

This chapter describes the hierarchical clock networks and phase-locked loops (PLLs) with advanced features in the Cyclone® IV device family. It includes details about the ability to reconfigure the PLL counter clock frequency and phase shift in real time, allowing you to sweep PLL output frequencies and dynamically adjust the output clock phase shift.



The Quartus® II software enables the PLLs and their features without external devices.


This chapter contains the following sections:

- “Clock Networks” on page 5-1
- “PLLs in Cyclone IV Devices” on page 5-18
- “Cyclone IV PLL Hardware Overview” on page 5-20
- “Clock Feedback Modes” on page 5-23
- “Hardware Features” on page 5-26
- “Programmable Bandwidth” on page 5-32
- “Phase Shift Implementation” on page 5-32
- “PLL Cascading” on page 5-33
- “PLL Reconfiguration” on page 5-34
- “Spread-Spectrum Clocking” on page 5-41
- “PLL Specifications” on page 5-41

Clock Networks

The Cyclone IV GX device provides up to 12 dedicated clock pins (CLK[15..4]) that can drive the global clocks (GCLKs). Cyclone IV GX devices support four dedicated clock pins on each side of the device except the left side. These clock pins can drive up to 30 GCLKs.

The Cyclone IV E device provides up to 15 dedicated clock pins (CLK[15..1]) that can drive up to 20 GCLKs. Cyclone IV E devices support three dedicated clock pins on the left side and four dedicated clock pins on the top, right, and bottom sides of the device except EP4CE6 and EP4CE10 devices. EP4CE6 and EP4CE10 devices only support three dedicated clock pins on the left side and four dedicated clock pins on the right side of the device.

 For more information about the number of GCLK networks in each device density, refer to the *Cyclone IV FPGA Device Family Overview* chapter.

GCLK Network

GCLKs drive throughout the entire device, feeding all device quadrants. All resources in the device (I/O elements, logic array blocks (LABs), dedicated multiplier blocks, and M9K memory blocks) can use GCLKs as clock sources. Use these clock network resources for control signals, such as clock enables and clears fed by an external pin. Internal logic can also drive GCLKs for internally generated GCLKs and asynchronous clears, clock enables, or other control signals with high fan-out.

Table 5-1, Table 5-2 on page 5-4, and Table 5-3 on page 5-7 list the connectivity of the clock sources to the GCLK networks.

Table 5-1. GCLK Network Connections for EP4CGX15, EP4CGX22, and EP4CGX30 ⁽¹⁾, ⁽²⁾ (Part 1 of 2)

GCLK Network Clock Sources	GCLK Networks																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
CLK4/DIFFCLK_2n	—	—	—	—	—	✓	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—
CLK5/DIFFCLK_2p	—	—	—	—	—	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—
CLK6/DIFFCLK_3n	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	—	—
CLK7/DIFFCLK_3p	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—
CLK8/DIFFCLK_5n	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	✓	—	—	—	—	—
CLK9/DIFFCLK_5p	—	—	—	—	—	—	—	—	—	—	—	✓	✓	—	—	—	—	—	—	—
CLK10/DIFFCLK_4n/RE FCLK1n	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—
CLK11/DIFFCLK_4p/RE FCLK1p	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—
CLK12/DIFFCLK_7p/RE FCLK0p	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	✓
CLK13/DIFFCLK_7n/RE FCLK0n	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	✓	—	—
CLK14/DIFFCLK_6p	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓
CLK15/DIFFCLK_6n	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—
PLL_1_C0	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—
PLL_1_C1	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓
PLL_1_C2	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—
PLL_1_C3	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—
PLL_1_C4	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓
PLL_2_C0	✓	—	—	✓	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—
PLL_2_C1	—	✓	—	—	✓	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—
PLL_2_C2	✓	—	✓	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—
PLL_2_C3	—	✓	—	✓	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—
PLL_2_C4	—	—	✓	—	✓	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—
PLL_3_C0	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	✓	—	—	✓	—

Table 5-1. GCLK Network Connections for EP4CGX15, EP4CGX22, and EP4CGX30 ^{(1), (2)} (Part 2 of 2)

GCLK Network Clock Sources	GCLK Networks																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
PLL_3_C1	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	✓	—	—	✓
PLL_3_C2	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	✓	—	✓	—	—
PLL_3_C3	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	✓	—	✓	—
PLL_3_C4	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	✓	—	✓
PLL_4_C0 ⁽³⁾	—	—	—	—	—	✓	—	—	✓	—	✓	—	—	✓	—	—	—	—	—	—
PLL_4_C1 ⁽³⁾	—	—	—	—	—	—	✓	—	—	✓	—	✓	—	—	✓	—	—	—	—	—
PLL_4_C2 ⁽³⁾	—	—	—	—	—	✓	—	✓	—	—	✓	—	✓	—	—	—	—	—	—	—
PLL_4_C3 ⁽³⁾	—	—	—	—	—	—	✓	—	✓	—	—	✓	—	✓	—	—	—	—	—	—
PLL_4_C4 ⁽³⁾	—	—	—	—	—	—	—	✓	—	✓	—	—	✓	—	✓	—	—	—	—	—
DPCLK2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—
DPCLK3 ⁽⁴⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—
DPCLK4 ⁽⁴⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—
DPCLK5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓
DPCLK6 ⁽⁴⁾	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—	—
DPCLK7	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK8	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—
DPCLK9 ⁽⁴⁾	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—
DPCLK11 ⁽⁴⁾	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—
DPCLK12 ⁽⁴⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—
DPCLK13	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—

Notes to Table 5-1:

- (1) EP4CGX30 information in this table refers to all EP4CGX30 packages except F484 package.
- (2) PLL_1 and PLL_2 are multipurpose PLLs while PLL_3 and PLL_4 are general purpose PLLs.
- (3) PLL_4 is only available in EP4CGX22 and EP4CGX30 devices in F324 package.
- (4) This pin applies to EP4CGX22 and EP4CGX30 devices.

Table 5–2. GCLK Network Connections for EP4CGX30, EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 Devices ^{(1), (2)} (Part 1 of 4)

GCLK Network Clock Sources	GCLK Networks																													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
CLKIO4/DIFFCLK_2n	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—
CLKIO5/DIFFCLK_2p	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—
CLKIO6/DIFFCLK_3n	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—	—
CLKIO7/DIFFCLK_3p	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—
CLKIO8/DIFFCLK_5n	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	✓	—	—	—	—	—	—	—
CLKIO9/DIFFCLK_5p	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	✓	—	—	✓	—	—	—	—	—	—
CLKIO10/DIFFCLK_4n/RE FCLK3n	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—	—	—
CLKIO11/DIFFCLK_4p/RE FCLK3p	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	✓	—	—	—	—	—	—
CLKIO12/DIFFCLK_7p/RE FCLK2p	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	✓	—
CLKIO13/DIFFCLK_7n/RE FCLK2n	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	✓	—	—	✓
CLKIO14/DIFFCLK_6p	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓	—
CLKIO15/DIFFCLK_6n	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	✓
PLL_1_C0	✓	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	✓
PLL_1_C1	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—
PLL_1_C2	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—
PLL_1_C3	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—
PLL_1_C4	—	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓
PLL_2_C0	—	—	—	—	—	—	✓	—	—	✓	—	✓	—	—	—	—	—	—	✓	—	—	✓	—	✓	—	—	—	—	—	—
PLL_2_C1	—	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	—
PLL_2_C2	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—
PLL_2_C3	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—
PLL_2_C4	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—

Table 5–2. GCLK Network Connections for EP4CGX30, EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 Devices ⁽¹⁾, ⁽²⁾ (Part 2 of 4)

GCLK Network Clock Sources	GCLK Networks																													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
PLL_3_C0	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	✓	—	—	—	—	—	—	✓	—	—	✓	—	✓
PLL_3_C1	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	—	—	✓	—	—	✓	—
PLL_3_C2	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—
PLL_3_C3	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—
PLL_3_C4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	✓	—	✓	✓
PLL_4_C0	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	✓	✓	—	—	✓	—	✓	—	—	—	—	—	—
PLL_4_C1	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	—	✓	—	—	✓	—	—	—	—	—	—	—
PLL_4_C2	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—
PLL_4_C3	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—
PLL_4_C4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	✓	—	✓	✓	—	—	—	—	—	—
PLL_5_C0	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_5_C1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_5_C2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_5_C3	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_5_C4	—	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_6_C0	✓	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_6_C1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_6_C2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_6_C3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_6_C4	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_7_C0 ⁽³⁾	—	—	—	—	—	—	✓	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_7_C1 ⁽³⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_7_C2 ⁽³⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_7_C3 ⁽³⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_7_C4 ⁽³⁾	—	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 5–2. GCLK Network Connections for EP4CGX30, EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 Devices ^{(1), (2)} (Part 3 of 4)

GCLK Network Clock Sources	GCLK Networks																													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
PLL_8_C0 ⁽³⁾	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_8_C1 ⁽³⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_8_C2 ⁽³⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_8_C3 ⁽³⁾	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_8_C4 ⁽³⁾	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK6	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK7	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK8	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK9	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK11	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK13	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK14	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK16	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

Table 5-2. GCLK Network Connections for EP4CGX30, EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 Devices ⁽¹⁾, ⁽²⁾ (Part 4 of 4)

GCLK Network Clock Sources	GCLK Networks																													
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
DPCLK17	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—

Notes to Table 5-2:

- (1) EP4CGX30 information in this table refers to only EP4CGX30 device in F484 package.
- (2) PLL_1, PLL_2, PLL_3, and PLL_4 are general purpose PLLs while PLL_5, PLL_6, PLL_7, and PLL_8 are multipurpose PLLs.
- (3) PLL_7 and PLL_8 are not available in EP4CGX30, EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices in F484 package.

Table 5-3. GCLK Network Connections for Cyclone IV E Devices ⁽¹⁾ (Part 1 of 3)

GCLK Network Clock Sources	GCLK Networks																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
CLK1	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CLK2/DIFFCLK_1p	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CLK3/DIFFCLK_1n	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CLK4/DIFFCLK_2p	—	—	—	—	—	✓	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—
CLK5/DIFFCLK_2n	—	—	—	—	—	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—
CLK6/DIFFCLK_3p	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—	—	—	—	—	—
CLK7/DIFFCLK_3n	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—
CLK8/DIFFCLK_5n ⁽²⁾	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	✓	—	—	—	—	—
CLK9/DIFFCLK_5p ⁽²⁾	—	—	—	—	—	—	—	—	—	—	—	✓	✓	—	—	—	—	—	—	—
CLK10/DIFFCLK_4n ⁽²⁾	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓	—	—	—	—	—
CLK11/DIFFCLK_4p ⁽²⁾	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—
CLK12/DIFFCLK_7n ⁽²⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	✓
CLK13/DIFFCLK_7p ⁽²⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	✓	—	—
CLK14/DIFFCLK_6n ⁽²⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	✓

Table 5-3. GCLK Network Connections for Cyclone IV E Devices ⁽¹⁾ (Part 2 of 3)

GCLK Network Clock Sources	GCLK Networks																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
CLK15/DIFFCLK_6p ⁽²⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—
PLL_1_C0 ⁽³⁾	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_1_C1 ⁽³⁾	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_1_C2 ⁽³⁾	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_1_C3 ⁽³⁾	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_1_C4 ⁽³⁾	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
PLL_2_C0 ⁽³⁾	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—	—
PLL_2_C1 ⁽³⁾	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—	—	—	—	—
PLL_2_C2 ⁽³⁾	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—	—
PLL_2_C3 ⁽³⁾	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—	—
PLL_2_C4 ⁽³⁾	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—	—	—	—
PLL_3_C0	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—	—
PLL_3_C1	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—	—	—	—	—
PLL_3_C2	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—	—
PLL_3_C3	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—	—
PLL_3_C4	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—	—	—	—
PLL_4_C0	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓	—
PLL_4_C1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	✓
PLL_4_C2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—	—
PLL_4_C3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓	—
PLL_4_C4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	✓
DPCLK0	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK1	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK7 ⁽⁴⁾	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
CDPCLK0, or CDPCLK7 ^{(2), (5)}	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—


Table 5-3. GCLK Network Connections for Cyclone IV E Devices ⁽¹⁾ (Part 3 of 3)

GCLK Network Clock Sources	GCLK Networks																			
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
DPCLK2 ⁽⁴⁾ CDPCLK1, or CDPCLK2 ^{(2), (5)}	—	—	—	✓	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK5 ⁽⁴⁾ DPCLK7 ⁽²⁾	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK4 ⁽⁴⁾ DPCLK6 ⁽²⁾	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK6 ⁽⁴⁾ CDPCLK5, or CDPCLK6 ^{(2), (5)}	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—	—	—	—
DPCLK3 ⁽⁴⁾ CDPCLK4, or CDPCLK3 ^{(2), (5)}	—	—	—	—	—	—	—	—	✓	✓	—	—	—	—	—	—	—	—	—	—
DPCLK8	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—	—
DPCLK11	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—	—
DPCLK9	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—	—	—	—
DPCLK10	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	✓	—	—	—	—	—
DPCLK5	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—	—
DPCLK2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—	—
DPCLK4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	—	—
DPCLK3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	✓	✓

Notes to Table 5-3:

- (1) EP4CE6 and EP4CE10 devices only have GCLK networks 0 to 9.
- (2) These pins apply to all Cyclone IV E devices except EP4CE6 and EP4CE10 devices.
- (3) EP4CE6 and EP4CE10 devices only have PLL_1 and PLL_2.
- (4) This pin applies only to EP4CE6 and EP4CE10 devices.
- (5) Only one of the two CDPCLK pins can feed the clock control block. You can use the other pin as a regular I/O pin.

