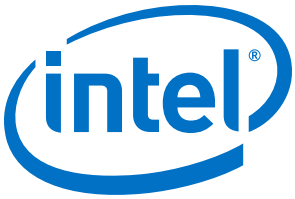

DisplayPort Intel® Cyclone 10 GX FPGA IP Design Example User Guide

Updated for Intel® Quartus® Prime Design Suite: **20.3**

IP Version: **19.4.0**

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Contents

1. DisplayPort Intel® FPGA IP Design Example Quick Start Guide

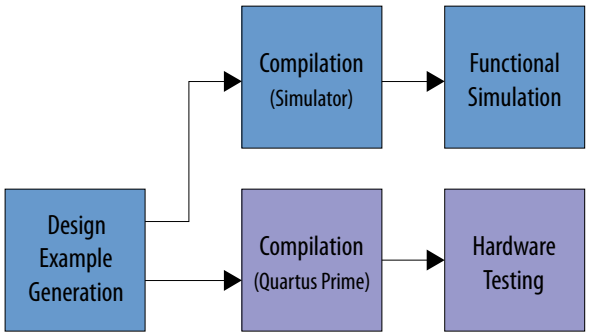
The DisplayPort Intel® FPGA IP design examples for Intel Cyclone® 10 GX devices feature a simulating testbench and a hardware design that supports compilation and hardware testing.

The DisplayPort Intel FPGA IP offers the following design examples:

- DisplayPort SST parallel loopback with a Pixel Clock Recovery (PCR) module
- DisplayPort SST parallel loopback without a PCR module
- DisplayPort MST parallel loopback with a PCR module
- DisplayPort MST parallel loopback without a PCR module

When you generate a design example, the parameter editor automatically creates the files necessary to simulate, compile, and test the design in hardware.

Figure 1. Development Steps



Related Information

DisplayPort Intel FPGA IP User Guide

1.1. Directory Structure

The directories contain the generated files for the DisplayPort design example.

Figure 2. Directory Structure for the Design Example

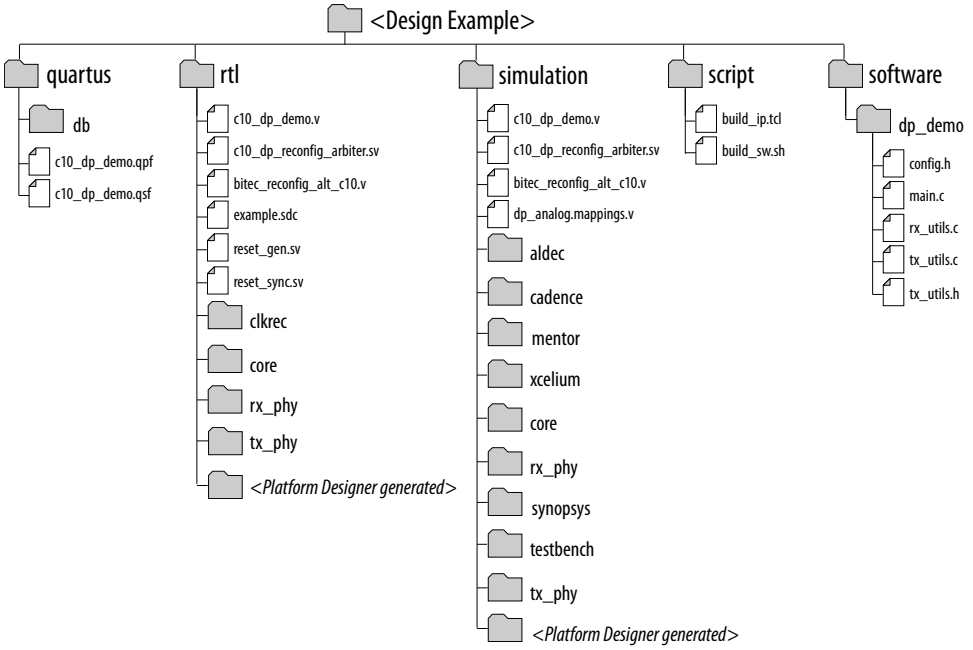


Table 1. Other Generated Files in RTL Folder

Folders	Files
clkrec	/altera_pll_reconfig_core.v
	/altera_pll_reconfig_mif_reader.v
	/altera_pll_reconfig_top.v
	/bitec_clkrec.qip
	/bitec_clkrec.sdc
	/bitec_clkrec.v
	/bitec_dp_add.v
	/bitec_dp_cdc.v
	/bitec_dp_cdc_fifo.v
	/bitec_dp_cdc_pulse.v
	/bitec_dp_cnt.v
	/bitec_dp_dcfifo.v
	/bitec_dp_dd.v
	/bitec_dp_div.v
	/bitec_dp_mult.v
	/bitec_fpll_calc.v
	/bitec_fpll_cntrl.v

continued...

Folders	Files
	/bitec_fpll_reconf.v
	/bitec_loop_cntrl.v
	/bitec_vsyngen.v
	/clkrec_pll135_c10.ip
	/clkrec_pll1_c10.ip
	/clkrec_reset_c10.ip
	<Platform Designer generated folder>
core	/dp_core.ip
	/dp_rx.ip
	/dp_tx.ip
	<Platform Designer generated folder>
rx_phy	/gxb_rx.ip
	/gxb_rx_reset.ip
	/rx_phy_top.v
	<Platform Designer generated folder>
tx_phy	/gxb_tx.ip
	/gxb_tx_reset.ip
	/gxb_tx_fpll.ip
	/tx_phy_top.v
	<Platform Designer generated folder>

Table 2. Other Generated Files in Simulation Folder

Folders	Files
aldec	/aldec.do
	/rivierapro_setup.tcl
cadence	/cds.lib
	/hdl.var
	/ncsim.sh
	/ncsim_setup.sh
	<cds_libs folder>
core	/dp_core.ip
	/dp_rx.ip
	/dp_tx.ip
	<Platform Designer generated folder>
mentor	/mentor.do

continued...

Folders	Files
	/msim_setup.tcl
xcelium	/cds.lib
	/hdl.var
	/xcelium_sim.sh
	/xcelium_setup.sh
	<cds_libs folder>
rx_phy	/gxb_rx.ip
	/rx_phy_top.v
	/gxb_rx_reset.ip
	<Platform Designer generated folder>
synopsys	/vcs/filelist.f
	/vcs/vcs_setup.sh
	/vcs/vcs_sim.sh
	/vcsmx/synopsys_sim_setup
	/vcsmx/vcsmx_setup.sh
	/vcsmx/vcsmx_sim.sh
testbench	/c10_dp_harness.sv
	/clk_gen.v
	/freq_check.v
	/rx_freq_check.v
	/tx_freq_check.v
	/vga_driver.v
tx_phy	/gxb_tx.ip
	/gxb_tx_reset.ip
	<Platform Designer generated folder>
	/gxb_tx_fpll.ip
	/tx_phy_top.v

1.2. Hardware and Software Requirements

Intel uses the following hardware and software to test the design example.

Hardware

- Intel Cyclone 10 GX FPGA Development Kit
- DisplayPort Source (Graphics Processing Unit (GPU))
- DisplayPort Sink (Monitor)
- Bitec DisplayPort FMC daughter card (Revisions 8.0 to 11.0)
- DisplayPort cables

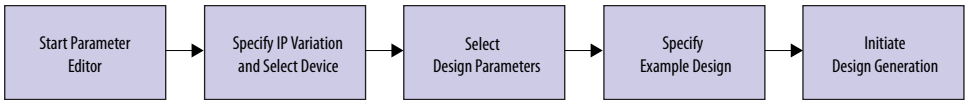
Software

- Intel Quartus® Prime Pro Edition (for hardware testing)
- ModelSim* - Intel FPGA Edition, ModelSim - Intel FPGA Starter Edition, NCSim (Verilog only), Riviera-PRO*, Xcelium*or VCS* (Verilog only)/VCS MX simulator

1.3. Generating the Design

Use the DisplayPort Intel FPGA IP parameter editor in the Intel Quartus Prime Pro Edition software to generate the design example.

Figure 3. Generating the Design Flow



1. Click **Tools ➤ IP Catalog**, and select Intel Cyclone 10 GX as the target device family.

   Note: The design example only support Intel Cyclone 10 GX devices.
2. In the IP Catalog, locate and double-click **DisplayPort Intel FPGA IP**. The **New IP Variation** window appears.
3. Specify a top-level name for your custom IP variation. The parameter editor saves the IP variation settings in a file named <*your_ip*>.ip.
4. You may select a specific Intel Arria® 10 device in the **Device** field, or keep the default Intel Quartus Prime software device selection.
5. Click **OK**. The parameter editor appears.
6. Configure the desired parameters for both TX and RX.

   Note: The Nios II software has the capability to read and print out the DisplayPort Main Stream Attribute (MSA) information in the Nios II terminal. To read or print the MSA information, turn on the **Enable GPU Control** parameter.
7. On the **Design Example** tab, select **DisplayPort SST Parallel Loopback With PCR**, **DisplayPort SST Parallel Loopback Without PCR**, **DisplayPort MST Parallel Loopback With PCR**, or **DisplayPort MST Parallel Loopback Without PCR**.
8. Select **Simulation** to generate the testbench, and select **Synthesis** to generate the hardware design example.

   Note: DisplayPort MST design examples are supported only in synthesis; they are not supported in simulation.

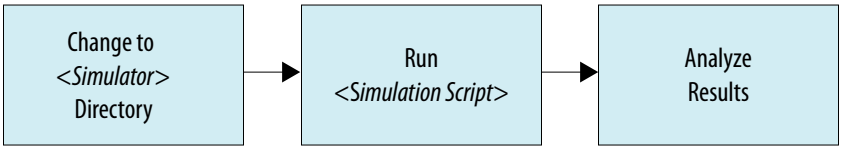
You must select at least one of these options to generate the design example files. If you select both, the generation time is longer.

9. For **Target Development Kit**, select **Cyclone 10 GX FPGA Development Kit**. If you select the development kit, then the target device (selected in **step 4**) changes to match the device on the development kit. For **Cyclone 10 GX FPGA Development Kit**, the default device is 10CX220YF780E5G..
10. Click **Generate Example Design** to generate the project files and the software Executable and Linking Format (ELF) programming file.

1.4. Simulating the Design

The DisplayPort Intel FPGA IP design example testbench simulates a serial loopback design from a TX instance to an RX instance. An internal video pattern generator module drives the DisplayPort TX instance and the RX instance video output connects to CRC checkers in the testbench.

Figure 4. Design Simulation Flow



1. Navigate to the simulation folder of your choice.
2. Run the simulation script for the supported simulator. The script compiles and runs the testbench in the simulator.
3. Analyze the results.

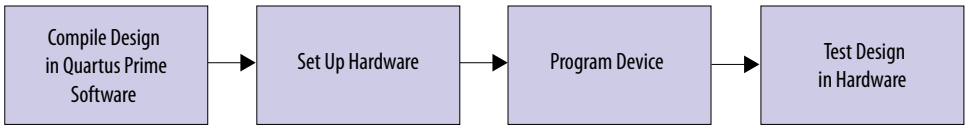
Table 3. Steps to Run Simulation

Simulator	Working Directory	Instructions
Riviera-PRO	`/simulation/aldec`	In the command line, type `vsim -c -do aldec.do`
ModelSim	`/simulation/mentor`	In the command line, type `vsim -c -do mentor.do`
NCSim	`/simulation/cadence`	In the command line, type `source ncsim.sh`
Xcelium	`/simulation/xcelium`	In the command line, type `source xcelium.sh`
VCS	`/simulation/synopsys/vcs`	In the command line, type `source vcs_sim.sh`
VCS MX	`/simulation/synopsys/vcsmx`	In the command line, type `source vcsmx_sim.sh`

A successful simulation ends with the following message:

```
# SINK CRC_R = ac9c, CRC_G = ac9c, CRC_B = ac9c,
# SOURCE CRC_R = ac9c, CRC_G = ac9c, CRC_B = ac9c,
# Pass: Test Completed
```

1.5. Compiling and Testing the Design



To compile and run a demonstration test on the hardware example design, follow these steps:

1. Ensure hardware example design generation is complete.
2. Launch the Intel Quartus Prime Pro Edition software and open <*project directory*>/quartus/c10_dp_demo.qpf.

Note: The latest Bitec DisplayPort FMC daughter card has different schematics compared to the earlier revisions.

Table 4. RX Transceiver Channel Mapping

Parameter	Revisions 8 and Earlier	Revision 10	Revision 11	Description
Polarity	Not inverted	Inverted	Inverted	• When RX polarity is inverted, each lane at the `rx_polinv` port of the Native PHY is driven to 1 in the `rx_phy_top.v` file. • When RX polarity is not inverted, each lane at the `rx_polinv` port of the Native PHY is driven to 0 in the `rx_phy_top.v` file.
Order	Not reversed	Not reversed	Reversed	The `rx_parallel_data` port of the Native PHY is directly mapped to the `rx_parallel_data` port of the DisplayPort IP.

