Intel® Arria® 10 CvP Initialization and Partial Reconfiguration over PCI Express User Guide
## Contents

1. **CvP Initialization in Intel® Arria® 10**
   - Benefits of Using CvP
   - CvP System
   - CvP Support for Intel Arria 10 Devices
   - CvP Initialization
   - CvP Compression and Encryption Features
   - CvP Pins

2. **Design Considerations for CvP Initialization in Intel Arria 10**
   - Designing CvP for an Open System
   - Designing CvP for a Closed System

3. **Understanding the Design Steps for CvP Initialization in Intel Arria 10**
   - Generating the Synthesis HDL Files for Intel Arria 10 PCI Express IP Core
   - Setting up the CvP Parameters in Device and Pin Options
   - Compiling the Design
   - Splitting the SOF File
   - Bringing up the Hardware
     - Installing Jungo WinDriver in Windows Systems
     - Installing Jungo WinDriver in Linux Systems
     - Installing Open Source CvP Driver in Linux System
     - Modifying MSEL/DIP switch on Intel Arria 10 Dev-Kit
   - Programming CvP Images

4. **CvP Driver and Registers**
   - CvP Driver Support
   - CvP Driver Flow
   - VSEC Registers for CvP
     - Altera-defined Vendor Specific Capability Header Register
     - Altera-defined Vendor Specific Header Register
     - Altera Marker Register
     - CvP Status Register
     - CvP Mode Control Register
     - CvP Data Registers
     - CvP Programming Control Register
     - Uncorrectable Internal Error Status Register
     - Uncorrectable Internal Error Mask Register
     - Correctable Internal Error Status Register
     - Correctable Internal Error Mask Register

5. **Partial Reconfiguration over PCI Express in Intel Arria 10**
   - Benefits of Using PR over PCI Express
   - PR over PCIe System
   - Partial Reconfiguration Design Flow
   - Partial Reconfiguration IP Core

6. **Understanding Design Steps for PR over PCI Express in Intel Arria 10**
1. CvP Initialization in Intel® Arria® 10

Configuration via Protocol (CvP) is a configuration scheme supported in Arria® V, Cyclone® V, Stratix® V, and Intel® Arria 10 device families. The CvP configuration scheme creates separate images for the periphery and core logic. You can store the periphery image in a local configuration device and the core image in the host memory, reducing system costs and increasing the security for the proprietary core image. CvP configures the FPGA fabric through the PCI Express* (PCIe) link and it is available for Endpoint variants only. CvP allows the PCIe endpoint to wake up within 200 ms.

Related Information

- **Introduction to Altera IP Cores**
  Provides general information about all Altera IP cores, including parameterizing, generating, upgrading, and simulating IP.
- **Project Management Best Practices**
  Guidelines for efficient management and portability of your project and IP files.

1.1. Benefits of Using CvP

The CvP configuration scheme has the following advantages:

- Reduces system costs by reducing the size of the local flash device used to store the periphery configuration data.
- Improves security for the proprietary core bitstream. CvP ensures that the PCIe host can exclusively access the FPGA core image.
- Provides a simpler software model for configuration. A smart host can use the PCIe protocol and the application topology to initialize and update the FPGA fabric.
- Facilitates hardware acceleration.

1.2. CvP System

The following figure shows the required components for a CvP system.
A CvP system typically consists of an FPGA, a PCIe host, and a configuration device.

1. The configuration device is connected to the FPGA using the conventional configuration interface. The configuration interface can be any of the supported schemes, such as active serial (AS), passive serial (PS), or fast passive parallel (FPP). The choice of the configuration device depends on your chosen configuration scheme.

2. PCIe Hard IP block (bottom left) for CvP and other PCIe applications.

3. PCIe Hard IP block only for PCIe applications and cannot be used for CvP.

Most Intel Arria 10 FPGAs include more than one Hard IP block for PCI Express. The CvP configuration scheme can only utilize the bottom left PCIe Hard IP block on each device. It must be configured as an Endpoint.

### 1.3. CvP Support for Intel Arria 10 Devices

<table>
<thead>
<tr>
<th>Device</th>
<th>CvP Modes Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intel Arria 10</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PCIe Gen 1</td>
</tr>
<tr>
<td>Intel Arria 10</td>
<td>CvP initialization</td>
</tr>
</tbody>
</table>

*Note:* For Intel Arria 10 devices, use Partial Reconfiguration over Protocol instead of CvP Update. You can use the PCIe bus to perform Partial Reconfiguration.
1.4. CvP Initialization

This scheme configures the core of the FPGA through the PCIe link upon system power up. Initialization refers to the initial fabric configuration image loaded in the FPGA fabric after power up.

Configuration Images

In CvP, you partition your design into two images: core image and periphery image.

You use the Intel Quartus® Prime software to generate the following images:

• Periphery image (*.periph.jic) — contains general purpose I/Os (GPIOs), I/O registers, the GCLK, QCLK, and RCLK clock networks, and logic that is implemented in hard IP such as the JTAG interface, PR block, CRC block, Oscillator block, Impedance control block, Chip ID, ASMI block, Remote update block, Temperature sensor, and Hard IP for PCI Express IP Core. These components are included in the periphery image because they are controlled by I/O periphery register bits. The entire periphery image is static and cannot be reconfigured.

• Core image (*.core.rbf) — contains logic that is programmed by configuration RAM (CRAM). This image includes LABs, DSP, and embedded memory. The single static core image may include PR reconfigurable regions.
  — Reconfigurable region — This region can be programmed in user mode while the PCIe link is up and fully enumerated. It must contain only resources that are controlled by CRAM such as LABs, embedded RAM blocks, and DSP blocks in the FPGA core image. It cannot contain any periphery components such as GPIOs, transceivers, PLL, I/O blocks, the Hard IP for PCI Express IP Core, or other components included in the periphery image.
  — Static region — This region cannot be modified.

The periphery image is stored in an external configuration device and is loaded into the FPGA through the conventional configuration scheme. The core image is stored in a host memory and loaded into the FPGA through the PCIe link. All other periphery and core resources are frozen until the FPGA enters user mode.

After the periphery image configuration is complete, the CONF_DONE signal goes high and allows the FPGA to start PCIe link training. During PCIe link training, the FPGA is not in user mode. When PCIe link training is complete, the PCIe link transitions to L0 state and then through PCIe enumeration. The PCIe host then initiates the core image configuration through the PCIe link.

After the core image configuration is complete, the CvP_CONFDONE pin goes high, indicating the FPGA is fully configured.
After the FPGA is fully configured, the FPGA enters user mode. If the INIT_DONE signal is enabled, the INIT_DONE signal goes high after initialization is complete and the FPGA enters user mode.

In user mode, the PCIe links are available for normal PCIe applications. You can also use PR over PCI Express to change re-configurable regions within the single CvP core image.