If you do not use dedicated clock pins to feed the GCLKs, you can use them as general-purpose input pins to feed the logic array. However, when using them as general-purpose input pins, they do not have support for an I/O register and must use LE-based registers in place of an I/O register.

 For more information about how to connect the clock and PLL pins, refer to the *Cyclone IV Device Family Pin Connection Guidelines*.

Clock Control Block


The clock control block drives the GCLKs. Clock control blocks are located on each side of the device, close to the dedicated clock input pins. GCLKs are optimized for minimum clock skew and delay.

Table 5-4 lists the sources that can feed the clock control block, which in turn feeds the GCLKs.

Table 5-4. Clock Control Block Inputs

Input	Description
Dedicated clock inputs	Dedicated clock input pins can drive clocks or global signals, such as synchronous and asynchronous clears, presets, or clock enables onto given GCLKs.
Dual-purpose clock (DPCLK and CDPCLK) I/O input	DPCLK and CDPCLK I/O pins are bidirectional dual function pins that are used for high fan-out control signals, such as protocol signals, TRDY and IRDY signals for PCI, via the GCLK. Clock control blocks that have inputs driven by dual-purpose clock I/O pins are not able to drive PLL inputs.
PLL outputs	PLL counter outputs can drive the GCLK.
Internal logic	You can drive the GCLK through logic array routing to enable internal logic elements (LEs) to drive a high fan-out, low-skew signal path. Clock control blocks that have inputs driven by internal logic are not able to drive PLL inputs.

In Cyclone IV devices, dedicated clock input pins, PLL counter outputs, dual-purpose clock I/O inputs, and internal logic can all feed the clock control block for each GCLK. The output from the clock control block in turn feeds the corresponding GCLK. The GCLK can drive the PLL input if the clock control block inputs are outputs of another PLL or dedicated clock input pins. There are five or six clock control blocks on each side of the device periphery—depending on device density; providing up to 30 clock control blocks in each Cyclone IV GX device. The maximum number of clock control blocks per Cyclone IV E device is 20. For the clock control block locations, refer to [Figure 5-2 on page 5-12](#), [Figure 5-3 on page 5-13](#), and [Figure 5-4 on page 5-14](#).

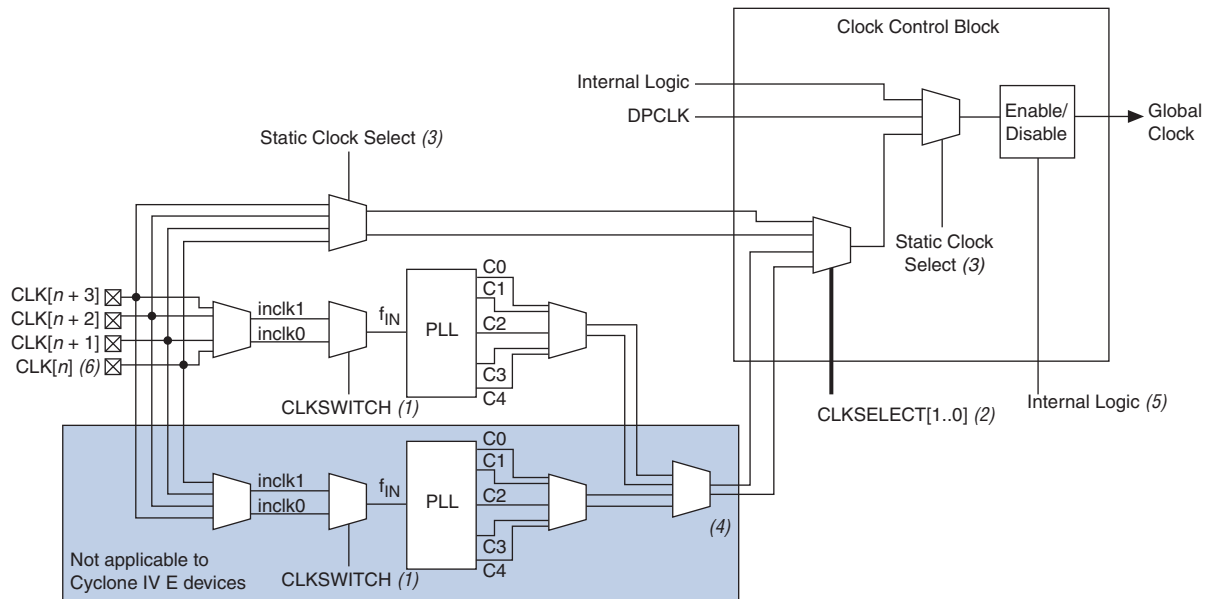
 The clock control blocks on the left side of the Cyclone IV GX device do not support any clock inputs.

The control block has two functions:

- Dynamic GCLK clock source selection (not applicable for DPCLK, CDPCLK, and internal logic input)
- GCLK network power down (dynamic enable and disable)

Figure 5-1 shows the clock control block.

Figure 5-1. Clock Control Block



Notes to Figure 5-1:

- (1) The `clkswitch` signal can either be set through the configuration file or dynamically set when using the manual PLL switchover feature. The output of the multiplexer is the input clock (f_{IN}) for the PLL.
- (2) The `clkselect[1..0]` signals are fed by internal logic and are used to dynamically select the clock source for the GCLK when the device is in user mode.
- (3) The static clock select signals are set in the configuration file. Therefore, dynamic control when the device is in user mode is not feasible.
- (4) Two out of four PLL clock outputs are selected from adjacent PLLs to drive into the clock control block.
- (5) You can use internal logic to enable or disable the GCLK in user mode.
- (6) `CLK[n]` is not available on the left side of Cyclone IV E devices.

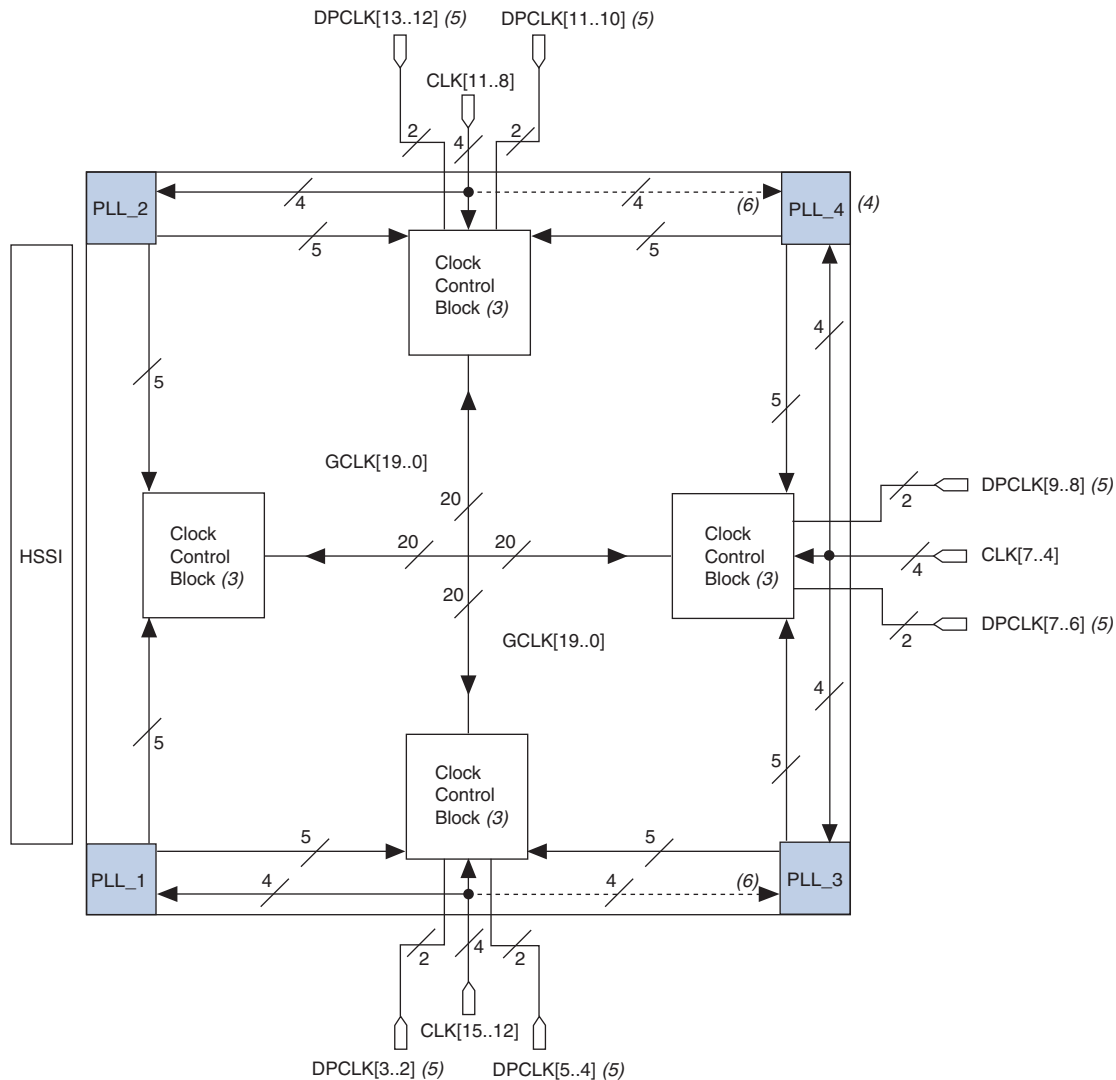
Each PLL generates five clock outputs through the `c[4..0]` counters. Two of these clocks can drive the GCLK through a clock control block, as shown in Figure 5-1.

 For more information about how to use the clock control block in the Quartus II software, refer to the *ALTCLKCTRL Megafunction User Guide*.

GCLK Network Clock Source Generation

Figure 5-2, Figure 5-3, and Figure 5-4 on page 5-14 show the Cyclone IV PLLs, clock inputs, and clock control block location for different Cyclone IV device densities.

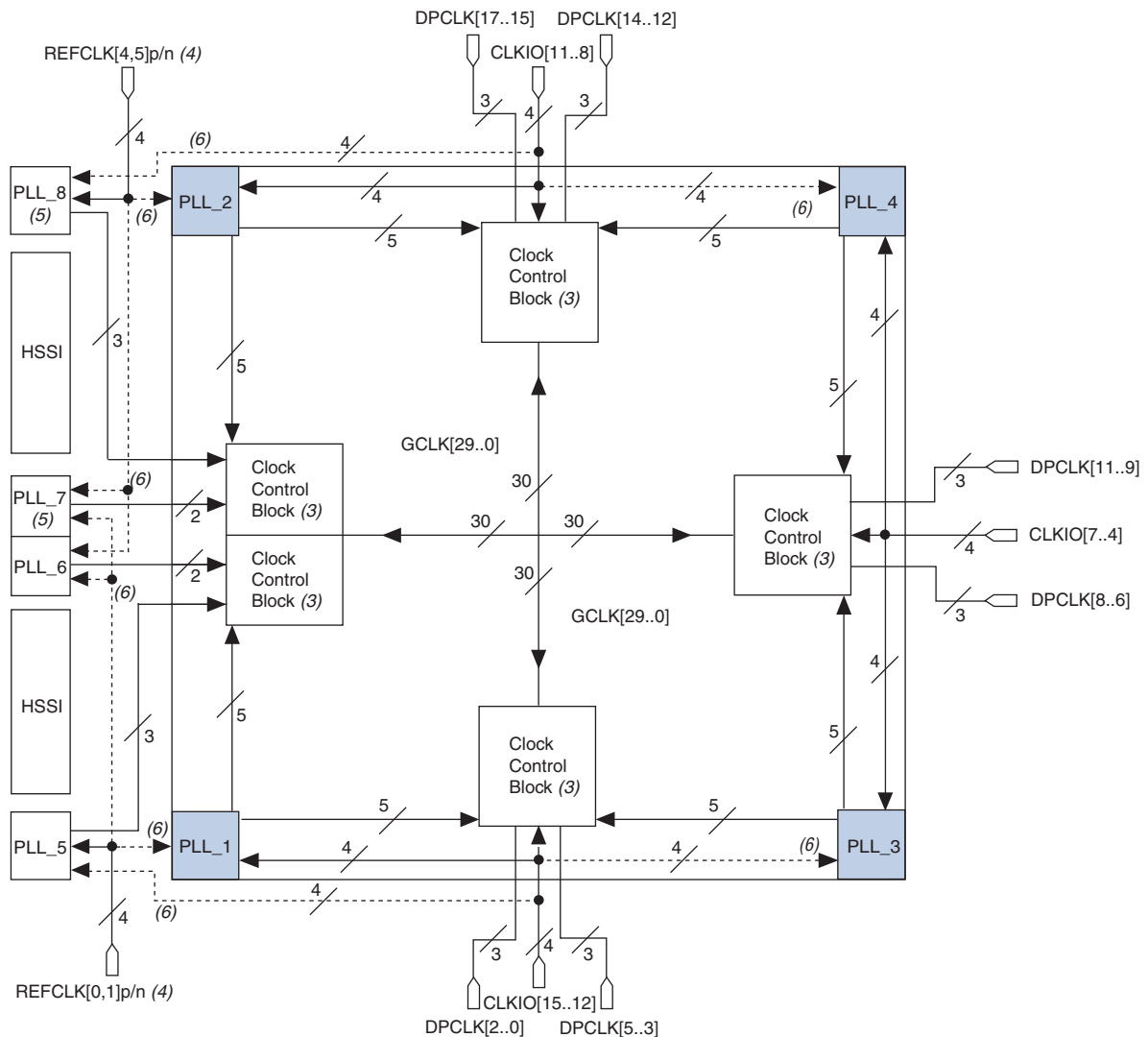
Figure 5-2. Clock Networks and Clock Control Block Locations in EP4CGX15, EP4CGX22, and EP4CGX30 Devices (1), (2)



