ECP5 and ECP5-5G sysCLOCK PLL/DLL Design and User Guide

Technical Note

FPGA-TN-02200-1.3

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## Acronyms in This Document

A list of acronyms used in this document.

<table>
<thead>
<tr>
<th>Acronym</th>
<th>Definition</th>
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<tbody>
<tr>
<td>BL</td>
<td>Bottom Left</td>
</tr>
<tr>
<td>BR</td>
<td>Bottom Right</td>
</tr>
<tr>
<td>DCCA</td>
<td>Dynamic Clock Select</td>
</tr>
<tr>
<td>DCSC</td>
<td>Dynamic Clock Control</td>
</tr>
<tr>
<td>DDR</td>
<td>Double Data Rate</td>
</tr>
<tr>
<td>FPGA</td>
<td>Field Programmable Gate Array</td>
</tr>
<tr>
<td>PLL</td>
<td>Phase-locked Loop</td>
</tr>
<tr>
<td>SED</td>
<td>Soft Error Detect</td>
</tr>
<tr>
<td>TL</td>
<td>Top Left</td>
</tr>
<tr>
<td>TR</td>
<td>Top Right</td>
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1. Introduction

This usage guide describes the clock resources available in the ECP5™ and ECP5-5G™ device architecture. Details are provided for primary clocks, edge clocks, PLLs, the internal oscillator, and clocking elements such as clock dividers, clock multiplexers, and clock stop blocks available in the ECP5 and ECP5-5G device. The number of PLLs, Edge clocks, and Clock dividers for each device is listed in Table 1.1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Description</th>
<th>LFE5-85</th>
<th>LFE5-45</th>
<th>LFE5-25</th>
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<tr>
<td>Number of PLLs</td>
<td>General purpose PLLs.</td>
<td>4</td>
<td>4</td>
<td>2</td>
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<tr>
<td>Number of Edge Clocks</td>
<td>Edge Clocks for high speed applications.</td>
<td>8</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Number of Clock Dividers</td>
<td>Edge Clock Dividers for DDR applications.</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Number of PCS Clock Dividers*</td>
<td>Clock dividers for domain crossing applications.</td>
<td>2</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Number of DDRDLLs</td>
<td>DDRDLL used to DDR memory and High Speed IO interfaces</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
</tbody>
</table>

*Note: LFE5U devices do not have PCS Clock Dividers.

It is very important to note that the user needs to validate their pinout so that correct pin placement is used. The Lattice Diamond® tools should be used to validate the pinout while designing the printed circuit board.

2. Clock/Control Distribution Network

ECP5 and ECP5-5G devices provide global clock distribution in the form of 16 global primary clocks. These Primary clocks can be divided into 16 clocks per each of the four quadrants; however there is a maximum of 60 unique clock input sources. The ECP5 and ECP5-5G primary clocking structure is enhanced as it features more Edge clock resources, more low-skew Primary clock resources and removes the Secondary clock resources.
3. ECP5 and ECP5-5G Top-Level View

A top level view of the major clocking resources for the ECP5 and ECP5-5G devices is shown in Figure 3.1.

![Figure 3.1. ECP5 and ECP5-5G Clocking Structure (LFE5-85)](image)

Note: LFE4U devices do not have PCS Clock Dividers

4. Clocking Architecture Overview

Below is a brief overview of the clocking structure, elements, and PLL. Greater detail is provided starting with the Appendix A. Primary Clock Sources and Distribution section.

4.1. Primary Clock Network

Up to 60 Primary Clock Sources (PLLs, External Inputs, SERDES, etc.) can be selected and routed to the Primary Clock Network. This gives the user an available 60 unique clock domains in the ECP5 and ECP5-5G.

The Primary Clock Network provides low-skew, high fanout clock distribution to all synchronous elements in the FPGA fabric. The Primary Clock Network is divided into four clocking quadrants: Top Left (TL), Bottom Left (BL), Top Right (TR), and Bottom Right (BR). Each of these quadrants has 16 clocks that can be distributed to the fabric in the quadrant. Initially, the Lattice Diamond software automatically routes each clock to all four quadrants; up to a maximum of 16 clocks since each clock is routed to all four quadrants. The user can change how the clocks are routed by specifying a preference in the Lattice Diamond software to locate the clock to specific quadrants.

4.2. Edge Clock Network

Edge clocks are low skew, high speed clock resources used to clock data into/out of the I/O logic of the ECP5 and ECP5-5G. There are two edge clocks per bank located on the left and right sides.
5. **Overview of Other Clocking Elements**

5.1. **Edge Clock Dividers (CLKDIVF)**
Clock dividers are provided to create the divided down clocks used with the I/O Mux/DeMux gearing logic (SCLK inputs to the DDR) and drives to the Primary Clock routing to the fabric. There are four clock dividers on the ECP5 and ECP5-5G device.

5.2. **PCS Clock Dividers (PCSCLKDIV)**
A new clock divider is provided to create phase-matched divided-down clocks for bus-widening/narrowing circuits. A port is provided to dynamically change the divide value of the input clock. The PCSCLKDIV will mainly be used to slow the clock rate from high speed SERDES applications by providing the clocks for domain crossing circuits. There is one PCSCLKDIV per SERDES on an LFESUM device.

5.3. **Dynamic Clock Select (DCSC)**
The ECP5 and ECP5-5G dynamic clock select provides run-time selectable glitchless or non-glitchless operation between two independent clock sources to the primary clock network. This clock select allows the selection of clock sources without leaving the dedicated clock resources in the device. There are two dynamic clock select blocks on the ECP5 and ECP5-5G device.

5.4. **Edge Clock Bridge with Clock Select (ECLKBRIDGECS)**
The ECLKBRIDGECS allows non-glitchless ECLK selection between two ECLks. The ECLKBRIDGECS will allow user bridge ECLK from one side to the other. There are two of these elements and they are used for ECLK clock bridging and ECLK selection.

5.5. **Edge Clock Stop (ECLKSYNCB)**
Each ECLK has a block to allow dynamic stopping of the edge clock. This allows the user to start and stop the clock synchronous to an event or external signal. These are important for applications requiring exact clock timing relationships on the inputs, such as DDR memories and video applications.

5.6. **Oscillator (OSCG)**
An internal programmable rate oscillator is provided. The oscillator can be used for master configuration modes when the FPGA sources the configuration clock, Soft Error Detect (SED), and as a user logic clock source that is available after FPGA configuration. There is one OSCG on the ECP5 and ECP5-5G device. The oscillator clock output is routed directly to primary clocking.

The oscillator output is not a high-accuracy clock, having a +/- 15% variation in its output frequency. It is mainly used for circuits that do not require a high degree of clock accuracy. Examples of usage would be asynchronous logic blocks such as a timer or reset generator, or other logic that require a constantly running clock.
6. sysCLOCK PLL Overview

The sysCLOCK PLLs can be used in a variety of clock management applications such as clock injection removal, clock phase adjustment, clock timing adjustment, and frequency synthesis (multiplication and division of a clock). The ECP5 and ECP5-5G Clarity Designer PLL GUI shows important timing parameters such as the VCO rate and the PLL loop bandwidth.

PLL Input sources are:
- Dedicated PLL Input Pins
- Primary Clock Routing
- Edge Clock Routing
- FPGA Fabric

![Figure 6.1. ECP5 and ECP5-5G PLL Block Diagram](image)

There are four PLLs on the bigger density devices LFE5-85 and LFE5-45 and two PLLs on the smaller density LFE5-25 device. There is one PLL on each corner of the device on the bigger density devices and the smaller density devices have one PLL only on the Lower Left and Lower Right corner. Each PLL has four outputs. All four PLL outputs can go to the Primary Clock network. Only the CLKOP and CLKOS outputs can go to the ECLK network.
7. PLL Features

7.1. Dedicated PLL Inputs

The PLLs have dedicated PLL input pins that are not Primary Clock input pins. Each of the Top Left and Right corner PLLs have two pairs of dedicated PLL input pins, one from the Left/Right side bank and the other from the Top bank. Either one of these can be used as input to the PLL.

The bottom two PLLs have one pair of dedicated input pin on the Left/Right side banks.

![Figure 7.1. PLL Input Pins for LFE5UM/LFE5UM5G-85 and LFE5UM/LFE5UM5G-45](image)

7.2. Input PLL Clock Selection (PLLREFCS)

The PLLREFCS component is a non-glitchless multiplexor that allows the user to dynamically select between two PLL input reference clocks. The PLLREFCS has the same input clock sources as the PLL. Since the dedicated PLL inputs are routed to the input of the PLLREFCS components a user can dynamically select between two external reference clock inputs for the top corners of the FPGA. This mux can also be used stand-alone with the PLL in bypass mode for more clock muxing capabilities.

7.3. Clock Injection Delay Removal

The clock injection delay removal feature of the PLL removes the delay associated with the PLL and clock tree. This feature is typically used to reduce clock to out timing and remove the delay differences between the PLL output clock and the data input. This feature is performed by aligning the input clock with a feedback clock from the clock tree. Optional delay may also be added to the feedback path to further reduce the clock injection time.
7.4. **Clock Phase Adjustment**

The clock phase adjustment feature of the PLL provides the ability to set a specific phase offset between the outputs of the PLL. New to the ECP5 and ECP5-5G device, phase adjustments can be calculated in much finer increments since the frequency is used to calculate the available phase increments. This feature is detailed further in the Dynamic Phase Adjustment section.

7.5. **Frequency Synthesis**

The PLL can be used to multiply up or divide down an input clock.

7.6. **Additional Features**

In addition to the major features, the PLL has several other options that can be used in conjunction with the major modes.

- A Standby mode to reduce power.
- Smaller phase shift increments are supported, based upon frequency.
8. Primary Clocks

8.1. Primary Clock Sources

The primary clock network has multiple inputs, called primary clock sources, which can be routed directly to the primary clock routing to clock the FPGA fabric.