**Related Information**
- *Arria 10 Core Fabric and General Purpose I/Os Handbook*
  Provides more information about the location of the transceiver banks and I/O banks.
- *Configuration Timing Waveforms*
  Provides more information with the timing diagrams for different configuration modes.

### 1.5. CvP Compression and Encryption Features

**Data Compression**
You can choose to compress the core image by turning on the *Generate compressed bitstream* option in the *Configuration* page of the *Device and Pin Options* dialog box in the Quartus Prime software. The periphery image cannot be compressed. Compressing the core image reduces the storage requirement.

**Data Encryption**
You can choose to encrypt the core image. The periphery image cannot be encrypted. To configure the FPGA with an encrypted core image, you must pre-program the FPGA with a security key. This key is then used to decrypt the incoming configuration bitstream.

A key-programmed FPGA can accept both encrypted and unencrypted bitstreams if you configure the FPGA using the AS, PS, or FPP scheme. However, if you use CvP, a key-programmed FPGA can only accept encrypted bitstreams. Use the same key to encrypt all revisions of the core image.

**Table 2. Supported Clock Source for Encrypted Configuration Data**
The following table lists the supported clock source for each conventional scheme used in a CvP system.

<table>
<thead>
<tr>
<th>Key Types</th>
<th>Active Serial</th>
<th>Passive Serial</th>
<th>Fast Passive Parallel</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>External Clock</td>
<td>Internal Clock</td>
<td>External Clock</td>
</tr>
<tr>
<td>Volatile key</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Non-volatile key</td>
<td>No</td>
<td>12.5 MHz</td>
<td>Yes</td>
</tr>
</tbody>
</table>

**Related Information**
- *Using the Design Security Features in Altera FPGAs*
- *Arria 10 Device Datasheet*
  Provides more information about the electrical characteristics, switching characteristics, configuration specifications, and I/O timing for Arria 10 devices.
## 1.6. CvP Pins

The following table lists the CvP pin descriptions and connection guidelines.

<table>
<thead>
<tr>
<th>Pin Name</th>
<th>Pin Type</th>
<th>Pin Description</th>
<th>Pin Connection</th>
</tr>
</thead>
<tbody>
<tr>
<td>CvP_CONF_DONE</td>
<td>Output</td>
<td>The CvP_CONF_DONE pin is driven low during configuration. When configuration via PCIe is complete, this signal is released and either actively driven high, or pulled high by an external pull-up resistor. During FPGA configuration in CvP initialization mode, you must observe this pin after the CONF_DONE pin goes high to determine if the FPGA is successfully configured. If you are not using the CvP modes, you can use this pin as a user I/O pin. If this pin is set as dedicated output, the VCCPGM power supply must meet the input voltage specification of the receiving side. If this pin is set as an open-drain output, connect the pin to an external 10-kΩ pull-up resistor to the VCCPGM power supply or a different pull-up voltage that meets the input voltage specification of the receiving side. This gives an advantage on the voltage leveling.</td>
<td></td>
</tr>
<tr>
<td>INIT_DONE</td>
<td>Output</td>
<td>When you enable this pin, a transition from low to high at the pin indicates the device has entered user mode. If the INIT DONE output is enabled, the INIT DONE pin cannot be used as a user I/O pin after configuration. This is a dual-purpose pin and can be used as an I/O pin when not enabled as the INIT DONE pin. When you use the optionally open-drain output dedicated INIT_DONE pin, connect this pin to an external 10-kΩ pull-up resistor to VCCPGM. When you use this pin in an AS or PS multi-device configuration mode, ensure you enable the INIT_DONE pin in the Intel Quartus Prime designs. When you do not use the dedicated INIT_DONE optionally open-drain output, and when this pin is not used as an I/O pin, connect this pin as defined in the Intel Quartus Prime software.</td>
<td></td>
</tr>
<tr>
<td>CONF_DONE</td>
<td>Bidirectional</td>
<td>Dedicated configuration done pin. As a status output, the CONF_DONE pin drives low before and during configuration. After all configuration data is received without error and the initialization cycle starts, CONF_DONE is released. As a status input, the CONF_DONE pin goes high after all data is received. Then the device initializes and enters user mode. This pin is not available as a user I/O pin. Connect an external 10-kΩ pull-up resistors to VCCPGM. VCCPGM must be high enough to meet the VIH specification of the I/O on the device and the external host. When you use passive configuration schemes, the configuration controller monitors this pin.</td>
<td></td>
</tr>
<tr>
<td>nPERST[L,R][0:1]</td>
<td>Input</td>
<td>This pin is connected to the Hard IP for PCIe Express IP Core as a dedicated fundamental reset pin for PCIe usage. If the signal is low, the transceivers and dedicated PCIe Hard IP block that you use for CvP operation are in the reset mode. Connect the nPERST[L,R]0/ nPERST[L,R]1 to the PERST# pin of the PCIe slot. This pin is powered by 1.8V supply and must be driven by 1.8V compatible I/O standards. Only one nPERST pin is used per PCIe Hard IP. These pins have the following locations: continued...</td>
<td></td>
</tr>
<tr>
<td>Pin Name</td>
<td>Pin Type</td>
<td>Pin Description</td>
<td>Pin Connection</td>
</tr>
<tr>
<td>--------------</td>
<td>----------</td>
<td>-----------------</td>
<td>---------------</td>
</tr>
<tr>
<td>nPERSTL0</td>
<td></td>
<td>Bottom Left PCIe HIP &amp; CvP</td>
<td></td>
</tr>
<tr>
<td>nPERSTL1</td>
<td></td>
<td>Top Left PCIe Hard IP (When available)</td>
<td></td>
</tr>
<tr>
<td>nPERSTR0</td>
<td></td>
<td>Bottom Right PCIe Hard IP (When available)</td>
<td></td>
</tr>
<tr>
<td>nPERSTR1</td>
<td></td>
<td>Top Right PCIe Hard IP (When available)</td>
<td></td>
</tr>
</tbody>
</table>

For maximum compatibility, always use the bottom left PCIe Hard IP first, as this is the only location that supports Configuration via Protocol (CvP) using the PCIe link.

**Related Information**

- Pin Connection Guidelines for Arria 10 device family
- Arria 10 Device Datasheet
2. Design Considerations for CvP Initialization in Intel Arria 10

2.1. Designing CvP for an Open System

While designing a CvP system for an Open System where you don’t control both ends of the PCIe link completely, ensure that you observe the guidelines provided in this section.

**FPGA Power Supplies Ramp Time Requirement**

For an open system, you must ensure that your design adheres to the FPGA power supplies ramp-up time requirement.

The power-on reset (POR) circuitry keeps the FPGA in the reset state until the power supply outputs are in the recommended operating range. A POR event occurs from when you power up the FPGA until the power supplies reach the recommended operating range within the maximum power supply ramp time, $t_{RAMP}$. If $t_{RAMP}$ is not met, the device I/O pins and programming registers remain tri-stated, during which device configuration could fail.

