



25G Ethernet Intel® Arria® 10 FPGA IP Design Example User Guide

Updated for Intel® Quartus® Prime Design Suite: **20.4**

IP Version: **19.4.1**



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UG-20048 | 2020.12.14

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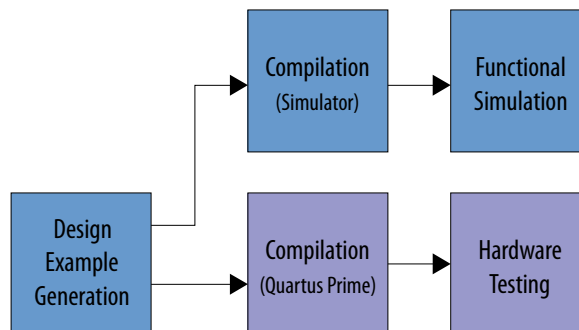
1. 25G Ethernet Intel FPGA IP Quick Start Guide

The 25G Ethernet Intel FPGA IP core provides a simulation testbench and a hardware design example that supports compilation and hardware testing. When you generate the design example, the parameter editor automatically creates the files necessary to simulate, compile, and test the design in hardware. You can download the compiled hardware design to an Intel Arria® 10 GT device.

Note: This design example targets the Intel Arria 10 GT device and requires a 25G retimer. Please contact your Intel FPGA representative to inquire about a platform suitable to run this hardware example. In some cases a loan of appropriate hardware may be available.

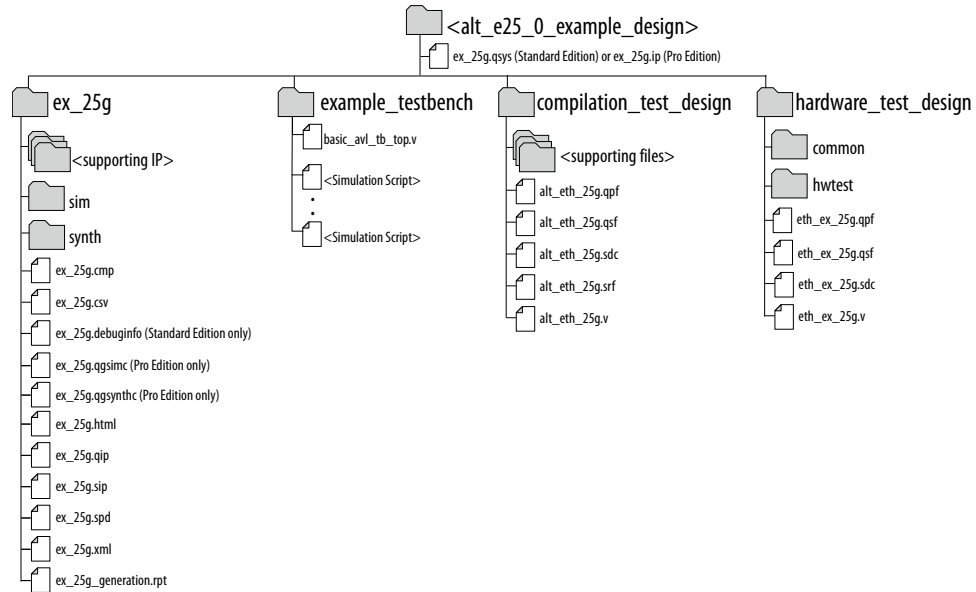
In addition, Intel provides a compilation-only example project that you can use to quickly estimate IP core area and timing.