The primary clock sources that can get to the primary clock routing are:

- Dedicated Clock Input Pins
- PLL Outputs
- CLKDIV Outputs
- Internal FPGA Fabric Entries (with minimum general routing)
- SERDES/PCS/PCSDIV clocks
- OSC Clock

All potential primary clock sources are multiplexed prior to going to the primary clock routing by a mid-mux. There are 56 mid-mux connections and four FPGA fabric connections, 60 total, routed to a multiplexor in the center of the chip called the centermux. From the centermux primary clocks are selected and distributed to the FPGA fabric. The maximum number of unique clock sources is 16 bottom mid-mux sources + 12 top mid-mux sources + 14 left midmux sources + 14 right mid-mux sources + 4 direct FPGA fabric entry points (from general routing) = 60. The basic clocking structure is shown in Figure 3.1 and elaborated in Appendix A. Primary Clock Sources and Distribution.

8.2. Primary Clock Routing

The primary clock routing network is made up of low skew clock routing resources with connectivity to every synchronous element of the device. Primary clock sources are selected at the mid-mux, then selected in the centermux and distributed on the primary clock routing to clock the synchronous elements in the FPGA fabric.

The primary clock routing network is divided into four sections, called quadrants. Figure 8.1 is a simplified view of Figure 3.1.
The centermux can source up to 16 independent primary clocks per quadrant which can clock the logic located in that quadrant. The centermux can also route each clock source to all quadrants. The Diamond software will automatically route a primary clock to all four quadrants in the FPGA.

8.3. Dedicated Clock Inputs

The ECP5 and ECP5-5G device has dedicated pins, called PCLK pins, to bring an external clock source into the FPGA and allow them to be used as FPGA primary clocks. These inputs route directly to the Primary clock network, or to Edge clock routing resources. A dedicated PCLK clock pin must always be used to route an external clock source to FPGA logic and I/O.

If an external input clock is being sourced to a PLL, then in most cases the input clock should use a dedicated PLL input pin. SERDES reference clocks also have dedicated SERDES reference clock pins. The ECP5 and ECP5-5G device allows a PLL reference clock or a SERDES reference clock to come from an external Primary Clock (PCLK) pin and route through the Primary clock network to drive the reference clock to the SERDES or the input of a PLL.
9. PCS Clock Dividers (PCSCLKDIV)

The ECP5 and ECP5-5G device has a new clock divider called the PCSCLKDIV. The PCSCLKDIV is built with our PCS / IP Core interaction in mind. Its main purpose is to allow our IP cores to do multi-rate clocking for cores that can change data rates. The specific features are:

- Capability to generate different divider clocks
- Input mux to change the divider value on-the-fly.
- Non-glitchless when the divider’s select mux input is changed.
- Data width changes in the fabric for widening / narrowing circuits. This element must allow clock domain crossing in the fabric registers.

There is one PCSCLKDIV per SERDES Channel on the bottom of the device where the SERDES blocks are located. The clock outputs of the PCSCLKDIV (CDIV1, CDIVX) are delay and phase matched to each other and has a run-time selectable divider value. The PCSCLKDIV clock input sources are:

- Up to four TX Channel Clocks
- Up to four RX Channel Clocks
- Clock from Routing

![Figure 9.1. PCSCLKDIV Connection Diagram](image)

The output PCS channel clocks route directly to the input of the PCSCLKDIV without requiring the use of a primary clock. The CDIV1 and CDIVX outputs route directly to the primary clock routing. Its function is to do bus widening/narrowing circuits in the FPGA fabric to reduce the fabric frequency. The PCSCLKDIV is not suitable for DDR I/O interfaces (ECLK to SCLK domain crossing).

![Figure 9.2. Logical Functional Timing of PCSCLKDIV Block](image)
An example design is shown in Figure 9.3. It is a flip-flop based clock domain crossing circuit between the CDIV1 and the CDIVX = 2 clock outputs of the PCSCLKDIV. In this example an IP core is using the PCSCLKDIV to change the operating frequency and bus width for a PCS (SERDES) application.

![Figure 9.3. PCSCLKDIV Example Usage](image)

### 9.1. PCSCLKDIV Component Definition

The PCSCLKDIV component can be instantiated in the source code of a design as defined in this section. Figure 9.4, Table 9.1 and Table 9.2 define the PCSCLKDIV component. Verilog and VHDL instantiations are included.

![Figure 9.4. PCSCLKDIV Component Symbol](image)

#### Table 9.1. PCSCLKDIV Component Port Definition

<table>
<thead>
<tr>
<th>Port Name</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLKI</td>
<td>I</td>
<td>Clock Input.</td>
</tr>
<tr>
<td>RST</td>
<td>I</td>
<td>Reset input – Active High, Asynchronously forces all outputs low.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— RST = 0 Clock output outputs are active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— RST = 1 Clock output outputs are OFF</td>
</tr>
<tr>
<td>SEL(2:0)</td>
<td>I</td>
<td>Signals are used for dynamically changing divide value.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— SEL = 000, Output = ‘0’</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— SEL = 001, +1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— SEL = 010, +2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— SEL = 011, +4</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— SEL = 100, +5</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— SEL = 101, +8</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— SEL = 110, +10</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— SEL = 111, Output = ‘0’</td>
</tr>
<tr>
<td>CDIV1</td>
<td>O</td>
<td>Output is the same frequency as the input clock. Delay matched to CDIVX.</td>
</tr>
<tr>
<td>CDIVX</td>
<td>O</td>
<td>Divide by 1, 2, 4, 5, 8, 10 Output Port.</td>
</tr>
</tbody>
</table>

#### Table 9.2. PCSCLKDIV Component Attribute Definition

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Value</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSR</td>
<td>Enable or Disable Global Reset Signal to Component</td>
<td>ENABLED, DISABLED</td>
<td>DISABLED</td>
</tr>
</tbody>
</table>
9.2. PCSCLKDIV Usage in VHDL

Component Instantiation
Library lattice;
use lattice.components.all;

Component and Attribute Declaration
component PCSCLKDIV
Generic (GSR : string);
Port (RST : in STD_LOGIC;
      CLKI : in STD_LOGIC;
      SEL : in STD_LOGIC_VECTOR(2 downto 0);
      CDIV1 : in STD_LOGIC;
      CDIVX : out STD_LOGIC);
end component;

PCSCLKDIV Instantiation
attribute GSR : string;
attribute GSR of I1 : label is “DISABLED”;
I1: PCSCLKDIV
generic map (GSR => “DISABLED”)
port map (RST => RST,
          CLKI => CLKI,
          SEL => SEL,
          CDIV1 => CDIV1,
          CDIVX => CDIVX);

9.3. PCSCLKDIV Usage in Verilog

Component and Attribute Declaration
module PCSCLKDIV (RST, CLKI, SEL, CDIV1, CDIVX);
parameter GSR = "DISABLED";// "ENABLED", "DISABLED"
input RST, CLKI;
input [2:0] SEL;
output CDIVX;
endmodule

PCSCLKDIV Instantiation
defparam I1.GSR = “DISABLED”;
PCSCLKDIV I1 (RST (RST),
      CLKI (CLKI),
      SEL (SEL),
      CDIV1 (CDIV1),
      CDIVX (CDIVX));
10. Dynamic Clock Select (DCSC)

The ECP5 and ECP5-5G device has two dynamic clock select (DCS) blocks that can drive to any or all the quadrants. The inputs to the DCS block come from all the output of MIDMUXs and local routing that is located at the center of the PLC array core. The output of the DCS is connected to one of the inputs of Primary Clock Center MUX.

Each DCS can select between two independent input clock sources. There are two modes of clock switching, a glitchless mode of operation, or a non-glitchless mode where the DCS operates as a regular mux. Figure 10.1 and Figure 10.2 show the glitchless / non-glitchless modes of operation. It should be noted that the clock source used as feedback into the GPLL should not be switched when using the DCS as it will lead to loss of lock for the GPLL.

As indicated there are two modes of clock switching. In non-glitchless mode (input MODESEL='1') the DCS acts like a regular mux, allowing glitches and runt pulses on the output, depending on when the clock is switched. The SEL and MODESEL inputs are driven by signals from the general routing fabric and are used to support the clock switching feature in the DCS.

In glitchless mode (input MODESEL='0') the DCS avoids glitches or runt pulses on the output clock, regardless of when the enable signal is toggled. In order to switch between clocks glitchlessly, both input clocks must be oscillating; otherwise the output clock will be ‘0’.

For glitchless operation, the “DCSMODE” attribute sets the behavior of the DCS output. The additional attribute values and their functions are shown in Table 10.2.

10.1. DCS Timing Diagrams

Figure 10.1 shows timing diagrams to show the operation of the DCS in Glitchless mode in conjunction with the DCSMODE attribute.
SEL[3:0] Changes to “0001”:
- Wait for CLK0 rising edge.
- Switch output at CLK1 rising edge.

SEL[3:0] Changes to “0010”:
- Wait for CLK0 falling edge.
- Switch output at CLK1 falling edge.

SEL[3:0] Changes to “0010”:
- Wait for CLK1 rising edge.
- Switch output at CLK0 rising edge.

SEL[3:0] Changes to “0001”:
- Wait for CLK1 falling edge.
- Switch output at CLK0 falling edge.

- Switch low @CLK0 falling edge.
- The attribute name indicates which clock will toggle. Other values of SEL will cause the output to remain low.
- SEL must not change during setup prior to rising clock.

- Switch low @CLK0 rising edge.
- The attribute name indicates which clock will toggle. Other values of SEL will cause the output to remain high.
- SEL must not change during setup prior to rising clock.