For CvP, the total $t_{RAMP}$ must be less than 10 ms, from the first power supply ramp-up to the last power supply ramp-up. You must select fast POR by setting the PORSEL pin to high. The fast POR delay time is in the range of 4–12 ms, allowing sufficient time after POR for the PCIe link to start initialization and configuration.
**Figure 2. Power Supplies Ramp-Up Time and POR**

![Power Supplies Ramp-Up Time and POR Diagram]

**PCIe Wake-Up Time Requirement**

For an open system, you must ensure that the PCIe link meets the PCIe wake-up time requirement as defined in the **PCI Express CARD Electromechanical Specification**. The transition from power-on to the link active (L0) state for the PCIe wake-up timing specification must be within 200 ms. The timing from FPGA power-up until the Hard IP for PCI Express IP Core in the FPGA is ready for link training must be within 120 ms.

**PCIe Wake-Up Time Requirement for CvP Initialization**

For CvP initialization mode, the Hard IP for PCI Express IP core is guaranteed to meet the 120 ms requirement because the periphery image configuration time is significantly less than the full FPGA configuration time. Therefore, you can choose any of the conventional configuration schemes for the periphery image configuration.

To ensure successful configuration, all POR-monitored power supplies must ramp up monotonically to the operating range within the 10 ms ramp-up time. The PERST# signal indicates when the FPGA power supplies are within their specified voltage tolerances and the REFCLK is stable. The embedded hard reset controller triggers after the internal status signal indicates that the periphery image has been loaded. This reset does not trigger off of PERST#. For CvP initialization mode, the PCIe link supports the FPGA core image configuration and PCIe applications in user mode.

**Note:**

For Gen 2 capable Endpoints, after loading the core .sof, Altera recommends that you verify that the link has been trained to the expected Gen 2 rate. If the link is not operating at Gen 2, host software can trigger the Endpoint to retrain.
Figure 3. **PCIe Timing Sequence in CvP Initialization Mode**

![Diagram showing PCIe timing sequence in CvP Initialization Mode]

**Table 4. Power-Up Sequence Timing in CvP Initialization Mode**

<table>
<thead>
<tr>
<th>Timing Sequence</th>
<th>Timing Range (ms)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>a</td>
<td>10</td>
<td>Maximum ramp-up time requirement for all POR-monitored power supplies in the FPGA to reach their respective operating range.</td>
</tr>
<tr>
<td>b</td>
<td>4–12</td>
<td>FPGA POR delay time.</td>
</tr>
<tr>
<td>c</td>
<td>100</td>
<td>Minimum PERST# signal active time from the host.</td>
</tr>
<tr>
<td>d</td>
<td>20</td>
<td>Minimum PERST# signal inactive time from the host before the PCIe link enters training state.</td>
</tr>
<tr>
<td>e</td>
<td>120</td>
<td>Maximum time from the FPGA power up to the end of periphery configuration in CvP initialization mode.</td>
</tr>
<tr>
<td>f</td>
<td>100</td>
<td>Maximum time PCIe device must enter L0 after PERST# is deasserted.</td>
</tr>
</tbody>
</table>

**Related Information**
- **Power Management in Arria 10 Devices**
  Provides more information about the power requirements.
- **PCI Express CARD Electromechanical Specification**

### 2.2. Designing CvP for a Closed System

While designing CvP for a closed system where you control both ends of the PCIe link completely, estimate the periphery configuration time for CvP initialization. You must ensure that the estimated configuration time is within the time allowed by the PCIe host.
3. Understanding the Design Steps for CvP Initialization in Intel Arria 10

CvP initialization divides the design into periphery and core images. The periphery image is stored in a local flash device on the PCB. You can program the periphery through JTAG. The core image is stored in host memory. You must download the core image to the FPGA using the PCI Express link.

You must specify CvP initialization mode in the Quartus Prime software by selecting the CvP Settings Power up and subsequent core configuration and also turn on Enable Configuration via Protocol in the Intel Arria 10 Hard IP for PCI Express. You might choose CvP initialization to prevent unauthorized access to the core image as well as save cost by storing the core image in the host memory.

Figure 4. Design Flow for CvP Initialization

The following figure provides the high-level steps for CvP Initialization with periphery image configured through Active Serial configuration mode.

![Design Flow for CvP Initialization Diagram]

Note:
(1) You can split .sof file into core.dsf and periph.pof if you are using Passive Serial or Fast Passive Parallel mode for periphery image configuration.
(2) You can use periph.pof if you are using Passive Serial or Fast Passive Parallel mode.
Note: For CvP initialization, you must use the CMU PLL and the Hard Reset Controller for the PCI Express Hard IP.

The CvP initialization demonstration walkthrough includes the following steps:
1. Generating the Synthesis HDL Files for Intel Arria 10 PCI Express IP Core on page 14
2. Setting up the CvP Parameters in Device and Pin Options on page 15
3. Compiling the Design on page 15
4. Splitting the SOF File on page 15
5. Bringing up the Hardware on page 17

3.1. Generating the Synthesis HDL Files for Intel Arria 10 PCI Express IP Core

Follow these steps to generate the synthesis HDL files with CvP enabled:
2. Open .qsys file of the project.
3. On the System Contents tab, right-click Intel Arria 10 Hard IP for PCI Express and select Edit.
4. Under System Settings, turn on Enable Configuration via Protocol as shown in the following figure:

Figure 5. Illustrating the specified option in Systems Setting dialog box

5. Click Finish.
6. On the Generation tab, specify your parameters to generate RTL. Then click Generate at the bottom of the window.

Related Information
Arria 10 Avalon-MM Interface for PCIe Solutions User Guide
3.2. Setting up the CvP Parameters in Device and Pin Options

Follow these steps to specify CvP parameters:

1. On the Quartus Prime Assignments menu, select **Device**, and then click **Device and Pin Options**.

2. Under **Category** select **General**, and then enable the following option:
   - **Auto-restart configuration after error**, enable this option to allow automatic restart of configuration attempts if an error is detected. Any restarted configuration may exceed the required PCIe startup time to allow bus enumeration and prevent the use of quartus_cvp for core programming.

   Leave all other options disabled.

3. Under Category, select **CvP Settings**, and specify the following settings:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration via Protocol</td>
<td>Core initialization</td>
</tr>
<tr>
<td>Enable CvP_CONF_DONE pin</td>
<td>Turn this option on.</td>
</tr>
<tr>
<td>Enable open drain on CvP_CONF_DONE pin</td>
<td>Turn this option on.</td>
</tr>
</tbody>
</table>

   **Figure 6. Illustrating the specified CvP parameters in Device and Pin options dialog box**

3.3. Compiling the Design

1. To compile the design, on the Processing menu, select **Start compilation** to create the **.SOF** file.

3.4. Splitting the SOF File

Follow these steps to split your **.SOF** file into separate images for the periphery and core logic.