Table 5. TX Transceiver Channel Mapping

Parameter	Revisions 8 and Earlier	Revision 10	Revision 11	Description
Polarity	Inverted	Not inverted	Not inverted	• When TX polarity is inverted, each lane at the `tx_polinv` port of the Native PHY is driven to 1 in the `tx_phy_top.v` file. • When TX polarity is not inverted, each lane at the `tx_polinv` port of the Native PHY is driven to 0 in the `tx_phy_top.v` file.
Order	Reversed	Not reversed	Not reversed	• When the lane order is reversed, the data input at the `tx_parallel_data` port of the Native PHY is swapped in the `tx_phy_top.v` file based on the lane count configuration. • When the lane order is not reversed, `tx_parallel_data` port of the Native PHY is directly mapped to the `tx_parallel_data` port of the DisplayPort IP.

To support all revisions, the design example top level RTL file at <*project directory*>`/rtl/c10_dp_demo.v` and the software `config.h` file include a local parameter for you to select the FMC revision.

DisplayPort Intel FPGA IP version 19.3.0:

```
localparam BITEC_DP_CARD_REV = 2;

// 0 = Bitec FMC DP card rev.4 - 8,

// 1 = rev.10

// 2 = rev.11
```

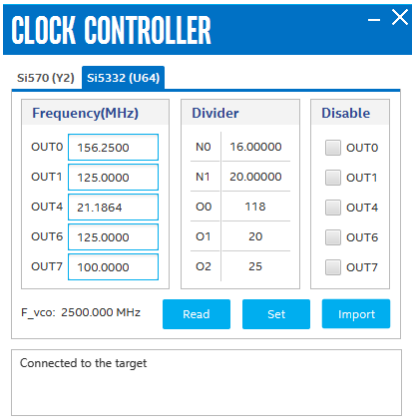
in <project>/software/dp_demo/config.h:

```
#define BITEC_DP_CARD_REV 2

// set to 0 = Bitec FMC DP card rev.4 - 8

// set to 1 = Bitec FMC DP card rev.10

// set to 2 = Bitec FMC DP card rev.11
```

The default value is 2. If the `config.h` file is updated, you must run `build_sw.sh` in the script folder before compiling the Intel Quartus Prime Pro Edition project to ensure the software is effective.

3. Click **Processing ➤ Start Compilation**.
4. Open the Clock Controller parameter editor, and set the clock frequency in the Si5332(U64) tab.

Figure 5. Clock Controller Parameter Editor



5. After successful compilation, the Intel Quartus Prime Pro Edition software generates a `.sof` file in your specified directory.
6. Connect the DisplayPort RX connector on the Bitec daughter card to an external video source, such as the graphics card on a PC.
7. Connect the DisplayPort TX connector on the Bitec daughter card to a video analyzer or a DisplayPort sink device, such as a PC monitor.
8. Ensure all switches on the development board are in default position.
9. Configure the selected Intel Cyclone 10 GX device on the development board using the generated `.sof` file (**Tools ➤ Programmer**).
10. The DisplayPort sink device displays the video generated from the video source.

Related Information

Intel Cyclone 10 GX FPGA Development Kit

1.5.1. Regenerating ELF File

By default, the ELF file is generated when you generate the dynamic design example. However, in some cases, you need to regenerate the ELF file if you modify the software file or regenerate the `dp_core.qsys` file. Regenerating the `dp_core.qsys` file updates the `.sopcinfo` file, which requires you to regenerate the ELF file.

1. Go to <*project directory*>`/software` and edit the code if necessary.
2. Go to <*project directory*>`/script` and execute the following build script:

   ```
   source build_sw.sh
   ```

   - On Windows, search and open Nios II Command Shell. In the Nios II Command Shell, go to <*project directory*>`/script` and execute `source build_sw.sh`.

     Note: To execute build script on Windows 10, your system requires Windows Subsystems for Linux (WSL). For more information about WSL installation steps, refer to the *Nios II Software Developer Handbook*.

   - On Linux, launch the Platform Designer, and open **Tools ➤ Nios II Command Shell**. In the Nios II Command Shell, go to <*project directory*>`/script` and execute `source build_sw.sh`.
3. Make sure an `.elf` file is generated in <*project directory*>`/software/dp_demo`.
4. Download the generated `.elf` file into the FPGA without recompiling the `.sof` file by running the following script:

   ```
   nios2-download <project directory>/software/dp_demo/*.elf
   ```
5. Push the reset button on the FPGA board for the new software to take effect.

Related Information

Nios II Software Developer Handbook
Provides information about how to install Windows Subsystem for Linux (WSL) on Windows.

1.6. DisplayPort Intel FPGA IP Design Example Parameters

Table 6. DisplayPort Intel FPGA IP Design Example Parameters for Intel Cyclone 10 GX Devices

Parameter	Value	Description
Available Design Example		
Select Design	• None • DisplayPort SST Parallel Loopback with PCR • DisplayPort SST Parallel Loopback without PCR • DisplayPort MST Parallel Loopback with PCR • DisplayPort MST Parallel Loopback without PCR	Select the design example to be generated. • None: No design example is available for the current parameter selection • DisplayPort SST Parallel Loopback with PCR: This design example demonstrates parallel loopback from DisplayPort sink to DisplayPort source through a Pixel Clock Recovery (PCR) module when you turn off the **Enable Video Input Image Port** parameter. • DisplayPort SST Parallel Loopback without PCR: This design example demonstrates parallel loopback from DisplayPort sink to DisplayPort source without a Pixel Clock Recovery (PCR) module when you turn on the **Enable Video Input Image Port** parameter. • DisplayPort MST Parallel Loopback with PCR: This design example demonstrates parallel loopback from DisplayPort sink to DisplayPort source through a Pixel Clock Recovery (PCR) module when you turn off the **Enable Video Input Image Port** parameter and turn on the **Support MST** parameter for TX and RX. • DisplayPort MST Parallel Loopback without PCR: This design example demonstrates parallel loopback from DisplayPort sink to DisplayPort source without a Pixel Clock Recovery (PCR) module when you turn on the **Enable Video Input Image Port** parameter and turn on the **Support MST** parameter for TX and RX.
Design Example Files		
Simulation	On, Off	Turn on this option to generate the necessary files for the simulation testbench.
Synthesis	On, Off	Turn on this option to generate the necessary files for Intel Quartus Prime compilation and hardware demonstration.
Generated HDL Format		
Generate File Format	Verilog, VHDL	Select your preferred HDL format for the generated design example fileset. *Note:* This option only determines the format for the generated top level IP files. All other files (e.g. example testbenches and top level files for hardware demonstration) are in Verilog HDL format.
Target Development Kit		
Select Board	• No Development Kit • Intel Cyclone 10 GX FPGA Development Kit • Custom Development Kit	Select the board for the targeted design example. • No Development Kit: This option excludes all hardware aspects for the design example. The IP core sets all pin assignments to virtual pins. • Intel Cyclone 10 GX FPGA Development Kit: This option automatically selects the project's target device to match the device on this development kit. You may change the target device using the **Change Target Device** parameter if your board revision has a different device variant. The IP core sets all pin assignments according to the development kit. • Custom Development Kit: This option allows the design example to be tested on a third-party development kit with an Intel FPGA. You may need to set the pin assignments on your own.

Target Device		
Change Target Device	On, Off	Turn on this option and select the preferred device variant for the development kit.

2. Parallel Loopback Design Examples

The DisplayPort Intel FPGA IP design examples demonstrate parallel loopback from DisplayPort RX instance to DisplayPort TX instance with or without a Pixel Clock Recovery (PCR) module.

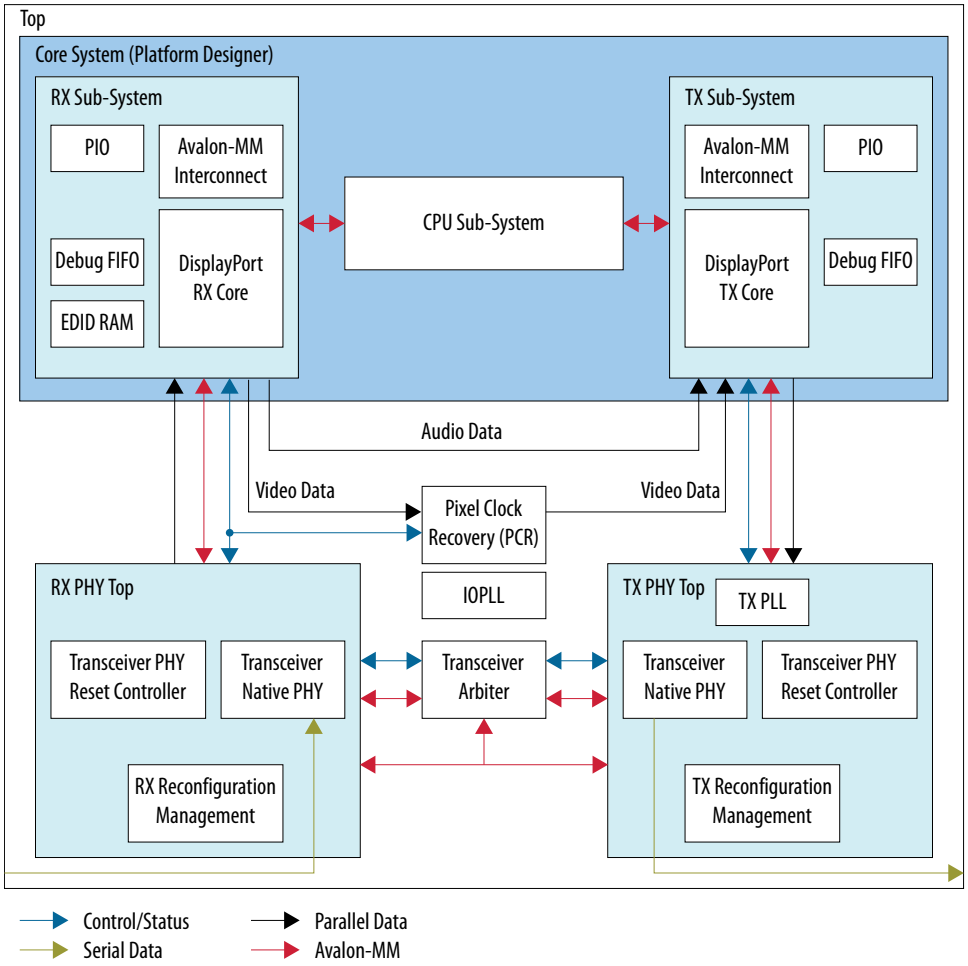
Table 7. DisplayPort Intel FPGA IP Design Example for Intel Cyclone 10 GX Devices

Design Example	Designation	Data Rate	Channel Mode	Loopback Type
DisplayPort SST parallel loopback with PCR	DisplayPort SST	HBR3, HBR2, HBR, and RBR	Simplex	Parallel with PCR
DisplayPort SST parallel loopback without PCR	DisplayPort SST	HBR3, HBR2, HBR, and RBR	Simplex	Parallel without PCR
DisplayPort MST parallel loopback with PCR	DisplayPort MST	HBR3, HBR2, HBR, and RBR	Simplex	Parallel with PCR
DisplayPort MST parallel loopback without PCR	DisplayPort MST	HBR3, HBR2, HBR, and RBR	Simplex	Parallel without PCR

2.1. Intel Cyclone 10 GX DisplayPort SST Parallel Loopback Design Features

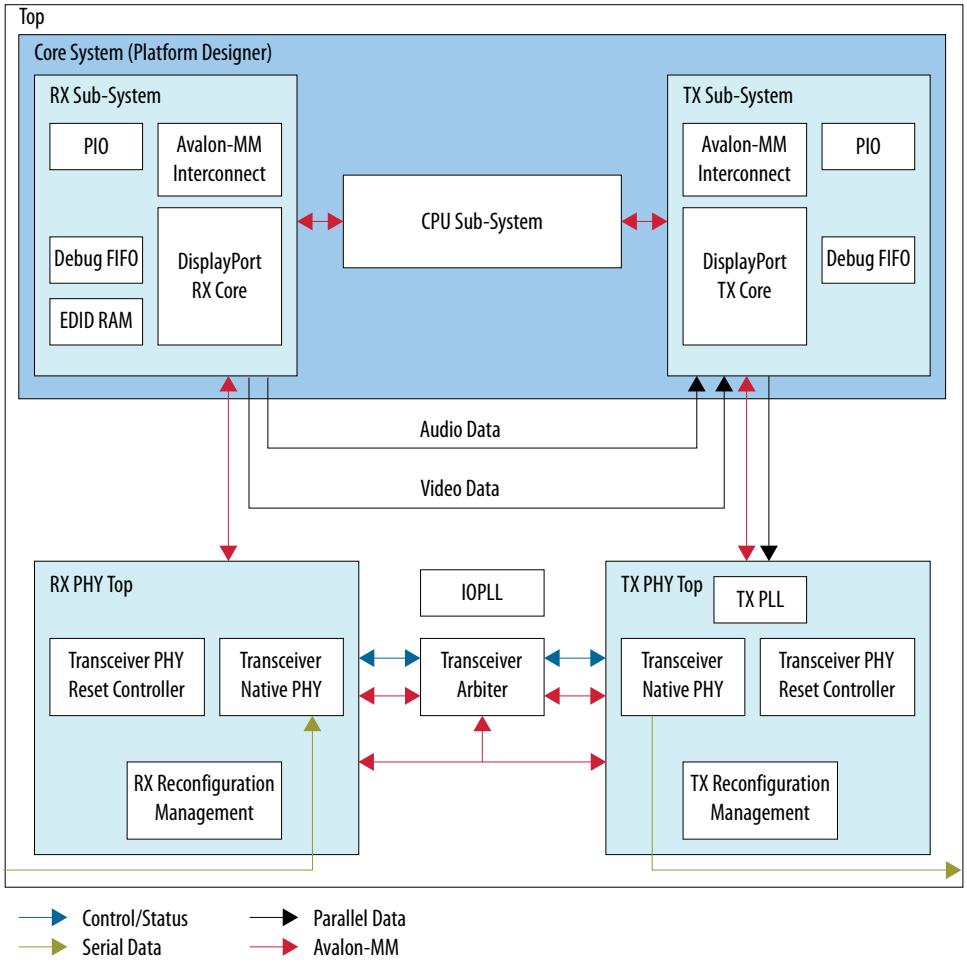
The SST parallel loopback design examples demonstrate the transmission of a single video stream from DisplayPort sink to DisplayPort source with or without Pixel Clock Recovery (PCR).

