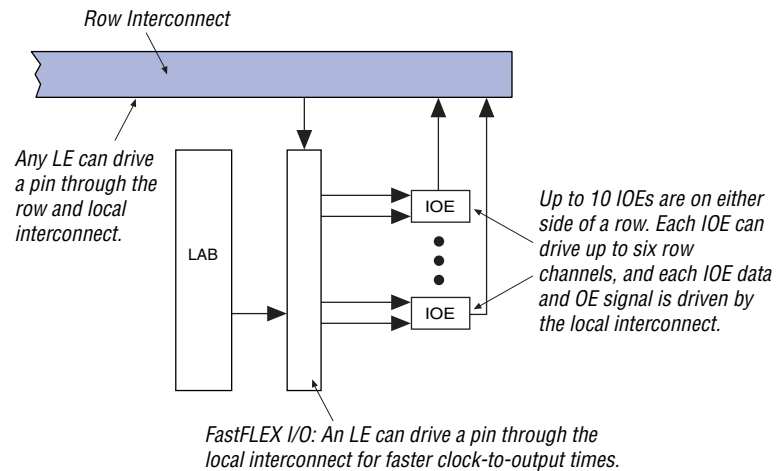


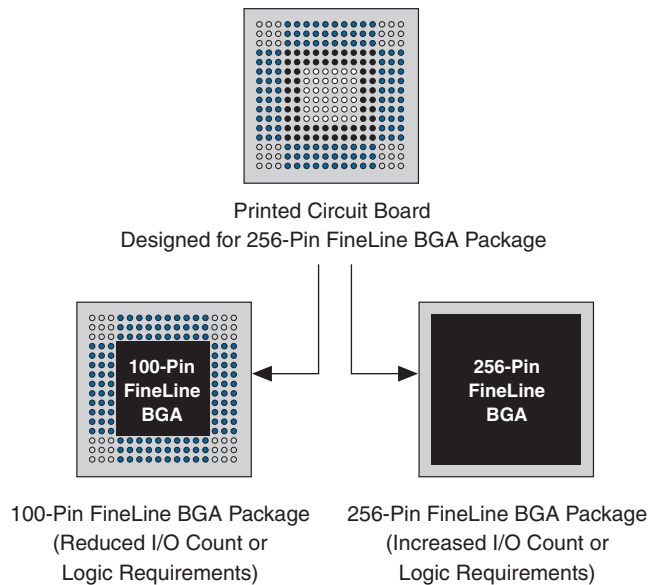
Figure 15. SameFrame Pin-Out Example

Table 6 lists the 3.3-V FLEX 6000 devices with the SameFrame pin-out feature.

Table 6. 3.3-V FLEX 6000 Devices with SameFrame Pin-Outs

Device	100-Pin FineLine BGA	256-Pin FineLine BGA
EPF6016A	V	V
EPF6024A		V

Output Configuration

This section discusses slew-rate control, the MultiVolt I/O interface, power sequencing, and hot-socketing for FLEX 6000 devices.

Slew-Rate Control

The output buffer in each IOE has an adjustable output slew-rate that can be configured for low-noise or high-speed performance. A slower slew-rate reduces system noise and adds a maximum delay of 6.8 ns. The fast slew-rate should be used for speed-critical outputs in systems that are adequately protected against noise. Designers can specify the slew-rate on a pin-by-pin basis during design entry or assign a default slew rate to all pins on a device-wide basis. The slew-rate setting affects only the falling edge of the output.

Open-drain output pins on 5.0-V or 3.3-V FLEX 6000 devices (with a pull-up resistor to the 5.0-V supply) can drive 5.0-V CMOS input pins that require a V_{IH} of 3.5 V. When the open-drain pin is active, it will drive low. When the pin is inactive, the trace will be pulled up to 5.0 V by the resistor. The open-drain pin will only drive low or tri-state; it will never drive high. The rise time is dependent on the value of the pull-up resistor and load impedance. The I_{OL} current specification should be considered when selecting a pull-up resistor.

Output pins on 5.0-V FLEX 6000 devices with $V_{CCIO} = 3.3$ V or 5.0 V (with a pull-up resistor to the 5.0-V supply) can also drive 5.0-V CMOS input pins. In this case, the pull-up transistor will turn off when the pin voltage exceeds 3.3 V. Therefore, the pin does not have to be open-drain.