Figure 1. Design Example Usage



1.1. Design Example Directory Structure

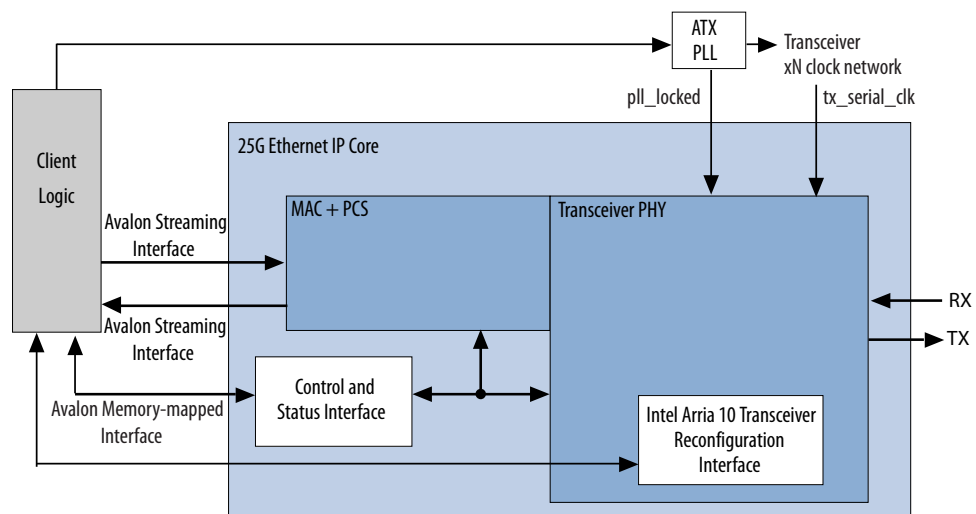
Figure 2. 25G Ethernet Intel FPGA IP Design Example Directory Structure



The hardware configuration and test files (the hardware design example) are located in `<design_example_dir>/hardware_test_design`. The simulation files (testbench for simulation only) are located in `<design_example_dir>/example_testbench`. The compilation-only design example is located in `<design_example_dir>/compilation_test_design`.

1.2. Simulation Design Example Components

Figure 3. 25G Ethernet Intel FPGA IP Simulation Design Example Block Diagram





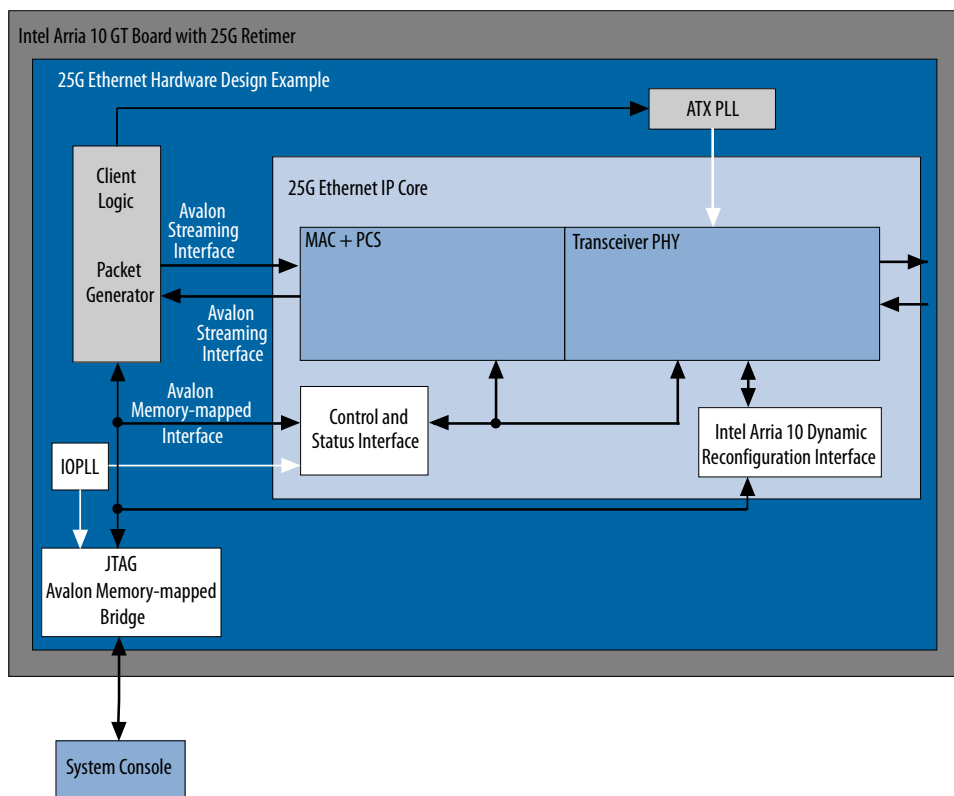
The simulation design example top-level test file is `basic_avl_tb_top.sv`. This file instantiates and connects an ATX PLL. It includes a task, `send_packets_25g_avl`, to send and receive 10 packets.

Table 1. 25G Ethernet Intel FPGA IP Core Testbench File Descriptions

File Name	Description
Testbench and Simulation Files	
<code>basic_avl_tb_top.sv</code>	Top-level testbench file. The testbench instantiates the DUT and runs Verilog HDL tasks to generate and accept packets.
Testbench Scripts	
<code>run_vsim.do</code>	The ModelSim script to run the testbench.
<code>run_vcs.sh</code>	The Synopsys VCS script to run the testbench.
<code>run_ncsim.sh</code>	The Cadence NCSim script to run the testbench.
<code>run_xcelium.sh</code>	The Cadence Xcelium* script to run the testbench.