Figure 6. Intel Cyclone 10 GX DisplayPort SST Parallel Loopback with PCR



- In this variant, the DisplayPort source's parameter, **TX_SUPPORT_IM_ENABLE**, is turned off and the standard VSYNC/HSYNC/DE video interface is used.
- The DisplayPort sink receives video and or audio streaming from external video source such as GPU and decodes it into parallel video interface.
- The IOPLL drives the video clock at a fixed frequency (in this case, 160 MHz).
- If DisplayPort sink's **MAX_LINK_RATE** is configured to **HBR2** and **PIXELS_PER_CLOCK** is configured to **Dual**, the video clock runs at 300 MHz to support 4Kp60 pixel rate (594/2 = 297 MHz). Otherwise, the video clock runs at 160 MHz.
- The design uses the pixel recovery clock (PCR) to recover the pixel clock according to the received MSA information from the sink and converts the RX parallel video interface to the standard VSYNC/HSYNC/DE interface.
- The PCR output drives the source video interface and encodes to the DisplayPort main link before transmitting to the monitor.
- The recovered clock drives the TX video clock.

Figure 7. Intel Cyclone 10 GX DisplayPort SST Parallel Loopback without PCR



- In this variant, the DisplayPort source's parameter, **TX_SUPPORT_IM_ENABLE**, is turned on ("1") and the video image interface is used.
- The DisplayPort sink receives video and or audio streaming from external video source such as GPU and decodes it into parallel video interface.
- The DisplayPort sink video output directly drives the DisplayPort source video interface and encodes to the DisplayPort main link before transmitting to the monitor.
- The IOPLL drives both the DisplayPort sink and source video clocks at a fixed frequency.
- If DisplayPort sink and source's **MAX_LINK_RATE** parameter is configured to **HBR2** and **PIXELS_PER_CLOCK** is configured to **Dual**, the video clock runs at 300 MHz to support 4Kp60 pixel rate (594/2 = 297 MHz). Otherwise, the video clock runs at 160 MHz.

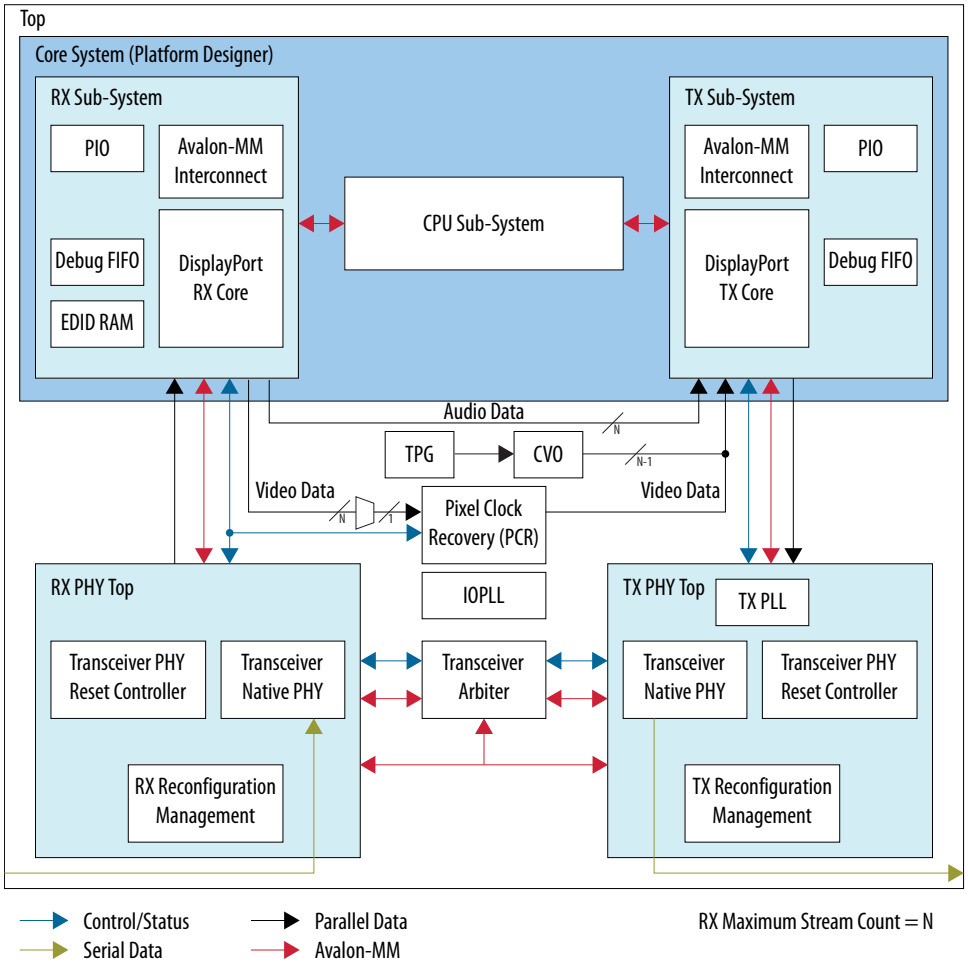
Table 8. Design Example Variant Comparison

Design Example	PCR Module	Enable Video Image Interface	Adaptive Sync	Video Interface
DisplayPort SST parallel loopback with PCR	Required	No	Not supported	Standard VSYNC/ HSYNC/DE interface (`txN_video_in`)
DisplayPort SST parallel loopback without PCR	Not required	Yes	Supported	Video Image Interface (`txN_video_in_im`)

2.2. Intel Cyclone 10 GX DisplayPort MST Parallel Loopback Design Features

The MST parallel loopback design examples demonstrate the transmission of two to four video streams from DisplayPort sink to DisplayPort source with or without Pixel Clock Recovery (PCR).

Figure 8. Intel Cyclone 10 GX DisplayPort MST Parallel Loopback with PCR



- In this variant, the DisplayPort source's parameter, **TX_SUPPORT_IM_ENABLE**, is turned off and the standard VSYNC/HSYNC/DE video interface is used.
- Due to the limitation of PLL numbers on the Intel Cyclone 10 GX board, by default the IP chooses only 1 stream from the input streams and transmits to the Pixel Clock Recovery block. The Test Pattern Generator (TPG) generates the remaining output streams and the streams display 1080p60 color bar image. For example, if the MST maximum stream count is four, one output video stream is chosen to display, and the remaining three video streams show the same image, which is 1080p60 color bar.
- You can change the video to a different stream using the `user_pb[1]` push button. Every time you press `user_pb[1]`, the next video stream displays.
- The design examples support up to four streams for audio and video data.
- The MST design examples use fixed EDID and do not support EDID passthrough.
- You can modify the bandwidth assignment for each stream in the `tx_utils.c` file.

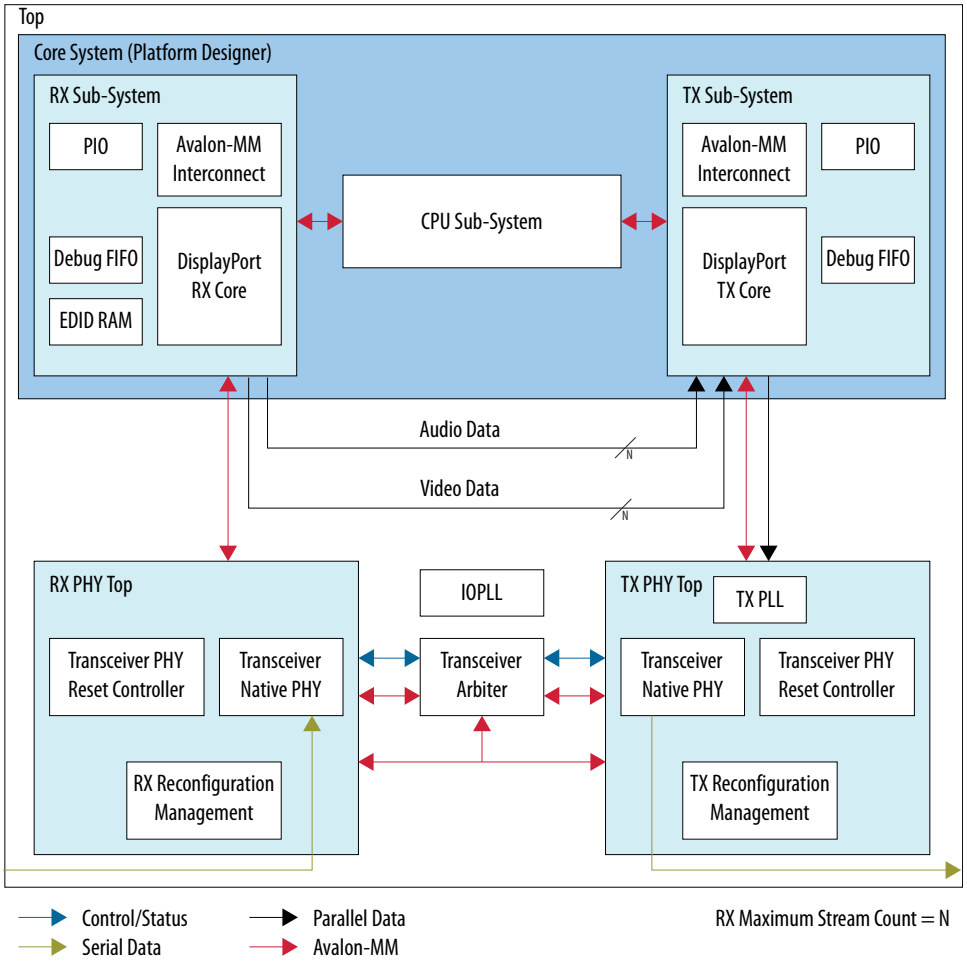
  stream 0: `btc_dptxll_stream_set_pixel_rate(0,0,594000/MST_RX_STREAMS);`

  stream 1: `btc_dptxll_stream_set_pixel_rate(0,1,594000/MST_RX_STREAMS);`

  stream 2: `btc_dptxll_stream_set_pixel_rate(0,2,594000/MST_RX_STREAMS);`

  stream 3: `btc_dptxll_stream_set_pixel_rate(0,3,594000/MST_RX_STREAMS);`
- The maximum resolution supported for 4 stream counts is 1080p60.

Figure 9. Intel Cyclone 10 GX DisplayPort MST Parallel Loopback without PCR



- In this variant, the DisplayPort source's parameter, **TX_SUPPORT_IM_ENABLE**, is turned on ("1") and the video image interface is used.
- The DisplayPort sink receives video and or audio streaming from external video source such as GPU and decodes it into parallel video interface.
- The DisplayPort sink video output directly drives the DisplayPort source video interface and encodes to the DisplayPort main link before transmitting to the monitors.
- The MST design examples support up to four streams for audio and video data.
- The design examples use fixed EDID and do not support EDID passthrough.

- The design examples support a total bandwidth of 594 MHz, distributed equally across the streams. For example, if you enable four streams, each stream would be 148.5 MHz.
- You can modify the bandwidth assignment for each stream in the `tx_utils.c` file.

  stream 0: `btc_dptxll_stream_set_pixel_rate(0,0,594000/MST_RX_STREAMS);`

  stream 1: `btc_dptxll_stream_set_pixel_rate(0,1,594000/MST_RX_STREAMS);`

  stream 2: `btc_dptxll_stream_set_pixel_rate(0,2,594000/MST_RX_STREAMS);`

  stream 3: `btc_dptxll_stream_set_pixel_rate(0,3,594000/MST_RX_STREAMS);`
- The maximum resolution supported for 4 stream counts is 1080p60.