Power Sequencing & Hot-Socketing

Because FLEX 6000 family devices can be used in a mixed-voltage environment, they have been designed specifically to tolerate any possible power-up sequence. The V_{CCIO} and V_{CCINT} power planes can be powered in any order.

Signals can be driven into 3.3-V FLEX 6000 devices before and during power up without damaging the device. Additionally, FLEX 6000 devices do not drive out during power up. Once operating conditions are reached, FLEX 6000 devices operate as specified by the user.

IEEE Std. 1149.1 (JTAG) Boundary-Scan Support

All FLEX 6000 devices provide JTAG BST circuitry that comply with the IEEE Std. 1149.1-1990 specification. [Table 8](#) shows JTAG instructions for FLEX 6000 devices. JTAG BST can be performed before or after configuration, but not during configuration (except when you disable JTAG support in user mode).

- 1 See [Application Note 39 \(IEEE 1149.1 \(JTAG\) Boundary-Scan Testing in Altera Devices\)](#) for more information on JTAG BST circuitry.

Table 8. FLEX 6000 JTAG Instructions

JTAG Instruction	Description
SAMPLE/PRELOAD	Allows a snapshot of the signals at the device pins to be captured and examined during normal device operation, and permits an initial data pattern to be output at the device pins.
EXTEST	Allows the external circuitry and board-level interconnections to be tested by forcing a test pattern at the output pins and capturing test result at the input pins.
BYPASS	Places the 1-bit bypass register between the TDI and TDO pins, which allows the BST data to pass synchronously through the selected device to adjacent devices during normal device operation.

The instruction register length for FLEX 6000 devices is three bits. [Table 9](#) shows the boundary-scan register length for FLEX 6000 devices.

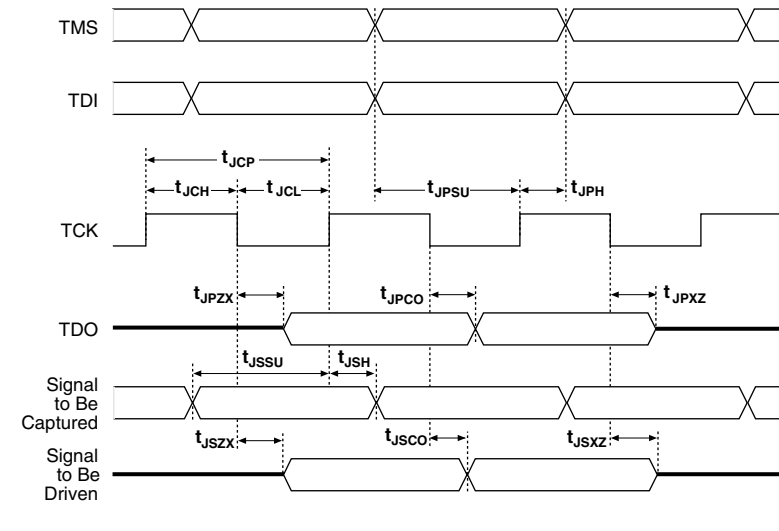
Table 9. FLEX 6000 Device Boundary-Scan Register Length	
Device	Boundary-Scan Register Length
EPF6010A	522
EPF6016	621
EPF6016A	522
EPF6024A	666

FLEX 6000 devices include a weak pull-up on JTAG pins.

f See [Application Note 39 \(IEEE 1149.1 \(JTAG\) Boundary-Scan Testing in Altera Devices\)](#) for more information.

[Figure 16](#) shows the timing requirements for the JTAG signals.

Figure 16. JTAG Waveforms



[Table 10](#) shows the JTAG timing parameters and values for FLEX 6000 devices.

Table 10. JTAG Timing Parameters & Values

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

Generic Testing

Each FLEX 6000 device is functionally tested. Complete testing of each configurable SRAM bit and all logic functionality ensures 100% configuration yield. AC test measurements for FLEX 6000 devices are made under conditions equivalent to those shown in [Figure 17](#). Multiple test patterns can be used to configure devices during all stages of the production flow.

Figure 17. AC Test Conditions

Power supply transients can affect AC measurements. Simultaneous transitions of multiple outputs should be avoided for accurate measurement. Threshold tests must not be performed under AC conditions. Large-amplitude, fast-ground-current transients normally occur as the device outputs discharge the load capacitances. When these transients flow through the parasitic inductance between the device ground pin and the test system ground, significant reductions in observable noise immunity can result. Numbers without parentheses are for 5.0-V devices or outputs. Numbers in parentheses are for 3.3-V devices or outputs. Numbers in brackets are for 2.5-V devices or outputs.