**Figure 10.1. Timing Diagrams by “DCSMODE” Attribute Setting, Glitchless Operation (MODESEL=’0’)***

**Figure 10.2. DCS Operation, Non-Glitchless Operation (MODESEL=’1’)**
10.2. DCSC Component Definition

The DCSC component can be instantiated in the source code of a design as defined in this section.

![DCSC Component Symbol](image)

**Figure 10.3. DCSC Component Symbol**

<table>
<thead>
<tr>
<th>Port Name</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLK0</td>
<td>I</td>
<td>Clock Input port 0 — Default.</td>
</tr>
<tr>
<td>CLK1</td>
<td>I</td>
<td>Clock Input port 1</td>
</tr>
<tr>
<td>SEL[1:0]</td>
<td>I</td>
<td>Input Clock Select bit (See Table 11.1 below)</td>
</tr>
<tr>
<td>MODESEL</td>
<td>I</td>
<td>Selects Glitchless ('0') or Non-Glitchless ('1') behavior.</td>
</tr>
<tr>
<td>DCSOUT</td>
<td>O</td>
<td>Clock Output Port</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Attribute Name</th>
<th>Description</th>
<th>SEL[1:0]</th>
<th>Attribute Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>DCSMODE Attributes</td>
<td></td>
<td>2'b01</td>
<td>2'b00/2'b11</td>
</tr>
<tr>
<td></td>
<td>Falling Edge Triggered</td>
<td>Clk0</td>
<td>Clk0_LOW</td>
</tr>
<tr>
<td></td>
<td>Rising Edge Triggered</td>
<td>Clk1</td>
<td>Clk1_LOW</td>
</tr>
<tr>
<td></td>
<td>Disabled Output is Low, Clk0</td>
<td>Clk0</td>
<td>Clk0_LOW</td>
</tr>
<tr>
<td></td>
<td>Disabled Output is High, Clk0</td>
<td>Clk0</td>
<td>Clk0_HIGH</td>
</tr>
<tr>
<td></td>
<td>Disabled Output is Low, Clk0</td>
<td>Clk1</td>
<td>Clk1_LOW</td>
</tr>
<tr>
<td></td>
<td>Disabled Output is High, Clk0</td>
<td>1</td>
<td>Clk1_HIGH</td>
</tr>
<tr>
<td></td>
<td>Clk0 Buffered</td>
<td>Clk0</td>
<td>Clk0</td>
</tr>
<tr>
<td></td>
<td>Clk1 Buffered</td>
<td>Clk1</td>
<td>Clk1</td>
</tr>
<tr>
<td></td>
<td>Tie Low</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Tie High</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>MODESEL= “1”</td>
<td>Non-Glitchless</td>
<td>Clk0</td>
</tr>
</tbody>
</table>
10.4. DCSC Usage in VHDL

Component Instantiation
Library lattice;
use lattice.components.all;

Component and Attribute Declaration
COMPONENT DCSC
GENERIC(DCSMODE : string := "POS");
PORT (CLK0 :IN STD_LOGIC;
CLK1 :IN STD_LOGIC;
SEL0 :IN STD_LOGIC;
SEL1:IN STD_LOGIC;
MODESEL :IN STD_LOGIC;
DCSOUT :OUT STD_LOGIC);
END COMPONENT;

DCSC Instantiation
attribute DCSMODE : string;
attribute DCSMODE of DCSinst0 : label is "POS";
I1: DCSC
generic map(
DCSMODE => "POS")
port map ( 
CLK0 => CLK0 ,
CLK1 => CLK1 ,
SEL0 => SEL0 ,
SEL1 => SEL1 ,
MODESEL => MODESEL ,
DCSOUT => DCSOUT);

10.5. DCSC Usage in Verilog

Component and Attribute Declaration
module DCSC(CLK0,CLK1,CLK2,CLK3,SEL0,SEL1,MODESEL,DCSOUT);
input CLK0;
input CLK1;
input SEL0;
input SEL1;
input MODESEL;
output DCSOUT;
endmodule

DCSC Instantiation
defparam DCSInst0.DCSMODE = “POS”;
DCSC DCSInst0 ( 
.CLK0 (CLK0),
.CLK1 (CLK1),
.SEL0 (SEL0),
.SEL1 (SEL1),
.MODESEL (MODESEL),
.DCSOUT (DCSOUT));
11. Dynamic Clock Control (DCCA)

The ECP5 and ECP5-5G device has a Dynamic Clock Control feature which allows internal logic dynamically to enable or disable quadrant primary clock network. The disable function will not create glitch and increase the clock latency to the primary clock network. Also, this dynamic clock control function can be disabled by a configuration memory fuse to always enable the primary clock network.

This DCC controls the clock sources from the Primary CLOCK MIDMUX before they are fed to the Primary Center MUXs that drive the quadrant clock network. When a clock network is disabled, all the logic fed by that clock does not toggle, hence reducing the overall power consumption of the device.

The ECP5 and ECP5-5G device clock architecture allows both DCC and DCS to function at the same. It should be noted that the clock source used as feedback into the GPLL should always keep enable signal “high” in the DCC, otherwise it will lead to loss of lock for the GPLL when toggling the enable signal.

![Glitchless DCC Functional Waveform](image)

Figure 11.1. Glitchless DCC Functional Waveform

11.1. DCCA Component Definition

The DCCA component can be instantiated in the source code of a design as defined in this section. Figure 11.2 and Table 11.1 show the DCCA definitions.

![DCCA Component Symbol](image)

Figure 11.2. DCCA Component Symbol

<table>
<thead>
<tr>
<th>Table 11.1. DCCA Component Port Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Port Name</strong></td>
</tr>
<tr>
<td>---------------</td>
</tr>
<tr>
<td>CLKI</td>
</tr>
<tr>
<td>CE</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>CLKO</td>
</tr>
</tbody>
</table>
11.2. DCCA Usage in VHDL

Component Instantiation
library lattice;
use lattice.components.all;
Component and Attribute Declaration
COMPONENT DCCA
  PORT (CLKI :IN STD_LOGIC;
        CE  :IN STD_LOGIC;
        CLKO :OUT STD_LOGIC);
END COMPONENT;

DCCA Instantiation
I1: DCCA
  port map (
    CLKI => CLKI,
    CE  => CE,
    CLKO => CLKO);

11.3. DCCA Usage in Verilog

Component and Attribute Declaration
module DCCA (CLKI,CE,CLKO);
  input CLKI;
  input CE;
  output CLKO;
endmodule

DCCA Instantiation
DCCA DCSInst0 (
  .CLKI (CLKI),
  .CE (CE),
  .CLKO (CLKO));
12. Internal Oscillator (OSCG)

The OSCG element performs multiple functions on the ECP5 and ECP5-5G device. It is used for configuration, SED, as well as optionally in user mode. In user mode, the OSCG element has the following features:

- It permits a design to be fully self-clocked, as long as the quality of the OSCG element’s silicon-based oscillator is adequate.
- It has a direct connection to primary clock routing through the left mid-mux.
- It can be configured for operation at a wide range of frequencies via configuration bits.

12.1. OSCG Component Definition

The OSCG component can be instantiated in the source code of a design as defined in this section. Figure 12.1 and Table 12.1 below show the OSCG definitions.

![Figure 12.1. OSCG Component Symbol](image)

Table 12.1. OSCG Component Port Definition

<table>
<thead>
<tr>
<th>Port Name</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>OSC</td>
<td>O</td>
<td>Clock Output Port</td>
</tr>
</tbody>
</table>

Table 12.2. OSCG Component Attribute Definition

<table>
<thead>
<tr>
<th>Port Name</th>
<th>Description</th>
<th>Value</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>DVI</td>
<td>Selects Divider Value</td>
<td>2 (~155.0 MHz) — 128 (~2.4 MHz)</td>
<td>2.4 MHz</td>
</tr>
</tbody>
</table>

12.2. OSCG Usage in VHDL

**OSCG Instantiation and AttributeDeclaration in VHDL**

```vhdl
COMPONENT OSCG
  -  synthesis translate_off
  GENERIC (DIV: integer := 128);
  -  synthesis translate_on
  PORT (  
    OSC : OUT std_logic);
END COMPONENT;

attribute DIV : integer;
attribute DIV of OSCInst0 : label is 128;

begin
  OSCInst0: OSCG
    - synthesis translate_off
  GENERIC MAP (DIV => 128)
    - synthesis translate_on
  PORT MAP (OSC => OSC);
```

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12.3. OSCG Usage in Verilog

**OSCG Instantiation and Attribute Declaration in Verilog**

```verilog
module OSC_TOP(OSC);
output OSC;
OSCG OSCinst0 (.OSC(OSC));
defparam OSCinst0.DIV = 128;
endmodule
```
13. Edge Clocks

Each ECP5 and ECP5-5G device I/O bank has four ECLK resources. These clocks, which have low injection time and skew, are used to clock I/O registers. Edge clock resources are designed for high speed I/O interfaces with high fan-out capability. Refer to Pinout Rules for Clocking in ECP5 and ECP5-5G Devices for detailed information on the ECLK locations and connectivity.

The sources of edge clocks are:

- Dedicated Clock (PCLK) pins
- DLLDEL output
- PLL outputs (CLKOP and CLKOS)
- ECLK Bridge
- Internal nodes

The ECP5 and ECP5-5G device has Edge Clock (ECLK) at the Left side and right side of the device. There are two ECLK network per bank IO. ECLK Input MUX collects all clock sources available shown in figure below. There are two ECLK Input MUXs, one on the left side and one on the right side. Each of these MUX will generate total of four ECLK Clock sources. Two of them drive the upper IO bank and two of them drive the lower IO bank. Two out of four also drive the ECLK Bridge Switch Block to form an ECLK Bridge high speed clock before drive the ECLK Tree Network.