Table 9. Design Example Variant Comparison

Design Example	PCR Module	Enable Video Image Interface	Adaptive Sync	Video Interface
DisplayPort MST parallel loopback with PCR	Required	No	Not supported	Standard VSYNC/ HSYNC/DE interface (`txN_video_in`)
DisplayPort MST parallel loopback without PCR	Not required	Yes	Supported	Video Image Interface (`txN_video_in_im`)

2.3. Enabling Adaptive Sync Support

To enable support for the Adaptive Sync feature in the design examples without PCR, you need to edit the `MSA_TIMING_PAR_IGNORED` bit of the DPCD 00007h register and the `MSA_TIMING_PAR_IGNORE_EN` bit of the DPCD 00107h register in the `rx_utils.c` file in the software folder.

Note: The Adaptive Sync feature is applicable only when you turn on the **Enable GPU control** parameter.

To edit the bits:

1. Locate `data[7] = 0x80; // DPCD_ADDR_DOWN_STREAM_PORT_COUNT`.
2. Change `0x80` to `0xC0`.
3. Locate `data[7] = 0x00; // DPCD_ADDR_DOWNSPREAD_CTRL`
4. Change `0x00` to `0x80`.
5. Regenerate the ELF file, refer to Regenerating ELF File on page 12.
6. After programming the SOF file into the FPGA, program the updated ELF file into the FPGA.

2.4. Design Components

The DisplayPort Intel FPGA IP design example requires these components.

Table 10. Core System Components

Module	Description
Core System (Platform Designer)	The core system consists of the Nios II Processor and its necessary components, DisplayPort RX and TX core sub-systems. This system provides the infrastructure to interconnect the Nios II processor with the DisplayPort Intel FPGA IP (RX and TX instances) through Avalon memory-mapped (Avalon-MM) interface within a single Platform Designer system to ease the software build flow. This system consists of: • CPU Sub-System • RX Sub-System • TX Sub-System
RX Sub-System (Platform Designer)	The RX sub-system consists of: • Clock Source—The clock source to the DisplayPort RX core. This sub-system has two clock sources integrated: 100 MHz and 16 MHz. • Reset Bridge—The bridge that connects the external signal to the sub-system. This bridge synchronizes to the respective clock source before it is used. • DisplayPort RX Core—DisplayPort Sink IP core, *VESA DisplayPort Standard version 1.4*. • Debug FIFO—This FIFO captures all DisplayPort RX auxiliary cycles, and prints out in the Nios II Debug terminal. • PIO—The parallel IO that triggers the MSA capture, and prints out when the on-board push button (PB) is pressed. • Avalon-MM Pipeline Bridge—This Avalon-MM bridge interconnects the Avalon-MM interface between components within the RX sub-system to the Nios II processor in the Core sub-system. • EDID—The EDID RAM is only used to store the desired EDID value in the RAM and connect to the DisplayPort Sink IP core. This component is only used when you disable the **Enable GPU Control** option in the RX core.
TX Sub-System (Platform Designer)	The TX sub-system consists of: • Clock Source—The clock source to the DisplayPort TX core. This sub-system has two clock sources integrated: 100 MHz and 16 MHz. • Reset Bridge—The bridge that connects the external signal to the sub-system. This bridge synchronizes to the respective clock source before it is used. • DisplayPort TX Core—DisplayPort Source IP core, *VESA DisplayPort Standard version 1.4*. • Debug FIFO—This FIFO captures all DisplayPort TX auxiliary cycles, and prints out in the Nios II Debug terminal. This component is only used when the TX_AUX_DEBUG parameter is turned on. • PIO—The parallel IO that triggers the DPTX register update in software (`tx_utils.c`). • Avalon-MM Pipeline Bridge—This Avalon-MM bridge interconnects the Avalon-MM interface between components within the TX sub-system to the Nios II processor in the Core sub-system.

Table 11. DisplayPort RX PHY Top and TX PHY Top Components

Module	Description
RX PHY Top	The RX PHY top level consists of the components related to the receiver PHY layer.

continued...

Module	Description
	• Transceiver Native PHY (RX)—The transceiver block that receives the serial data from an external video source and deserializes it to 20-bit or 40-bit parallel data to the DisplayPort sink IP core. This block supports up to 8.1 Gbps (HBR3) data rate with 4 channels. • Transceiver PHY Reset Controller—The RX Reconfiguration Management module triggers the reset input of this controller to generate the corresponding analog and digital reset signals to the Transceiver Native PHY block according to the reset sequencing. • RX Reconfiguration Management—This block reconfigures and recalibrates the Transceiver Native PHY block to receive serial data in the supported data rates (RBR, HBR, HBR2, and HBR3).
TX PHY Top	The TX PHY top level consists of the components related to the transmitter PHY layer. • Transceiver Native PHY (TX)—The transceiver block that receives 20-bit or 40-bit parallel data from the DisplayPort Intel FPGA IP and serializes the data before transmitting it. This block supports up to 8.1 Gbps (HBR3) data rate with 4 channels. *Note:* You must set the TX channel bonding mode to **PMA and PCS bonding** and the **PCS TX Channel bonding master** parameter to 0 (default is auto). • Transceiver PHY Reset Controller—The TX Reconfiguration Management module triggers the reset input of this controller to generate the corresponding analog and digital reset signals to the Transceiver Native PHY block according to the reset sequencing. • TX Reconfiguration Management—This block reconfigures and recalibrates the Transceiver Native PHY and TX PLL blocks to transmit serial data in the required data rates (RBR, HBR, HBR2, and HBR3). • TX PLL—The transmitter PLL block provides a fast serial fast clock to the Transceiver Native PHY block. For the DisplayPort Intel FPGA IP design example, Intel uses transmitter fractional PLL (FPLL).

Table 12. Top-Level Common Blocks

Module	Description
Transceiver Arbiter	This generic functional block prevents transceivers from recalibrating simultaneously when either RX or TX transceivers within the same physical channel require reconfiguration. The simultaneous recalibration impacts applications where RX and TX transceivers within the same channel are assigned to independent IP implementations. This transceiver arbiter is an extension to the resolution recommended for merging simplex TX and simplex RX into the same physical channel. This transceiver arbiter also assists in merging and arbitrating the Avalon-MM RX and TX reconfiguration requests targeting simplex RX and TX transceivers within a channel as the reconfiguration interface port of the transceivers can only be accessed sequentially. The transceiver arbiter is not required when only either RX or TX transceiver is used in a channel. The transceiver arbiter identifies the requester of a reconfiguration through its Avalon-MM reconfiguration interfaces and ensures that the corresponding `tx_reconfig_cal_busy` or `rx_reconfig_cal_busy` is gated accordingly.
IOPLL	IOPLL generates common source clock: `dp_rx_vid_clkout` and `clk_16` (16 MHz) for the DisplayPort system. • `dp_rx_vid_clkout`—used as RX core video clock of the video data stream input clock. • `clk_16`—Used as DisplayPort auxiliary clock reference clock.

2.5. Clocking Scheme

The clocking scheme illustrates the clock domains in the DisplayPort Intel FPGA IP design example.

Figure 10. DisplayPort Intel FPGA IP Design Example Clocking Scheme

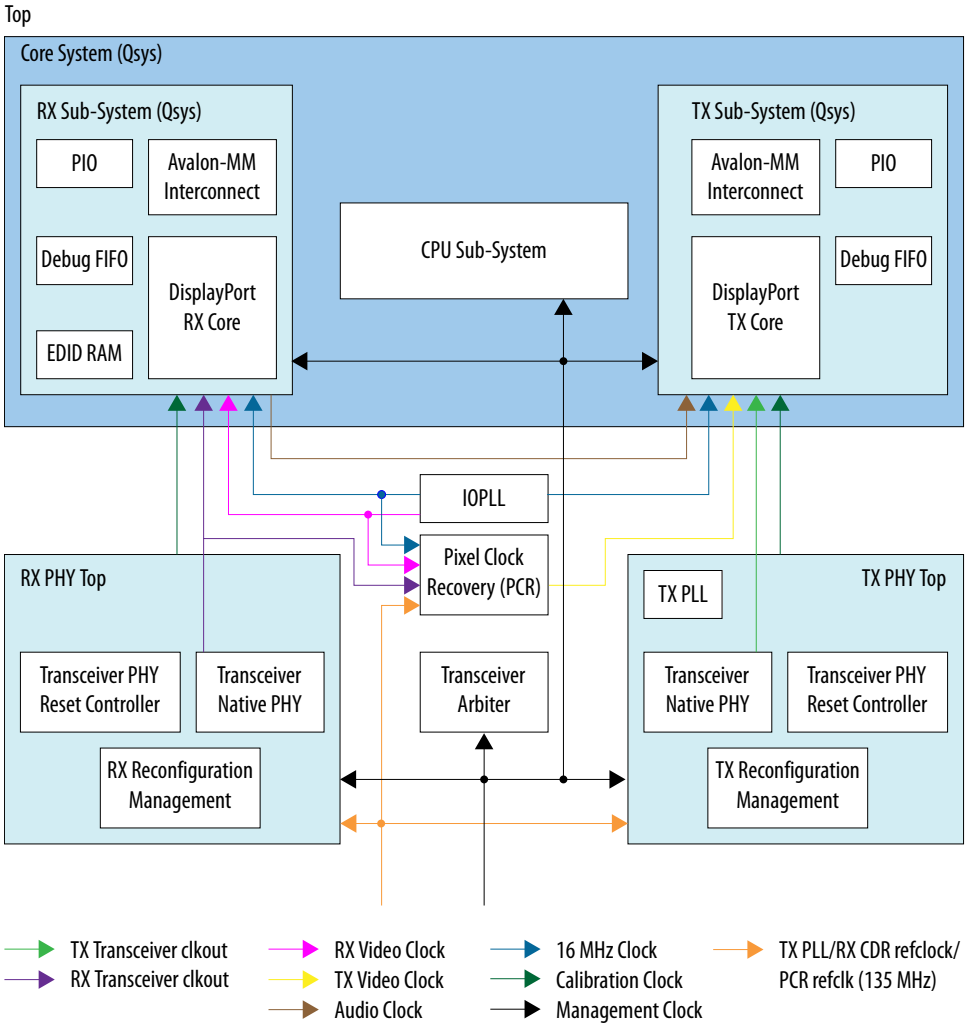
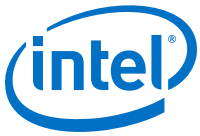


Table 13. Clocking Scheme Signals

Clock	Signal Name in Design	Description
TX PLL Refclock	`tx_pll_refclk`	135 MHz TX PLL reference clock, that is divisible by the transceiver for all DisplayPort data rates (1.62 Gbps, 2.7 Gbps, and 5.4 Gbps). *Note:* The reference clock source of the TX PLL refclock is located at the HSSI `refclk` pin.
TX Transceiver Clockout	`gxb_tx_clkout`	TX clock recovered from the transceiver, and the frequency varies depending on the data rate and symbols per clock.

Data Rate	Symbols per Clock	Frequency (MHz)
RBR (1.62 Gbps)	2 (dual)	81
	4 (quad)	40.5
HBR (2.7 Gbps)	2 (dual)	135

continued...



Clock	Signal Name in Design	Description		
			4 (quad)	67.5
		HBR2 (5.4 Gbps)	2 (dual)	270
			4 (quad)	135
		HBR3 (8.1 Gbps)	4 (quad)	202.5
TX PLL Serial Clock	gxb_tx_bonding_clocks	Serial fast clock generated by TX PLL. The clock frequency is set based on the data rate.		
RX Refclock	rx_cdr_refclk	135 MHz transceiver clock data recovery (CDR) reference clock, that is divisible by all DisplayPort data rates (1.62 Gbps, 2.7 Gbps, and 5.4 Gbps). *Note:* The reference clock source of the RX refclock is located at the HSSI refclk pin.		
RX Transceiver Clockout	gxb_rx_clkout	RX clock recovered from the transceiver, and the frequency varies depending on the data rate and symbols per clock.		
		Data Rate	**Symbols per Clock**	**Frequency (MHz)**
		RBR (1.62 Gbps)	2 (dual)	81
			4 (quad)	40.5
		HBR (2.7 Gbps)	2 (dual)	135
			4 (quad)	67.5
		HBR2 (5.4 Gbps)	2 (dual)	270
			4 (quad)	135
		HBR3 (8.1 Gbps)	4 (quad)	202.5
Management Clock	rx_rcfg_mgmt_clk tx_rcfg_mgmt_clk	A free running 100 MHz clock for both Avalon-MM interfaces for reconfiguration and PHY reset controller for transceiver reset sequence.		
		Component		**Required Frequency (MHz)**
		Avalon-MM reconfiguration		100 – 125
		Transceiver PHY reset controller		1 – 500
Audio Clock	dp_audio_clk	DisplayPort audio clock.		
16 MHz Clock	clk_16	160 MHz clock used to encode and decode auxiliary channel in the DisplayPort Intel FPGA IP source and sink IP cores. This clock is also used as a reference clock in the Pixel Clock module for fractional calculation.		
Calibration Clock	dp_rx_clk_cal dp_tx_clk_cal	A 50 MHz calibration clock input that must be synchronous to the Transceiver Reconfiguration module's clock. This clock is used in the DisplayPort Intel FPGA IP core's reconfiguration logic.		
RX Video Clock	dp_rx_vid_clkout	Video clock for DisplayPort sink to clock video data stream.		

continued...