1. After the **.SOF file** is generated, under File menu, select **Convert Programming File**.

2. Under **Output programming file** section, specify the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Programming file type</td>
<td>JTAG Indirect Configuration File (*.jic)</td>
</tr>
<tr>
<td>Configuration device</td>
<td>EPCQL1024</td>
</tr>
</tbody>
</table>

   **continued...**
3. Under Input files to convert, specify the following parameters:

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flash Loader</td>
<td>10AX115S1F45I1SG</td>
</tr>
<tr>
<td>SOF Data</td>
<td>*.sof</td>
</tr>
</tbody>
</table>

4. Make sure to turn on the **Create CvP files**.
   
   *Note: If you do not check this box, the Quartus Prime software does not create separate files for the periphery and core images.*

   **Figure 7. Illustrating the above specified options in the Convert Programming File GUI**

5. Click Generate to create ***.periph.jic** and ***.core.rbf** files. Alternatively, you can use the following command to generate CvP periphery image (***.jam**) file for the JTAG configuration:

   ```
   quartus_cpf -c <filename>.sof <filename>.jam --cvp
   ```
3.5. Bringing up the Hardware

Before testing the design in hardware, you must install Jungo WinDriver or CvP driver in your DUT system. You can also install RW Utilities or other system verification tools to monitor the link status of the Endpoint and to observe traffic on the link. You can download these utilities for free from many web sites.

Note: Intel does not provide Jungo WinDriver as a part of Intel Quartus Prime install package starting with software version 19.1. You can develop your own custom CvP driver for Linux using the sample Linux driver source code provided by Intel.

Note: The Linux driver provided by Intel is not a production driver. You must adapt this driver to your design’s strategy.

The test setup includes the following components:

- Intel Arria 10 FPGA Development Kit
- USB Blaster
- A DUT PC with PCI Express slot to plug in the Intel Arria 10 FPGA Development Kit
- A host PC running the Quartus Prime software to program the periphery image, .sof or .jic file

Although a separate host PC is not strictly necessary, it makes testing less cumbersome.

3.5.1. Installing Jungo WinDriver in Windows Systems

1. Navigate to `<Quartus Prime installation path>/quartus/drivers/wdvr/windows<32 or 64>`.
2. Run the command:
   - `wdreg -inf windrvr6.inf install`
3. Copy the `wdapi1021.dll` file to the `%windir%\system32` directory.

3.5.2. Installing Jungo WinDriver in Linux Systems

1. Navigate to `<Quartus Prime installation path>/quartus/drivers/wdvr/Linux<32 or 64>`.
2. Run the following commands:
   a. `./configure --disable-usb-support`
   b. `make`
   c. `su`
   d. `make install`
3. You can change the permissions for the device file. For example, `chmod 666 /dev/windrivr6`.
4. For 64-bit Linux systems, set the `Quartus_64BIT` environment variable before you run `quartus_cvp` using the following command:
5. You can use the `quartus_cvp` command to download *.core .rbf files to your FPGA. The following table lists the `quartus_cvp` commands for all modes.

Table 5. Syntax for `quartus_cvp` Commands

<table>
<thead>
<tr>
<th>Mode</th>
<th><code>quartus_cvp</code> Command</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uncompressed</td>
<td><code>quartus_cvp --vid=&lt;Vendor ID&gt; --did=&lt;Device ID&gt; &lt;Core .rbf file path&gt;</code></td>
</tr>
<tr>
<td>Unencrypted</td>
<td></td>
</tr>
<tr>
<td>Compressed</td>
<td><code>quartus_cvp -c --vid=&lt;Vendor ID&gt; --did=&lt;Device ID&gt; &lt;Core .rbf file path&gt;</code></td>
</tr>
<tr>
<td>Encrypted</td>
<td><code>quartus_cvp -e --vid=&lt;Vendor ID&gt; --did=&lt;Device ID&gt; &lt;Core .rbf file path&gt;</code></td>
</tr>
<tr>
<td>Compressed and</td>
<td><code>quartus_cvp -c -e --vid=&lt;Vendor ID&gt; --did=&lt;Device ID&gt; &lt;Core .rbf file path&gt;</code></td>
</tr>
<tr>
<td>encrypted</td>
<td></td>
</tr>
</tbody>
</table>

3.5.3. Installing Open Source CvP Driver in Linux System

1. Download the open source CvP driver from the CvP Driver.
2. Navigate to the driver directory.
3. Unzip the driver by typing the following command:
   ```bash
tar -zxvf .<driver>.tar.bz2
   ```
4. Run the installation by typing the following commands:
   ```bash
   sudo make
   sudo make install
   ```
5. Once the installation completed successfully, it generates the `altera_cvp` file in the following location: directory/dev/altera_cvp.

3.5.4. Modifying MSEL/DIP switch on Intel Arria 10 Dev-Kit

The MSEL/DIP switch labeled `SW5` on the back of the Intel Arria 10 FPGA Development Kit. The right position signifies logic zero and the left position signifies logic one. For example, to set the `MSEL [2:0] = 011` follow the sequence as left, left, right from top to bottom.

Table 6. MSEL Pin Settings for Each Configuration Scheme of Intel Arria 10 Devices

- Do not drive the MSEL pins with a microprocessor or another device.
- Use PS or FPP MSEL pin setting for configuration via HPS.

<table>
<thead>
<tr>
<th>Configuration Scheme</th>
<th>$V_{CCPGM}$ (V)</th>
<th>Power-On Reset (POR) Delay</th>
<th>Valid MSEL[2..0]</th>
</tr>
</thead>
<tbody>
<tr>
<td>JTAG-based configuration</td>
<td>—</td>
<td>—</td>
<td>Use any valid MSEL pin settings below</td>
</tr>
<tr>
<td>AS (x1 and x4)</td>
<td>1.8</td>
<td>Fast</td>
<td>010</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Standard</td>
<td>011</td>
</tr>
<tr>
<td>PS and</td>
<td>1.2/1.5/1.8</td>
<td>Fast</td>
<td>000</td>
</tr>
<tr>
<td>FPP (x8, x16, and x32)</td>
<td></td>
<td>Standard</td>
<td>001</td>
</tr>
</tbody>
</table>
3.5.5. Programming CvP Images

You must program the periphery image (`.periph.jic`) if you are using Active Serial mode and then download the core image (`.core.rbf`) using the PCIe Link. You can use JTAG to load different programming files (i.e., `.sof/.jic/periph.pof`) into your selected CvP initialization enabled Intel Arria 10 device.

After loading the periphery image via the JTAG port, the link should reach the expected data rate and link width. You can confirm the PCIe link status using the RW Utilities.