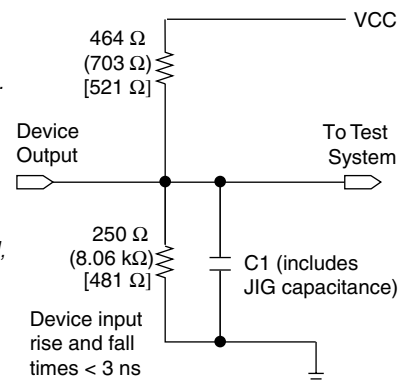


Table 13. FLEX 6000 5.0-V Device DC Operating Conditions Notes (5), (6)

Symbol	Parameter	Conditions	Min	Typ	Max	Unit
V_{IH}	High-level input voltage		2.0		$V_{CCINT} + 0.5$	V
V_{IL}	Low-level input voltage		-0.5		0.8	V
V_{OH}	5.0-V high-level TTL output voltage	$I_{OH} = -8$ mA DC, $V_{CCIO} = 4.75$ V (7)	2.4			V
	3.3-V high-level TTL output voltage	$I_{OH} = -8$ mA DC, $V_{CCIO} = 3.00$ V (7)	2.4			V
	3.3-V high-level CMOS output voltage	$I_{OH} = -0.1$ mA DC, $V_{CCIO} = 3.00$ V (7)	$V_{CCIO} - 0.2$			V
V_{OL}	5.0-V low-level TTL output voltage	$I_{OL} = 8$ mA DC, $V_{CCIO} = 4.75$ V (8)			0.45	V
	3.3-V low-level TTL output voltage	$I_{OL} = 8$ mA DC, $V_{CCIO} = 3.00$ V (8)			0.45	V
	3.3-V low-level CMOS output voltage	$I_{OL} = 0.1$ mA DC, $V_{CCIO} = 3.00$ V (8)			0.2	V
I_I	Input pin leakage current	$V_I = V_{CC}$ or ground (8)	-10		10	μ A
I_{OZ}	Tri-stated I/O pin leakage current	$V_O = V_{CC}$ or ground (8)	-40		40	μ A
I_{CC0}	V_{CC} supply current (standby)	$V_I =$ ground, no load		0.5	5	mA

Table 14. FLEX 6000 5.0-V Device Capacitance Note (9)

Symbol	Parameter	Conditions	Min	Max	Unit
C_{IN}	Input capacitance for I/O pin	$V_{IN} = 0$ V, $f = 1.0$ MHz		8	pF
C_{INCLK}	Input capacitance for dedicated input	$V_{IN} = 0$ V, $f = 1.0$ MHz		12	pF
C_{OUT}	Output capacitance	$V_{OUT} = 0$ V, $f = 1.0$ MHz		8	pF

Notes to tables:

- (1) See the *Operating Requirements for Altera Devices Data Sheet*.
- (2) Minimum DC input is -0.5 V. During transitions, the inputs may undershoot to -2.0 V or overshoot to 7.0 V for input currents less than 100 mA and periods shorter than 20 ns.
- (3) Numbers in parentheses are for industrial-temperature-range devices.
- (4) Maximum V_{CC} rise time to 100 ms. V_{CC} must rise monotonically.
- (5) Typical values are for $T_A = 25^\circ$ C and $V_{CC} = 5.0$ V.
- (6) These values are specified under the FLEX 6000 Recommended Operating Conditions shown in Table 12 on page 31.
- (7) The I_{OH} parameter refers to high-level TTL or CMOS output current.
- (8) The I_{OL} parameter refers to low-level TTL, PCI, or CMOS output current. This parameter applies to open-drain pins as well as output pins.
- (9) Capacitance is sample-tested only.