![Figure 13.1. Edge Clock Sources Per Bank](image)

13.1. Edge Clock Dividers (CLKDIVF)

There are four edge clock dividers available in the ECP5 and ECP5-5G device, two per side of the device. The clock divider provides a single divided output with available divide values of 2 or 3.5. The inputs to the clock dividers are the edge clocks, PLL outputs and Primary Clock Input pins. The outputs of the clock divider drive the primary clock network and are mainly used for DDR I/O domain crossing.

13.2. CLKDIVF Component Definition

The CLKDIVF component can be instantiated in the source code of a design as defined in this section. Figure 13.2, Table 13.1, and Table 13.2 define the CLKDIVF component. Verilog and VHDL instantiations are included.
Table 13.1. CLKDIVF Component Port Definition

<table>
<thead>
<tr>
<th>Port Name</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLKI</td>
<td>I</td>
<td>Clock Input</td>
</tr>
<tr>
<td>RST</td>
<td>I</td>
<td>Reset input — Active High, Asynchronously forces all outputs low.</td>
</tr>
<tr>
<td>— RST = 0</td>
<td></td>
<td>Clock outputs are active</td>
</tr>
<tr>
<td>— RST = 1</td>
<td></td>
<td>Clock outputs are OFF</td>
</tr>
<tr>
<td>ALIGNWD</td>
<td>I</td>
<td>Signal is used for word alignment.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>When enabled it slips the output one cycle relative to the input clock.</td>
</tr>
<tr>
<td>CDIVX</td>
<td>O</td>
<td>Divide by 2 or 3.5 Output Port</td>
</tr>
</tbody>
</table>

Table 13.2. CLKDIVF Component Attribute Definition

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Value</th>
<th>Default</th>
</tr>
</thead>
<tbody>
<tr>
<td>GSR</td>
<td>Enable or Disable Global Reset Signal to Component</td>
<td>ENABLED, DISABLED</td>
<td>DISABLED</td>
</tr>
<tr>
<td>DIV</td>
<td>CLK Divider Value</td>
<td>2.0 or 3.5</td>
<td>2.0</td>
</tr>
</tbody>
</table>

The ALIGNWD input is intended for use with high-speed data interfaces such as DDR or 7:1 LVDS Video.

13.3. CLKDIVF Usage in VHDL

**Component Instantiation**

```vhdl
Library lattice;
use lattice.components.all;

Component and Attribute Declaration

component CLKDIVF
    Generic (DIV : string;
              GSR : string);
    Port (RST : in STD_LOGIC;
           CLKI : in STD_LOGIC;
           ALIGNWD : in STD_LOGIC;
           CDIVX : out STD_LOGIC);
end component;

CLKDIVF Instantiation

attribute DIV : string;
attribute DIV of I1 : label is "2.0";
attribute GSR : string;
attribute GSR of I1 : label is "DISABLED";

I1: CLKDIVF
    generic map (DIV => "2.0",
                 GSR => "DISABLED")
    port map (RST => RST,
              CLKI => CLKI,
              ALIGNWD => ALIGNWD,
              CDIVX => CDIVX);
```

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### 13.4. CLKDIVF Usage in Verilog

**Component and Attribute Declaration**

```verilog
module CLKDIVF (RST, CLKI, ALIGNWD, CDIVX);

parameter DIV = "2.0"; // "2.0", "3.5"
parameter GSR = "DISABLED"; // "ENABLED", "DISABLED"

input RST, CLKI, ALIGNWD;
output CDIVX;
endmodule
```

**CLKDIVF Instantiation**

```verilog
defparam I1.DIV = "2.0";
defparam I1.GSR = "DISABLED";
CLKDIVF I1 (  
    .RST   (RST)  
    ,.CLKI  (CLKI)  
    ,.ALIGNWD (ALIGNWD)  
    ,.CDIVX  (CDIVX)));
```
14. Edge Clock Bridge (ECLKBRIDGECS)

ECLK Clock Bridge provides to bridge the ECLK for banks on the same side or the ECLK of the left side and the right side. The ECLK Bridge enhances the communication of high speed clocks of the two edges with minimum skew to ECLK tree. There are two ECLK bridge components in the ECP5 and ECP5-5G device. There are two ECLK muxes on the left and two ECLK muxes on the right and they allow a user to bridge edge clocks to the left and right sides of the chip with minimal skew.

In the edge clock bridge there is a non-glitchless clock select mux that allows a design to switch between two different clock sources for each edge clock. This clock select mux is instantiated using the ECLKBRIDGECS primitive. Not all edge clocks can drive the ECLKBRIDGECS, one of the two ECLKs on the left and right side can be bridged. When connected to the ECLKBRIDGECS it would use up the ECLK1 of both banks on the left side and ECLK0 of both banks on the right side of the device.

14.1. ECLKBRIDGECS Component Definition

The ECLKBRIDGECS component must be instantiated in the source code of a design in order to bridge Edge clocks. Figure 14.1 and Table 14.1 define the ECLKBRIDGECS.

Note that an ECLKSYNCB module has to be always used after the ECLKBRIDGECS instance to be able to connect to the ECLK tree.

![Figure 14.1. ECLKBRIDGECS Component Symbol]

<table>
<thead>
<tr>
<th>Port Name</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLK0</td>
<td>I</td>
<td>Clock Input Port 0 — Default</td>
</tr>
<tr>
<td>CLK1</td>
<td>I</td>
<td>Clock Input Port 1</td>
</tr>
<tr>
<td>SEL</td>
<td>I</td>
<td>Select Port  — SEL = 0 for CLK0  — SEL = 1 for CLK1</td>
</tr>
<tr>
<td>ECSOUT</td>
<td>O</td>
<td>Clock Output Port</td>
</tr>
</tbody>
</table>
14.2. ECLKBRIDGECS Usage in VHDL

Component Instantiation
Library lattice;
use lattice.components.all;

Component and Attribute Declaration
COMPONENT ECLKBRIDGECS
  PORT
      (CLK0 : IN STD_LOGIC;
       CLK1 : IN STD_LOGIC;
       SEL  : IN STD_LOGIC;
       ECSOUT : OUT STD_LOGIC);
END COMPONENT;

ECLKBRIDGECS Instantiation
I1: ECLKBRIDGECS
port map
    (CLK0 => CLK0,
     CLK1 => CLK1,
     SEL  => SEL,
     ECSOUT => ECSOUT);

14.3. ECLKBRIDGECS Usage in Verilog

Component and Attribute Declaration
module ECLKBRIDGECS (CLK0,CLK1,SEL,ECSOUT);
  input CLK0;
  input CLK1;
  input SEL;
  output ECSOUT;
endmodule

DCSC Instantiation
ECLKBRIDGECS ECSInst0
    ECLKBRIDGECS
    .CLK0 (CLK0),
    .CLK1 (CLK1),
    .SEL  (SEL),
    .ECSOUT (ECSOUT));
15. Edge Clock Synchronization (ECLKSYNCB)

ECPS and ECP5-5G devices have dynamic edge clock synchronization control (ECLKSYNCB) which allows each edge clock to be disabled or enabled glitchlessly from core logic if desired. This allows the designer to synchronize the edge clock to an event or external signal if desired. It also allows the design to dynamically disable a clock and its associated logic in the design when it is not needed and thus save power. Applications such as DDR2, DDR3 and 7:1 LVDS for displays will use this component for clock synchronization.

15.1. ECLKSYNCB Component Definition

The ECLKSYNCB component can be instantiated in the source code of a design as defined in this section. Asserting the STOP control signal has the ability to stop the edge clock in order to synchronize the signals derived from ECLK and used in high speed DDR mode applications as DDR memory, generic DDR and 7:1 LVDS.

Control signal STOP is synchronized with ECLK when asserted. When control signal STOP is asserted, the clock output will be forced to low after the fourth falling edge of the input ECLKI. When the STOP signal is released, the clock output starts to toggle at the fourth (4th) rising edge of the input ECLKI clock.

Figure 15.1 and Table 15.1 show the ECLKSYNCB component definition.

![Figure 15.1. ECLKSYNCB Component Symbol](image)

Table 15.1. ECLKSYNCB Component Port Definition

<table>
<thead>
<tr>
<th>Port Name</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECLKI</td>
<td>I</td>
<td>Clock Input port.</td>
</tr>
<tr>
<td>STOP</td>
<td>I</td>
<td>Control signal to stop Edge Clock</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— STOP = 0 Clock is Active</td>
</tr>
<tr>
<td></td>
<td></td>
<td>— STOP = 1 Clock is Off</td>
</tr>
<tr>
<td>ECLKO</td>
<td>O</td>
<td>Clock Output Port</td>
</tr>
</tbody>
</table>

![Figure 15.2. ECLKSYNC Functional Waveform](image)
15.2. ECLKSYNCB Usage in VHDL

Component Instantiation

```vhdl
Library lattice;
use lattice.components.all;
```

Component and Attribute Declaration

```vhdl
COMPONENT ECLKSYNCB
PORT
  (ECLKI : IN STD_LOGIC;
   STOP : IN STD_LOGIC;
   ECLKO : OUT STD_LOGIC);
END COMPONENT;
```

ECLKSYNCB Instantiation

```vhdl
I1: ECLKSYNCB
port map (
  ECLKI => ECLKI,
  STOP => STOP,
  ECLKO => ECLKO);
```

ECLKSYNCB Usage in Verilog

Component and Attribute Declaration

```verilog
module ECLKSYNCB (ECLKI,STOP,ECLKO);
input ECLKI;
input STOP;
output ECLKO;
endmodule
```

ECLKSYNCB Instantiation

```verilog
ECLKSYNCB ECLKSYNCInst0 (
  .ECLKI (ECLKI),
  .STOP (STOP),
  .ECLKO (ECLKO));
```
16. General Routing for Clocks

The ECP5 and ECP5-5G device architecture supports the ability to use data routing, or general routing, for a clock. This capability is intended to be used for small areas of the design to allow additional flexibility in linking dedicated clocking resources and building very small clock trees. General routing cannot be used for edge clocks for applications that use the DDR registers in the I/O components of the FPGA.