Notes to Figure 5-2:

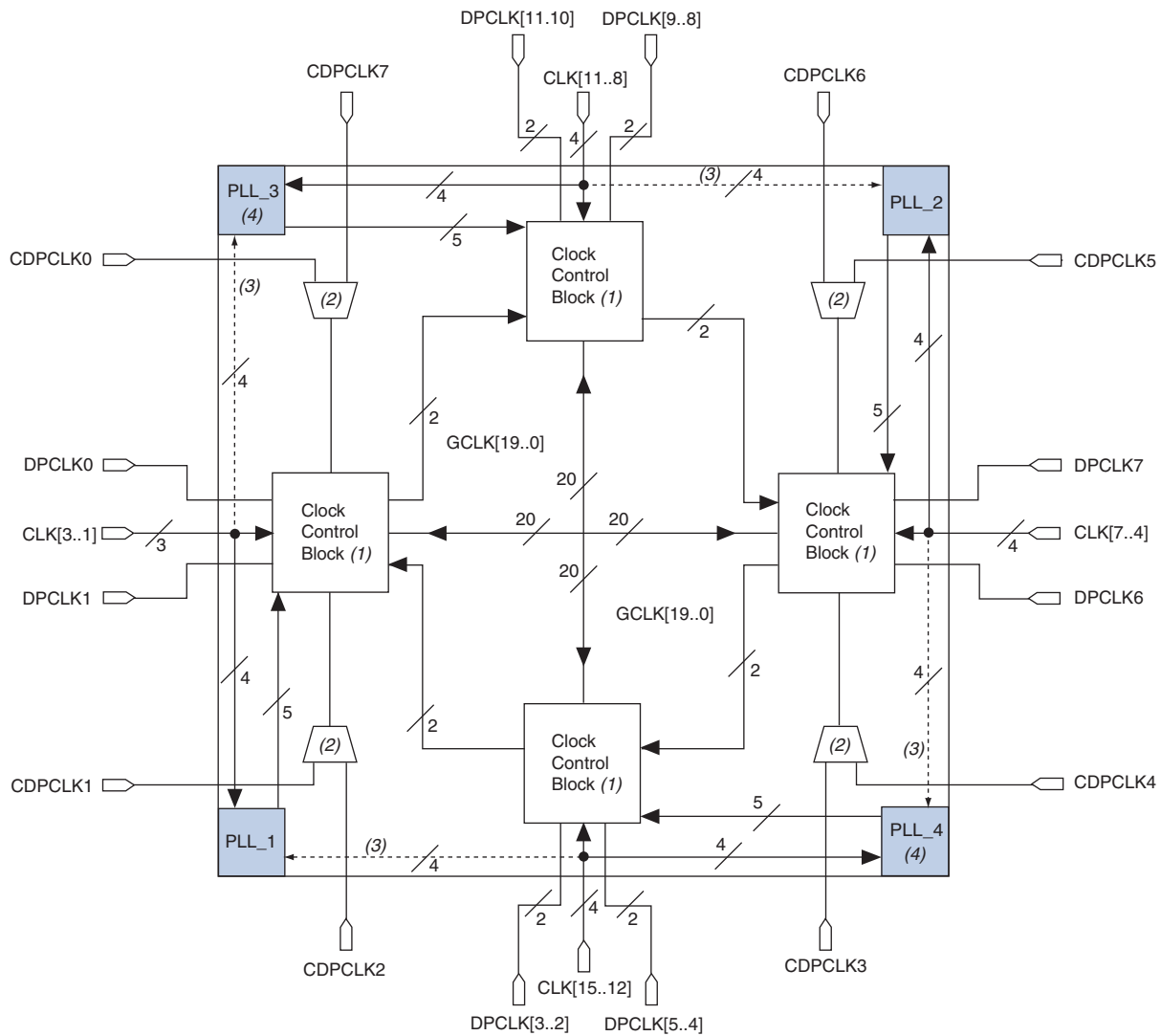
- (1) The clock networks and clock control block locations apply to all EP4CGX15, EP4CGX22, and EP4CGX30 devices except EP4CGX30 device in F484 package.
- (2) PLL_1 and PLL_2 are multipurpose PLLs while PLL_3 and PLL_4 are general purpose PLLs.
- (3) There are five clock control blocks on each side.
- (4) PLL_4 is only available in EP4CGX22 and EP4CGX30 devices in F324 package.
- (5) The EP4CGX15 device has two DPCLK pins on three sides of the device: DPCLK2 and DPCLK5 on bottom side, DPCLK7 and DPCLK8 on the right side, DPCLK10 and DPCLK13 on the top side of device.
- (6) Dedicated clock pins can feed into this PLL. However, these paths are not fully compensated.

Figure 5-3. Clock Networks and Clock Control Block Locations in EP4CGX30, EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 Devices (1), (2)



Notes to Figure 5-3:

- (1) The clock networks and clock control block locations in this figure apply to only the EP4CGX30 device in F484 package and all EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices.
- (2) PLL_1, PLL_2, PLL_3, and PLL_4 are general purpose PLLs while PLL_5, PLL_6, PLL_7, and PLL_8 are multipurpose PLLs.
- (3) There are 6 clock control blocks on the top, right and bottom sides of the device and 12 clock control blocks on the left side of the device.
- (4) REFCLK[0,1]p/n and REFCLK[4,5]p/n can only drive the general purpose PLLs and multipurpose PLLs on the left side of the device. These clock pins do not have access to the clock control blocks and GCLK networks. The REFCLK[4,5]p/n pins are not available in devices in F484 package.
- (5) Not available for EP4CGX30, EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices in F484 package.
- (6) Dedicated clock pins can feed into this PLL. However, these paths are not fully compensated.

Figure 5-4. Clock Networks and Clock Control Block Locations in Cyclone IV E Devices**Notes to Figure 5-4:**

- (1) There are five clock control blocks on each side.
- (2) Only one of the corner CDPCLK pins in each corner can feed the clock control block at a time. You can use the other CDPCLK pins as general-purpose I/O (GPIO) pins.
- (3) Dedicated clock pins can feed into this PLL. However, these paths are not fully compensated.
- (4) PLL_3 and PLL_4 are not available in EP4CE6 and EP4CE10 devices.

The inputs to the clock control blocks on each side of the Cyclone IV GX device must be chosen from among the following clock sources:

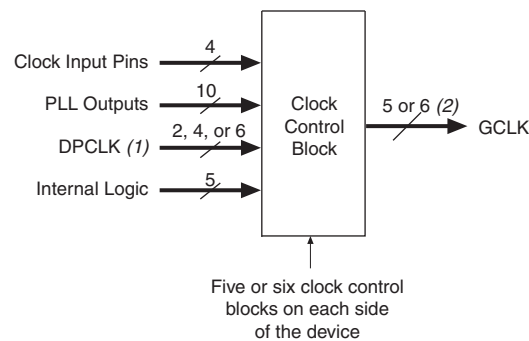
- Four clock input pins
- Ten PLL counter outputs (five from each adjacent PLLs)
- Two, four, or six DPCLK pins from the top, bottom, and right sides of the device
- Five signals from internal logic

From the clock sources listed above, only two clock input pins, two out of four PLL clock outputs (two clock outputs from either adjacent PLLs), one DPCLK pin, and one source from internal logic can drive into any given clock control block, as shown in Figure 5-1 on page 5-11.

Out of these six inputs to any clock control block, the two clock input pins and two PLL outputs are dynamically selected to feed a GCLK. The clock control block supports static selection of the signal from internal logic.

Figure 5-5 shows a simplified version of the clock control blocks on each side of the Cyclone IV GX device periphery.

Figure 5-5. Clock Control Blocks on Each Side of Cyclone IV GX Device



Notes to Figure 5-5:

- (1) The EP4CGX15 device has two DPCLK pins; the EP4CGX22 and EP4CGX30 devices have four DPCLK pins; the EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices have six DPCLK pins.
- (2) Each clock control block in the EP4CGX15, EP4CGX22, and EP4CGX30 devices can drive five GCLK networks. Each clock control block in the EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices can drive six GCLK networks.

The inputs to the five clock control blocks on each side of the Cyclone IV E device must be chosen from among the following clock sources:

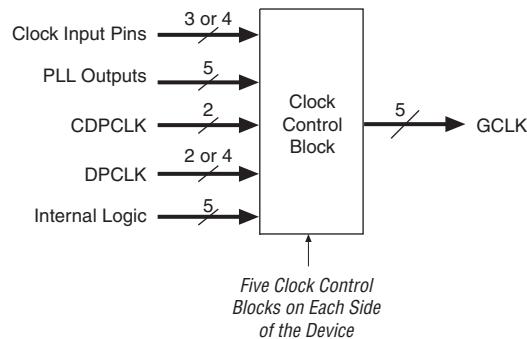
- Three or four clock input pins, depending on the specific device
- Five PLL counter outputs
- Two DPCLK pins and two CDPCLK pins from both the left and right sides and four DPCLK pins from both the top and bottom
- Five signals from internal logic

From the clock sources listed above, only two clock input pins, two PLL clock outputs, one DPCLK or CDPCLK pin, and one source from internal logic can drive into any given clock control block, as shown in Figure 5-1 on page 5-11.

Out of these six inputs to any clock control block, the two clock input pins and two PLL outputs are dynamically selected to feed a GCLK. The clock control block supports static selection of the signal from internal logic.

Figure 5-6 shows a simplified version of the five clock control blocks on each side of the Cyclone IV E device periphery.

Figure 5-6. Clock Control Blocks on Each Side of Cyclone IV E Device ⁽¹⁾



Note to Figure 5-6:

(1) The left and right sides of the device have two DPCLK pins; the top and bottom of the device have four DPCLK pins.

GCLK Network Power Down

You can disable a Cyclone IV device's GCLK (power down) using both static and dynamic approaches. In the static approach, configuration bits are set in the configuration file generated by the Quartus II software, which automatically disables unused GCLKs. The dynamic clock enable or disable feature allows internal logic to control clock enable or disable the GCLKs in Cyclone IV devices.

When a clock network is disabled, all the logic fed by the clock network is in an off-state, thereby reducing the overall power consumption of the device. This function is independent of the PLL and is applied directly on the clock network, as shown in Figure 5-1 on page 5-11.

You can set the input clock sources and the `clkena` signals for the GCLK multiplexers through the Quartus II software using the `ALTCLKCTRL` megafunction.

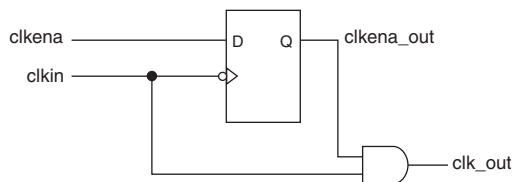
 For more information, refer to the [ALTCLKCTRL Megafunction User Guide](#).

clkena Signals

Cyclone IV devices support `clkena` signals at the GCLK network level. This allows you to gate-off the clock even when a PLL is used. Upon re-enabling the output clock, the PLL does not need a resynchronization or re-lock period because the circuit gates off the clock at the clock network level. In addition, the PLL can remain locked independent of the `clkena` signals because the loop-related counters are not affected.

Figure 5-7 shows how to implement the `clkena` signal with a single register.

Figure 5-7. `clkena` Implementation

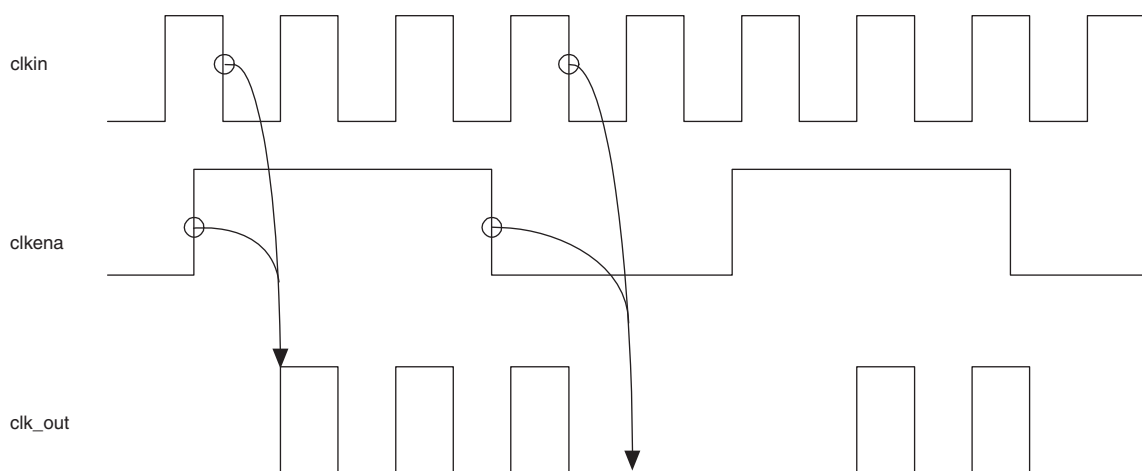


The `clkena` circuitry controlling the output C0 of the PLL to an output pin is implemented with two registers instead of a single register, as shown in Figure 5-7.