Table 15. FLEX 6000 3.3-V Device Absolute Maximum Ratings *Note (1)*

Symbol	Parameter	Conditions	Min	Max	Unit
V _{CC}	Supply voltage	With respect to ground (2)	−0.5	4.6	V
V _I	DC input voltage		−2.0	5.75	V
I _{OUT}	DC output current, per pin		−25	25	mA
T _{STG}	Storage temperature	No bias	−65	150	°C
T _{AMB}	Ambient temperature	Under bias	−65	135	°C
T _J	Junction temperature	PQFP, PLCC, and BGA packages		135	°C

Table 16. FLEX 6000 3.3-V Device Recommended Operating Conditions

Symbol	Parameter	Conditions	Min	Max	Unit
V _{CCINT}	Supply voltage for internal logic and input buffers	(3), (4)	3.00 (3.00)	3.60 (3.60)	V
V _{CCIO}	Supply voltage for output buffers, 3.3-V operation	(3), (4)	3.00 (3.00)	3.60 (3.60)	V
	Supply voltage for output buffers, 2.5-V operation	(3), (4)	2.30 (2.30)	2.70 (2.70)	V
V _I	Input voltage		−0.5	5.75	V
V _O	Output voltage		0	V _{CCIO}	V
T _J	Operating temperature	For commercial use	0	85	°C
		For industrial use	−40	100	°C
t _R	Input rise time			40	ns
t _F	Input fall time			40	ns

Figure 18 shows the typical output drive characteristics of 5.0-V and 3.3-V FLEX 6000 devices with 5.0-V, 3.3-V, and 2.5-V V_{CCIO} . When $V_{CCIO} = 5.0$ V on EPF6016 devices, the output driver is compliant with the *PCI Local Bus Specification, Revision 2.2* for 5.0-V operation. When $V_{CCIO} = 3.3$ V on the EPF6010A and EPF6016A devices, the output driver is compliant with the *PCI Local Bus Specification, Revision 2.2* for 3.3-V operation.

Figure 18. Output Drive Characteristics

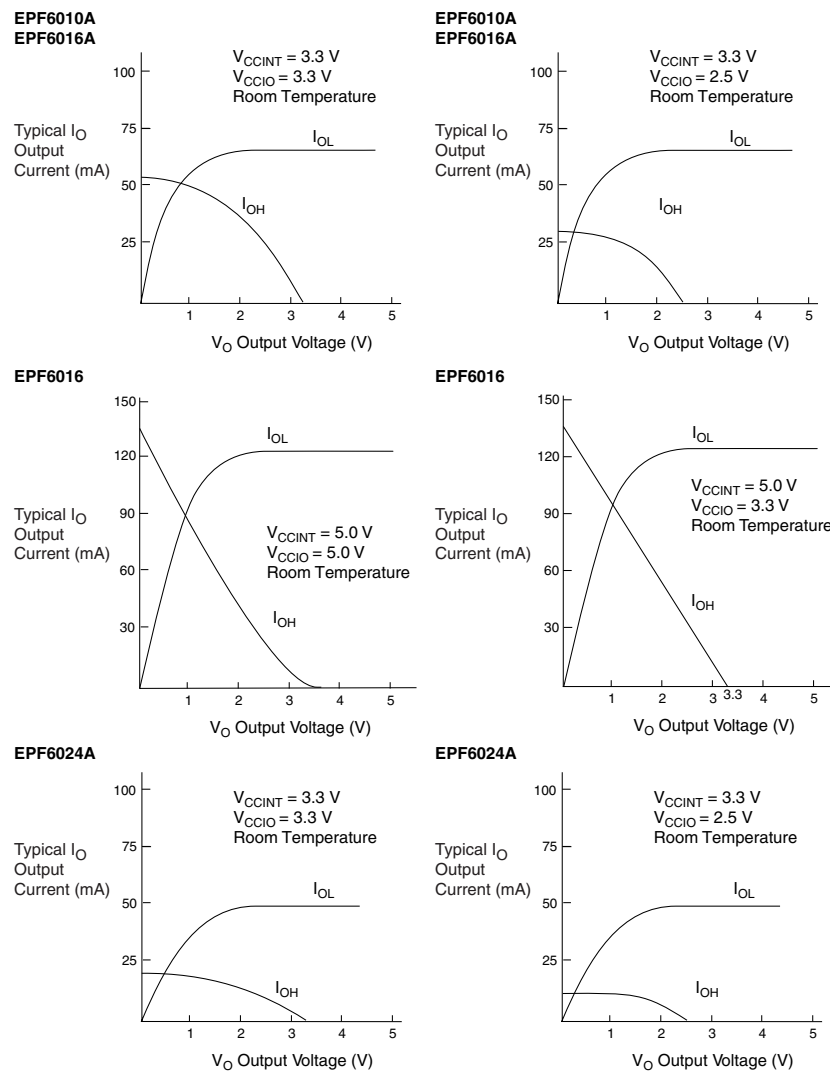


Table 24. LE Timing Microparameters for EPF6010A & EPF6016A Devices (Part 2 of 2)