Software will limit the distance of a general routing based (gated) clock to one PLC in distance to a primary clock entry point. If the software cannot place the clock gating logic close enough to a primary clock entry point then an error will occur:

ERROR – par: Unable to reach a primary clock entry point for general route clock <net> in the minimum required distance of one PLC.

There are multiple entry points to the Primary clock routing throughout the ECP5 and ECP5-5G device fabric. In this case it is recommended to add a preference for this gated clock to use primary routing.

![Diagram 1](image1.png)

**Figure 16.1. Gated Clock to the Primary Clock Routing**

For a very small clock domain, the user can limit the distance of a general routing based (gated) clock to one PLC in distance to the logic it clocks. The user must group this logic (UGROUP) with a BBOX = “1, 1” (see Diamond Help > Constraints Reference Guide > Preferences > UGROUP) as well as specify a “PROHIBIT PRIMARY” on the generated clock. If the software cannot place the logic tree within the BBOX, then an error message will occur.

![Diagram 2](image2.png)

**Figure 16.2. Gated Clock to Small Logic Domain**
17. General Routing PCLK Pins

Some Dedicated pins (GR_PCLK) can access some CIBs along the edge of the device and can drive the primary clock routing from this CIB. These will go through some general routing but have direct access to the primary clock from this dedicated CIB. There are four at the left side and right side, four at the top side of the device. These pins can be used when user runs out of PCLK pins. Note that for any DDR interface, it is still required to use dedicated clock pins and clock trees.
18. sysCLOCK PLL

The ECP5 and ECP5-5G PLL provides features such as clock injection delay removal, frequency synthesis, and phase adjustment. Figure 18.1 shows a block diagram of the ECP5 and ECP5-5G PLL.

![Figure 18.1. ECP5 and ECP5-5G PLL Block Diagram](image)

Figure 18.2. PLL Component Instance

![Figure 18.2. PLL Component Instance](image)
### Table 18.1. PLL Component Port Definition

<table>
<thead>
<tr>
<th>Signal</th>
<th>I/O</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLKI</td>
<td>I</td>
<td>Input Clock to PLL.</td>
</tr>
<tr>
<td>CLKFB</td>
<td>I</td>
<td>Feedback Clock.</td>
</tr>
<tr>
<td>CLKINTFB</td>
<td>O</td>
<td>Internal Feedback Clock.</td>
</tr>
<tr>
<td>PHASESEL[1:0]</td>
<td>I</td>
<td>Select the output affected by Dynamic Phase adjustment.</td>
</tr>
<tr>
<td>PHASEDIR</td>
<td>I</td>
<td>Dynamic Phase adjustment direction.</td>
</tr>
<tr>
<td>PHASESTEP</td>
<td>I</td>
<td>Dynamic Phase adjustment step.</td>
</tr>
<tr>
<td>PHASELOADREG</td>
<td>I</td>
<td>Load dynamic phase adjustment values into PLL.</td>
</tr>
<tr>
<td>STDBY</td>
<td>I</td>
<td>Standby signal to power down the PLL.</td>
</tr>
<tr>
<td>RST</td>
<td>I</td>
<td>Resets the whole PLL.</td>
</tr>
<tr>
<td>ENCLKOP</td>
<td>I</td>
<td>Enable PLL output CLKOP.</td>
</tr>
<tr>
<td>ENCLKOS</td>
<td>I</td>
<td>Enable PLL output CLKOS.</td>
</tr>
<tr>
<td>ENCLKOS2</td>
<td>I</td>
<td>Enable PLL output CLKOS2.</td>
</tr>
<tr>
<td>ENCLKOS3</td>
<td>I</td>
<td>Enable PLL output CLKOS3.</td>
</tr>
<tr>
<td>PLLWAKESYNC</td>
<td>I</td>
<td>Enable PLL switching from internal feedback to user feedback path when PLL wake up.</td>
</tr>
<tr>
<td>CLKOP</td>
<td>O</td>
<td>PLL main output clock.</td>
</tr>
<tr>
<td>CLKOS</td>
<td>O</td>
<td>PLL output clock.</td>
</tr>
<tr>
<td>CLKOS2</td>
<td>O</td>
<td>PLL output clock.</td>
</tr>
<tr>
<td>CLKOS3</td>
<td>O</td>
<td>PLL output clock.</td>
</tr>
<tr>
<td>LOCK</td>
<td>O</td>
<td>PLL LOCK to CLKI, Asynchronous signal. Active high indicates PLL lock.</td>
</tr>
<tr>
<td>INTLOCK</td>
<td>O</td>
<td>Internal Lock Signal.</td>
</tr>
<tr>
<td>REFCLK</td>
<td>O</td>
<td>Output of Reference clock mux.</td>
</tr>
</tbody>
</table>

### 18.1. Functional Description

#### 18.1.1. Refclk (CLKI) Divider
The CLKI divider is used to control the input clock frequency into the PLL block. The valid input frequency range is specified in the device data sheet.

#### 18.1.2. Feedback Loop (CLKFB) Divider
The CLKFB divider is used to divide the feedback signal, effectively multiplying the output clock. The VCO block increases the output frequency until the divided feedback frequency equals the input frequency. The output of the feedback divider must be within the phase detector frequency range specified in the device data sheet. This port is only available to user interface when “user clock” option is selected for feedback clock, otherwise this port will be connected by the tool to appropriate signal as selected by the user in the software.

#### 18.1.3. Output Clock Dividers (CLKOP, CLKOS, CLKOS2, CLKOS3)
The output clock dividers allow the VCO frequency to be scaled up to the maximum range to minimize jitter. Each of the output dividers is independent of the other dividers and each uses the VCO as the source by default. Each of the output dividers can be set to a value of 1 to 128.

#### 18.1.4. Phase Adjustment (Static Mode)
The CLKOP, CLKOS, CLKOS2, and CLKOS3 outputs can be phase adjusted relative to the enabled unshifted output clock. New to the ECP5 and ECP5-5G device, phase adjustments are now calculated values in the software tools based on VCO clock frequency. This provides a finer phase shift depending on the required frequency. The clock output selected as the feedback cannot use the static phase adjustment feature since it will cause the PLL to unlock. For example if the FB_MODE is INT_OP or CLKOP, then there should be no phase shift on CLKOP. Similar restriction would apply on other clocks.
18.1.5. Phase Adjustment (Dynamic Mode)

The phase adjustments can also be controlled in a dynamic mode using the PHASESEL, PHASEDIR, PHASESTEP, and PHASELOADREG ports. The clock output selected as the feedback should not use the dynamic phase adjustment feature. Please see the Dynamic Phase Adjustment section in this document for usage details. The clock output selected as the feedback cannot use the dynamic phase adjustment feature since it will cause the PLL to unlock. For example if the FB_MODE is INT_OP or CLKOP, then there should be no phase shift on CLKOP.

Similar restriction would apply on other clocks.

18.2. PLL Features

18.2.1. Dedicated PLL Inputs

Every PLL has a dedicated low skew input that will route directly to its reference clock input. These are the recommended inputs for a PLL. It is possible to route a PLL input from the Primary clock routing, but it incurs more clock input injection delay, which is not natively compensated for using feedback, than a dedicated PLL input. There is one PLLs in each corner of the FPGA on bigger densities. Each of the PLL on the top left and right corners have two pairs dedicated PLL inputs that user can choose from. Both of these inputs can route to the PLL in the top side corner. The PLLs on the bottom corners each have one pair of dedicated PLL input pin.

18.2.2. PLL Input Clock Mux (PLLREFCS)

Each ECP5 and ECP5-5G PLL contains an input mux to dynamically switch between two input reference clocks. The output of the PLLREFCS is routed directly into the PLL. There is one PLLREFCS component in each top left and right corner of the FPGA. In order to enhance the clock muxing capability of the ECP5 and ECP5-5G device, the dedicated clock inputs for the PLLs in each corner are routed to the PLLREFCS component in a corner along with the other potential PLL sources such as edge clocks and primary clocks. This structure is seen in Figure 18.3.

![Figure 18.3. PLL Dedicated Inputs to the PLLREFCS Component for Top Left and Right PLL](image)

This adds a lot of flexibility for designs that need to switch between two external clocks.

18.2.3. Standby Mode

The ECP5 and ECP5-5G device PLL contains a Standby Mode that allows the PLL to be placed into a standby state to save power when not needed in the design. Standby mode is very similar to holding the PLL in reset since the VCO will be turned off and will need to regain lock when exiting standby. In both cases, reset and standby mode, the PLL will retain its programming.

Users MUST hold the PLL in standby for a minimum of 1 ms in order to be sure the PLL analog circuits are fully reset and to have a stable analog startup.
18.3. PLL Inputs and Outputs

18.3.1. CLKI Input
The CLKI signal is the reference clock for the PLL. It must conform to the specifications in the data sheet in order for the PLL to operate correctly. The CLKI signal can come from a dedicated PLL input pin or from internal routing. The dedicated dual-purpose I/O pin provides a low skew input path and is the recommended source for the PLL. The reference clock can be divided by the input (M) divider to create one input to the phase detector of the PLL.