Follow these steps to program and test the CvP functionality:

1. Plug the Intel Arria 10 FPGA Development Kit into the PCI Express slot of the DUT PC and power it ON. Altera recommends that you use the ATX power supply that the development kit includes.
2. On the host PC, open the Quartus Prime Tools menu and select Programmer.
3. Click Auto Detect to verify that the USB Blaster recognizes the Intel Arria 10 FPGA.
4. Follow these steps to program the periphery image:
   a. Select Intel Arria 10 device, and then right click None under File column.
   b. Navigate to `.periph.jic` file and click Open.
   c. Under Program/Configure column, select the respective devices. For example, 10AX115S1E2 and EPCQL1024.
   d. Click start to program the periphery image into EPCQL1024 flash.

5. After the `.periph.jic` is programmed, the FPGA must be powered cycle to allow the new peripheral image to load from the on-board flash into the FPGA. To force the host PC to re-enumerate the link with the new image, power cycle the DUT PC and the Intel Arria 10 FPGA Development Kit.

6. You can use RW Utilities or another system software driver to verify the link status. You can also confirm expected link speed and width.

7. Follow these steps to program the core image:
   a. Copy the `.core.rbf` file to appropriate Quartus Prime bin install directory. Depending on the 32-bit or 64-bit system, the folder is `.../quartus/bin32` or `.../quartus/bin64`.
   b. Open a Command Prompt in Windows, change the directory to the same mentioned above where the file is copied.
   c. Type the following command to program the core image:

```
quartus_cvp --vid=<Vendor ID> --did=<Device ID>
xxx.core.rbf
```
where the value of Vendor ID and Device ID are in hexadecimal and specified in the Hard IP for PCI Express dialog box. For example, `quartus_cvp --vid=1172 --did=e003 xxx.core.rbf`.

d. The figure below shows the results of a successful CvP programming.

Figure 9. Command Prompt Console

If you implement your own software driver to program the core image, refer to the 
CvP Driver Support on page 21 section.

If you are using the open source Linux driver, perform the following steps to program the core image:

a. Copy the `.core.rbf` file to your working directory.

b. Open a console in Linux. Change directory to the same mentioned above where the file is copied.

c. Program the core image by typing the following command:

```
cp *.core.rbf /dev/altera_cvp
```
4. CvP Driver and Registers

4.1. CvP Driver Support

You can develop your own custom CvP driver for Linux using the sample Linux driver source code provided by Intel\(^1\). The sample driver is written in C and can be downloaded from the Configuration via Protocol webpage.

**Note:** The Linux driver provided by Intel is not a production driver. You must adapt this driver to your design's strategy.

You can also develop your own CvP driver using the Jungo WinDriver tool. You need to purchase a WinDriver license for this purpose.

**Note:** Intel does not provide Jungo WinDriver as a part of Intel Quartus Prime install package starting with software version 19.1. You can develop your own custom CvP driver for Linux using the sample Linux driver source code provided by Intel.

**Related Information**
- Configuration via Protocol
  Provides more information about sample Linux device source code.
- Download the Open Source Linux CvP Driver

4.2. CvP Driver Flow

The following figure shows the flow of the provided CvP driver. The flow assumes that the FPGA is powered up and the control block has already configured the FPGA with the periphery image, which is indicated by the \texttt{CVP\_EN} bit in the CvP status register.

As this figure indicates, the third step of the Start Teardown Flow requires 244 dummy configuration writes to the \texttt{CVP\_DATA} register or 244 memory writes to an address defined by a memory space BAR for this device. Memory writes are preferred because they are higher throughput than configuration writes. The dummy writes cause a 2 ms delay, allowing the control block to complete required operations.

\(^1\) You must set the value of the \texttt{CVP\_NUMCLKS} register to specific constant value as mentioned in \textit{Cvp Mode Control Register} section to leverage the code of the sample Linux driver.
Figure 10. CvP Driver Flow

For high density devices such as Intel Arria 10, it may be necessary to wait up to 500 ms for the CvP status register bit assertion.

4.3. VSEC Registers for CvP

(1) Wait for periphery load completion.
The Vendor Specific Extended Capability (VSEC) registers occupy byte offset 0x200 to 0x240 in the PCIe Configuration Space. The PCIe host uses these registers to communicate with the FPGA control block. The following table shows the VSEC register map. Subsequent tables provide the fields and descriptions of each register.

**Table 7. VSEC Registers for CvP**

<table>
<thead>
<tr>
<th>Byte Offset</th>
<th>Register Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>0x200</td>
<td>Altera-defined Vendor Specific Capability Header</td>
</tr>
<tr>
<td>0x204</td>
<td>Altera-defined Vendor Specific Header</td>
</tr>
<tr>
<td>0x208</td>
<td>Altera Marker</td>
</tr>
<tr>
<td>0x20C:0x218</td>
<td>Reserved</td>
</tr>
<tr>
<td>0x21C</td>
<td>CvP Status</td>
</tr>
<tr>
<td>0x220</td>
<td>CvP Mode Control</td>
</tr>
<tr>
<td>0x224</td>
<td>CvP Data 2</td>
</tr>
<tr>
<td>0x228</td>
<td>CvP Data</td>
</tr>
<tr>
<td>0x22C</td>
<td>CvP Programming Control</td>
</tr>
<tr>
<td>0x230</td>
<td>Reserved</td>
</tr>
<tr>
<td>0x234</td>
<td>Uncorrectable Internal Error Status Register</td>
</tr>
<tr>
<td>0x238</td>
<td>Uncorrectable Internal Error Mask Register</td>
</tr>
<tr>
<td>0x23C</td>
<td>Correctable Internal Error Status Register</td>
</tr>
<tr>
<td>0x240</td>
<td>Correctable Internal Error Mask Register</td>
</tr>
</tbody>
</table>

### 4.3.1. Altera-defined Vendor Specific Capability Header Register

**Table 8. Altera-defined Vendor Specific Capability Header Register (Byte Offset: 0x200)**

<table>
<thead>
<tr>
<th>Bits</th>
<th>Name</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[15:0]</td>
<td>PCI Express Extended</td>
<td>0x000B</td>
<td>RO</td>
<td>PCIe specification defined value for VSEC Capability ID.</td>
</tr>
<tr>
<td></td>
<td>Capability ID</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[19:16]</td>
<td>Version</td>
<td>0x1</td>
<td>RO</td>
<td>PCIe specification defined value for VSEC version.</td>
</tr>
<tr>
<td>[31:20]</td>
<td>Next Capability Offset</td>
<td>Variable</td>
<td>RO</td>
<td>Starting address of the next Capability Structure implemented, if any.</td>
</tr>
</tbody>
</table>