Table 24. LE Timing Microparameters for EPF6010A & EPF6016A Devices (Part 2 of 2)							
Parameter	Speed Grade						Unit
	-1		-2		-3		
	Min	Max	Min	Max	Min	Max	
t_{CO}		0.3		0.4		0.4	ns
t_{CLR}		0.4		0.4		0.5	ns
t_C		1.8		2.1		2.6	ns
t_{LD_CLR}		1.8		2.1		2.6	ns
$t_{CARRY_TO_CARRY}$		0.1		0.1		0.1	ns
$t_{REG_TO_CARRY}$		1.6		1.9		2.3	ns
$t_{DATA_TO_CARRY}$		2.1		2.5		3.0	ns
$t_{CARRY_TO_CASC}$		1.0		1.1		1.4	ns
$t_{CASC_TO_CASC}$		0.5		0.6		0.7	ns
$t_{REG_TO_CASC}$		1.4		1.7		2.1	ns
$t_{DATA_TO_CASC}$		1.1		1.2		1.5	ns
t_{CH}	2.5		3.0		3.5		ns
t_{CL}	2.5		3.0		3.5		ns

Table 25. IOE Timing Microparameters for EPF6010A & EPF6016A Devices

Table 25. IOE Timing Microparameters for EPF6010A & EPF6016A Devices							
Parameter	Speed Grade						Unit
	-1		-2		-3		
	Min	Max	Min	Max	Min	Max	
t_{OD1}		1.9		2.2		2.7	ns
t_{OD2}		4.1		4.8		5.8	ns
t_{OD3}		5.8		6.8		8.3	ns
t_{XZ}		1.4		1.7		2.1	ns
t_{XZ1}		1.4		1.7		2.1	ns
t_{XZ2}		3.6		4.3		5.2	ns
t_{XZ3}		5.3		6.3		7.7	ns
t_{IOE}		0.5		0.6		0.7	ns
t_{IN}		3.6		4.1		5.1	ns
t_{IN_DELAY}		4.8		5.4		6.7	ns

Table 30. IOE Timing Microparameters for EPF6016 Devices

Table 30. IOE Timing Microparameters for EPF6016 Devices					
Parameter	Speed Grade				Unit
	-2		-3		
	Min	Max	Min	Max	
t_{OD3}		4.7		5.2	ns
t_{XZ}		2.3		2.8	ns
t_{ZX1}		2.3		2.8	ns
t_{ZX2}		4.6		5.1	ns
t_{ZX3}		4.7		5.2	ns
t_{IOE}		0.5		0.6	ns
t_{IN}		3.3		4.0	ns
t_{IN_DELAY}		4.6		5.6	ns

Table 31. Interconnect Timing Microparameters for EPF6016 Devices

Table 31. Interconnect Timing Microparameters for EPF6016 Devices					
Parameter	Speed Grade				Unit
	-2		-3		
	Min	Max	Min	Max	
t_{LOCAL}		0.8		1.0	ns
t_{ROW}		2.9		3.3	ns
t_{COL}		2.3		2.5	ns
t_{DIN_D}		4.9		6.0	ns
t_{DIN_C}		4.8		6.0	ns
$t_{LEGLOBAL}$		3.1		3.9	ns
$t_{LABCARRY}$		0.4		0.5	ns
$t_{LABCASC}$		0.8		1.0	ns

Table 32. External Reference Timing Parameters for EPF6016 Devices

Table 32. External Reference Timing Parameters for EPF6016 Devices					
Parameter	Speed Grade				Unit
	-2		-3		
	Min	Max	Min	Max	
t ₁		53.0		65.0	ns
t _{DDR}		16.0		20.0	ns

Table 33. External Timing Parameters for EPF6016 Devices

Parameter	Speed Grade				Unit
	-2		-3		
	Min	Max	Min	Max	
t _{INSU}	3.2		4.1		ns
t _{INH}	0.0		0.0		ns
t _{OUTCO}	2.0	7.9	2.0	9.9	ns

Tables 34 through 38 show the timing information for EPF6024A devices.