Clock	Signal Name in Design	Description
		If MAX_LINK_RATE = HBR2 and PIXELS_PER_CLOCK = Dual, video clock uses 300 MHz. Otherwise, fixed to 160 MHz.
TX Video Clock	tx_vid_clk	Recovered video clock from the PCR module that reflects the actual video clock frequency. Used when DisplayPort source's TX_SUPPORT_IM_ENABLE = 0.
TX IM Clock	tx_im_clk	Video clock for DisplayPort source to clock video data stream. Must be the same as the RX video clock in this design. Used when DisplayPort source's TX_SUPPORT_IM_ENABLE = 1.

2.6. Interface Signals and Parameter

The tables list the signals and parameter for the DisplayPort Intel FPGA IP design example.

Table 14. Top-Level Signals

Signal	Direction	Width	Description
On-board Oscillator Signal			
refclk2_p	Input	1	100 MHz clock source used as IOPLL reference clock and Avalon-MM management clock
User Push Buttons and LEDs			
user_pb[0]	Input	1	Push button to trigger MSA print out during debug
user_pb[1]	Input	1	Push button to switch to the next video stream, for the MST parallel loopback with PCR design example.
user_pb[2]	Input	1	Global reset
user_led_g	Output	4	Green LED display *Note:* Refer to Hardware Setup on page 38 for the on-board user LED functions.
DisplayPort FMC Daughter Card Pins on FMC			
fmc_gbtclk_m2c_p	Input	1	135 MHz dedicated transceiver reference clock from FMC port
fmc_dp_m2c_p	Input	*N*	DisplayPort RX serial data *Note: N* = RX maximum lane count
fmc_dp_c2m_p	Output	*N*	DisplayPort TX serial data *Note: N* = TX maximum lane count
fmc_la_tx_p_10	Input	1	DisplayPort RX cable detect • 1 = Cable detected • 0 = Cable not detected
fmc_la_rx_n_8	Input	1	DisplayPort RX power detect • 1 = Power not detected • 0 = Power detected
fmc_la_tx_n_9	Input	1	DisplayPort RX Aux In

continued...

DisplayPort FMC Daughter Card Pins on FMC			
fmc_la_rx_n_6	Output	1	DisplayPort RX Aux Out
fmc_la_tx_p_9	Output	1	DisplayPort RX Aux OE
fmc_la_rx_p_6	Output	1	DisplayPort RX HPD • 1 = HPD asserted • 0 = HPD deasserted
fmc_la_rx_n_9	Input	1	DisplayPort TX HPD • 1 = HPD asserted • 0 = HPD deasserted
fmc_la_tx_p_12	Input	1	DisplayPort TX Aux In
fmc_la_rx_p_10	Output	1	DisplayPort TX Aux Out
fmc_la_rx_n_10	Output	1	DisplayPort TX Aux OE
fmca_la_tx_n_12	Output	1	TX CAD for Bitec FMC Rev. 8
fmca_la_tx_p_14	Output	1	TX CAD for Bitec FMC Rev. 10 and 11
FMC On-board Retimer Reconfiguration Interface			
fmca_la_tx_p_0	Inout	1	Bitec FMC Rev. 10: PS8460_SDA Bitec FMC Rev. 11: MCDP6000_SDA
fmca_la_tx_n_0	Inout	1	Bitec FMC Rev. 10: PS8460_SCL Bitec FMC Rev. 11: MCDP6000_SDL
fmca_la_rx_p_0	Output	1	Bitec FMC Rev. 10: PS8460_EQ0 Bitec FMC Rev. 11: Unused
fmca_la_rx_n_0	Output	1	Bitec FMC Rev. 10: PS8460_EQ1 Bitec FMC Rev. 11: Unused
fmca_la_tx_p_1	Output	1	Bitec FMC Rev. 10: PS8460_PDN Bitec FMC Rev. 11: Unused
fmca_la_tx_n_1	Output	1	Bitec FMC Rev. 10: PS8460_CFG0 Bitec FMC Rev. 11: Unused
fmca_la_tx_p_2	Output	1	Bitec FMC Rev. 10: PS8460_CFG1 Bitec FMC Rev. 11: Unused
fmca_la_tx_n_2	Output	1	Bitec FMC Rev. 10: PS8460_CFG2 Bitec FMC Rev. 11: Unused

Table 15. DisplayPort Intel FPGA IP Signals (Platform Designer System)

Signal	Direction	Width	Description
Clock and Reset			
clk_100_in_clk	Input	1	100 MHz clock to CPU sub-system
cpu_reset_bridge_in_reset_n	Input	1	Reset to CPU sub-system (active low)

DisplayPort RX Signals			
dp_rx_reset_bridge_in_reset_n	Input	1	Reset to RX sub-system (active low)
dp_rx_clk_16_in_clk	Input	1	RX Auxiliary clock (16 MHz)
dp_rx_dp_sink_clk_cal	Input	1	RX reconfiguration calibration clock
dp_rx_pio_0_in_port	Input	1	Push button IO for debug purpose
dp_rx_dp_sink_rx_audio_valid	Output	1	RX Audio Interface *Note: M* = RX audio channel
dp_rx_dp_sink_rx_audio_mute	Output	1	
dp_rx_dp_sink_rx_audio_infoframe	Output	40	
dp_rx_dp_sink_rx_audio_lpcm_data	Output	*M**32	
dp_rx_dp_sink_rx_aux_in	Input	1	RX auxiliary interface
dp_rx_dp_sink_rx_aux_out	Output	1	
dp_rx_dp_sink_rx_aux_oe	Output	1	
dp_rx_dp_sink_rx_hpd	Output	1	RX HPD
dp_rx_dp_sink_rx_cable_detect	Input	1	RX cable detect (active high)
dp_rx_dp_sink_rx_pwr_detect	Input	1	RX power detect (active high)
dp_rx_dp_sink_rx_msa	Output	217	DisplayPort RX MSA
dp_rx_dp_sink_rx_lane_count	Output	5	DisplayPort RX lane count
dp_rx_dp_sink_rx_link_rate	Output	2	RX Link Rate 2-bit indicator, used in PCR • RBR: 2'b00 • HBR: 2'b01 • HBR2: 2'b10 • HBR3: 2'b11
dp_rx_dp_sink_rx_link_rate_8bits	Output	8	RX Link Rate 8-bit indicator, used in transceiver reconfiguration management • RBR: 0x06 • HBR: 0x0A • HBR2: 0x14 • HBR3: 0x1E
dp_rx_dp_sink_rx_ss_valid	Output	1	DisplayPort RX secondary stream interface
dp_rx_dp_sink_rx_ss_data	Output	160	
dp_rx_dp_sink_rx_ss_sop	Output	1	

continued...

DisplayPort RX Signals			
dp_rx_dp_sink_rx_ss_eop	Output	1	
dp_rx_dp_sink_rx_ss_clk	Output	1	
dp_rx_dp_sink_rx_stream_valid	Output	1	RX post scrambler stream data. For debug purpose. *Note: S* = RX symbols per clock
dp_rx_dp_sink_rx_stream_clk	Output	1	
dp_rx_dp_sink_rx_stream_data	Output	*S*32	
dp_rx_dp_sink_rx_stream_ctrl	Output	*S*4	
dp_rx_dp_sink_rx_vid_clk	Input	1	DisplayPort RX video stream interface. *Note: B* = RX bits per component, *P* = RX pixels per clock
dp_rx_dp_sink_rx_vid_sol	Output	1	
dp_rx_dp_sink_rx_vid_eol	Output	1	
dp_rx_dp_sink_rx_vid_sof	Output	1	
dp_rx_dp_sink_rx_vid_eof	Output	1	
dp_rx_dp_sink_rx_vid_locked	Output	1	
dp_rx_dp_sink_rx_vid_interlace	Output	1	
dp_rx_dp_sink_rx_vid_field	Output	1	
dp_rx_dp_sink_rx_vid_overflow	Output	1	
dp_rx_dp_sink_rx_vid_data	Output	*B*P*3	
dp_rx_dp_sink_rx_vid_valid	Output	*P*	
dp_rx_dp_sink_rx_parallel_data	Input	*N* *S*10	DisplayPort parallel data from RX Native PHY *Note: N* = RX maximum lane count, *S* = RX symbols per clock
dp_rx_dp_sink_rx_std_clkout	Input	*N*	CDR clock out from RX Native PHY *Note: N* = RX maximum lane count
dp_rx_dp_sink_rx_restart	Output	1	Reset signal to RX Native PHY Reset controller when RX data loses alignment. Triggered by the DisplayPort RX core.
dp_rx_dp_sink_rx_reconfig_req	Output	1	Transceiver reconfiguration interface to the RX reconfiguration management module *Note: N* = RX maximum lane count

continued...

DisplayPort RX Signals			
dp_rx_dp_sink_rx_reconfig_ack	Input	1	
dp_rx_dp_sink_rx_reconfig_busy	Input	1	
dp_rx_dp_sink_rx_bitslip	Output	*N*	
dp_rx_dp_sink_rx_cal_busy	input	*N*	
dp_rx_dp_sink_rx_analogreset	Output	*N*	
dp_rx_dp_sink_rx_digitalreset	Output	*N*	
dp_rx_dp_sink_rx_is_lockedtoref	Input	*N*	
dp_rx_dp_sink_rx_is_lockedtodata	Input	*N*	
dp_rx_dp_sink_rx_set_locktoref	Output	*N*	
dp_rx_dp_sink_rx_set_locktodata	Output	*N*	

DisplayPort TX Signals			
dp_tx_reset_bridge_in_reset_n	Input	1	Reset to TX sub-system
dp_tx_clk_16_in_clk	Input	1	TX Auxiliary clock (16 MHz)
dp_tx_dp_source_clk_cal	Input	1	TX reconfiguration calibration clock
dp_tx_dp_source_tx_audio_valid	Input	1	TX audio channel interface *Note: M* = TX audio channel
dp_tx_dp_source_tx_audio_mute	Input	1	
dp_tx_dp_source_tx_audio_lpcm_data	Input	*M**32	
dp_tx_dp_source_tx_audio_clk	Input	1	
dp_tx_dp_source_tx_aux_in	Input	1	TX auxiliary interface
dp_tx_dp_source_tx_aux_out	Output	1	
dp_tx_dp_source_tx_aux_oe	Output	1	
dp_tx_dp_source_tx_hpd	Input	1	TX HPD

continued...

DisplayPort TX Signals			
dp_tx_dp_source_tx_link_rate	Output	2	TX Link Rate 2-bit indicator, used in transceiver reconfiguration management • RBR: 2'b00 • HBR: 2'b01 • HBR2: 2'b10 • HBR3: 2'b11
dp_tx_dp_source_tx_link_rate_8bits	Output	8	TX Link Rate 8-bit indicator, used in transceiver reconfiguration management • RBR: 0x06 • HBR: 0x0A • HBR2: 0x14 • HBR3: 0x1E
dp_tx_dp_source_tx_ss_ready	Output	1	DisplayPort TX secondary stream interface
dp_tx_dp_source_tx_ss_valid	Input	1	
dp_tx_dp_source_tx_ss_data	Input	128	
dp_tx_dp_source_tx_ss_sop	Input	1	
dp_tx_dp_source_tx_ss_eop	Input	1	
dp_tx_dp_source_tx_ss_clk	Output	1	
dp_tx_dp_source_tx_vid_clk	Input	1	DisplayPort TX video stream (VYSNC/HSYNC/DE) interface (only used when TX_SUPPORT_IM_ENABLE = 0) *Note:* *B* = TX bits per component, *P* = TX pixels per clock.
dp_tx_dp_source_tx_vid_data	Input	*B***P**3	
dp_tx_dp_source_tx_vid_v_sync	Input	*P*	
dp_tx_dp_source_tx_vid_h_sync	Input	*P*	
dp_tx_dp_source_tx_vid_de	Input	*P*	
dp_tx_dp_source_tx_im_clk	Input	1	DisplayPort TX video image interface (only used when TX_SUPPORT_IM_ENABLE = 1) *Note:* *B* = TX bits per component, *P* = TX pixels per clock.
dp_tx_dp_source_tx_im_sol	Input	1	
dp_tx_dp_source_tx_im_eol	Input	1	
dp_tx_dp_source_tx_im_sof	Input	1	
dp_tx_dp_source_tx_im_eof	Input	1	
dp_tx_dp_source_tx_im_data	Input	*B***P**3	

continued...