### 4.3.2. Altera-defined Vendor Specific Header Register

**Table 9. Altera-defined Vendor Specific Header Register (Byte Offset: 0x204)**

<table>
<thead>
<tr>
<th>Bits</th>
<th>Name</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[15:0]</td>
<td>VSEC ID</td>
<td>0x1172</td>
<td>RO</td>
<td>A user configurable VSEC ID.</td>
</tr>
<tr>
<td>[19:16]</td>
<td>VSEC Revision</td>
<td>0</td>
<td>RO</td>
<td>A user configurable VSEC revision.</td>
</tr>
<tr>
<td>[31:20]</td>
<td>VSEC Length</td>
<td>0x044</td>
<td>RO</td>
<td>Total length of this structure in bytes.</td>
</tr>
</tbody>
</table>
### 4.3.3. Altera Marker Register

Table 10.  Altera Marker Register (Byte Offset: 0x208)

<table>
<thead>
<tr>
<th>Bits</th>
<th>Name</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:0]</td>
<td>Altera Marker</td>
<td>Device Value</td>
<td>RO</td>
<td>An additional marker. If you use the standard Altera Programmer software to configure the device with CvP, this marker provides a value that the programming software reads to ensure that it is operating with the correct VSEC.</td>
</tr>
</tbody>
</table>

### 4.3.4. CvP Status Register

Table 11.  CvP Status Register (Byte Offset: 0x21C)

<table>
<thead>
<tr>
<th>Bits</th>
<th>Name</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:26]</td>
<td>—</td>
<td>0x00</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[25]</td>
<td>PLD_CORE_READY</td>
<td>Variable</td>
<td>RO</td>
<td>From FPGA fabric. This status bit is provided for debug.</td>
</tr>
<tr>
<td>[24]</td>
<td>PLD_CLK_IN_USE</td>
<td>Variable</td>
<td>RO</td>
<td>From clock switch module to fabric. This status bit is provided for debug.</td>
</tr>
<tr>
<td>[23]</td>
<td>CVP_CONFIG_DONE</td>
<td>Variable</td>
<td>RO</td>
<td>Indicates that the FPGA control block has completed the device configuration via CvP and there were no errors.</td>
</tr>
<tr>
<td>[22]</td>
<td>—</td>
<td>Variable</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[21]</td>
<td>USERMODE</td>
<td>Variable</td>
<td>RO</td>
<td>Indicates if the configurable FPGA fabric is in user mode.</td>
</tr>
<tr>
<td>[20]</td>
<td>CVP_EN</td>
<td>Variable</td>
<td>RO</td>
<td>Indicates if the FPGA control block has enabled CvP mode.</td>
</tr>
<tr>
<td>[19]</td>
<td>CVP_CONFIG_ERROR</td>
<td>Variable</td>
<td>RO</td>
<td>Reflects the value of this signal from the FPGA control block, checked by software to determine if there was an error during configuration.</td>
</tr>
<tr>
<td>[18]</td>
<td>CVP_CONFIG_READY</td>
<td>Variable</td>
<td>RO</td>
<td>Reflects the value of this signal from the FPGA control block, checked by software during programming algorithm.</td>
</tr>
<tr>
<td>[17:0]</td>
<td>—</td>
<td>Variable</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
</tbody>
</table>

### 4.3.5. CvP Mode Control Register

Table 12.  CvP Mode Control Register (Byte Offset: 0x220)

<table>
<thead>
<tr>
<th>Bits</th>
<th>Name</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:16]</td>
<td>—</td>
<td>0x0000</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[15:8]</td>
<td>CVP_NUMCLKS</td>
<td>0x00</td>
<td>RW</td>
<td>This is the number of clocks to send for every CvP data write. This is also known as CDRATIO (clock to data ratio).</td>
</tr>
</tbody>
</table>

continued...
### Bits

<table>
<thead>
<tr>
<th>Bits</th>
<th>Name</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[7:3]</td>
<td>—</td>
<td>0x0</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[2]</td>
<td>CVP_FULLCONFIG</td>
<td>1'b0</td>
<td>RW</td>
<td>A value of 1 indicates a request to the control block to reconfigure the entire FPGA including the Hard IP for PCI Express and bring the PCIe link down.</td>
</tr>
</tbody>
</table>
| [1]  | HIP_CLK_SEL        | 1'b0        | RW     | Selects between PMA and fabric clock when USER_MODE = 1 and PLD_CORE_READY = 1. The following encodings are defined:  
  - 1: Selects internal clock from PMA which is required for CVP_MODE.  
  - 0: Selects the clock from soft logic fabric. This setting should only be used when the fabric is configured in USER_MODE with a configuration file that connects the correct clock.  
  To ensure that there is no clock switching during CvP, you should only change this value when the Hard IP for PCI Express has been idle for 10 µs and wait 10 µs after changing this value before resuming activity. |
| [0]  | CVP_MODE           | 1'b0        | RW     | Controls whether the Hard IP for PCI Express is in CVP_MODE or normal mode. The following encodings are defined:  
  - 1: CVP_MODE is active. Signals to the FPGA control block active and all TLPs are routed to the Configuration Space. This CVP_MODE cannot be enabled if CVP_EN = 0.  
  - 0: The IP core is in normal mode and TLPs are route to the FPGA fabric. |
4.3.6. CvP Data Registers

Table 13. CvP Data Register (Byte Offsets: 0x224 - 0x228)

<table>
<thead>
<tr>
<th>Bits</th>
<th>Name</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:0]</td>
<td>CVP_DATA2</td>
<td>0x00000000</td>
<td>RW</td>
<td>Contains the upper 32 bits of a 64-bit configuration data. Software must ensure that all Bytes in both dwords are enabled. Use of 64-bit configuration data is optional.</td>
</tr>
<tr>
<td>[31:0]</td>
<td>CVP_DATA</td>
<td>0x00000000</td>
<td>RW</td>
<td>Write the configuration data to this register. The data is transferred to the FPGA control block to configure the device. Every write to this register sets the data output to the FPGA control block and generates (&lt;n&gt;) clock cycles to the FPGA control block as specified by the CVP_NUM_CLKS field in the CvP Mode Control register. Software must ensure that all bytes in the memory write dword are enabled. You can access this register using configuration writes. Alternatively, when in CvP mode, this register can also be written by a memory write to any address defined by a memory space BAR for this device. Using memory writes are higher throughput than configuration writes.</td>
</tr>
</tbody>
</table>

4.3.7. CvP Programming Control Register

Table 14. CvP Programming Control Register (Byte Offset: 0x22C)

<table>
<thead>
<tr>
<th>Bits</th>
<th>Name</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:2]</td>
<td>—</td>
<td>0x0000</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[1]</td>
<td>START_XFER</td>
<td>1'b0</td>
<td>RW</td>
<td>Sets the CvP output to the FPGA control block indicating the start of a transfer.</td>
</tr>
<tr>
<td>[0]</td>
<td>CVP_CONFIG</td>
<td>1'b0</td>
<td>RW</td>
<td>When set to 1, the FPGA control block begins a transfer via CvP.</td>
</tr>
</tbody>
</table>
4.3.8. Uncorrectable Internal Error Status Register

This register reports the status of the internally checked errors that are uncorrectable. When specific errors are enabled by the Uncorrectable Internal Error Mask register, they are handled as Uncorrectable Internal Errors as defined in the PCI Express Base Specification 3.0. This register is for debug only. Use this register to observe behavior, not to drive custom logic.