Table 34. LE Timing Microparameters for EPF6024A Devices

Parameter	Speed Grade						Unit
	-1		-2		-3		
	Min	Max	Min	Max	Min	Max	
$t_{REG_TO_REG}$		1.2		1.3		1.6	ns
$t_{CASC_TO_REG}$		0.7		0.8		1.0	ns
$t_{CARRY_TO_REG}$		1.6		1.8		2.2	ns
$t_{DATA_TO_REG}$		1.3		1.4		1.7	ns
$t_{CASC_TO_OUT}$		1.2		1.3		1.6	ns
$t_{CARRY_TO_OUT}$		2.0		2.2		2.6	ns
$t_{DATA_TO_OUT}$		1.8		2.1		2.6	ns
$t_{REG_TO_OUT}$		0.3		0.3		0.4	ns
t_{SU}	0.9		1.0		1.2		ns
t_H	1.3		1.4		1.7		ns
t_{CO}		0.2		0.3		0.3	ns
t_{CLR}		0.3		0.3		0.4	ns
t_C		1.9		2.1		2.5	ns
t_{LD_CLR}		1.9		2.1		2.5	ns
$t_{CARRY_TO_CARRY}$		0.2		0.2		0.3	ns
$t_{REG_TO_CARRY}$		1.4		1.6		1.9	ns
$t_{DATA_TO_CARRY}$		1.3		1.4		1.7	ns
$t_{CARRY_TO_CASC}$		1.1		1.2		1.4	ns
$t_{CASC_TO_CASC}$		0.7		0.8		1.0	ns
$t_{REG_TO_CASC}$		1.4		1.6		1.9	ns
$t_{DATA_TO_CASC}$		1.0		1.1		1.3	ns
t_{CH}	2.5		3.0		3.5		ns
t_{CL}	2.5		3.0		3.5		ns

Table 35. IOE Timing Microparameters for EPF6024A Devices

Table 35. IOE Timing Microparameters for EPF6024A Devices							
Parameter	Speed Grade						Unit
	-1		-2		-3		
	Min	Max	Min	Max	Min	Max	
t_{OD1}		1.9		2.1		2.5	ns
t_{OD2}		4.0		4.4		5.3	ns
t_{OD3}		7.0		7.8		9.3	ns
t_{XZ}		4.3		4.8		5.8	ns
t_{XZ1}		4.3		4.8		5.8	ns
t_{XZ2}		6.4		7.1		8.6	ns
t_{XZ3}		9.4		10.5		12.6	ns
t_{IOE}		0.5		0.6		0.7	ns
t_{IN}		3.3		3.7		4.4	ns
t_{IN_DELAY}		5.3		5.9		7.0	ns

Table 36. Interconnect Timing Microparameters for EPF6024A Devices

Table 36. Interconnect Timing Microparameters for EPF6024A Devices							
Parameter	Speed Grade						Unit
	-1		-2		-3		
	Min	Max	Min	Max	Min	Max	
t_{LOCAL}		0.8		0.8		1.1	ns
t_{ROW}		3.0		3.1		3.3	ns
t_{COL}		3.0		3.2		3.4	ns
t_{DIN_D}		5.4		5.6		6.2	ns
t_{DIN_C}		4.6		5.1		6.1	ns
$t_{LEGLOBAL}$		3.1		3.5		4.3	ns
$t_{LABCARRY}$		0.6		0.7		0.8	ns
$t_{LABCASC}$		0.3		0.3		0.4	ns

Table 37. External Reference Timing Parameters for EPF6024A Devices

Table 37. External Reference Timing Parameters for EPF6024A Devices							
Parameter	Speed Grade						Unit
	-1		-2		-3		
	Min	Max	Min	Max	Min	Max	
t ₁		45.0		50.0		60.0	ns

This calculation provides an I_{CC} estimate based on typical conditions with no output load. The actual I_{CC} should be verified during operation because this measurement is sensitive to the actual pattern in the device and the environmental operating conditions.

To better reflect actual designs, the power model (and the constant K in the power calculation equations shown above) for continuous interconnect FLEX devices assumes that LEs drive FastTrack Interconnect channels. In contrast, the power model of segmented FPGAs assumes that all LEs drive only one short interconnect segment. This assumption may lead to inaccurate results, compared to measured power consumption for an actual design in a segmented interconnect FPGA.

Figure 20 shows the relationship between the current and operating frequency for EPF6010A, EPF6016, EPF6016A, and EPF6024A devices.



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