Figure 5-8 shows the waveform example for a clock output enable. The `clkena` signal is sampled on the falling edge of the clock (`clkkin`).

This feature is useful for applications that require low power or sleep mode.

Figure 5-8. `clkena` Implementation: Output Enable



The `clkena` signal can also disable clock outputs if the system is not tolerant to frequency overshoot during PLL resynchronization.


Altera recommends using the `clkena` signals when switching the clock source to the PLLs or the GCLK. The recommended sequence is:

1. Disable the primary output clock by de-asserting the `clkena` signal.
2. Switch to the secondary clock using the dynamic select signals of the clock control block.
3. Allow some clock cycles of the secondary clock to pass before reasserting the `clkena` signal. The exact number of clock cycles you must wait before enabling the secondary clock is design-dependent. You can build custom logic to ensure glitch-free transition when switching between different clock sources.


PLLs in Cyclone IV Devices

Cyclone IV GX devices offer two variations of PLLs: general purpose PLLs and multipurpose PLLs. Cyclone IV E devices only have the general purpose PLLs.

The general purpose PLLs are used for general-purpose applications in the FPGA fabric and periphery such as external memory interfaces. The multipurpose PLLs are used for clocking the transceiver blocks. When the multipurpose PLLs are not used for transceiver clocking, they can be used for general-purpose clocking.

 For more details about the multipurpose PLLs used for transceiver clocking, refer to the *Cyclone IV Transceivers* chapter.

Cyclone IV GX devices contain up to eight general purpose PLLs and multipurpose PLLs while Cyclone IV E devices have up to four general purpose PLLs that provide robust clock management and synthesis for device clock management, external system clock management, and high-speed I/O interfaces.

 For more information about the number of general purpose PLLs and multipurpose PLLs in each device density, refer to the *Cyclone IV Device Family Overview* chapter.


 The general I/O pins cannot drive the PLL clock input pins.

Table 5-5 lists the features available in Cyclone IV GX PLLs.

Table 5-5. Cyclone IV GX PLL Features (Part 1 of 2)

Features	Availability									
	General Purpose PLLs				Multipurpose PLLs					
	PLL 1 (1), (10)	PLL 2 (1), (10)	PLL 3 (2)	PLL 4 (3)	PLL 1 (4)	PLL 2 (4)	PLL 5 (1), (10)	PLL 6 (1), (10)	PLL 7 (1)	PLL 8 (1)
C (output counters)	5									
M, N, C counter sizes	1 to 512 ⁽⁵⁾									
Dedicated clock outputs	1 single-ended or 1 differential pair									
Clock input pins	12 single-ended or 6 differential pairs ⁽⁶⁾ and 4 differential pairs ⁽⁷⁾									
Spread-spectrum input clock tracking	✓ ⁽⁸⁾									
PLL cascading	Through GCLK									
Source-Synchronous Mode	✓	✓	✓	✓	✓	✓	✓	—	—	✓
No Compensation Mode	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Normal Mode	✓	✓	✓	✓	✓	✓	✓	—	—	✓
Zero Delay Buffer Mode	✓	✓	✓	✓	✓	✓	✓	—	—	✓
Deterministic Latency Compensation Mode	✓	✓	—	—	✓	✓	✓	✓	✓	✓
Phase shift resolution ⁽⁹⁾	Down to 96 ps increments									
Programmable duty cycle	✓									
Output counter cascading	✓									

Table 5-5. Cyclone IV GX PLL Features (Part 2 of 2)

Features	Availability									
	General Purpose PLLs				Multipurpose PLLs					
	PLL 1 (1), (10)	PLL 2 (1), (10)	PLL 3 (2)	PLL 4 (3)	PLL 1 (4)	PLL 2 (4)	PLL 5 (1), (10)	PLL 6 (1), (10)	PLL 7 (1)	PLL 8 (1)
Input clock switchover					✓					
User mode reconfiguration					✓					
Loss of lock detection					✓					
PLL drives TX Serial Clock, TX Load Enable, and TX Parallel Clock	✓	✓	—	—				✓		
VCO output drives RX clock data recovery (CDR) clock			—					✓		
PLL drives FREF for ppm detect	✓	✓	—	—				✓		

Notes to Table 5-5:

- (1) This is only applicable to EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices in F672 and F896 package.
- (2) This is applicable to all Cyclone IV devices.
- (3) This is applicable to all Cyclone IV devices except EP4CGX15 devices in all packages, EP4CGX22, and EP4CGX30 devices in F169 package.
- (4) This is only applicable to EP4CGX15, EP4CGX22, and all EP4CGX30 devices except EP4CGX30 in the F484 package.
- (5) C counters range from 1 through 512 if the output clock uses a 50% duty cycle. For any output clocks using a non-50% duty cycle, the post-scale counters range from 1 through 256.
- (6) These clock pins can access the GCLK networks.
- (7) These clock pins are only available in EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices and cannot access the GCLK networks. CLK[17, 19, 20, 21]_P can be used as single-ended clock input pins.
- (8) Only applicable if the input clock jitter is in the input jitter tolerance specifications.
- (9) The smallest phase shift is determined by the voltage-controlled oscillator (VCO) period divided by eight. For degree increments, Cyclone IV GX devices can shift all output frequencies in increments of at least 45°. Smaller degree increments are possible depending on the frequency and divide parameters.
- (10) This is applicable to the EP4CGX30, EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices in F484 package.

Table 5-6 lists the features available in Cyclone IV E PLLs.

Table 5-6. Cyclone IV E PLL Features (Part 1 of 2)

Hardware Features	Availability
C (output counters)	5
M, N, C counter sizes	1 to 512 (1)
Dedicated clock outputs	1 single-ended or 1 differential pair
Clock input pins	4 single-ended or 2 differential pairs
Spread-spectrum input clock tracking	✓ (2)
PLL cascading	Through GCLK
Compensation modes	Source-Synchronous Mode, No Compensation Mode, Normal Mode, and Zero Delay Buffer Mode
Phase shift resolution	Down to 96-ps increments (3)
Programmable duty cycle	✓
Output counter cascading	✓
Input clock switchover	✓
User mode reconfiguration	✓

Table 5-6. Cyclone IV E PLL Features (Part 2 of 2)

Hardware Features	Availability
Loss of lock detection	✓

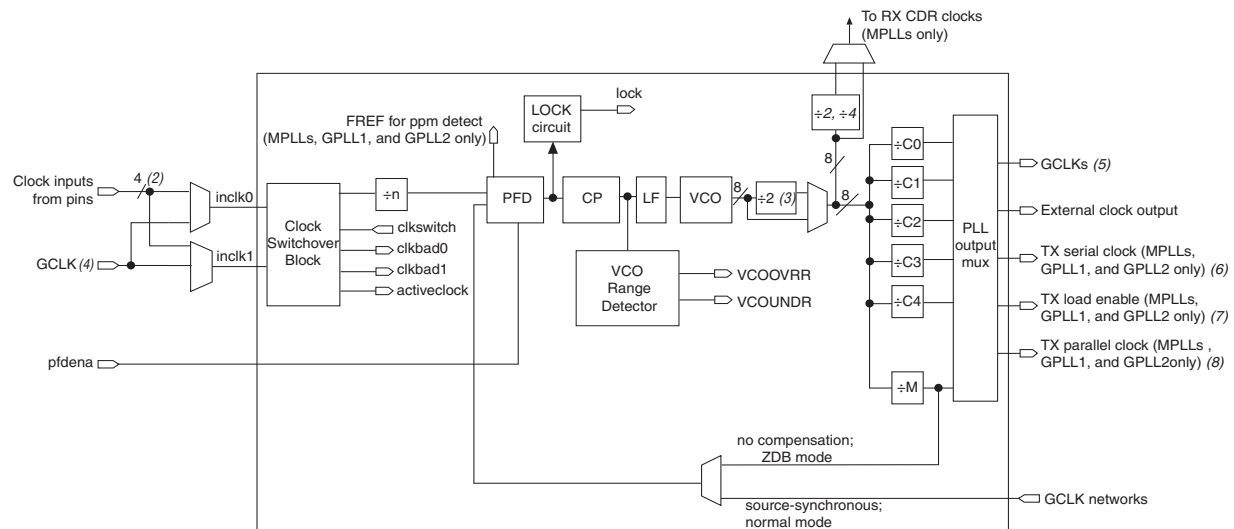
Notes to Table 5-6:

- (1) C counters range from 1 through 512 if the output clock uses a 50% duty cycle. For any output clocks using a non-50% duty cycle, the post-scale counters range from 1 through 256.
- (2) Only applicable if the input clock jitter is in the input jitter tolerance specifications.
- (3) The smallest phase shift is determined by the VCO period divided by eight. For degree increments, Cyclone IV E devices can shift all output frequencies in increments of at least 45°. Smaller degree increments are possible depending on the frequency and divide parameters.

Cyclone IV PLL Hardware Overview

This section gives a hardware overview of the Cyclone IV PLL.

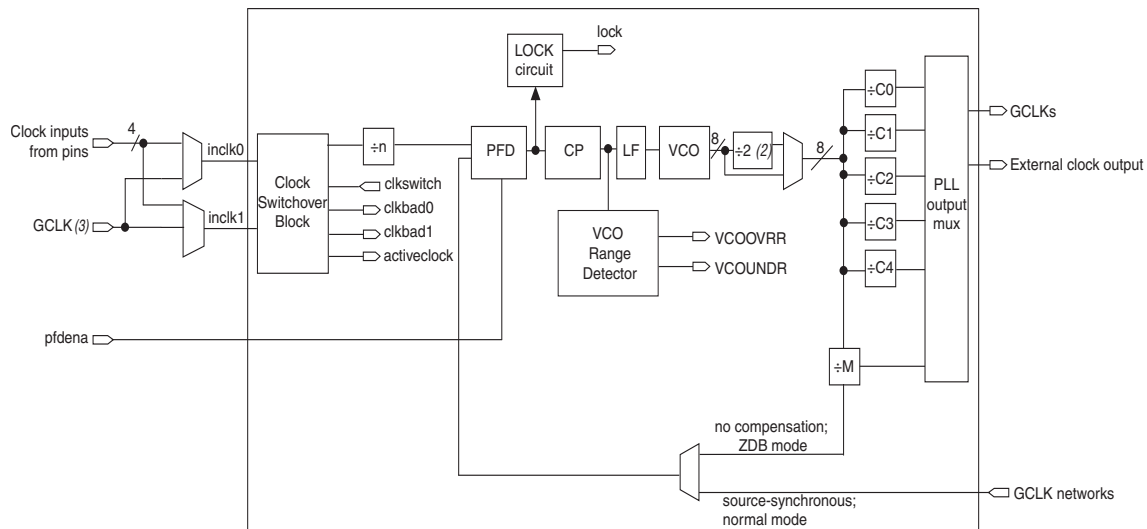
Figure 5-9 shows a simplified block diagram of the major components of the PLL of Cyclone IV GX devices.

Figure 5-9. Cyclone IV GX PLL Block Diagram (1)**Notes to Figure 5-9:**

- (1) Each clock source can come from any of the four clock pins located on the same side of the device as the PLL.
- (2) There are additional 4 pairs of dedicated differential clock inputs in EP4CGX50, EP4CGX75, EP4CGX110, and EP4CGX150 devices that can only drive general purpose PLLs and multipurpose PLLs on the left side of the device. CLK[19..16] can access PLL_2, PLL_6, PLL_7, and PLL_8 while CLK[23..20] can access PLL_1, PLL_5, PLL_6, and PLL_7. For the location of these clock input pins, refer to Figure 5-3 on page 5-13.
- (3) This is the VCO post-scale counter K.
- (4) This input port is fed by a pin-driven dedicated GCLK, or through a clock control block if the clock control block is fed by an output from another PLL or a pin-driven dedicated GCLK. An internally generated global signal cannot drive the PLL.
- (5) For the general purpose PLL and multipurpose PLL counter outputs connectivity to the GCLKs, refer to Table 5-1 on page 5-2 and Table 5-2 on page 5-4.
- (6) Only the C1 output counter can drive the TX serial clock.
- (7) Only the C2 output counter can drive the TX load enable.
- (8) Only the C3 output counter can drive the TX parallel clock.


Figure 5-10 shows a simplified block diagram of the major components of the PLL of Cyclone IV E devices.

Figure 5-10. Cyclone IV E PLL Block Diagram ⁽¹⁾



Notes to Figure 5-10:

- (1) Each clock source can come from any of the four clock pins located on the same side of the device as the PLL.
- (2) This is the VCO post-scale counter K.
- (3) This input port is fed by a pin-driven dedicated GCLK, or through a clock control block if the clock control block is fed by an output from another PLL or a pin-driven dedicated GCLK. An internally generated global signal cannot drive the PLL.