Table 15. Uncorrectable Internal Error Status Register (Byte Offset: 0x234)

<table>
<thead>
<tr>
<th>Bits</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:12]</td>
<td>0x00</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[11]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates an RX buffer overflow condition in a posted request or Completion segment.</td>
</tr>
<tr>
<td>[10]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a parity error was detected on the R2CSEB interface.</td>
</tr>
<tr>
<td>[9]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a parity error was detected on the Configuration Space to TX bus interface.</td>
</tr>
<tr>
<td>[8]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a parity error was detected on the TX to Configuration Space bus interface.</td>
</tr>
<tr>
<td>[7]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a parity error was detected in a TX TLP and the TLP is not sent.</td>
</tr>
<tr>
<td>[6]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates that the Application Layer has detected an uncorrectable internal error.</td>
</tr>
<tr>
<td>[5]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a configuration error has been detected in CvP mode which is reported as uncorrectable. This CVP_CONFIG_ERROR_LATCHED bit is set whenever a CVP_CONFIG_ERROR is asserted while in CVP_MODE.</td>
</tr>
<tr>
<td>[4]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a parity error was detected by the TX Data Link Layer.</td>
</tr>
<tr>
<td>[3]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a parity error has been detected on the RX to Configuration Space bus interface.</td>
</tr>
<tr>
<td>[2]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a parity error was detected at input to the RX Buffer.</td>
</tr>
<tr>
<td>[1]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a retry buffer uncorrectable ECC error.</td>
</tr>
<tr>
<td>[0]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a RX buffer uncorrectable ECC error.</td>
</tr>
</tbody>
</table>
4.3.9. Uncorrectable Internal Error Mask Register

This register controls which errors are forwarded as internal uncorrectable errors. With the exception of the configuration errors detected in CvP mode, all of the errors are severe and may place the device or PCIe link in an inconsistent state. The configuration error detected in CvP mode may be correctable depending on the design of the programming software.

<table>
<thead>
<tr>
<th>Bits</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:12]</td>
<td>0x00</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[10]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for parity error on the R2CSEB interface.</td>
</tr>
<tr>
<td>[9]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for parity error on the Configuration Space to TX bus interface.</td>
</tr>
<tr>
<td>[8]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for parity error on the TX to Configuration Space bus interface.</td>
</tr>
<tr>
<td>[7]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for parity error in the transaction layer packet.</td>
</tr>
<tr>
<td>[6]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for parity error in the application layer.</td>
</tr>
<tr>
<td>[5]</td>
<td>1'b0</td>
<td>RWS</td>
<td>Mask for configuration error in CvP mode.</td>
</tr>
<tr>
<td>[4]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for data parity errors detected during TX Data Link LCRC generation.</td>
</tr>
<tr>
<td>[3]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for data parity errors detected on the RX to Configuration Space Bus interface.</td>
</tr>
<tr>
<td>[2]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for data parity error detected at the input to the RX Buffer.</td>
</tr>
<tr>
<td>[1]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for the retry buffer uncorrectable ECC error.</td>
</tr>
<tr>
<td>[0]</td>
<td>1'b1</td>
<td>RWS</td>
<td>Mask for the RX buffer uncorrectable ECC error.</td>
</tr>
</tbody>
</table>

4.3.10. Correctable Internal Error Status Register

This register reports the status of the internally checked errors that are correctable. When these specific errors are enabled by the Correctable Internal Error Mask register, they are forwarded as Correctable Internal Errors as defined in the PCI Express Base Specification 3.0. This register is for debug only. Use this register to observe behavior, not to drive custom logic.

<table>
<thead>
<tr>
<th>Bits</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:7]</td>
<td>0x000</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[6]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates that the Application Layer has detected a correctable internal error.</td>
</tr>
<tr>
<td>[5]</td>
<td>1'b0</td>
<td>RW1CS</td>
<td>A value of 1 indicates a configuration error has been detected in CvP mode, which is reported as correctable. This bit is set whenever a CVP_CONFIG_ERROR occurs while in CVP_MODE.</td>
</tr>
</tbody>
</table>

---

**Table 16. Uncorrectable Internal Error Mask Register (Byte Offset: 0x238)**

**Table 17. Correctable Internal Error Status Register (Byte Offset: 0x23C)**

continued...
4.3.11. Correctable Internal Error Mask Register

This register controls which errors are forwarded as Internal Correctable Errors. This register is for debug only.

Table 18. Correctable Internal Error Mask Register (Byte Offset: 0x240)

<table>
<thead>
<tr>
<th>Bits</th>
<th>Reset Value</th>
<th>Access</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>[31:7]</td>
<td>0x000</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[6]</td>
<td>1'b0</td>
<td>RWS</td>
<td>Mask for corrected internal error reported by the Application Layer.</td>
</tr>
<tr>
<td>[5]</td>
<td>1'b0</td>
<td>RWS</td>
<td>Mask for configuration error detected in CvP mode.</td>
</tr>
<tr>
<td>[4:2]</td>
<td>0x0</td>
<td>RO</td>
<td>Reserved.</td>
</tr>
<tr>
<td>[1]</td>
<td>1'b0</td>
<td>RWS</td>
<td>Mask for retry buffer correctable ECC error.</td>
</tr>
<tr>
<td>[0]</td>
<td>1'b0</td>
<td>RWS</td>
<td>Mask for RX buffer correctable ECC error.</td>
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</table>
5. Partial Reconfiguration over PCI Express in Intel Arria 10

Partial reconfiguration (PR) is an advanced feature which allows you to reconfigure a portion of the FPGA design’s core logic dynamically, whilst the remainder of the FPGA device continues to operate. Partial reconfiguration is supported in Cyclone V, Stratix V, and Intel Arria 10 device families. Partial Reconfiguration over Protocol offers a solution for configuring the FPGA fabric through the PCI Express (PCIe) link.

Note: For Intel Arria 10 devices, you need the Intel Quartus Prime Pro Edition software to utilize the advanced features like partial reconfiguration.

Related Information
- Introduction to Altera IP Cores
  Provides general information about all Altera IP cores, including parameterizing, generating, upgrading, and simulating IP.
- Project Management Best Practices
  Guidelines for efficient management and portability of your project and IP files.
- Creating a Partial Reconfiguration Design
  Provides more information about the Partial Reconfiguration methodology and utilization.