DisplayPort TX Signals			
dp_tx_dp_source_tx_im_valid	Input	1	
dp_tx_dp_source_tx_im_locked	Input	1	
dp_tx_dp_source_tx_im_interlace	Input	1	
dp_tx_dp_source_tx_im_field	Input	1	
dp_tx_dp_source_tx_parallel_data	Output	*N***S**10	DisplayPort parallel data to TX Native PHY *Note: N* = TX maximum lane count, *S* = TX symbols per clock
dp_tx_dp_source_tx_std_clkout	Input	*N*	TX Native PHY clock out *Note: N* = TX maximum lane count
dp_tx_dp_source_tx_pll_locked	Input	1	TX PLL locked indicator
dp_tx_dp_source_tx_reconfig_req	Output	1	Transceiver Reconfiguration interface to TX reconfiguration management module *Note: N* = TX maximum lane count
dp_tx_dp_source_tx_reconfig_ack	Input	1	
dp_tx_dp_source_tx_reconfig_busy	Input	1	
dp_tx_dp_source_tx_pll_powerdown	Output	1	
dp_tx_dp_source_tx_analog_reconfig_req	Output	1	
dp_tx_dp_source_tx_analog_reconfig_ack	Input	1	
dp_tx_dp_source_tx_analog_reconfig_busy	Input	1	
dp_tx_dp_source_tx_vod	Output	*N**2	
dp_tx_dp_source_tx_emp	Output	*N**2	
dp_tx_dp_source_tx_analogreset	Output	*N*	
dp_tx_dp_source_tx_digitalreset	Output	*N*	
dp_tx_dp_source_tx_cal_busy	Input	*N*	

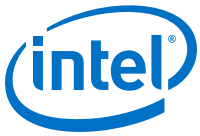


Table 16. RX PHY Top-Level Signals

Signal	Direction	Width	Description
rx_cdr_refclk	Input	1	RX Native PHY CDR reference clock. This design example uses 135 MHz.
dp_rx_clk_cal	Output	1	50 MHz DisplayPort RX reconfiguration calibration clock. This clock must be synchronous to rcfg_mgmt_clk.
rx_cdr_resetn	Input	1	RX Native PHY reset (active low)
video_pll_locked	Input	1	This signal indicates that the video PLL (video clock and clk16) is stable and locked. Use as reset to the DisplayPort Intel FPGA IP and the transceiver.
dp_rx_link_rate_8bits	Input	8	RX link rate indicator, used in transceiver reconfiguration management
rx_rcfg_mgmt_reset	Input	1	RX reconfiguration reset
rx_rcfg_mgmt_clk	Input	1	RX reconfiguration management clock (100 MHz)
rx_rcfg_en	Output	1	RX reconfiguration enable signal
rx_rcfg_write	Output	1	Reconfiguration Avalon® memory-mapped interfaces that interact with Transceiver Arbiter *Note: N* = RX maximum lane count (1, 2, or 4)
rx_rcfg_read	Output	1	
rx_rcfg_address	Output	12	
rx_rcfg_writedata	Output	32	
rx_rcfg_readdata	Input	32	
rx_rcfg_waitrequest	Input	1	
rx_rcfg_cal_busy	Input	*N*	
gxb_rx_rcfg_write	Input	*N*	Reconfiguration Avalon memory-mapped interfaces from Transceiver Arbiter *Note: N* = RX maximum lane count (1, 2, or 4)
gxb_rx_rcfg_read	Input	*N*	
gxb_rx_rcfg_address	Input	*N**10	
gxb_rx_rcfg_writedata	Input	*N**32	
gxb_rx_rcfg_readdata	Output	*N**32	
gxb_rx_rcfg_waitrequest	Output	*N*	
gxb_rx_rcfg_cal_busy	Output	*N*	
gxb_rx_clkout	Output	*N*	RX Native PHY CDR clock out *Note: N* = RX maximum lane count (1, 2, or 4)
gxb_rx_serial_data	Input	*N*	DisplayPort Serial Data to RX Native PHY *Note: N* = RX maximum lane count (1, 2, or 4)
dp_rx_parallel_data	Output	*N***S**10	DisplayPort parallel data to DisplayPort RX core *Note: N* = RX maximum lane count (1, 2, or 4), *S* = RX symbols per clock (2 or 4)
dp_rx_restart	Input	1	Reset signal to the RX Native PHY Reset controller when RX data loses alignment. Triggered by the DisplayPort RX core.

continued...

Signal	Direction	Width	Description
dp_rx_rcfg_req	Input	1	Transceiver Reconfiguration interface from the DisplayPort RX core *Note: N* = RX maximum lane count (1, 2, or 4)
dp_rx_rcfg_ack	Output	1	
dp_rx_rcfg_busy	Output	1	
dp_rx_is_lockedtoref	Output	*N*	
dp_rx_is_lockedtodata	Output	*N*	
dp_rx_bitslip	Input	*N*	
dp_rx_cal_busy	Output	1	
dp_rx_set_locktoref	Input	*N*	
dp_rx_set_locktodata	Input	*N*	

Table 17. TX PHY Top-Level Signals

Signal	Direction	Width	Description
tx_pll_refclk	Input	1	TX transceiver PLL reference clock. This design example uses 135 MHz.
dp_tx_clk_cal	Output	1	50 MHz DisplayPort TX reconfiguration calibration clock. This clock must be synchronous to rcfg_mgmt_clk.
tx_pll_resetn	Input	1	TX transceiver PLL reset (active low)
video_pll_locked	Input	1	This signal indicates that the video PLL (video clock and clk16) is stable and locked. Use as reset to the DisplayPort Intel FPGA IP and the transceiver.
tx_cad	Output	1	Driven to FMC card TX CAD. Tied to 0.
dp_tx_link_rate_8bits	Input	8	TX Link Rate indicator, used in transceiver reconfiguration management. • RBR: 0x06 • HBR: 0x0A • HBR2: 0x14 • HBR3: 0x1E
tx_rcfg_mgmt_reset	Input	1	TX reconfiguration reset
tx_rcfg_mgmt_clk	Input	1	TX reconfiguration management clock (100 MHz)
tx_rcfg_en	Output	1	TX reconfiguration enable signal
tx_rcfg_write	Output	1	Reconfiguration Avalon memory-mapped interfaces to Transceiver Arbiter *Note: N* = TX maximum lane count (1, 2, or 4)
tx_rcfg_read	Output	1	
tx_rcfg_address	Output	12	
tx_rcfg_writedata	Output	32	
tx_rcfg_readdata	Input	32	
tx_rcfg_waitrequest	Input	1	
tx_rcfg_cal_busy	Input	*N*	
gxb_tx_rcfg_write	Input	*N*	Reconfiguration Avalon memory-mapped interfaces from Transceiver Arbiter

continued...

Signal	Direction	Width	Description
gxb_tx_rcfg_read	Input	*N*	*Note: N* = TX maximum lane count (1, 2, or 4)
gxb_tx_rcfg_address	Input	*N**10	
gxb_tx_rcfg_writedata	Input	*N**32	
gxb_tx_rcfg_readdata	Output	*N**32	
gxb_tx_rcfg_waitrequest	Output	*N*	
gxb_tx_rcfg_cal_busy	Output	*N*	
gxb_tx_clkout	Output	*N*	Transceiver clock out *Note: N* = TX maximum lane count (1, 2, or 4)
gxb_tx_serial_data	Output	*N*	DisplayPort Serial Data from Transceiver *Note: N* = TX maximum lane count
dp_tx_parallel_data	Input	*N***S**10	DisplayPort Parallel Data from DisplayPort TX Core *Note: N* = TX maximum lane count (1, 2, or 4), *S* = TX symbols per clock (2 or 4)
dp_tx_rcfg_req	Input	1	Transceiver Reconfiguration interface from DisplayPort TX Core *Note: N* = TX maximum lane count (1, 2, or 4)
dp_tx_rcfg_ack	Output	1	
dp_tx_rcfg_vod	Input	8	
dp_tx_rcfg_emp	Input	8	
dp_txpll_rcfg_req	Input	1	
dp_txpll_rcfg_ack	Output	1	
dp_tx_rcfg_busy	Output	1	
dp_txpll_powerdown	Input	1	
dp_tx_cal_busy	Output	*N*	
dp_txpll_locked	Output	1	

Table 18. Transceiver Arbiter Signals

Signal	Direction	Width	Description
clk	Input	1	Reconfiguration clock. This clock must share the same clock with the reconfiguration management blocks.
reset	Input	1	Reset signal. This reset must share the same reset with the reconfiguration management blocks.
rx_rcfg_en	Input	1	RX reconfiguration enable signal
tx_rcfg_en	Input	1	TX reconfiguration enable signal
rx_rcfg_ch	Input	2	Indicates which channel to be reconfigured on the RX core. This signal must always remain asserted.
tx_rcfg_ch	Input	2	Indicates which channel to be reconfigured on the TX core. This signal must always remain asserted.
rx_reconfig_mgmt_write	Input	1	Reconfiguration Avalon memory-mapped interfaces from the RX reconfiguration management

continued...

Signal	Direction	Width	Description
rx_reconfig_mgmt_read	Input	1	
rx_reconfig_mgmt_address	Input	10	
rx_reconfig_mgmt_writedata	Input	32	
rx_reconfig_mgmt_readdata	Output	32	
rx_reconfig_mgmt_waitrequest	Output	1	
tx_reconfig_mgmt_write	Input	1	Reconfiguration Avalon memory-mapped interfaces from the TX reconfiguration management
tx_reconfig_mgmt_read	Input	1	
tx_reconfig_mgmt_address	Input	10	
tx_reconfig_mgmt_writedata	Input	32	
tx_reconfig_mgmt_readdata	Output	32	
tx_reconfig_mgmt_waitrequest	Output	1	
reconfig_write	Output	1	Reconfiguration Avalon memory-mapped interfaces to the transceiver
reconfig_read	Output	1	
reconfig_address	Output	10	
reconfig_writedata	Output	32	
rx_reconfig_readdata	Input	32	
rx_reconfig_waitrequest	Input	1	
tx_reconfig_readdata	Input	1	
tx_reconfig_waitrequest	Input	1	
rx_cal_busy	Input	1	Calibration status signal from the RX transceiver
tx_cal_busy	Input	1	Calibration status signal from the TX transceiver
rx_reconfig_cal_busy	Output	1	Calibration status signal to the RX transceiver PHY reset control
tx_reconfig_cal_busy	Output	1	Calibration status signal from the TX transceiver PHY reset control

Table 19. Pixel Clock Recovery Signals

The PCR module in the dynamic generation design example is an enhanced version where 2 Fractional PLLs (FPLLs) are used.

Signal	Direction	Width	Description
areset	Input	1	PCR reset
clk	Input	1	Control loop clock (16 MHz)
clk_135	Input	1	135 MHz clock
rx_link_clk	Input	1	RX Native PHY CDR clock out
rx_link_rate	Input	2	RX link rate 2-bit indicator
rx_msa	Input	217	RX MSA
vidin_clk	Input	1	RX video clock. If MAX_LINK_RATE = HBR2 and PIXELS_PER_CLOCK = Dual, uses 300 MHz. Otherwise, fixed to 160 MHz.
vidin_data	Input	*B***P**3	RX video stream interface from RX core *Note: B* = RX bits per component, *P* = RX pixels per clock.
vidin_valid	Input	1	
vidin_locked	Input	1	
vidin_sof	Input	1	
vidin_eof	Input	1	
vidin_sol	Input	1	
vidin_eol	Input	1	
rec_clk	Output	1	Reconstructed/recovered video clock
rec_clk_x2	Output	1	Reconstructed/recovered video clock (2x faster); not used
vidout	Output	*B***P**3	TX video stream interface *Note: B* = TX bits per component, *P* = TX pixels per clock.
hsync	Output	1	
vsync	Output	1	
de	Output	1	
field2	Output	1	

Table 20. Pixel Clock Recovery Parameters

You can use these parameters to configure the clock recovery core.

Parameter	Default Value	Description
PIXELS_PER_CLOCK	1	Specifies how many pixels in parallel (for each clock cycle) are gathered from the DisplayPort RX core (1, 2 or 4).
BPP	24	Specifies the width (in bits) of a single pixel. 1 bit per pixel is equivalent to 3* bits per component.

continued...

Parameter	Default Value	Description
CLK_PERIOD_NS	10	Specifies the period (in nanoseconds) of the clock signal connected to the port. In this design example, the value used is 62.
DEVICE_FAMILY	Cyclone 10 GX	Identifies the family of the device used.
FIXED_NVID	0	Specifies the configuration of the DisplayPort RX received video clocking used. • 1 if GPU NVID is fixed to 'h8000 • 0 if GPU NVID is not fixed Select 0 if you require the PCR to inter-operate with any GPU. Select 1 if you want to optimize resources but take note that this option may not work with certain GPUs.

2.7. Hardware Setup

The DisplayPort Intel FPGA IP design example is 4Kp60 capable and performs a loop-through for a standard DisplayPort video stream.