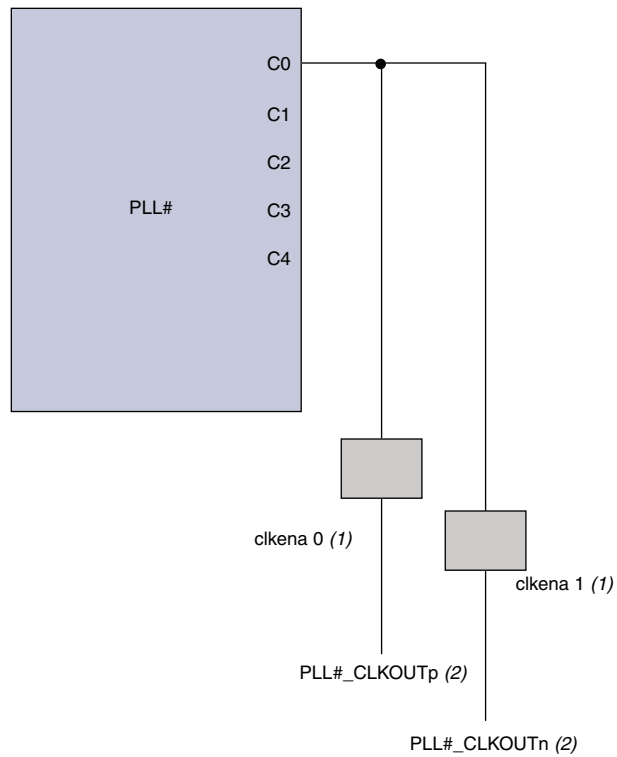
 The VCO post-scale counter K is used to divide the supported VCO range by two. The VCO frequency reported by the Quartus II software in the PLL summary section of the compilation report takes into consideration the VCO post-scale counter value. Therefore, if the VCO post-scale counter has a value of 2, the frequency reported is lower than the f_{VCO} specification specified in the *Cyclone IV Device Datasheet* chapter.

External Clock Outputs

Each PLL of Cyclone IV devices supports one single-ended clock output or one differential clock output. Only the C0 output counter can feed the dedicated external clock outputs, as shown in Figure 5-11, without going through the GCLK. Other output counters can feed other I/O pins through the GCLK.

Figure 5–11 shows the external clock outputs for PLLs.

Figure 5–11. External Clock Outputs for PLLs



Notes to Figure 5–11:

- (1) These external clock enable signals are available only when using the ALTCLKCTRL megafunction.
- (2) `PLL#_CLKOUTp` and `PLL#_CLKOUTn` pins are dual-purpose I/O pins that you can use as one single-ended clock output or one differential clock output. When using both pins as single-ended I/Os, one of them can be the clock output while the other pin is configured as a regular user I/O.

Each pin of a differential output pair is 180° out of phase. The Quartus II software places the NOT gate in your design into the I/O element to implement 180° phase with respect to the other pin in the pair. The clock output pin pairs support the same I/O standards as standard output pins.

 To determine which I/O standards are supported by the PLL clock input and output pins, refer to the *Cyclone IV Device I/O Features* chapter.

Cyclone IV PLLs can drive out to any regular I/O pin through the GCLK. You can also use the external clock output pins as GPIO pins if external PLL clocking is not required.

Clock Feedback Modes

Cyclone IV PLLs support up to five different clock feedback modes. Each mode allows clock multiplication and division, phase shifting, and programmable duty cycle. For the supported feedback modes, refer to [Table 5-5 on page 5-18](#) for Cyclone IV GX PLLs and [Table 5-6 on page 5-19](#) for Cyclone IV E PLLs.



Input and output delays are fully compensated by the PLL only if you are using the dedicated clock input pins associated with a given PLL as the clock sources.

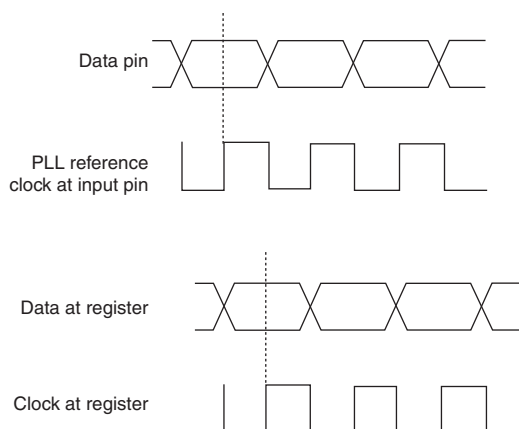
When driving the PLL using the GCLK network, the input and output delays may not be fully compensated in the Quartus II software.

Source-Synchronous Mode

If the data and clock arrive at the same time at the input pins, the phase relationship between the data and clock remains the same at the data and clock ports of any I/O element input register.

[Figure 5-12](#) shows an example waveform of the data and clock in this mode. Use this mode for source-synchronous data transfers. Data and clock signals at the I/O element experience similar buffer delays as long as the same I/O standard is used.

Figure 5-12. Phase Relationship Between Data and Clock in Source-Synchronous Mode



Source-synchronous mode compensates for delay of the clock network used, including any difference in the delay between the following two paths:

- Data pin to I/O element register input
- Clock input pin to the PLL phase frequency detector (PFD) input



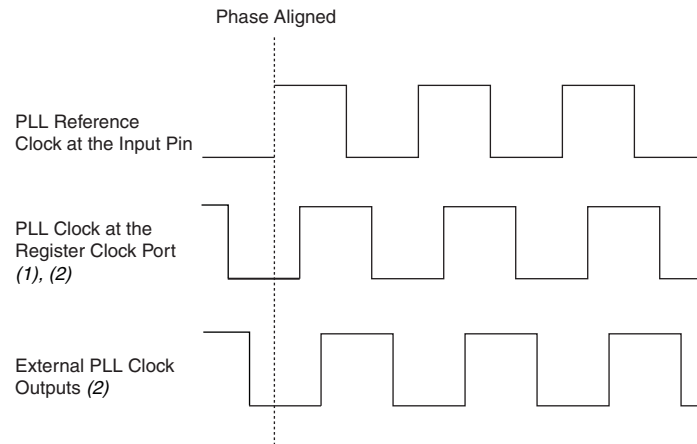
Set the input pin to the register delay chain in the I/O element to zero in the Quartus II software for all data pins clocked by a source-synchronous mode PLL. Also, all data pins must use the **PLL COMPENSATED logic** option in the Quartus II software.

No Compensation Mode

In no compensation mode, the PLL does not compensate for any clock networks. This provides better jitter performance because clock feedback into the PFD does not pass through as much circuitry. Both the PLL internal and external clock outputs are phase shifted with respect to the PLL clock input.

Figure 5-13 shows a waveform example of the phase relationship of the PLL clock in this mode.

Figure 5-13. Phase Relationship Between PLL Clocks in No Compensation Mode



Notes to Figure 5-13:

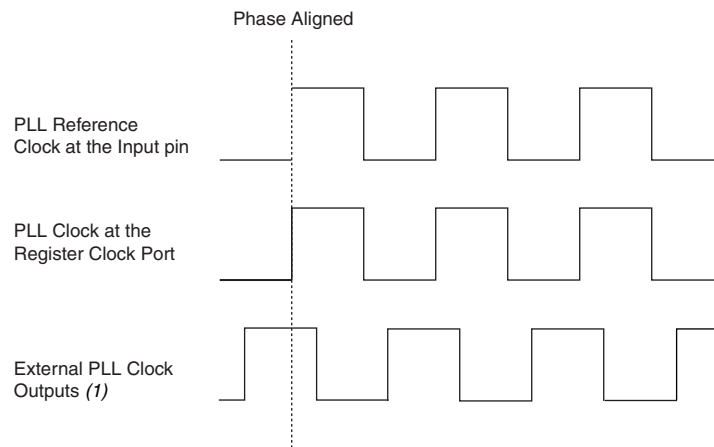
- (1) Internal clocks fed by the PLL are phase-aligned to each other.
- (2) The PLL clock outputs can lead or lag the PLL input clocks.

Normal Mode

An internal clock in normal mode is phase-aligned to the input clock pin. The external clock output pin has a phase delay relative to the clock input pin if connected in this mode. The Quartus II software timing analyzer reports any phase difference between the two. In normal mode, the PLL fully compensates the delay introduced by the GCLK network.

Figure 5-14 shows a waveform example of the phase relationship of the PLL clocks in this mode.

Figure 5-14. Phase Relationship Between PLL Clocks in Normal Mode



Note to Figure 5-14:

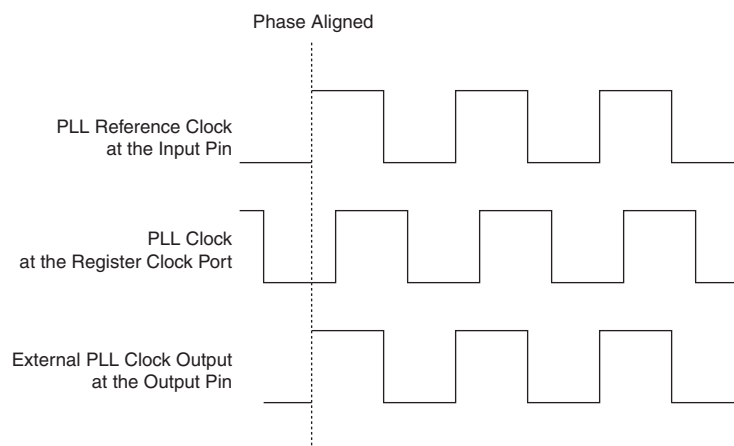
(1) The external clock output can lead or lag the PLL internal clock signals.

Zero Delay Buffer Mode

In zero delay buffer (ZDB) mode, the external clock output pin is phase-aligned with the clock input pin for zero delay through the device. When using this mode, use the same I/O standard on the input clock and output clocks to guarantee clock alignment at the input and output pins.

Figure 5-15 shows an example waveform of the phase relationship of the PLL clocks in ZDB mode.

Figure 5-15. Phase Relationship Between PLL Clocks in ZDB Mode



Deterministic Latency Compensation Mode

The deterministic latency mode compensates for the delay of the multipurpose PLLs through the clock network and serializer in Common Public Radio Interface (CPRI) applications. In this mode, the PLL PFD feedback path compensates the latency uncertainty in Tx dataout and Tx clkout paths relative to the reference clock.

Hardware Features

Cyclone IV PLLs support several features for general-purpose clock management. This section discusses clock multiplication and division implementation, phase shifting implementations, and programmable duty cycles.

Clock Multiplication and Division

Each Cyclone IV PLL provides clock synthesis for PLL output ports using $M/(N \times \text{post-scale counter})$ scaling factors. The input clock is divided by a pre-scale factor, N , and is then multiplied by the M feedback factor. The control loop drives the VCO to match $f_{IN} (M/N)$. Each output port has a unique post-scale counter that divides down the high-frequency VCO. For multiple PLL outputs with different frequencies, the VCO value is the least common multiple of the output frequencies that meets its frequency specifications. For example, if output frequencies required from one PLL are 33 and 66 MHz, the Quartus II software sets the VCO to 660 MHz (the least common multiple of 33 and 66 MHz in the VCO range). Then, the post-scale counters scale down the VCO frequency for each output port.

There is one pre-scale counter, N , and one multiply counter, M , per PLL, with a range of 1 to 512 for both M and N . The N counter does not use duty cycle control because the purpose of this counter is only to calculate frequency division. There are five generic post-scale counters per PLL that can feed GCLKs or external clock outputs. These post-scale counters range from 1 to 512 with a 50% duty cycle setting. The post-scale counters range from 1 to 256 with any non-50% duty cycle setting. The sum of the high/low count values chosen for a design selects the divide value for a given counter.

The Quartus II software automatically chooses the appropriate scaling factors according to the input frequency, multiplication, and division values entered into the ALTPLL megafunction.

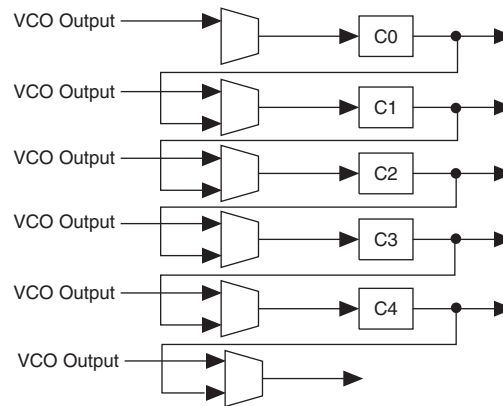


Phase alignment between output counters is determined using the t_{PLL_PSERR} specification.

Post-Scale Counter Cascading

PLLs of Cyclone IV devices support post-scale counter cascading to create counters larger than 512. This is implemented by feeding the output of one C counter into the input of the next C counter, as shown in Figure 5-16.

Figure 5-16. Counter Cascading



When cascading counters to implement a larger division of the high-frequency VCO clock, the cascaded counters behave as one counter with the product of the individual counter settings.

For example, if $C0 = 4$ and $C1 = 2$, the cascaded value is $C0 \times C1 = 8$.



Post-scale counter cascading is automatically set by the Quartus II software in the configuration file. Post-scale counter cascading cannot be performed using the PLL reconfiguration.

Programmable Duty Cycle

The programmable duty cycle allows PLLs to generate clock outputs with a variable duty cycle. This feature is supported on the PLL post-scale counters. You can achieve the duty cycle setting by a low and high time count setting for the post-scale counters. The Quartus II software uses the frequency input and the required multiply or divide rate to determine the duty cycle choices. The post-scale counter value determines the precision of the duty cycle. The precision is defined by 50% divided by the post-scale counter value. For example, if the C0 counter is 10, steps of 5% are possible for duty cycle choices between 5 to 90%.