18.3.2. CLKFB Input
The CLKFB signal is the feedback signal to the PLL. The feedback signal is used by the Phase Frequency Detector inside the PLL to determine if the output clock needs adjustment to maintain the correct frequency and phase. The CLKFB signal can come from a primary clock net (feedback mode = CLKO[P/S/S2/S3]) to remove the primary clock routing injection delay, from a dedicated external dual-purpose I/O pin (feedback mode = UserClock) to account for board level clock alignment, or an internal PLL connection (feedback mode = INT_O[P/S/S2/S3]) for simple feedback. The feedback clock signal will be divided by the feedback (N) divider to create an input to the VCO of the PLL. A bypassed PLL output cannot be used as the feedback signal.

18.3.3. RST Input
At power-up an internal power-up reset signal from the configuration block resets the PLL. At runtime an active high, asynchronous, user-controlled PLL reset signal can be provided as a part of the PLL module. The RST signal can be driven by an internally generated reset function or by an I/O pin. This RST signal resets the PLL core (VCO, phase detector, and charge pump) and the output dividers which will cause the outputs to be logic ‘0’. In bypass mode the output will not be reset.

After the RST signal is de-asserted the PLL will start the lock-in process and will take tLOCK time, about 16 ms, to complete PLL lock. Figure below shows the timing diagram of the RST input. The RST signal is active high. The RST signal is optional. Trst = 1 ms reset pulse width, Trstrec = 1 ns time after a reset before the divider output starts counting again.

![Figure 18.4. RST Input Timing Diagram](image-url)
18.3.4. Dynamic Clock Enables

Each PLL output has a user input signal to dynamically enable / disable its output clock glitchlessly. When the clock enable signal is set to logic ‘0’, the corresponding output clock is held to logic ‘0’.

Table 18.2. PLL Clock Output Enable Signal List

<table>
<thead>
<tr>
<th>Clock Enable Signal Name</th>
<th>Corresponding PLL Output</th>
<th>Clarity Designer Option Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>ENCLKOP</td>
<td>CLKOP</td>
<td>&quot;Clock Enable OP&quot;</td>
</tr>
<tr>
<td>ENCLKOS</td>
<td>CLKOS</td>
<td>&quot;Clock Enable OS&quot;</td>
</tr>
<tr>
<td>ENCLKOS2</td>
<td>CLKOS2</td>
<td>&quot;Clock Enable OS2&quot;</td>
</tr>
<tr>
<td>ENCLKOS3</td>
<td>CLKOS3</td>
<td>&quot;Clock Enable OS3&quot;</td>
</tr>
</tbody>
</table>

This allows the user to save power by stopping the corresponding output clock when not in use. The clock enable signals are optional and will only be available if the user has selected the corresponding option in Clarity Designer. If a clock enable signal is not requested, its corresponding output will be active at all times when the PLL is instantiated unless the PLL is placed into standby mode. The user cannot access a clock enable signal in Clarity Designer when using it for external feedback in order to avoid shutting off the feedback clock input.

18.3.5. STDBY Input

The STDBY signal is used to put the PLL into a low power standby mode when it is not required. The STDBY signal is optional and will only be available if the user has selected the Standby port option in Clarity Designer. The STDBY signal is active high. When asserted the PLL outputs are pulled to “0” and the PLL will be reset. Users need to stay in the STDBY mode for at least 1 ms to make sure the PLL analog circuits are fully reset and to have a stable analog startup.

18.3.6. Dynamic Phase Shift Inputs

The ECP5 and ECP5-5G PLL has five ports to allow for dynamic phase adjustment from FPGA logic. The Dynamic Phase Adjustment section will elaborate on how the user should drive these ports.

18.3.7. PHASESEL Input

The PHASESEL[1:0] inputs are used to specify which PLL output port will be affected by the dynamic phase adjustment ports. The settings available are shown in the Dynamic Phase Adjustment section. The PHASESEL signal must be stable for 5 ns before the PHASESTEP or PHASELOADREG signals are pulsed. The PHASESEL signal is optional and will be available if the user has selected the “Dynamic Phase Ports” option in Clarity Designer.

Table 18.3. PHASESEL signal settings definition

<table>
<thead>
<tr>
<th>PHASESEL[1:0]</th>
<th>PLL Output Shifted</th>
</tr>
</thead>
<tbody>
<tr>
<td>00</td>
<td>CLKOS</td>
</tr>
<tr>
<td>01</td>
<td>CLKOS2</td>
</tr>
<tr>
<td>10</td>
<td>CLKOS3</td>
</tr>
<tr>
<td>11</td>
<td>CLKOP</td>
</tr>
</tbody>
</table>

18.3.8. PHASEDIR Input

The PHASEDIR input is used to specify which direction the dynamic phase shift will occur, advanced (leading) or delayed (lagging). When PHASEDIR = 0 then the phase shift will be delayed. When PHASEDIR = 1 then the phase shift will be advanced. The PHASEDIR signal must be stable for 5 ns before the PHASESTEP or PHASELOADREG signals are pulsed. The PHASEDIR signal is optional and will be available if the user has selected the Dynamic Phase ports option in Clarity Designer.

Table 18.4. PHASEDIR signal settings definition

<table>
<thead>
<tr>
<th>PHASEDIR</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Delayed (lagging)</td>
</tr>
<tr>
<td>1</td>
<td>Advanced (leading)</td>
</tr>
</tbody>
</table>
18.3.9. PHASESTEP Input

The PHASESTEP signal is used to initiate a VCO dynamic phase shift for the clock output port and in the direction specified by the PHASESEL and PHASEDIR inputs. This phase adjustment is done by changing the phase of the VCO in 45° increments. The VCO phase changes on the negative edge of the PHASESTEP input after four VCO cycles. This is an active low signal and the minimum pulse width (both high and low) of PHASESTEP pulse is four cycles of VCO running period. The PHASESTEP signal is optional and will be available if the user has selected the Dynamic Phase ports option in Clarity Designer. The PHASESEL and PHASEDIR are required to have a setup time of 5 ns prior to PHASESTEP falling edge.

18.3.10. PHASELOADREG Input

The PHASELOADREG signal is used to initiate a post-divider dynamic phase shift, relative to the unshifted output, for the clock output port and in the direction specified by the PHASESEL and PHASEDIR inputs. A phase shift is started on the falling edge of the PHASELOADREG signal and there is a minimum pulse width of 10 ns from assertion to deassertion. The PHASESEL and PHASEDIR are required to have a setup time of 5 ns prior to PHASELOADREG falling edge. The PHASELOADREG signal is optional and will be available if the user has selected the Dynamic Phase ports option in Clarity Designer.

18.3.11. PLL Clock Outputs

The PLL has four outputs, listed in Table 18.5. All four outputs can be routed to the Primary clock routing of the FPGA. All four outputs can be phase shifted statically or dynamically if external feedback on the clock is not used. They can also statically or dynamically adjust their output duty cycle. The outputs can come from their output divider or the reference clock input (PLL bypass). In bypass mode the output divider can be bypassed or used to divide the reference clock.

Table 18.5. PLL Clock Outputs and ECLK Connectivity

<table>
<thead>
<tr>
<th>Clock Output Name</th>
<th>Edge Clock Connectivity</th>
<th>Selectable Output</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLKOP</td>
<td>Right, Left ECLKs</td>
<td>Always Enabled</td>
</tr>
<tr>
<td>CLKOS</td>
<td>Right, Left ECLKs</td>
<td>Selectable via Clarity Designer</td>
</tr>
<tr>
<td>CLKOS2</td>
<td>No ECLK Connection</td>
<td>Selectable via Clarity Designer</td>
</tr>
<tr>
<td>CLKOS3</td>
<td>No ECLK Connection</td>
<td>Selectable via Clarity Designer</td>
</tr>
</tbody>
</table>

18.3.12. LOCK Output

The LOCK output provides information about the status of the PLL. After the device is powered up and the input clock is valid, the PLL will achieve lock within 16 ms. Once lock is achieved, the PLL LOCK signal will be asserted. The LOCK signal can be set in Clarity Designer in either the default “unsticky” frequency lock mode by checking the “Provide PLL Lock Signal” or sticky lock mode by selecting “PLL Lock is Sticky”. In sticky lock mode, once the LOCK signal is asserted (logic ‘1’) it will stay asserted until a PLL reset is asserted. In the default lock mode of “unsticky” frequency lock, if during operation the input clock or feedback signals to the PLL become invalid the PLL will lose lock and the LOCK output will de-assert (logic ‘0’). It is recommended to assert PLL RST to re-synchronize the PLL to the reference clock when the PLL loses lock. The LOCK signal is available to the FPGA routing to implement the generation of the RST signal if requested by the designer. The LOCK signal is optional and will be available if the user has selected the Provide PLL Lock signal option in Clarity Designer.
18.4. Dynamic Phase Adjustment

Dynamic phase adjustment of the PLL output clocks can be affected without reconfiguring the FPGA by using the dedicated dynamic phase-shift ports of the PLL. All four output clocks, CLKOP, CLKOS, CLKOS2 & CLKOS3 have the dynamic phase adjustment feature but only one output clock can be adjusted at a time. Table above shows the output clock selection settings available for the PHASESEL[1:0] signal. The PHASESEL signal must be stable for 5 ns before the PHASESTEP or PHASELOADREG signals are pulsed.

The selected output clock phase will either be advanced or delayed depending upon the value of the PHASEDIR port or signal. Table 18.4 shows the PHASEDIR settings available. The PHASEDIR signal must be stable for 5 ns before the PHASESTEP or PHASELOADREG signals are pulsed.

18.4.1. VCO Phase Shift

Once the PHASESEL and PHASEDIR have been set, a VCO phase adjustment is made by toggling the PHASESTEP signal from the current setting. Each pulse of the PHASESTEP signal will generate a phase step based on this equation:

\[
\frac{(CLKO<n>_FPHASE - m + n)}{(8*CLKO<n>_DIV)} \times 360 
\]

- where m is the number of toggles when PHASEDIR=0 and n is the number of toggles when PHASEDIR=1.
- Where \(<n>\) is the clock output specified by PHASESEL (CLKOP/OS2/OS3). Values for CLKO<\(<n>\>_FPHASE and CLKO<\(<n>\>_DIV are located in the HDL source file.