1. To run the hardware test, connect a DisplayPort-enabled source device to the DisplayPort FMC daughter card sink input.
2. The DisplayPort sink decodes the port into a standard video stream and sends it to the clock recovery core.
3. The clock recovery core synthesizes the original video pixel clock to be transmitted together with the received video data.

   Note: You require the clock recovery feature to produce video without using a frame buffer.
4. The clock recovery core then sends the video data to the DisplayPort source and the Transceiver Native PHY TX block.
5. Connect the DisplayPort FMC daughter card source port to a monitor to display the image.

Table 21. On-board User LED Functions

LEDs	Function
USER_LED[0]	This LED indicates that the source is successfully lane-trained. At this point, the IP core asserts `rx0_vid_locked`.
USER_LED[1]	This LED indicates that the source Transceiver PLL is locked at the link training data rate.
USER_LED[3:2]	These LEDs indicate the RX link rate. • 2'b00 = RBR • 2'b01 = HBR • 2'b10 = HBR2 • 2'b11 = HBR3

2.8. Simulation Testbench

The simulation testbench simulates the DisplayPort TX serial loopback to RX.

Figure 11. DisplayPort Intel FPGA IP Simplex Mode Simulation Testbench Block Diagram

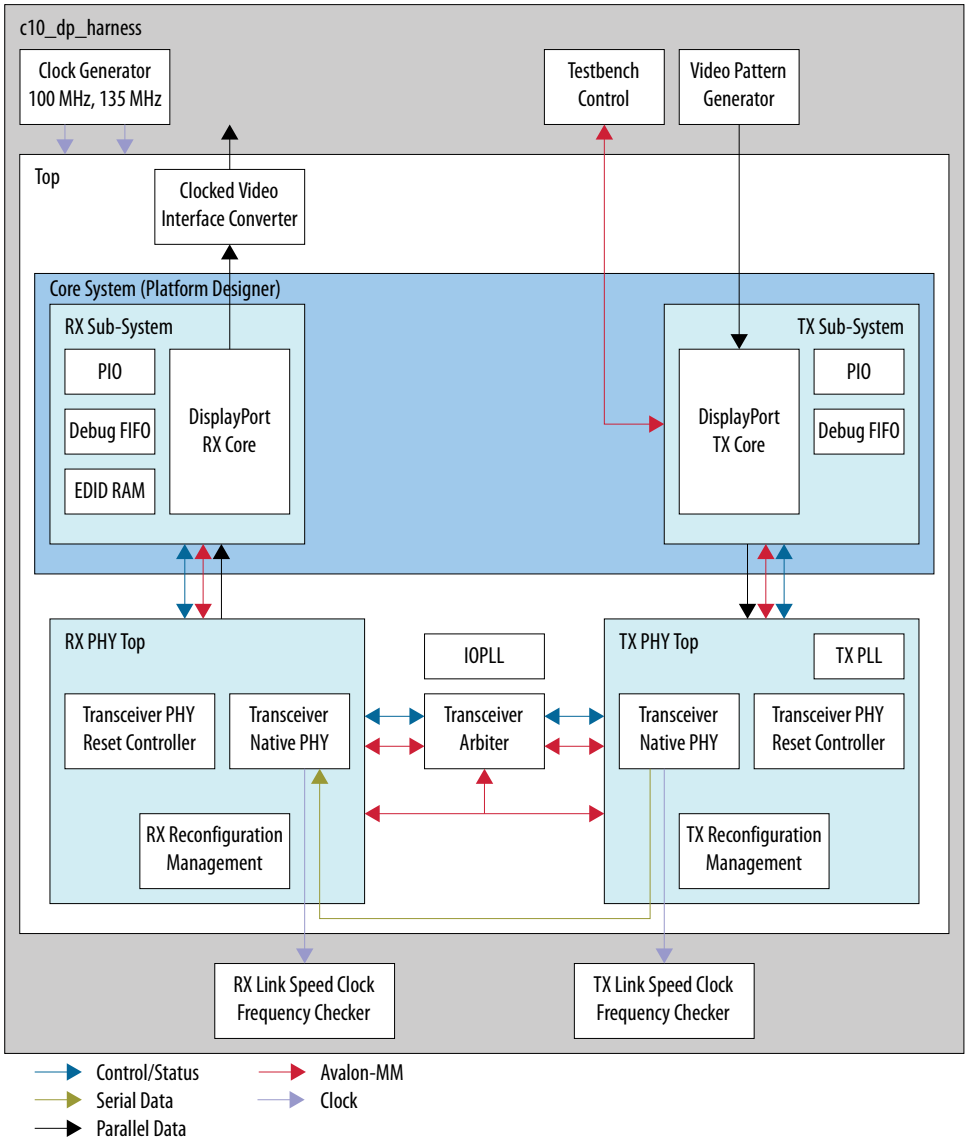


Table 22. Testbench Components

Component	Description
Video Pattern Generator	This generator produces color bar patterns that you can configure. You can parameterize the video format timing.
Testbench Control	This block controls the test sequence of the simulation and generates the necessary stimulus signals to the TX core. The testbench control block also reads the CRC value from both source and sink to make comparisons.
RX Link Speed Clock Frequency Checker	This checker verifies if the RX transceiver recovered clock frequency matches the desired data rate.
TX Link Speed Clock Frequency Checker	This checker verifies if the TX transceiver recovered clock frequency matches the desired data rate.

The simulation testbench does the following verifications:

Test Criteria	Verification
• Link Training sweep across all data rates from HBR3 to HBR2 to HBR and RBR • Read the DPCD registers to check if the DP Status sets and measures both TX and RX Link Speed frequency.	Integrates Frequency Checker to measure the Link Speed clock's frequency output from the TX and RX transceiver.
• Run video pattern from TX to RX. • Verify the CRC for both source and sink to check if they match.	• Connects video pattern generator to the DisplayPort Source to generate the video pattern. • Testbench control next reads out both Source and Sink CRC from DPTX and DPRX registers and compares to ensure both CRC values are identical. *Note:* To ensure CRC is calculated, you must enable the **Support CTS test automation** parameter.

A successful simulation ends with the following message:

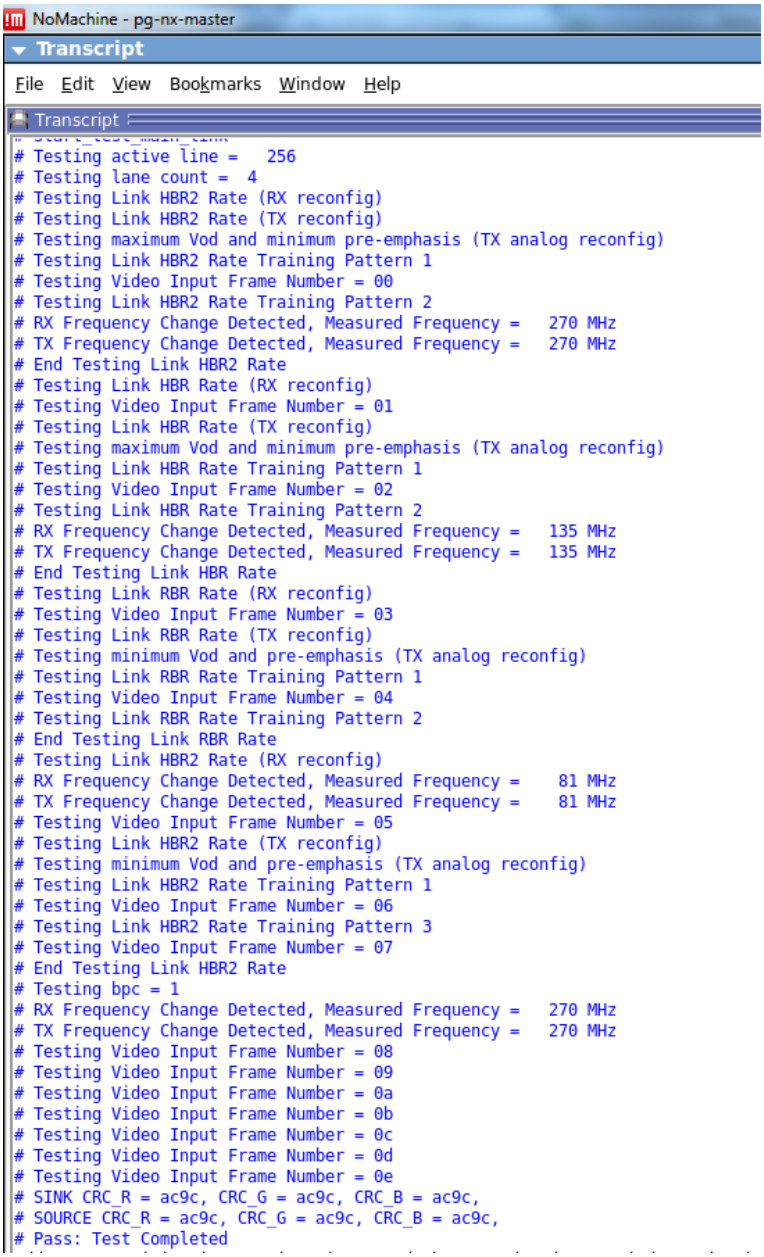


Table 23. DisplayPort Design Example Supported EDA Simulators

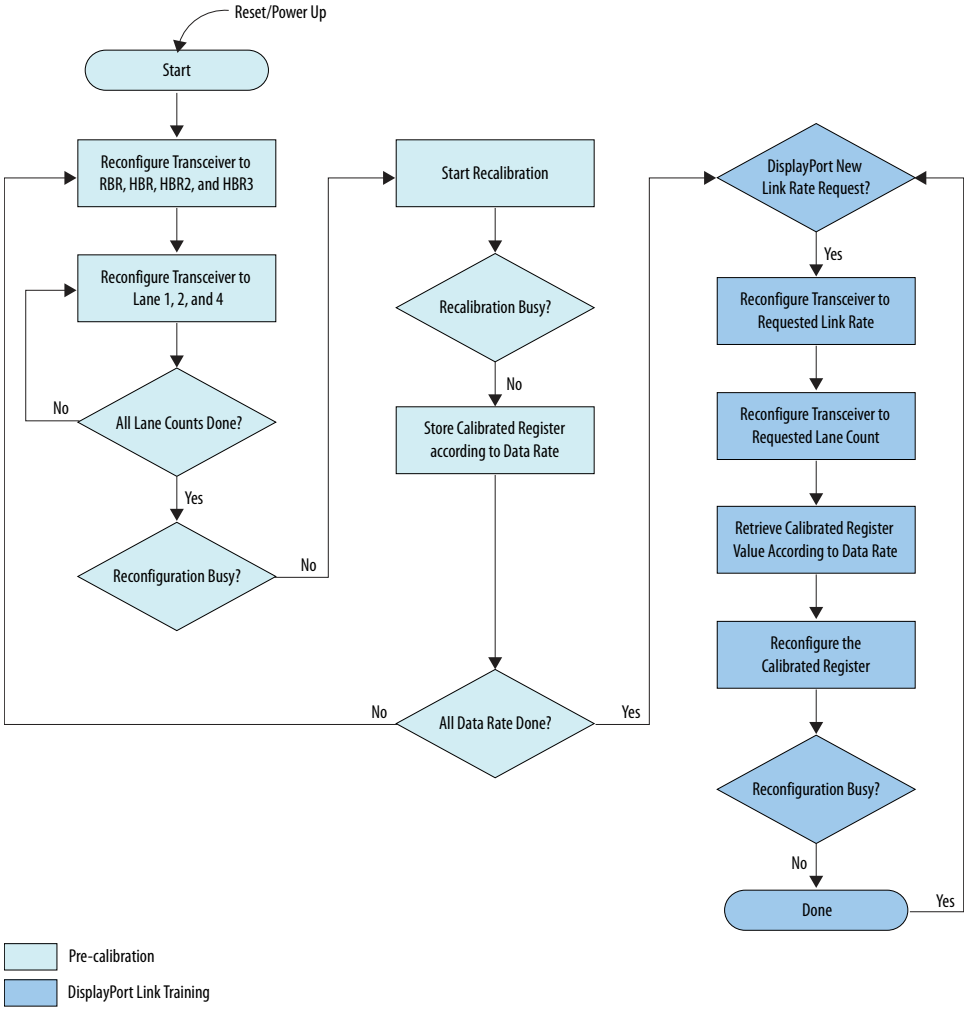
Simulator	Supported Platform	Supported Language
Riviera-PRO	Windows/Linux	VHDL and Verilog HDL
ModelSim	Windows/Linux	VHDL and Verilog HDL
NCSim	Linux	Verilog HDL
Xcelium Parallel	Linux	Verilog HDL
VCS/VCS MX	Linux	VHDL and Verilog HDL

2.9. DisplayPort Transceiver Reconfiguration Flow

The *VESA DisplayPort Standard version 1.4* supports 4 link rates (8.1 Gbps, 5.4 Gbps, 2.7 Gbps, and 1.62 Gbps). You can dynamically switch from 1 data rate to another. Transceiver reconfiguration is required to support dynamic link rate switching.