Combining the programmable duty cycle with programmable phase shift allows the generation of precise non-overlapping clocks.

PLL Control Signals

You can use the `pfdena`, `areset`, and `locked` signals to observe and control the PLL operation and resynchronization.



For more information about the PLL control signals, refer to the *ALTPLL Megafunction User Guide*.

Clock Switchover

The clock switchover feature allows the PLL to switch between two reference input clocks. Use this feature for clock redundancy or for a dual-clock domain application, such as a system that turns on the redundant clock if the previous clock stops running. Your design can automatically perform clock switchover when the clock is no longer toggling, or based on the user control signal, `clkswitch`.

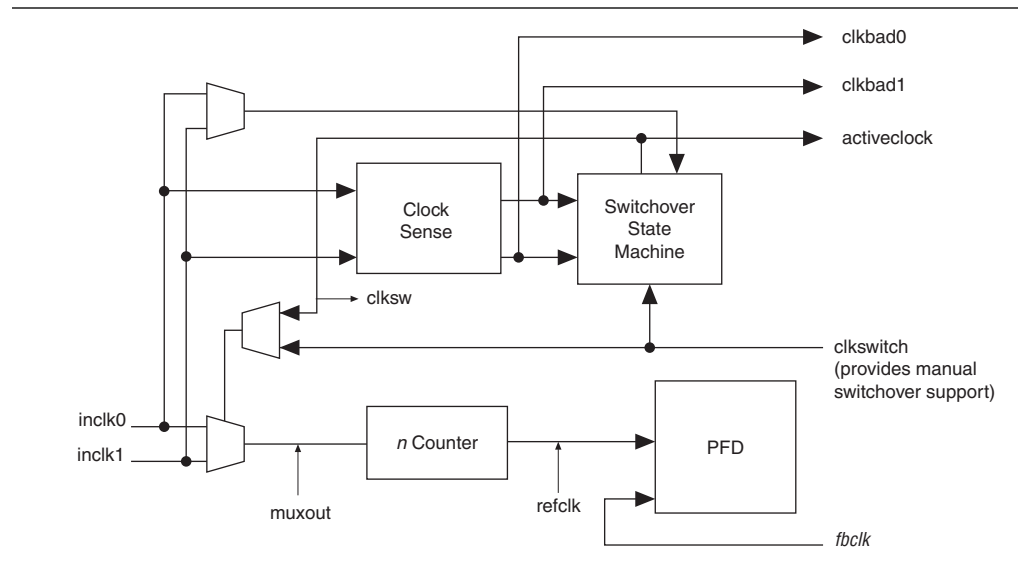
Automatic Clock Switchover

PLLs of Cyclone IV devices support a fully configurable clock switchover capability.

When the current reference clock is not present, the clock-sense block automatically switches to the backup clock for PLL reference. The clock switchover circuit also sends out three status signals—`clkbad0`, `clkbad1`, and `activeclock`—from the PLL to implement a custom switchover circuit. You can select a clock source at the backup clock by connecting it to the `inclk1` port of the PLL in your design.

Figure 5-17 shows the block diagram of the switchover circuit built into the PLL.

Figure 5-17. Automatic Clock Switchover Circuit



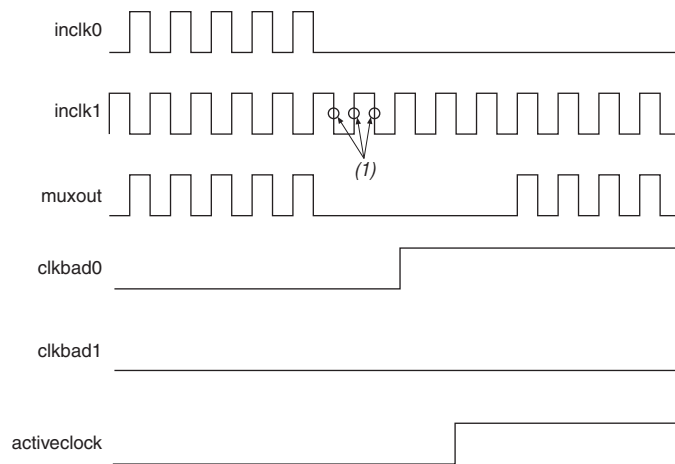
There are two ways to use the clock switchover feature:

- Use the switchover circuitry for switching from `inclk0` to `inclk1` running at the same frequency. For example, in applications that require a redundant clock with the same frequency as the reference clock, the switchover state machine generates a signal that controls the multiplexer select input shown in Figure 5-17. In this case, `inclk1` becomes the reference clock for the PLL. This automatic switchover can switch back and forth between the `inclk0` and `inclk1` clocks any number of times, when one of the two clocks fails and the other clock is available.
- Use the `clkswitch` input for user- or system-controlled switch conditions. This is possible for same-frequency switchover or to switch between inputs of different frequencies. For example, if `inclk0` is 66 MHz and `inclk1` is 200 MHz, you must control the switchover because the automatic clock-sense circuitry cannot monitor primary and secondary clock frequencies with a frequency difference of more than

20%. This feature is useful when clock sources can originate from multiple cards on the backplane, requiring a system-controlled switchover between frequencies of operation. Choose the secondary clock frequency so the VCO operates in the recommended frequency range. Also, set the M, N, and C counters accordingly to keep the VCO operating frequency in the recommended range.

Figure 5-18 shows a waveform example of the switchover feature when using automatic loss of clock detection. Here, the `inclk0` signal remains low. After the `inclk0` signal remains low for approximately two clock cycles, the clock-sense circuitry drives the `clkbad0` signal high. Also, because the reference clock signal is not toggling, the switchover state machine controls the multiplexer through the `clksw` signal to switch to `inclk1`.

Figure 5-18. Automatic Switchover Upon Clock Loss Detection (1)



Note to Figure 5-18:

- (1) Switchover is enabled on the falling edge of `inclk0` or `inclk1`, depending on which clock is available. In this figure, switchover is enabled on the falling edge of `inclk1`.

Manual Override

If you are using the automatic switchover, you must switch input clocks with the manual override feature with the `clkswitch` input.

Figure 5-19 shows an example of a waveform illustrating the switchover feature when controlled by `clkswitch`. In this case, both clock sources are functional and `inclk0` is selected as the reference clock. A low-to-high transition of the `clkswitch` signal starts the switchover sequence. The `clkswitch` signal must be high for at least three clock cycles (at least three of the longer clock period if `inclk0` and `inclk1` have different frequencies). On the falling edge of `inclk0`, the reference clock of the counter, `muxout`, is gated off to prevent any clock glitching. On the falling edge of `inclk1`, the reference clock multiplexer switches from `inclk0` to `inclk1` as the PLL reference, and the `activeclock` signal changes to indicate which clock is currently feeding the PLL.

In this mode, the `activeclock` signal mirrors the `clkswitch` signal. As both blocks are still functional during the manual switch, neither `clkbad` signals go high. Because the switchover circuit is positive edge-sensitive, the falling edge of the `clkswitch` signal does not cause the circuit to switch back from `inclk1` to `inclk0`. When the `clkswitch` signal goes high again, the process repeats. The `clkswitch` signal and the automatic switch only works depending on the availability of the clock that is switched to. If the clock is unavailable, the state machine waits until the clock is available.


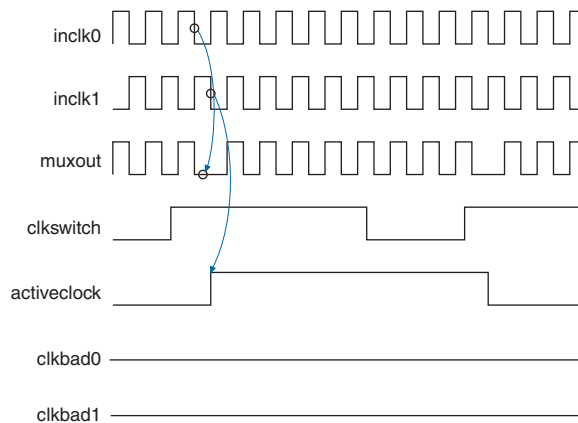
 When `CLKSWITCH = 1`, it overrides the automatic switch-over function. As long as `clkswitch` signal is high, further switch-over action is blocked.

Figure 5-19. Clock Switchover Using the `clkswitch` Control ⁽¹⁾




Note to Figure 5-19:

(1) Both `inclk0` and `inclk1` must be running when the `clkswitch` signal goes high to start a manual clock switchover event.

Manual Clock Switchover

PLLs of Cyclone IV devices support manual switchover, in which the `clkswitch` signal controls whether `inclk0` or `inclk1` is the input clock to the PLL. The characteristics of a manual switchover are similar to the manual override feature in an automatic clock switchover, in which the switchover circuit is edge-sensitive. When the `clkswitch` signal goes high, the switchover sequence starts. The falling edge of the `clkswitch` signal does not cause the circuit to switch back to the previous input clock.

 For more information about PLL software support in the Quartus II software, refer to the [ALTPLL Megafunction User Guide](#).

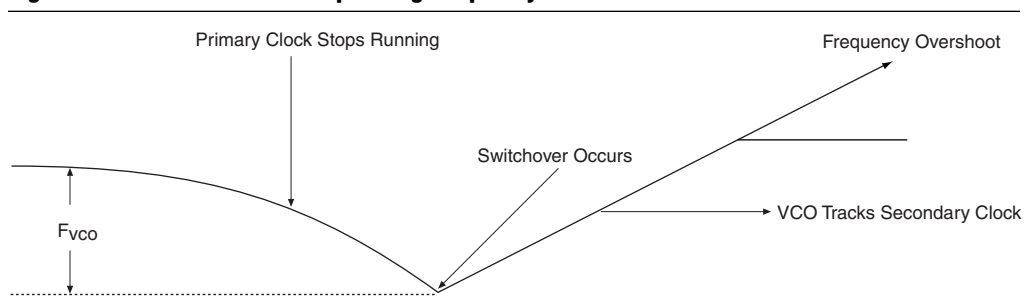
Guidelines

Use the following guidelines to design with clock switchover in PLLs:

- Clock loss detection and automatic clock switchover require the `inclk0` and `inclk1` frequencies be within 20% of each other. Failing to meet this requirement causes the `clkbad0` and `clkbad1` signals to function improperly.

- When using manual clock switchover, the difference between `inclk0` and `inclk1` can be more than 20%. However, differences between the two clock sources (frequency, phase, or both) can cause the PLL to lose lock. Resetting the PLL ensures that the correct phase relationships are maintained between the input and output clocks.
- Both `inclk0` and `inclk1` must be running when the `clkswitch` signal goes high to start the manual clock switchover event. Failing to meet this requirement causes the clock switchover to malfunction.
- Applications that require a clock switchover feature and a small frequency drift must use a low-bandwidth PLL. When referencing input clock changes, the low-bandwidth PLL reacts slower than a high-bandwidth PLL. When the switchover happens, the low-bandwidth PLL propagates the stopping of the clock to the output slower than the high-bandwidth PLL. The low-bandwidth PLL filters out jitter on the reference clock. However, the low-bandwidth PLL also increases lock time.
- After a switchover occurs, there may be a finite resynchronization period for the PLL to lock onto a new clock. The exact amount of time it takes for the PLL to re-lock is dependent on the PLL configuration.
- If the phase relationship between the input clock to the PLL and output clock from the PLL is important in your design, assert `areset` for 10 ns after performing a clock switchover. Wait for the locked signal (or gated lock) to go high before re-enabling the output clocks from the PLL.
- **Figure 5-20** shows how the VCO frequency gradually decreases when the primary clock is lost and then increases as the VCO locks on to the secondary clock. After the VCO locks on to the secondary clock, some overshoot can occur (an over-frequency condition) in the VCO frequency.

Figure 5-20. VCO Switchover Operating Frequency



- Disable the system during switchover if the system is not tolerant to frequency variations during the PLL resynchronization period. You can use the `clkbad0` and `clkbad1` status signals to turn off the PFD (`pfdena = 0`) so the VCO maintains its last frequency. You can also use the switchover state machine to switch over to the secondary clock. Upon enabling the PFD, output clock enable signals (`clkena`) can disable clock outputs during the switchover and resynchronization period. After the lock indication is stable, the system can re-enable the output clock or clocks.

Programmable Bandwidth

The PLL bandwidth is the measure of the PLL's ability to track the input clock and its associated jitter. PLLs of Cyclone IV devices provide advanced control of the PLL bandwidth using the programmable characteristics of the PLL loop, including loop filter and charge pump. The closed-loop gain 3-dB frequency in the PLL determines the PLL bandwidth. The bandwidth is approximately the unity gain point for open loop PLL response.

Phase Shift Implementation

Phase shift is used to implement a robust solution for clock delays in Cyclone IV devices. Phase shift is implemented with a combination of the VCO phase output and the counter starting time. The VCO phase output and counter starting time are the most accurate methods of inserting delays, because they are based only on counter settings that are independent of process, voltage, and temperature.

You can phase shift the output clocks from the PLLs of Cyclone IV devices in one of two ways:

- Fine resolution using VCO phase taps
- Coarse resolution using counter starting time

Fine resolution phase shifts are implemented by allowing any of the output counters (C[4..0]) or the M counter to use any of the eight phases of the VCO as the reference clock. This allows you to adjust the delay time with a fine resolution.

Equation 5-1 shows the minimum delay time that you can insert using this method.