The PHASESTEP signal is latched in on the falling edge and is subject to a minimum wait of four VCO cycles prior to pulsing the signal again. One step size is the smallest phase shift that can be generated by the PLL in one pulse. The dynamic phase adjustment results in a glitch free adjustment when delaying the output clock, but glitches may result when advancing the output clock.

\[\text{Figure 18.5. PLL Phase Shifting Using the PHASESTEP Signal}\]

For Example:
PHASESEL[1:0]=2'b00 to select CLKOS for phase shift
PHASEDIR =1'b0 for selecting delayed (lagging) phase
Assume the output is divided by 2, CLKOS_DIV = 2
The CLKOS_FPHASE is set to 1
The above signals need to be stable for 5 ns before the falling edge of PHASESTEP and the minimum pulse width of PHASESTEP should be four VCO clock cycles. It should also stay low for four VCO Clock Cycles.
For each toggling of PHASESTEP, you will get \([1/(8*2)] \times 360 = 22.5\) degree phase shift (delayed).

18.4.2. Divider Phase Shift

Once the PHASESEL and PHASEDIR have been set a post-divider phase adjustment is made by toggling the PHASELOADREG signal. Each pulse of the PHASELOADREG signal will generate a phase shift. The step size relative to the unshifted output is specified by this equation:

\[
\frac{(CLKO<n>_CPHASE - CLKO<n>_DIV)}{(CLKO<n>_DIV + 1)} \times 360\]
Where <n> is the clock output specified by PHASESEL (CLKOP/OS/OS2/OS3). Values for CLKO<n>_CPHASE and CLKO<n>_DIV are located in the HDL source file. Please note that if these values are both “1”, no shift will be made.

*Note: Minimum Time Before Shifting Again Equation = 2.5*(CLKO<n>_DIV + 1) + (CLKO<n>_CPHASE +1) ] * (Period of Divider Clock).

18.5. Low Power Features

The ECP5 and ECP5-5G PLL contains several features that allow the user to reduce the power usage of a design including Standby mode support and Dynamic clock enable.

18.5.1. Dynamic Clock Enable

The Dynamic Clock Enable feature allows the user to glitchlessly enable and disable selected output clocks during periods when not used in the design. A disabled output clock will be logic ‘0’. Re-enabled clocks start on the falling edge of CLKOP. To support this feature each output clock has an independent Output Enable signal that can be selected. The Output Enable signals are ENCLKOP, ENCLKOS, ENCLKOS2, and ENCLKOS3. Each clock enable port has an option in the Clarity Designer GUI to bring the signal to the top level ports of the PLL. If external feedback is used on a port or if the clock’s output is not enabled its dynamic clock enable port is unavailable.

18.5.2. Standby Mode

The PLL can also be put into standby mode. This is similar to reset in that the PLL is still powered, however the VCO is not running and the clock outputs driven low. The PLL will enter Standby mode when the STDBY signal is driven high and the outputs will be driven low. Users need to stay in the STDBY mode for at least 1 ms to make sure the PLL analog circuits are fully reset and to have a stable analog startup. The PLL can be restarted when it is needed again and the output clocks will be reactivated. It will take Tlock_time = 16 us to achieve PLL lock again. To support this mode the “Standby Port” option is in the Clarity Designer GUI and will cause the STDBY port to be brought out to the top level of the PLL module.
18.6. PLL Usage in Clarity Designer

It is expected that Clarity Designer will be used to create and configure a PLL. PLL can be found in the Catalog tab of Clarity Designer under Module - Architecture Modules. The graphical user interface is used to select parameters for the PLL. The result is an HDL block to be used in the simulation and synthesis flow.

The main window when the PLL is selected is shown in Figure 18.8. When opening Clarity Designer inside a Diamond project, the only entry required is the file name as the other entries are set to the project settings. If Clarity Designer is opened as a stand-alone tool then it is necessary to supply the additional parameters shown on this screen. After entering the module name of choice, clicking on Customize will open the PLL configuration window as shown in Figure 18.8.

18.6.1. Configuration Tab

The configuration window lists all user accessible attributes with default values set. Upon completion, clicking Generate generates the source.

18.6.2. PLL Frequency and Phase Configuration

Enter the input and output clock frequencies and the software will calculate the divider settings. After the input and output frequencies are entered clicking the Calculate button will display the divider values and the closest achievable frequency will be displayed in the “Actual Frequency” text box. If an entered value is out of range it will be displayed in red and an error message will be displayed. The user can also select a tolerance value from the “Tolerance %” drop-down box. When the Calculate button is pressed the calculation will be considered accurate if the result is within the entered tolerance percentage range.

New to the ECP5 and ECP5-5G PLL GUI, the user enters the desired phase shift and the software will calculate the closest achievable shift. After the desired phase is entered, clicking the Calculate button will display the closest achievable phase shift in the “Actual Phase” text box. If an entered value is out of range it will be displayed in red and an error message will be displayed.
Figure 18.9. ECP5 and ECP5-5G PLL Frequency Configuration Tab
<table>
<thead>
<tr>
<th>User Parameters</th>
<th>Description</th>
<th>Range</th>
<th>Default</th>
<th>Corresponding HDL Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLKI</td>
<td>Frequency Input</td>
<td>8 — 400 MHz</td>
<td>100 MHz</td>
<td>FREQUENCY_PIN_CLKI</td>
</tr>
<tr>
<td>Refclk Divider</td>
<td>Shows the reference clock divider value</td>
<td>—</td>
<td>—</td>
<td>CLKI_DIV</td>
</tr>
<tr>
<td>Enable High Bandwidth</td>
<td>Sets the PLL to high bandwidth mode</td>
<td>ON/OFF</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CLKFB</td>
<td>Feedback mode</td>
<td>CLKOP, CLKOS, CLKOS2, CLKOS3, INT_OP, INT_OS, INT_OS2, INT_OS3, User-Clock</td>
<td>CLKOP</td>
<td>FEEDBK_PATH</td>
</tr>
<tr>
<td></td>
<td>Feedback Divider (read only)</td>
<td>1 — 128</td>
<td>1</td>
<td>CLKFB_DIV</td>
</tr>
<tr>
<td>CLKOP</td>
<td>Enable</td>
<td>ON/OFF</td>
<td>OFF</td>
<td>CLKOP_ENABLE</td>
</tr>
<tr>
<td></td>
<td>Bypass</td>
<td>ON/OFF</td>
<td>OFF</td>
<td>OUTDIVIDER_MUXA</td>
</tr>
<tr>
<td></td>
<td>Output Divider (read only)</td>
<td>—</td>
<td>—</td>
<td>CLKOP_DIV</td>
</tr>
<tr>
<td></td>
<td>Desired Frequency*</td>
<td>3.125 — 400 MHz</td>
<td>100 MHz</td>
<td>FREQUENCY_PIN_CLKOP</td>
</tr>
<tr>
<td></td>
<td>Tolerance (%)</td>
<td>0.0, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0</td>
<td>0.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Actual Frequency (read only)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CLKOS</td>
<td>Enable</td>
<td>ON/OFF</td>
<td>OFF</td>
<td>CLKOS_Enable</td>
</tr>
<tr>
<td></td>
<td>Bypass</td>
<td>ON/OFF</td>
<td>OFF</td>
<td>OUTDIVIDER_MUXB</td>
</tr>
<tr>
<td></td>
<td>Clock Divider (read only)</td>
<td>—</td>
<td>—</td>
<td>CLKOS_DIV</td>
</tr>
<tr>
<td></td>
<td>Desired Frequency*</td>
<td>3.125 — 400 MHz</td>
<td>100 MHz</td>
<td>FREQUENCY_PIN_CLKOS</td>
</tr>
<tr>
<td></td>
<td>Tolerance (%)</td>
<td>0.0, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0</td>
<td>0.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Actual Frequency (read only)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CLKOS2</td>
<td>Enable</td>
<td>ON/OFF</td>
<td>OFF</td>
<td>CLKOS2_Enable</td>
</tr>
<tr>
<td></td>
<td>Bypass</td>
<td>ON/OFF</td>
<td>OFF</td>
<td>OUTDIVIDER_MUXC</td>
</tr>
<tr>
<td></td>
<td>Clock Divider (read only)</td>
<td>—</td>
<td>—</td>
<td>CLKOS2_DIV</td>
</tr>
<tr>
<td></td>
<td>Desired Frequency*</td>
<td>3.125 — 400 MHz</td>
<td>100 MHz</td>
<td>FREQUENCY_PIN_CLKOS2</td>
</tr>
<tr>
<td></td>
<td>Tolerance (%)</td>
<td>0.0, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0</td>
<td>0.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Actual Frequency (read only)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CLKOS3</td>
<td>Enable</td>
<td>ON/OFF</td>
<td>OFF</td>
<td>CLKOS3_Enable</td>
</tr>
<tr>
<td></td>
<td>Bypass</td>
<td>ON/OFF</td>
<td>OFF</td>
<td>OUTDIVIDER_MUXD</td>
</tr>
<tr>
<td></td>
<td>Clock Divider (read only)</td>
<td>—</td>
<td>—</td>
<td>CLKOS3_DIV</td>
</tr>
<tr>
<td></td>
<td>Desired Frequency*</td>
<td>3.125 — 400 MHz</td>
<td>100 MHz</td>
<td>FREQUENCY_PIN_CLKOS3</td>
</tr>
<tr>
<td></td>
<td>Tolerance (%)</td>
<td>0.0, 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0</td>
<td>0.0</td>
<td>—</td>
</tr>
<tr>
<td></td>
<td>Actual Frequency (read only)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