1.3. Hardware Design Example Components

Figure 4. 25G Ethernet Intel FPGA IP Hardware Design Example High Level Block Diagram



The 25G Ethernet Intel FPGA IP hardware design example includes the following components:

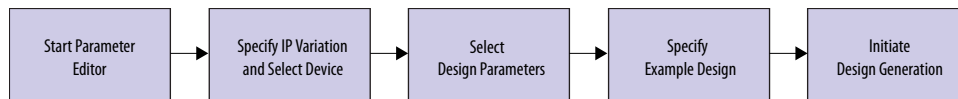
- 25G Ethernet Intel FPGA IP core.
- Client logic that coordinates the programming of the IP core and packet generation.
- ATX PLL to drive the device transceiver channel.
- IOPLL to generate a 100 MHz clock from a 50 MHz input clock to the hardware design example.
- JTAG controller that communicates with the System Console. You communicate with the client logic through the System Console.

Table 2. 25G Ethernet Intel FPGA IP Core Hardware Design Example File Descriptions

File Names	Description
eth_ex_25g.qpf	Quartus Prime project file
eth_ex_25g.qsf	Quartus project settings file
eth_ex_25g.sdc	Synopsys Design Constraints file. You can copy and modify this file for your own 25G Ethernet Intel FPGA IP design.
eth_ex_25g.v	Top-level Verilog HDL design example file
common/	Hardware design example support files
hwtest/main.tcl	Main file for accessing System Console

1.4. Generating the Design Example

Figure 5. Procedure



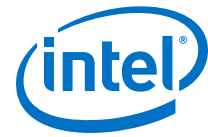
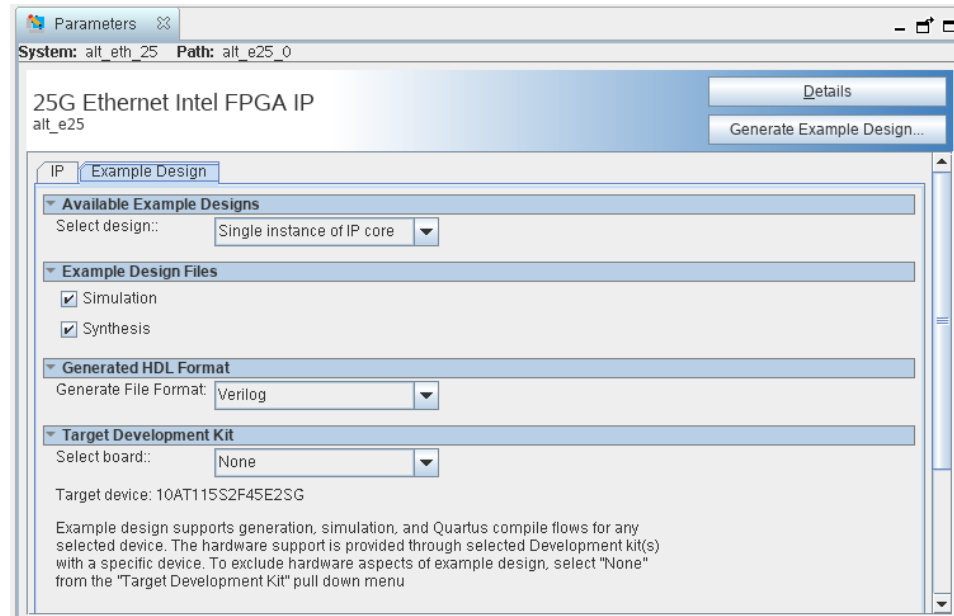


Figure 6. Example Design Tab in the 25G Ethernet Intel FPGA IP Parameter Editor



Follow these steps to generate the hardware design example and testbench:

1. Depending on whether you are using the Intel Quartus® Prime Pro Edition software or the Intel Quartus Prime Standard Edition software, perform one of the following actions:
 - In the Intel Quartus Prime Pro Edition, click **File > New Project Wizard** to create a new Quartus Prime project, or **File > Open Project** to open an existing Quartus Prime project. The wizard prompts you to specify a device.
 - In the Intel Quartus Prime Standard Edition software, in the IP Catalog (**Tools > IP Catalog**), select the Intel Arria 10 target device family.
2. In the IP Catalog, locate and select **25G Ethernet**. The **New IP Variation** window appears.
3. Specify a top-level name for your IP variation and click **OK**. The parameter editor adds the top-level `.qsys` (in Intel Quartus Prime Standard Edition) or `.ip` (in Intel Quartus Prime Pro Edition) file to the current project automatically. If you are prompted to manually add the `.qsys` or `.ip` file to the project, click **Project > Add/Remove Files in Project** to add the file.
4. In the Intel Quartus Prime Standard Edition software, you must select a specific Intel Arria 10 device in the **Device** field, or keep the default device the Quartus Prime software proposes.
5. Click **OK**. The parameter editor appears.
6. On the **IP** tab, specify the parameters for your IP core variation.
7. On the **Example Design** tab, for **Example Design Files**, select the **Simulation** option to generate the testbench, and select the **Synthesis** option to generate the hardware design example. Only Verilog HDL files are generated.

Note: A functional VHDL IP core is not available. Specify Verilog HDL only, for your IP core design example.

8. Click the **Generate Example Design** button. The **Select Example Design Directory** window appears.
9. If you wish to modify the design example directory path or name from the defaults displayed (`alt_e25_0_example_design`), browse to the new path and type the new design example directory name (`<design_example_dir>`).
10. Click **OK**.
11. Refer to the KDB Answer *How do I compensate for the jitter of PLL cascading or non-dedicated clock path for Arria 10 PLL reference clock?* for a workaround you should apply in the `hardware_test_design` directory in the `.sdc` file.

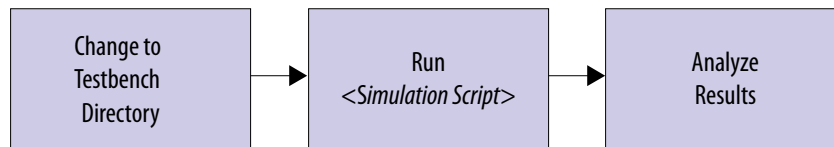
Note: You must consult this KDB Answer because the RX path in the 25G Ethernet Intel FPGA IP core includes cascaded PLLs. Therefore, the IP core clocks might experience additional jitter in Intel Arria 10 devices. This KDB Answer clarifies the software releases in which the workaround is necessary.

Related Information

[KDB Answer: How do I compensate for the jitter of PLL cascading or non-dedicated clock path for Arria 10 PLL reference clock?](#)

1.5. Simulating the 25G Ethernet Intel FPGA IP Design Example Testbench

Figure 7. Procedure



Follow these steps to simulate the testbench:

1. Change to the testbench simulation directory `<design_example_dir>/example_testbench`.
2. Run the simulation script for the supported simulator of your choice. The script compiles and runs the testbench in the simulator. Refer to the table "Steps to Simulate the Testbench".
3. Analyze the results. The successful testbench sends ten packets, receives ten packets, and displays "Testbench complete."

Table 3. Steps to Simulate the Testbench

Simulator	Instructions
ModelSim	In the command line, type <code>vsim -do run_vsim.do</code> If you prefer to simulate without bringing up the ModelSim GUI, type <code>vsim -c -do run_vsim.do</code> <i>Note:</i> The ModelSim* - Intel FPGA Edition simulator does not have the capacity to simulate this IP core. You must use another supported ModelSim simulator such as ModelSim SE.
NCSim	In the command line, type <code>sh run_ncsim.sh</code>
VCS	In the command line, type <code>sh run_vcs.sh</code>
Xcelium	In the command line, type <code>sh run_xcelium.sh</code>



The successful test run displays output confirming the following behavior:

1. Waiting for RX clock to settle
2. Printing PHY status
3. Sending 10 packets
4. Receiving 10 packets
5. Displaying "Testbench complete."