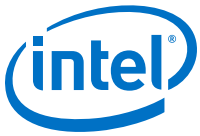
The DisplayPort Intel FPGA IP design examples require some level of reconfiguration and recalibration but with some modification. In these design examples, the pre-calibration method is implemented to reduce the transceiver reconfiguration duration.

Figure 12. Transceiver Reconfiguration Flowchart



The following sequences describe the flow.

1. Upon power up or push button reset, the DisplayPort reconfiguration module initiates the transceiver reconfiguration to sweep across all supported link rate and all lane count.
   a. For TX FPLL, these register offsets are reconfigured:



- 10'h12B (TXPLL M Counter)
- 10'h12C (TXPLL L Counter)

b. For RX CDR, these register offsets are reconfigured:

- 10'h13a (RX L PFD and PD Counter)
- 10'h13b (RX M Counter)

2. After reconfiguration completes, recalibration initiates per data rate.
3. After calibration completes, the pre-defined calibrated registers will be stored according to the respective data rate.

a. For TX FPLL, these register offsets are recalibrated:

- 10'h10A (PLL VCO Frequency Band 0 fix low bits)
- 10'h10B (PLL VCO Frequency Band 0 dyn)
- 10'h142 (PLL VCO Frequency Band 0 fix high bits)
- 10'h123 (PLL VCO Frequency Band 1 fix)
- 10'h124 (PLL VCO Frequency Band 1 dyn)
- 10'h125
- 10'h126

b. For RX CDR, these register offsets are recalibrated:

- 10'h132 (CDR VCO Speed fix)
- 10'h133 (Charge Pump Vcc register)
- 10'h134 (CDR VCO Speed fix)
- 10'h135 (LF PFD and PD Register)
- 10'h136 (CDR VCO Speed fix)
- 10'h137 (CDR VCO Speed fix)
- 10'h139 (Charge Pump current PFD and PD register)

4. Steps 1 through 3 are repeated until all supported data rates are covered.
5. When the pre-calibration steps complete, the reconfiguration module is ready to start DisplayPort link training.
6. Whenever the DisplayPort Intel FPGA IP sends a new link rate request, the reconfiguration module initiates reconfiguration to the transceiver.
7. The reconfiguration flow includes retrieving the calibrated register offset value that corresponds to the link rate and reconfigure it to the transceiver. No recalibration is required.
8. When reconfiguration completes, the transceiver is ready to receive the link rate.
9. The DisplayPort reconfiguration module continues to monitor if a new link rate request is detected. If it detects a new request, the module repeats step 5.

2.10. Transceiver Lane Configurations

If you want to configure your design to use 1, 2 or 4 lanes targeting different versions of Bitec FMC daughter cards, you have to configure the pin assignments accordingly in the Intel Quartus Prime Pro Settings File (QSF).

To configure the DisplayPort Intel FPGA IP design example using 1, 2 or 4 lanes, follow these steps:

1. In both the DisplayPort Source and Sink parameter editors, set the **Maximum lane count** parameter to 1, 2 or 4.
2. Generate the design example.
3. Make the following assignments in the Assignment Editor.

Table 24. Pin Assignments for Bitec FMC Revision 8 or Earlier

DisplayPort	Pin Location (Intel Cyclone 10 GX Development Kit)	Four Lanes	Two Lanes	One Lane
Source	AG28	fmca_dp_c2m_p[0]	Not applicable	Not applicable
	AG27	fmca_dp_c2m_n[0]		
	AE28	fmca_dp_c2m_p[1]		
	AE27	fmca_dp_c2m_n[1]		
	AC28	fmca_dp_c2m_p[2]	fmca_dp_c2m_p[0]	
	AC27	fmca_dp_c2m_n[2]	fmca_dp_c2m_n[0]	
	AA28	fmca_dp_c2m_p[3]	fmca_dp_c2m_p[1]	fmca_dp_c2m_p[0]
	AA27	fmca_dp_c2m_n[3]	fmca_dp_c2m_n[1]	fmca_dp_c2m_n[0]
Sink	AF26	fmca_dp_m2c_p[0]	fmca_dp_m2c_p[0]	fmca_dp_m2c_p[0]
	AF25	fmca_dp_m2c_n[0]	fmca_dp_m2c_n[0]	fmca_dp_m2c_n[0]
	AD26	fmca_dp_m2c_p[1]	fmca_dp_m2c_p[1]	Not applicable
	AD25	fmca_dp_m2c_n[1]	fmca_dp_m2c_n[1]	
	AB26	fmca_dp_m2c_p[2]	Not applicable	
	AB25	fmca_dp_m2c_n[2]		
	Y26	fmca_dp_m2c_p[3]		
	Y25	fmca_dp_m2c_n[3]		
Transceiver Avalon Memory-Mapped Interface Group	XCVR_RECONFIG_GROUP	Enable	Disable	Disable

Table 25. Pin Assignments for Bitec FMC Revision 10

DisplayPort	Pin Location (Intel Cyclone 10 GX Development Kit)	Four Lanes	Two Lanes	One lane
Source	AG28	fmc_dp_c2m_p[0]	fmc_dp_c2m_p[0]	fmc_dp_c2m_p[0]
	AG27	fmc_dp_c2m_n[0]	fmc_dp_c2m_n[0]	fmc_dp_c2m_n[0]
	AE28	fmc_dp_c2m_p[1]	fmc_dp_c2m_p[1]	Not Applicable
	AE27	fmc_dp_c2m_n[1]	fmc_dp_c2m_n[1]	
	AC28	fmc_dp_c2m_p[2]	Not Applicable	
	AC27	fmc_dp_c2m_n[2]		
	AA28	fmc_dp_c2m_p[3]		

continued...

DisplayPort	Pin Location (Intel Cyclone 10 GX Development Kit)	Four Lanes	Two Lanes	One lane
	AA27	fmc_dp_c2m_n[3]		
Sink	AF26	fmc_dp_m2c_p[0]	fmc_dp_m2c_p[0]	fmc_dp_m2c_p[0]
	AF25	fmc_dp_m2c_n[0]	fmc_dp_m2c_n[0]	fmc_dp_m2c_n[0]
	AD26	fmc_dp_m2c_p[1]	fmc_dp_m2c_p[1]	Not Applicable
	AD25	fmc_dp_m2c_n[1]	fmc_dp_m2c_n[1]	
	AB26	fmc_dp_m2c_p[2]	Not Applicable	
	AB25	fmc_dp_m2c_n[2]		
	Y26	fmc_dp_m2c_p[3]		
	Y25	fmc_dp_m2c_n[3]		
Merging of Reconfiguration Interfaces	XCVR_RECONFIG_GROUP	Enable	Enable	Enable

Table 26. Pin Assignments for Bitec FMC Revision 11

DisplayPort	Pin Location (Intel Cyclone 10 GX Development Kit)	Four Lanes	Two Lanes	One Lane
Source	AG28	fmca_dp_c2m_p[0]	fmca_dp_c2m_p[0]	fmca_dp_c2m_p[0]
	AG27	fmca_dp_c2m_n[0]	fmca_dp_c2m_n[0]	fmca_dp_c2m_n[0]
	AE28	fmca_dp_c2m_p[1]	fmca_dp_c2m_p[1]	Not applicable
	AE27	fmca_dp_c2m_n[1]	fmca_dp_c2m_n[1]	
	AC28	fmca_dp_c2m_p[2]	Not applicable	
	AC27	fmca_dp_c2m_n[2]		
	AA28	fmca_dp_c2m_p[3]		
	AA27	fmca_dp_c2m_n[3]		
Sink	AF26	fmca_dp_m2c_p[0]	Not applicable	Not applicable
	AF25	fmca_dp_m2c_n[0]		
	AD26	fmca_dp_m2c_p[1]		
	AD25	fmca_dp_m2c_n[1]		
	AB26	fmca_dp_m2c_p[2]	fmca_dp_m2c_p[0]	
	AB25	fmca_dp_m2c_n[2]	fmca_dp_m2c_n[0]	
	Y26	fmca_dp_m2c_p[3]	fmca_dp_m2c_p[1]	fmca_dp_m2c_p[0]
	Y25	fmca_dp_m2c_n[3]	fmca_dp_m2c_n[1]	fmca_dp_m2c_n[0]
Transceiver Avalon Memory-Mapped Interface Group	XCVR_RECONFIG_GROUP	Enable	Disable	Disable

Note: You can disable the non-applicable pin assignments in the Assignment Editor.

3. DisplayPort Intel Cyclone 10 GX FPGA IP Design Example User Guide Archives

IP versions are the same as the Intel Quartus Prime Design Suite software versions up to 19.1. From Intel Quartus Prime Design Suite software version 19.2 or later, IP cores have a new IP versioning scheme.

If an IP core version is not listed, the user guide for the previous IP core version applies.

Intel Quartus Prime Version	IP Core Version	User Guide
20.1	19.3.0	DisplayPort Intel Cyclone 10 GX FPGA IP Design Example User Guide
19.2	19.1.0	DisplayPort Intel Cyclone 10 GX FPGA IP Design Example User Guide
19.1	19.1	DisplayPort Intel Cyclone 10 GX FPGA IP Design Example User Guide
17.1.1	17.1.1	Intel FPGA DisplayPort IP Core Design Example User Guide for Intel Cyclone 10 GX Devices

4. Revision History for DisplayPort Intel Cyclone 10 GX FPGA IP Design Example User Guide

Date	Intel Quartus Prime Version	Intel FPGA IP Version	Changes
2020.09.28	20.3	19.4.0	• Updated and renamed the *Configuring Single or Dual Lanes* section to *Transceiver Lane Configurations*. • Added pin assignments for Bitec FMC revision 10 in the *Transceiver Lane Configurations* section. • Updated the pin assignments for Bitec FMC revision 8 or earlier, and revision 11 with transceiver Avalon memory-mapped interface group information in the *Transceiver Lane Configurations* section.
2020.04.13	20.1	19.3.0	• Updated the Bitec DisplayPort card revision and the IP version in the local parameter in the RTL file at `<project directory>/rtl/c10_dp_demo.v` and the software `config.h` file in the *Compiling and Testing the Design* section. • Updated the description for the `fmca_la_tx_n_12` signal and added a new signal, `fmca_la_tx_p_14` for DisplayPort FMC daughter card pins in the *Interface Signals and Parameters* section. • Replaced the description about the Parade Tech PS8460 Retimer signals with the FMC On-board Retimer Reconfiguration Interface signals in the *Interface Signals and Parameters* section.
2019.07.30	19.2	19.1.0	• Added information about the DisplayPort MST parallel loopback with and without a PCR module design examples in the *DisplayPort Intel FPGA IP Design Example Quick Start Guide* section. • Updated the files and folders in the *Directory Structure* section. • Added support for the Bitec DisplayPort FMC daughter card revision 11 in the *Hardware and Software Requirements* section. • Added information about the DisplayPort MST parallel loopback with and without a PCR module design examples in the *Generating the Design*, *DisplayPort Intel FPGA IP Design Example Parameters*, and *DisplayPort Intel FPGA IP Design Example Detailed Description* sections.

continued...

Date	Intel Quartus Prime Version	Intel FPGA IP Version	Changes
			• Updated the *Regenerating ELF File* section to include information about WSL and provided a link to the *Nios II Software Developer Handbook*. • Updated the *Compiling and Testing the Design* section to include information about the Bitec DisplayPort FMC daughter card revision 11, channel mapping, and clock controller setting. • Updated the *Configuring Single or Dual Lanes* section with information about the Bitec DisplayPort FMC daughter card revision 11.
2019.04.05	19.1	19.1	• Removed the `/altera_avalon_i2c` file from the *Directory Structure* section. It is not added in the core folder. • Updated the *Directory Structure* section to add the Xcelium Parallel simulator files. • Added instructions to run simulation using the Xcelium Parallel simulator in the *Simulating the Design* section. • Edited the *DisplayPort Design Example Supported EDA Simulators* table in the *Simulation Testbench* section to include Xcelium Parallel simulator and the supported platforms. • Moved the `.c` and `.h` software files to a new folder in the *Directory Structure* section. These files are now in the `dp_demo` subfolder in version 19.1 of the DisplayPort Intel FPGA IP. • Updated the Bitec DisplayPort FMC daughter card local parameter in the *Compiling and Testing the Design* section. • Edited the note about CRC calculation in the *Simulation Testbench* section. To ensure CRC is calculated, you must enable the **Support CTS test automation** parameter. • Updated the frequency rate for HBR quad symbols per clock to 67.5 for the RX and TX Transceiver Clockout descriptions in the *Clocking Scheme* section. • Added the *Intel Cyclone 10 GX DisplayPort SST Parallel Loopback with Adaptive Sync Support* section to provide guidelines to add the Adaptive Sync feature, • Added the *Configuring Single or Dual Lanes* section to provide guidelines to make the correct pin assignments for single and dual lanes.
2017.12.25	17.1.1	17.1.1	Initial release.