**Note:** If this clock is selected as feedback, the minimum output frequency that is achievable is 10 MHz.
Figure 18.10. ECP5 and ECP5-5G PLL Phase Configuration Tab

Table 18.7. Tab 2, PLL Phase Settings, Clarity Designer GUI

<table>
<thead>
<tr>
<th>User Parameters</th>
<th>Description</th>
<th>Range</th>
<th>Default</th>
<th>Corresponding HDL Attribute</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLKOP</td>
<td>Desired Phase*</td>
<td>Based on Frequency</td>
<td>100 MHz</td>
<td>CLKOP_CPHASE, CLKOP_FPHASE</td>
</tr>
<tr>
<td></td>
<td>Actual Phase (read only)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CLKOS</td>
<td>Desired Phase*</td>
<td>Based on Frequency</td>
<td>100 MHz</td>
<td>CLKOP_CPHASE, CLKOP_FPHASE</td>
</tr>
<tr>
<td></td>
<td>Actual Phase (read only)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CLKOS2</td>
<td>Desired Phase*</td>
<td>Based on Frequency</td>
<td>100 MHz</td>
<td>CLKOP_CPHASE, CLKOP_FPHASE</td>
</tr>
<tr>
<td></td>
<td>Actual Phase (read only)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td>CLKOS3</td>
<td>Desired Phase*</td>
<td>Based on Frequency</td>
<td>100 MHz</td>
<td>CLKOP_CPHASE, CLKOP_FPHASE</td>
</tr>
<tr>
<td></td>
<td>Actual Phase (read only)</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
</tbody>
</table>

Note: Phase is now a calculated value based on frequency parameters, which gives finer phase resolution.
For the PLL, Clarity Designer sets attributes in the HDL module that are specific to the data rate selected. Although these attributes can be easily changed, they should only be modified by re-running the GUI so that the performance of the PLL is maintained. After the MAP stage in the design flow, FREQUENCY preferences will be included in the preference file to automatically constrain the clocks produced by the PLL. For a step by step guide to using Clarity Designer, refer to the Clarity Designer User Manual.
## 19. PLL Reference Clock Switch Primitive (PLLREFCS)

The ECP5 and ECP5-5G PLL contains an input mux to dynamically switch between two input reference clocks. This mux is modeled by the PLLREFCS component. This mux may allow glitches and runt pulses through depending on when the clock is switched. It is expected that the input clocks have the same frequency. Table B. defines the I/O ports of the PLLREFCS block.

This component is instantiated in the PLL wrapper when the “Enable Clock Select” option is checked in the Clarity Designer GUI. It can also be directly instantiated and software will automatically assign it to an unused PLL in bypass mode and route the output to the CLKOP port.

![Figure 19.1. PLLREFCS Component Symbol](image)

<table>
<thead>
<tr>
<th>Port Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>CLK0</td>
<td>CLK0</td>
</tr>
<tr>
<td>CLK1</td>
<td>CLK1</td>
</tr>
<tr>
<td>SEL</td>
<td>SEL = '0', CLK0 is selected</td>
</tr>
<tr>
<td>SEL = '1', CLK1 is selected</td>
<td>—</td>
</tr>
<tr>
<td>PLLCSOUT</td>
<td>PLLCSOUT</td>
</tr>
</tbody>
</table>

### 19.1. PLLREFCS Usage in VHDL

**Component Declaration**

```vhdl
COMPONENT PLLREFCS
PORT (
    CLK0 : IN STD_LOGIC;
    CLK1 : IN STD_LOGIC;
    SEL  : IN STD_LOGIC;
    PLLCSOUT : OUT STD_LOGIC);
END COMPONENT;
```

**PLLREFCS Instantiation**

```vhdl
PLLREFCS PLLREFCSInst0 : PLLREFCS
PORT MAP (  
    CLK0 => CLK_0
  ,CLK1 => CLK_1
  ,SEL => SELECT
  ,PLLCSOUT => CLK_OUT);
```

**PLLREFCS Usage in Verilog**

```verilog
module PLLREFCS(CLK0, CLK1, SEL, PLLCSOUT);
input  CLK0, CLK1, SEL;
output PLLCSOUT;
endmodule;
```

**PLLREFCS Instantiation**

```verilog
PLLREFCS PLLREFCSInst0 (  
    .CLK0 (CLK_0)
  ,.CLK1 (CLK_1)
  ,.SEL (SELECT)
  ,.PLLCSOUT (CLK_OUT));
```
Appendix A. Primary Clock Sources and Distribution

The following figures show the inputs into the Primary Clock Network through the mid-mux into the centermux for each device. There are DCC components at the input of the centermux to allow the user to stop the clock in order to save power. All mid-mux inputs with the nomenclature “<quadrant>_pclkcib<#>” are fabric entry points to the PCLK network. All mid-mux inputs with the nomenclature “<location>_DQS_CLK” are DQS clocks from the I/O.

Figure A.1. ECP5 and ECP5-5G Primary Clock Sources and Distribution, LFE5UM/LFE5UM5G-85 Devices
Figure A.2. ECP5 and ECP5-5G Primary Clock Sources and Distribution, LFESUM/LFESUM5G-45 Devices
Figure A.3. ECP5 and ECP5-5G Primary Clock Sources and Distribution, LFE5UM/LFE5UM5G-25 Devices
Appendix B. Pinout Rules for Clocking in ECP5 and ECP5-5G Devices

In the ECP5 and ECP5-5G device, as with all other architectures, there are general rules and guidelines for board designers which are required to be followed. These rules will give the best possible timing and allow for a successful design.

In the .csv file where pins are listed, under the “Dual Function” section, you will see the PCLK and PLL input pins listed as below:

Primary Clock Input Pin — PCLKT<Bank>_<<0/1>
Dedicated PLL Input Pin — <LOC>_GPLL0T_IN

Table B.1. Clock Input Selection

<table>
<thead>
<tr>
<th>Clock Input</th>
<th>Pin to Use</th>
<th>Clock Routing Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clock Input to Logic Directly</td>
<td>PCLK Input Pin</td>
<td>Uses Primary Clock Routing for the Clock.</td>
</tr>
<tr>
<td>Clock Input to PLL Only</td>
<td>PLL Input Pin</td>
<td>Uses a Dedicated PLL Input. No Primary Clock Routing is Used.</td>
</tr>
<tr>
<td>Clock Input to Logic and PLL</td>
<td>PCLK Input Pin</td>
<td>Uses Primary Clock Routing for the Clock.</td>
</tr>
<tr>
<td>Clock input to more than 1 PLL</td>
<td>PCLK Input Pin</td>
<td>Uses Primary Clock Routing for the Clock.</td>
</tr>
</tbody>
</table>
Technical Support Assistance
Submit a technical support case through www.latticesemi.com/techsupport.
# Revision History

## Revision 1.3, April 2022

<table>
<thead>
<tr>
<th>Section</th>
<th>Change Summary</th>
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</thead>
<tbody>
<tr>
<td>All</td>
<td>Changed document title from ECP5 and ECP5-5G sysCLOCK PLL/DLL Design and Usage Guide to ECP5 and ECP5-5G sysCLOCK PLL/DLL Design and User Guide.</td>
</tr>
</tbody>
</table>
| Dynamic Clock Select (DCSC)          | • Updated the DCSC declaration and Instantiations in 10.4. DCSC Usage in VHDL and 10.5. DCSC Usage in Verilog section. Corrected the SEL inputs from vector to bit to match the actual primitive.  
• Updated the section 11.2 DCCA Usage in VHDL to remove DCCA Usage in Verilog.  
• Added section 11.3 DCCA Usage in Verilog. |
| Internal Oscillator (OSCG)           | Corrected OSCG Instantiation and Attribute Declaration in section 12.3 OSCG Usage in Verilog.                                                   |
| sysCLOCK PLL                         | • Updated range for CLKI. from 10-400 MHz to 8-400 MHz in Table 18.6. Page 1, PLL Frequency Settings, Clarity Designer GUI.  
• Corrected the VCO Phase shift formula for ECP5 Dynamic Phase Adjustment in section 18.4.1 VCO Phase Shift. |

## Revision 1.2, January 2021

<table>
<thead>
<tr>
<th>Section</th>
<th>Change Summary</th>
</tr>
</thead>
</table>
| All                                  | • Changed document number from TN1263 to FPGA-TN-02200.  
• Updated document template.        |
| Disclaimers                          | Added this section.                                                                                                                             |
| Acronyms in This Document            | Added this section.                                                                                                                             |
| Internal Oscillator (OSCG)           | • Removed OSCG element features  
• Updated OSCG Usage in VHDL code  
• Updated OSCG Usage in Verilog code |
| Appendix B. Pinout Rules for Clocking in ECP5 and ECP5-5G Devices | Updated Clock Input item to ... more than 1 PLL in Table B.1. Clock Input Selection.                                                       |

## Revision 1.1, November 2015

<table>
<thead>
<tr>
<th>Section</th>
<th>Change Summary</th>
</tr>
</thead>
</table>
| All                                  | • Added support for ECP5-5G.  
• Changed document title to ECP5 and ECP5-5G sysCLOCK PLL/DLL Design and Usage Guide. |
| Overview of Other Clocking Elements  | Updated Oscillator (OSCG) section. Removed paragraph on STDBY port.                                                                                   |
| sysCLOCK PLL                         | Updated PLL Usage in Clarity Designer section. Replaced Figure 18.8. Clarity Designer Main Window for PLL Module.                                         |
| Technical Support Assistance         | Updated Technical Support Assistance section.                                                                                                          |

## Revision 1.0, March 2014

<table>
<thead>
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<th>Section</th>
<th>Change Summary</th>
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</thead>
<tbody>
<tr>
<td>All</td>
<td>Initial release.</td>
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