The following sample output illustrates a successful simulation test run:

```
#Ref clock is run at 625 MHz so whole numbers can used for all clock periods.
#Multiply reported frequencies by 33/32 to get actual clock frequencies.
#Waiting for RX alignment
#RX deskew locked
#RX lane alignment locked
#TX enabled
***Sending Packet 1...
***Sending Packet 2...
***Sending Packet 3...
***Sending Packet 4...
***Sending Packet 5...
***Sending Packet 6...
***Sending Packet 7...
***Received Packet 1...
***Sending Packet 8...
***Received Packet 2...
***Sending Packet 9...
***Received Packet 3...
***Sending Packet 10...
***Received Packet 4...
***Received Packet 5...
***Received Packet 6...
***Received Packet 7...
***Received Packet 8...
***Received Packet 9...
***Received Packet 10...
***
*** Testbench complete.
***
#*****
```

1.6. Compiling and Configuring the Design Example in Hardware

To compile the hardware design example and configure it on your Intel Arria 10 GT device, follow these steps:

1. Ensure hardware design example generation is complete.
2. In the Intel Quartus Prime software, open the Intel Quartus Prime project `<design_example_dir>/hardware_test_design/eth_ex_25g.qpf`.
3. Before compiling, ensure you have implemented the workaround from the KDB Answer *How do I compensate for the jitter of PLL cascading or non-dedicated clock path for Arria 10 PLL reference clock?* if relevant for your software release.
4. On the Processing menu, click **Start Compilation**.
5. After you generate a SRAM object file `.sof`, follow these steps to program the hardware design example on the Intel Arria 10 device:



- a. On the **Tools** menu, click **Programmer**.
- b. In the Programmer, click **Hardware Setup**.
- c. Select a programming device.
- d. Select and add the Intel Arria 10 GT board with 25G retimer to your Intel Quartus Prime session.
- e. Ensure that **Mode** is set to **JTAG**.
- f. Select the Intel Arria 10 device and click **Add Device**. The Programmer displays a block diagram of the connections between the devices on your board.
- g. In the row with your `.sof`, check the box for the `.sof`.
- h. Check the box in the **Program/Configure** column.
- i. Click **Start**.

Note: This design example targets the Intel Arria 10 GT device. Please contact your Intel FPGA representative to inquire about a platform suitable to run this hardware example

Related Information

- [KDB Answer: How do I compensate for the jitter of PLL cascading or non-dedicated clock path for Arria 10 PLL reference clock?](#)
- [Incremental Compilation for Hierarchical and Team-Based Design](#)
- [Programming Intel FPGA Devices](#)

1.7. Testing the 25G Ethernet Intel FPGA IP Hardware Design Example

After you compile the 25G Ethernet Intel FPGA IP core design example and configure it on your Intel Arria 10 GT device, you can use the System Console to program the IP core and its embedded Native PHY IP core registers.

To turn on the System Console and test the hardware design example, follow these steps:

1. After the hardware design example is configured on the Intel Arria 10 device, in the Intel Quartus Prime software, on the **Tools** menu, click **System Debugging Tools > System Console**.
2. In the Tcl Console pane, type `cd hwtest` to change directory to `<design_example_dir>/hardware_test_design/hwtest`.
3. Type `source main.tcl` to open a connection to the JTAG master.

You can program the IP core with the following design example commands:

- `chkphy_status`: Displays the clock frequencies and PHY lock status.
- `chkmac_stats`: Displays the values in the MAC statistics counters.
- `clear_all_stats`: Clears the IP core statistics counters.
- `start_pkt_gen`: Starts the packet generator.
- `stop_pkt_gen`: Stops the packet generator.
- `loop_on`: Turns on internal serial loopback



- `loop_off`: Turns off internal serial loopback.
- `reg_read <addr>`: Returns the IP core register value at `<addr>`.
- `reg_write <addr> <data>`: Writes `<data>` to the IP core register at address `<addr>`.

Related Information

- [25G Ethernet Intel FPGA IP Design Example Registers](#) on page 13
Register map for hardware design example.
- [Analyzing and Debugging Designs with System Console](#)

2. Design Example Description

The design example demonstrates the functions of the 25G Ethernet Intel FPGA IP core with transceiver interface compliant with the IEEE 802.3ba standard CAUI-4 specification. You can generate the design from the **Example Design** tab in the 25G Ethernet Intel FPGA IP parameter editor.

To generate the design example, you must first set the parameter values for the IP core variation you intend to generate in your end product. Generating the design example creates a copy of the IP core; the testbench and hardware design example use this variation as the DUT. If you do not set the parameter values for the DUT to match the parameter values in your end product, the design example you generate does not exercise the IP core variation you intend.

Note: The testbench demonstrates a basic test of the IP core. It is not intended to be a substitute for a full verification environment. You must perform more extensive verification of your own 25G Ethernet Intel FPGA IP design in simulation and in hardware.