5.1. Benefits of Using PR over PCI Express

The PR over PCI Express solution has the following advantages:

- Enables dynamic updates to portions of the FPGA design’s core such as LAB, MLAB, DSP and RAM while the rest of the design continues to run.
- Facilitates hardware acceleration.
- Design protection: PR over PCIe ensures the PCIe host can exclusively access the FPGA fabric image which provides protection against unauthorized design tampering or copying.
- Image update without system down time: Allows a portion of the FPGA fabric to be updated through the PCIe link without a host reboot or FPGA full chip re-initialization.
- Unlike Configuration via Protocol (CvP) which requires the bottom left PCIe Hard IP block be used, any Hard IP for PCI Express IP Core can be used for PR over PCIe. The Hard IP Core must be configured as an Endpoint.

(2) The partial reconfiguration feature is available for Cyclone V E, GX, SE, and SX devices with the "SC" suffix in their part number.
5.2. PR over PCIe System

This is a generic design organization for any PR over PCIe design.

Figure 11. Block Diagram of PR over PCIe AVMM Design

As shown in the diagram, a PCIe card with Altera FPGA plugged in a host PC. The host PC sends the PR bit-stream to the Hard IP for PCIe in the form of packets using the application software. The packets are then received by the PR IP core through Avalon MM slave interface. The PR IP core acts as the master to the hard PR control block. It controls the flow of control and data bits to the PR control block as well as sends back the status from the PR control block to the host PC through the PCIe endpoint.

Related Information
Partial Reconfiguration Concepts
Provides more information about the commonly-used partial reconfiguration terminology.

5.3. Partial Reconfiguration Design Flow

The PR design flow requires initial planning. This planning involves setting up one or more design partitions, and then determining the placement assignments in the floorplan. Well-planned PR partitions improve design area utilization and performance. The Intel Quartus Prime software also allows you to create nested PR regions as part of an HPR flow. Reprogramming a child PR region does not affect the parent or the static region. In the HPR flow, reprogramming the parent region, reprograms the associated child region with the default child persona, without affecting the static region. The HPR flow does not impose any restrictions on the number of sub-partitions you can create in your design.

The PR design flow uses the project revisions feature in the Intel Quartus Prime software. Your initial design is the base revision, where you define the static region boundaries and reconfigurable regions on the FPGA. From the base revision, you create multiple revisions. These revisions contain the different implementations for the PR regions. However, all PR implementation revisions use the same top-level placement and routing results from the base revision.
5. Partial Reconfiguration over PCI Express in Intel Arria 10

5.4. Partial Reconfiguration IP Core

PR over PCIe is performed using the PR IP core as an internal host residing in the core logic, which automatically instantiates the corresponding `crcblock` and `prblock` WYSIWYG atom primitives.

(1) Recommended to compile the base revision before verifying timing closure.
Figure 13. **PR IP Core as an Internal Host**

During partial reconfiguration, the PR Control Block (CB) is in Passive Parallel x16 or x32 programming mode.

Figure 14. **PR IP Core Components**

When you instantiate the PR IP core, the Main Controller module which includes the Control Block Interface Controller, Freeze/Unfreeze Controller, and the Data Source Controller are all instantiated. A Data Source Interface module provides you with a JTAG Debug Interface and PR Data Interface.

**Related Information**
- **Partial Reconfiguration IP Core User Guide**
  Provides more information about the PR IP Core and how to instantiate it.
- **Instantiate Partial Reconfiguration Control Block in the Design**
  Provides more information about the PR IP core instantiation using the Quartus Prime software.
6. Understanding Design Steps for PR over PCI Express in Intel Arria 10

Partial reconfiguration is based on the use of revisions in the Quartus Prime Pro edition software. Your initial design is the base revision, where you define the boundaries of the static region and reconfigurable regions on the FPGA. From the base revision, you create multiple revisions, which contain the static region and describe the differences in the reconfigurable regions.

The PR design flow requires more initial planning than a standard design flow. Planning requires setting up the design logic for partitioning, and determining placement assignments to create a floorplan. You should have well-planned partitions to improve the design area utilization and performance, and make timing closure easier.

Refer to the following application notes that provides a comprehensive walkthrough using the dedicated reference designs:

- AN784: Partial Reconfiguration over Protocol Reference Design for Intel Arria 10 Devices
- AN770: Partially Reconfiguring a Design on Intel Arria 10 SoC Development Board

You can extend these reference designs to meet your requirements, then run your custom design on the fully functional system that enables communication over PCIe.
### 7. Document Revision History for the Intel Arria 10 CvP Initialization and Partial Reconfiguration over PCI Express User Guide

<table>
<thead>
<tr>
<th>Date</th>
<th>Changes</th>
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| 2020.09.01   | • Added information about custom CvP driver for Linux in section *Bringing Up the Hardware*.  
• Added a note about the availability of Jungo WinDriver in the following sections:  
  — *Bringing Up the Hardware*  
  — *CvP Driver Support*  
• Added new section *Installing Open Source CvP Driver in Linux System*.  
• Added steps to program the core image using the open source Linux driver in section *Programming CvP Images*. |
| 2019.10.11   | • Added a command to generate CvP periphery image (.*jam) file for the JTAG configuration in section *Splitting the SOF File*.  
• Clarified the use of .*pof file for the Passive Serial or Fast Passive Serial configuration mode.  
• Implemented Intel rebranding. |
| 2019.04.12   | Corrected the Figure: *PCIE Timing Sequence in CvP Initialization Mode* for link training state.                                                                                                           |
| 2016.10.31   | • Changed the document title from 'Arria CvP Initialization and Partial Reconfiguration via Protocol User Guide' to 'Arria CvP Initialization and Partial Reconfiguration over PCI Express User Guide'.  
• Removed the topic *Autonomous Mode*, instead refer to the *Intel Arria 10 Avalon-MM/ST Interface for PCIe Solutions User Guide*.  
• Added the pin descriptions for INIT_DONE and CONF_DONE.  
• Corrected the *PCie Timing Sequence* diagram for CvP initialization.  
• Added the timeout value for CvP_CONFIG_READY in the Figure: *CvP Driver Flow*.  
• Added the topic *Partial Reconfiguration Design Flow* to the Chapter: *Partial Reconfiguration over Protocol in Intel Arria 10*.  
• Removed the Design Planning for PR over PCI Express in Intel Arria 10 chapter. Instead refer to *Creating a Partial Reconfiguration Design*.  
• Removed the following topics from Chapter: *Understanding Design Steps for PR over PCI Express in Intel Arria 10*:  
  — Creating a Qsys design  
  — Creating User Logic and Top Level File  
  — Creating PR Partition  
  — Generating Base SOF/RBF Bitstreams  
  — Creating PR Revision  
  — Generating PR Bitstreams  
  — Bringing Up the Hardware  
• Fixed assorted typos and formatting issues. |
| 2016.05.02   | Initial release                                                                                                                                                                                                |