Equation 5-1. Fine Resolution Phase Shift

$$\tau_{\text{fine}} = \frac{T_{VCO}}{8} = \frac{1}{8f_{VCO}} = \frac{N}{8Mf_{REF}}$$

in which f_{REF} is the input reference clock frequency.

For example, if f_{REF} is 100 MHz, $N = 1$, and $M = 8$, then $f_{VCO} = 800$ MHz, and $\Phi_{\text{fine}} = 156.25$ ps. The PLL operating frequency defines this phase shift, a value that depends on reference clock frequency and counter settings.

Coarse resolution phase shifts are implemented by delaying the start of the counters for a predetermined number of counter clocks. Equation 5-2 shows the coarse phase shift.

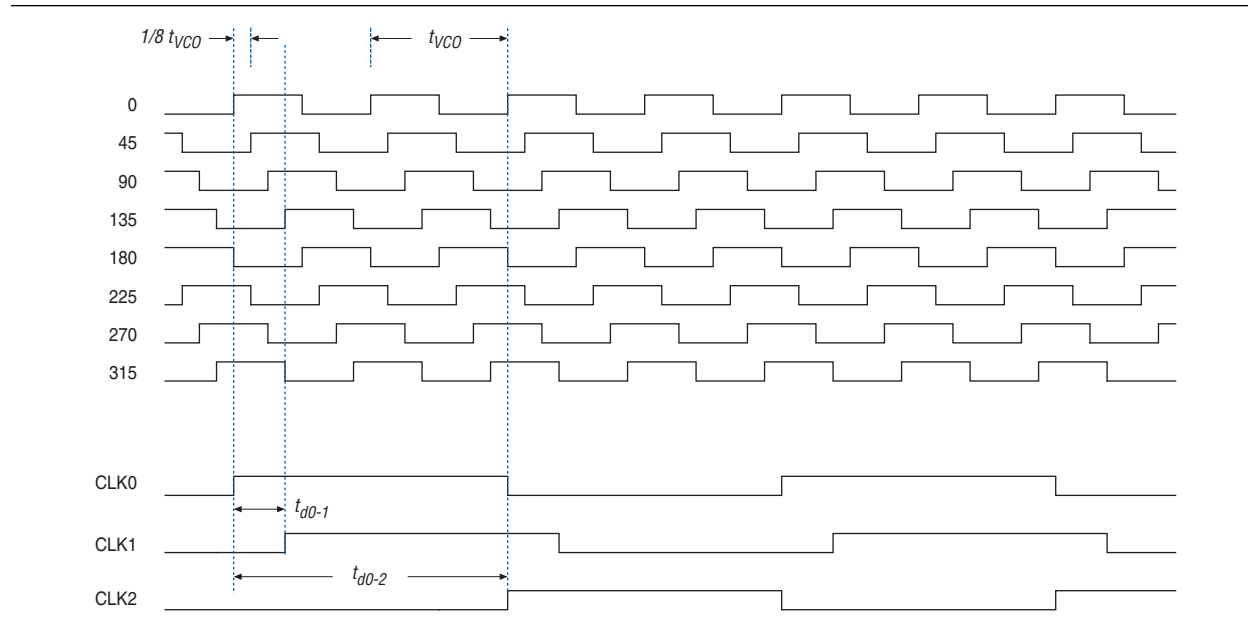
Equation 5-2. Coarse Resolution Phase Shift

$$\Phi_{\text{coarse}} = \frac{C-1}{f_{VCO}} = \frac{(C-1)N}{Mf_{REF}}$$

C is the count value set for the counter delay time (this is the initial setting in the PLL usage section of the compilation report in the Quartus II software). If the initial value is 1, $C - 1 = 0^\circ$ phase shift.

Figure 5–21 shows an example of phase shift insertion using fine resolution through VCO phase taps method. The eight phases from the VCO are shown and labeled for reference. In this example, CLK0 is based on 0° phase from the VCO and has the C value for the counter set to one. The CLK1 signal is divided by four, two VCO clocks for high time and two VCO clocks for low time. CLK1 is based on the 135° phase tap from the VCO and has the C value for the counter set to one. The CLK1 signal is also divided by four. In this case, the two clocks are offset by $3 \Phi_{\text{fine}}$. CLK2 is based on the 0° phase from the VCO but has the C value for the counter set to three. This creates a delay of two Φ_{coarse} (two complete VCO periods).

Figure 5–21. Delay Insertion Using VCO Phase Output and Counter Delay Time





You can use the coarse and fine phase shifts to implement clock delays in Cyclone IV devices.

Cyclone IV devices support dynamic phase shifting of VCO phase taps only. The phase shift is configurable for any number of times. Each phase shift takes about one `scanclk` cycle, allowing you to implement large phase shifts quickly.

PLL Cascading

Cyclone IV devices allow cascading between general purpose PLLs and multipurpose PLLs in normal or direct mode through the GCLK network. If your design cascades PLLs, the source (upstream) PLL must have a low-bandwidth setting, while the destination (downstream) PLL must have a high-bandwidth setting.

-  PLL_6 and PLL7 have upstream cascading capability only.
-  PLL cascading is not supported when used in transceiver applications.

PLL Reconfiguration

PLLs use several divide counters and different VCO phase taps to perform frequency synthesis and phase shifts. In PLLs of Cyclone IV devices, you can reconfigure both counter settings and phase shift the PLL output clock in real time. You can also change the charge pump and loop filter components, which dynamically affects PLL bandwidth. You can use these PLL components to update the output clock frequency, PLL bandwidth, and phase shift in real time, without reconfiguring the entire FPGA.

The ability to reconfigure the PLL in real time is useful in applications that might operate at multiple frequencies. It is also useful in prototyping environments, allowing you to sweep PLL output frequencies and adjust the output clock phase dynamically. For instance, a system generating test patterns is required to generate and send patterns at 75 or 150 MHz, depending on the requirements of the device under test. Reconfiguring PLL components in real time allows you to switch between two such output frequencies in a few microseconds.

You can also use this feature to adjust clock-to-out (t_{CO}) delays in real time by changing the PLL output clock phase shift. This approach eliminates the need to regenerate a configuration file with the new PLL settings.

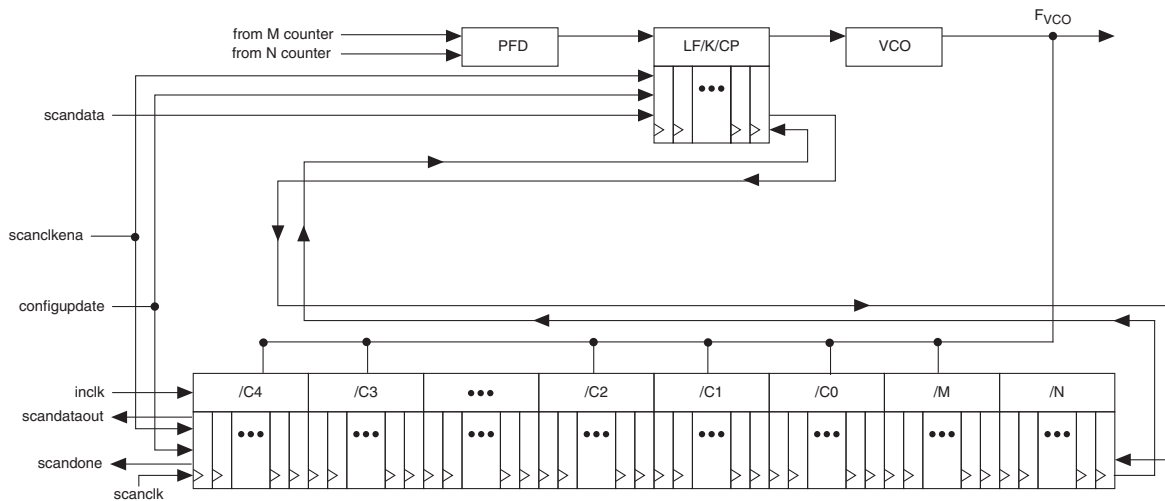
PLL Reconfiguration Hardware Implementation

The following PLL components are configurable in real time:

- Pre-scale counter (N)
- Feedback counter (M)
- Post-scale output counters (C0–C4)
- Dynamically adjust the charge pump current (I_{CP}) and loop filter components (R, C) to facilitate on-the-fly reconfiguration of the PLL bandwidth

Figure 5–22 shows how to adjust PLL counter settings dynamically by shifting their new settings into a serial shift register chain or scan chain. Serial data shifts to the scan chain via the `scandata` port, and shift registers are clocked by `scanc1k`. The maximum `scanc1k` frequency is 100 MHz. After shifting the last bit of data, asserting the `configupdate` signal for at least one `scanc1k` clock cycle synchronously updates the PLL configuration bits with the data in the scan registers.

Figure 5–22. PLL Reconfiguration Scan Chain



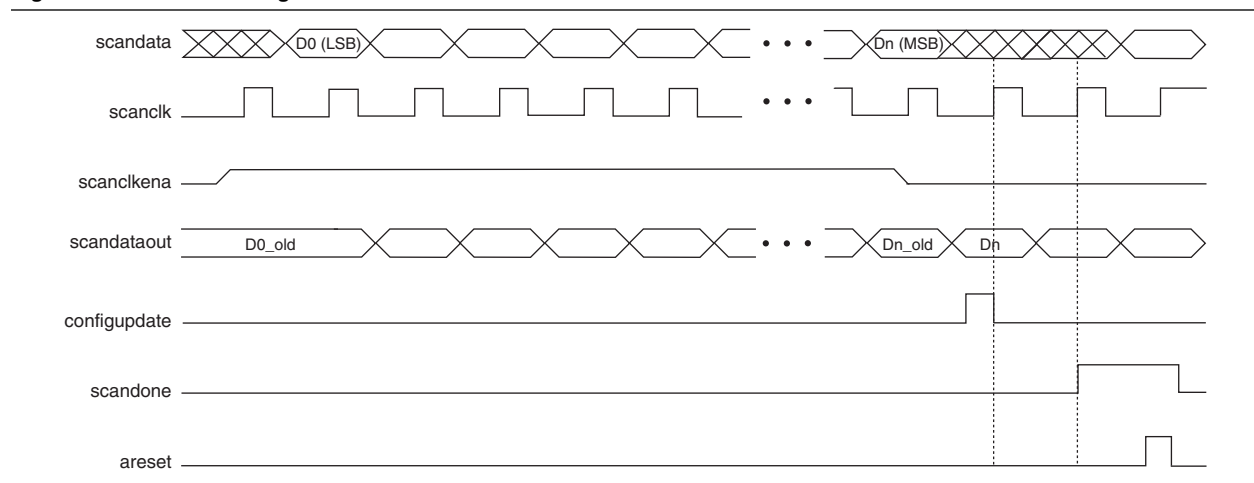
The counter settings are updated synchronously to the clock frequency of the individual counters. Therefore, not all counters update simultaneously.


To reconfigure the PLL counters, perform the following steps:

1. The `scanc1kena` signal is asserted at least one `scanc1k` cycle prior to shifting in the first bit of `scandata` (D0).
2. Serial data (`scandata`) is shifted into the scan chain on the second rising edge of `scanc1k`.
3. After all 144 bits have been scanned into the scan chain, the `scanc1kena` signal is de-asserted to prevent inadvertent shifting of bits in the scan chain.
4. The `configupdate` signal is asserted for one `scanc1k` cycle to update the PLL counters with the contents of the scan chain.
5. The `scandone` signal goes high indicating that the PLL is being reconfigured. A falling edge indicates that the PLL counters have been updated with new settings.
6. Reset the PLL using the `areset` signal if you make any changes to the M, N, post-scale output C counters, or the I_{CP} , R, C settings.
7. You can repeat steps 1 through 5 to reconfigure the PLL any number of times.

Figure 5-23 shows a functional simulation of the PLL reconfiguration feature.

Figure 5-23. PLL Reconfiguration Scan Chain



 When reconfiguring the counter clock frequency, the corresponding counter phase shift settings cannot be reconfigured using the same interface. You can reconfigure phase shifts in real time using the dynamic phase shift reconfiguration interface. If you reconfigure the counter frequency, but wish to keep the same non-zero phase shift setting (for example, 90°) on the clock output, you must reconfigure the phase shift after reconfiguring the counter clock frequency.

Post-Scale Counters (C0 to C4)

You can configure multiply or divide values and duty cycle of post-scale counters in real time. Each counter has an 8-bit high time setting and an 8-bit low time setting. The duty cycle is the ratio of output high or low time to the total cycle time, that is the sum of the two. Additionally, these counters have two control bits, `rbypass`, for bypassing the counter, and `rse1odd`, to select the output clock duty cycle.

When the `rbypass` bit is set to 1, it bypasses the counter, resulting in a divide by one. When this bit is set to 0, the PLL computes the effective division of the VCO output frequency based on the high and low time counters. For example, if the post-scale divide factor is 10, the high and low count values are set to 5 and 5, to achieve a 50–50% duty cycle. The PLL implements this duty cycle by transitioning the output clock from high-to-low on the rising edge of the VCO output clock. However, a 4 and 6 setting for the high and low count values, respectively, would produce an output clock with a 40–60% duty cycle.

The `rse1odd` bit indicates an odd divide factor for the VCO output frequency with a 50% duty cycle. For example, if the post-scale divide factor is three, the high and low time count values are 2 and 1, respectively, to achieve this division. This implies a 67%–33% duty cycle. If you need a 50%–50% duty cycle, you must set the `rse1odd` control bit to 1 to achieve this duty cycle despite an odd division factor. The PLL implements this duty cycle by transitioning the output clock from high-to-low on a falling edge of the VCO output clock. When you set `rse1odd` = 1, subtract 0.5 cycles from the high time and add 0.5 cycles to the low time.