Related Information

[25G Ethernet Intel Arria 10 FPGA IP User Guide](#)

2.1. Design Example Behavior

The testbench sends traffic through the IP core, exercising the transmit side and receive side of the IP core. In the hardware design example, you can program the IP core in internal serial loopback mode and generate traffic on the transmit side that loops back through the receive side.

2.2. Design Example Interface Signals

The 25G Ethernet Intel FPGA IP testbench is self-contained and does not require you to drive any input signals.

Table 4. 25G Ethernet Intel FPGA IP Hardware Design Example Interface Signals

Signal	Direction	Comments
clk50	Input	Drive at 50 MHz. The intent is to drive this from a 50 Mhz oscillator on the board.
clk_ref	Input	Drive at 644.53125 MHz.
cpu_resetn	Input	Resets the IP core. Active low. Drives the global hard reset <code>csr_reset_n</code> to the IP core.
<i>continued...</i>		



Signal	Direction	Comments
tx_serial	Output	Transceiver PHY output serial data.
rx_serial	Input	Transceiver PHY input serial data.
user_led[7:0]	Output	Status signals. The hardware design example connects these bits to drive LEDs on the target board. Individual bits reflect the following signal values and clock behavior: <ul style="list-style-type: none"> [0]: Main reset signal to IP core [1]: Divided version of clk_ref [2]: Divided version of clk50 [3]: Divided version of 100 MHz status clock [4]: tx_lanes_stable [5]: rx_block_lock [6]: rx_am_lock [7]: rx_pcs_ready

Related Information

Interfaces and Signal Descriptions

Provides detailed descriptions of the 25G Ethernet Intel FPGA IP core signals and the interfaces to which they belong.

2.3. 25G Ethernet Intel FPGA IP Design Example Registers

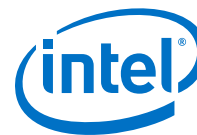
Table 5. 25G Ethernet Intel FPGA IP Hardware Design Example Register Map

Lists the memory mapped register ranges for the hardware design example. You access these registers with the `reg_read` and `reg_write` functions in the System Console.

Word Offset	Register Category
0x300–0xDFF	25G Ethernet Intel FPGA IP core registers.
0x4000–0x4C00	Intel Arria 10 dynamic reconfiguration registers. Register base address is 0x4000.

Related Information

- [Testing the 25G Ethernet Intel FPGA IP Hardware Design Example](#) on page 10
System Console commands to access the IP core and Native PHY registers.
- [25G Ethernet Intel FPGA IP Control, Status, and Statistics Register Descriptions](#)
Describes the 25G Ethernet Intel FPGA IP core registers.



3. 25G Ethernet Intel Arria 10 FPGA IP Design Example User Guide Archives

IP versions are the same as the Intel Quartus Prime Design Suite software versions up to v19.1. 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
16.1	16.1	25G Ethernet Design Example User Guide



4. Document Revision History for 25G Ethernet Intel Arria 10 FPGA IP Design Example User Guide

Document Version	Intel Quartus Prime Version	IP Version	Changes
2020.12.14	20.4	19.4.1	<ul style="list-style-type: none"> Renamed document title to <i>25G Ethernet Intel Arria 10 FPGA IP Design Example User Guide</i>. Updated Figure: <i>Example Design Tab in the 25G Ethernet Intel FPGA IP Parameter Editor</i>. Removed step related to hardware board selection in <i>Generating the Design Example</i>. Added IOPLL to components list and figure in <i>Hardware Design Example Components</i>. Added entry for <code>.sdc</code> file in <i>Design Example Directory Structure</i> and noted it can be used as a starting point to develop the <code>.sdc</code> file for any other 25G Ethernet Intel FPGA IP design. Updated <i>Design Example Description</i> to provide individual bit information about <code>user_led[7:0]</code>. Clarified that the testbench does not provide a full verification environment. Refer to Design Example Description on page 12 Added section <i>25G Ethernet Intel Arria 10 FPGA IP Design Example User Guide Archives</i>.

Date	Release	Changes
2017.11.08	16.1	<p>Added link to KDB Answer that provides workaround for potential jitter on Intel Arria 10 devices due to cascading ATX PLLs in the IP core. Refer to Generating the Design Example on page 6 and Compiling and Configuring the Design Example in Hardware on page 9.</p> <p>This design example user guide has not been updated to reflect minor changes in design generation in Intel Quartus Prime releases later than the Intel Quartus Prime software release v16.1.</p> <p><i>Note:</i></p>
2016.10.31	16.1	Initial release.

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