For example:

- High time count = 2 cycles

- Low time count = 1 cycle
- `rse1odd = 1` effectively equals:
 - High time count = 1.5 cycles
 - Low time count = 1.5 cycles
 - Duty cycle = $(1.5/3)\%$ high time count and $(1.5/3)\%$ low time count

Scan Chain Description

Cyclone IV PLLs have a 144-bit scan chain.

Table 5-7 lists the number of bits for each component of the PLL.

Table 5-7. Cyclone IV PLL Reprogramming Bits

Block Name	Number of Bits		
	Counter	Other	Total
C4 ⁽¹⁾	16	2 ⁽²⁾	18
C3	16	2 ⁽²⁾	18
C2	16	2 ⁽²⁾	18
C1	16	2 ⁽²⁾	18
C0	16	2 ⁽²⁾	18
M	16	2 ⁽²⁾	18
N	16	2 ⁽²⁾	18
Charge Pump	9	0	9
Loop Filter ⁽³⁾	9	0	9
Total number of bits:			144

Notes to Table 5-7:

- (1) LSB bit for C4 low-count value is the first bit shifted into the scan chain.
- (2) These two control bits include `rbypass`, for bypassing the counter, and `rse1odd`, to select the output clock duty cycle.
- (3) MSB bit for loop filter is the last bit shifted into the scan chain.

Figure 5-24 shows the scan chain order of the PLL components.

Figure 5-24. PLL Component Scan Chain Order

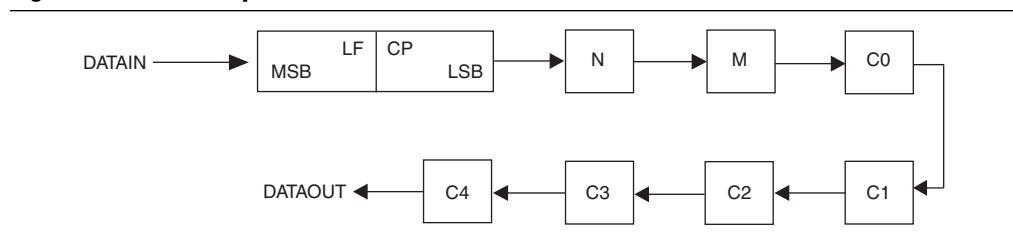
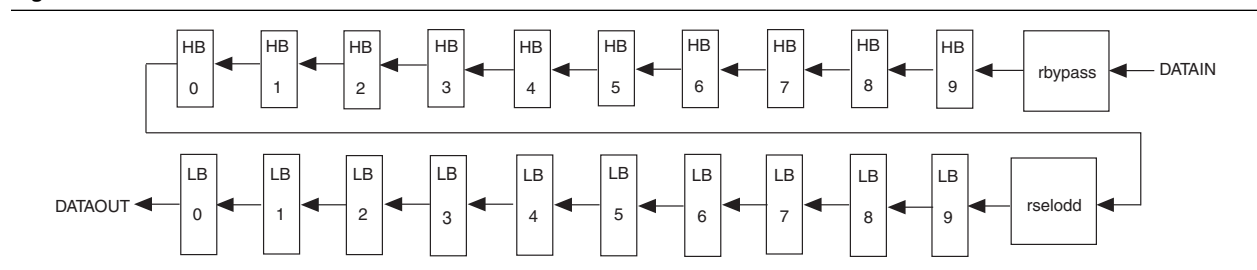


Figure 5-25 shows the scan chain bit order sequence for one PLL post-scale counter in PLLs of Cyclone IV devices.

Figure 5-25. Scan Chain Bit Order



Charge Pump and Loop Filter

You can reconfigure the charge pump and loop filter settings to update the PLL bandwidth in real time. Table 5-8 through Table 5-10 list the possible settings for charge pump current (I_{CP}), loop filter resistor (R), and capacitor (C) values for PLLs of Cyclone IV devices.

Table 5-8. Charge Pump Bit Control

CP[2]	CP[1]	CP[0]	Setting (Decimal)
0	0	0	0
1	0	0	1
1	1	0	3
1	1	1	7

Table 5-9. Loop Filter Resistor Value Control

LFR[4]	LFR[3]	LFR[2]	LFR[1]	LFR[0]	Setting (Decimal)
0	0	0	0	0	0
0	0	0	1	1	3
0	0	1	0	0	4
0	1	0	0	0	8
1	0	0	0	0	16
1	0	0	1	1	19
1	0	1	0	0	20
1	1	0	0	0	24
1	1	0	1	1	27
1	1	1	0	0	28
1	1	1	1	0	30

Table 5–10. Loop Filter Control of High Frequency Capacitor

LFC[1]	LFC[0]	Setting (Decimal)
0	0	0
0	1	1
1	1	3

Bypassing a PLL Counter

Bypassing a PLL counter results in a divide (N, C0 to C4 counters) factor of one.

Table 5–11 lists the settings for bypassing the counters in PLLs of Cyclone IV devices.

Table 5–11. PLL Counter Settings

PLL Scan Chain Bits [0..8] Settings									Description
LSB								MSB	
X	X	X	X	X	X	X	X	1 ⁽¹⁾	PLL counter bypassed
X	X	X	X	X	X	X	X	0 ⁽¹⁾	PLL counter not bypassed

Note to Table 5–11:

(1) Bypass bit.

To bypass any of the PLL counters, set the bypass bit to 1. The values on the other bits are then ignored.

Dynamic Phase Shifting

The dynamic phase shifting feature allows the output phase of individual PLL outputs to be dynamically adjusted relative to each other and the reference clock without sending serial data through the scan chain of the corresponding PLL. This feature simplifies the interface and allows you to quickly adjust t_{CO} delays by changing output clock phase shift in real time. This is achieved by incrementing or decrementing the VCO phase-tap selection to a given C counter or to the M counter. The phase is shifted by 1/8 the VCO frequency at a time. The output clocks are active during this phase reconfiguration process.

Table 5–12 lists the control signals that are used for dynamic phase shifting.

Table 5–12. Dynamic Phase Shifting Control Signals (Part 1 of 2)

Signal Name	Description	Source	Destination
phasecounterselect [2..0]	Counter Select. Three bits decoded to select either the M or one of the C counters for phase adjustment. One address map to select all C counters. This signal is registered in the PLL on the rising edge of <code>scanclk</code> .	Logic array or I/O pins	PLL reconfiguration circuit
phaseupdown	Selects dynamic phase shift direction; 1= UP, 0 = DOWN. Signal is registered in the PLL on the rising edge of <code>scanclk</code> .	Logic array or I/O pins	PLL reconfiguration circuit
phasestep	Logic high enables dynamic phase shifting.	Logic array or I/O pins	PLL reconfiguration circuit

Table 5-12. Dynamic Phase Shifting Control Signals (Part 2 of 2)

Signal Name	Description	Source	Destination
scanclk	Free running clock from core used in combination with <code>phasetestep</code> to enable or disable dynamic phase shifting. Shared with <code>scanclk</code> for dynamic reconfiguration.	GCLK or I/O pins	PLL reconfiguration circuit
phasedone	When asserted, it indicates to core logic that the phase adjustment is complete and PLL is ready to act on a possible second adjustment pulse. Asserts based on internal PLL timing. De-asserts on the rising edge of <code>scanclk</code> .	PLL reconfiguration circuit	Logic array or I/O pins

Table 5-13 lists the PLL counter selection based on the corresponding `PHASECOUNTERSELECT` setting.

Table 5-13. Phase Counter Select Mapping

phasecounterselect			Selects
[2]	[1]	[0]	
0	0	0	All Output Counters
0	0	1	M Counter
0	1	0	C0 Counter
0	1	1	C1 Counter
1	0	0	C2 Counter
1	0	1	C3 Counter
1	1	0	C4 Counter

To perform one dynamic phase-shift, follow these steps:

1. Set `PHASEUPDOWN` and `PHASECOUNTERSELECT` as required.
2. Assert `PHASESTEP` for at least two `SCANCLK` cycles. Each `PHASESTEP` pulse allows one phase shift.
3. Deassert `PHASESTEP` after `PHASEDONE` goes low.
4. Wait for `PHASEDONE` to go high.
5. Repeat steps 1 through 4 as many times as required to perform multiple phase-shifts.

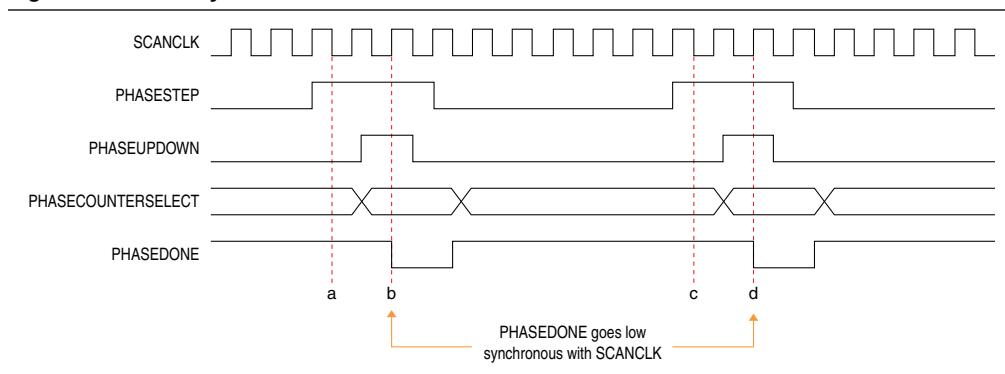
`PHASEUPDOWN` and `PHASECOUNTERSELECT` signals are synchronous to `SCANCLK` and must meet the t_{su} and t_h requirements with respect to the `SCANCLK` edges.



You can repeat dynamic phase-shifting indefinitely. For example, in a design where the VCO frequency is set to 1,000 MHz and the output clock frequency is set to 100 MHz, performing 40 dynamic phase shifts (each one yields 125 ps phase shift) results in shifting the output clock by 180°, in other words, a phase shift of 5 ns.

Figure 5-26 shows the dynamic phase shifting waveform.

Figure 5-26. PLL Dynamic Phase Shift



The PHASESTEP signal is latched on the negative edge of SCANCLK (a,c) and must remain asserted for at least two SCANCLK cycles. Deassert PHASESTEP after PHASEDONE goes low. On the second SCANCLK rising edge (b,d) after PHASESTEP is latched, the values of PHASEUPDOWN and PHASECOUNTERSELECT are latched and the PLL starts dynamic phase-shifting for the specified counters, and in the indicated direction. PHASEDONE is deasserted synchronous to SCANCLK at the second rising edge (b,d) and remains low until the PLL finishes dynamic phase-shifting. Depending on the VCO and SCANCLK frequencies, PHASEDONE low time may be greater than or less than one SCANCLK cycle.


You can perform another dynamic phase-shift after the PHASEDONE signal goes from low to high. Each PHASESTEP pulse enables one phase shift. PHASESTEP pulses must be at least one SCANCLK cycle apart.

 For information about the ALTPLL_RECONFIG MegaWizard™ Plug-In Manager, refer to the [ALTPLL_RECONFIG Megafunction User Guide](#).

Spread-Spectrum Clocking

Cyclone IV devices can accept a spread-spectrum input with typical modulation frequencies. However, the device cannot automatically detect that the input is a spread-spectrum signal. Instead, the input signal looks like deterministic jitter at the input of the PLL. PLLs of Cyclone IV devices can track a spread-spectrum input clock as long as it is in the input jitter tolerance specifications and the modulation frequency of the input clock is below the PLL bandwidth, that is specified in the fitter report. Cyclone IV devices cannot generate spread-spectrum signals internally.

PLL Specifications

 For information about PLL specifications, refer to the [Cyclone IV Device Datasheet](#) chapter.

Document Revision History

Table 5-14 lists the revision history for this chapter.

Table 5-14. Document Revision History

Date	Version	Changes
October 2012	2.4	<ul style="list-style-type: none"> ■ Updated “Manual Override” and “PLL Cascading” sections. ■ Updated Figure 5-9.
November 2011	2.3	<ul style="list-style-type: none"> ■ Updated the “Dynamic Phase Shifting” section. ■ Updated Figure 5-26.
December 2010	2.2	<ul style="list-style-type: none"> ■ Updated for the Quartus II software version 10.1 release. ■ Updated Figure 5-3 and Figure 5-10. ■ Updated “GCLK Network Clock Source Generation”, “PLLs in Cyclone IV Devices”, and “Manual Override” sections. ■ Minor text edits.
July 2010	2.1	<ul style="list-style-type: none"> ■ Updated Figure 5-2, Figure 5-3, Figure 5-4, and Figure 5-10. ■ Updated Table 5-1, Table 5-2, and Table 5-5. ■ Updated “Clock Feedback Modes” section.
February 2010	2.0	<ul style="list-style-type: none"> ■ Added Cyclone IV E devices information for the Quartus II software version 9.1 SP1 release. ■ Updated “Clock Networks” section. ■ Updated Table 5-1 and Table 5-2. ■ Added Table 5-3. ■ Updated Figure 5-2, Figure 5-3, and Figure 5-9. ■ Added Figure 5-4 and Figure 5-10.
November 2009	1.0	Initial release.