AN 014: Using the Trion® T20 Dual-Camera MIPI Example Design

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Contents

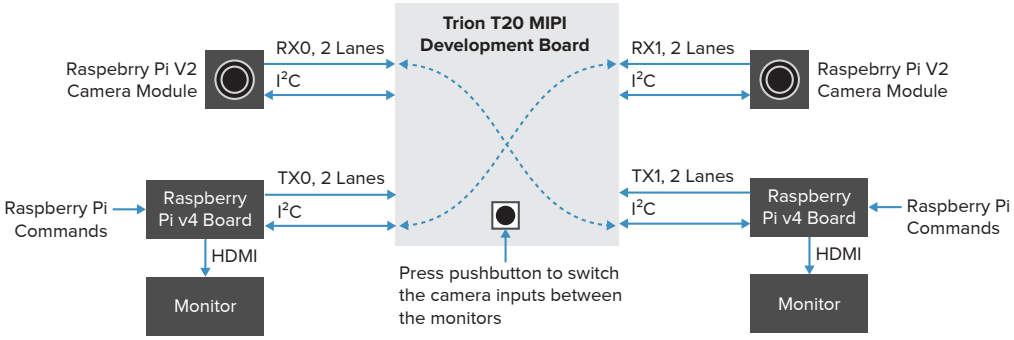
Introduction

The Raspberry Pi MIPI CSI-2 dual-camera bridge example design illustrates how the Trion® T20 FPGA can receive high-speed video data from multiple cameras, process it with a filter, and then transmit the video over a high-speed interface to an application processor. The demonstration uses the Trion® T20 MIPI Development Board, two Raspberry Pi v2 camera modules, two Raspberry Pi computers, and two monitors.

Figure 1: T20 Dual-Camera CSI-2 Example Design Setup[1]

T20 FPGAs have two MIPI TX and two MIPI RX hardened interfaces. In this example, each interface has two lanes, each of which runs at 1.5 Gbps. The Raspberry Pi cameras connect to the T20 MIPI CSI-2 RX interfaces and send streaming video. The video passes through the T20 FPGA to the MIPI CSI-2 TX interfaces, which send the video to Raspberry Pi computers. The computers display the video on monitors.

Figure 2: T20 Dual-Camera MIPI CSI-2 Example Design Overview

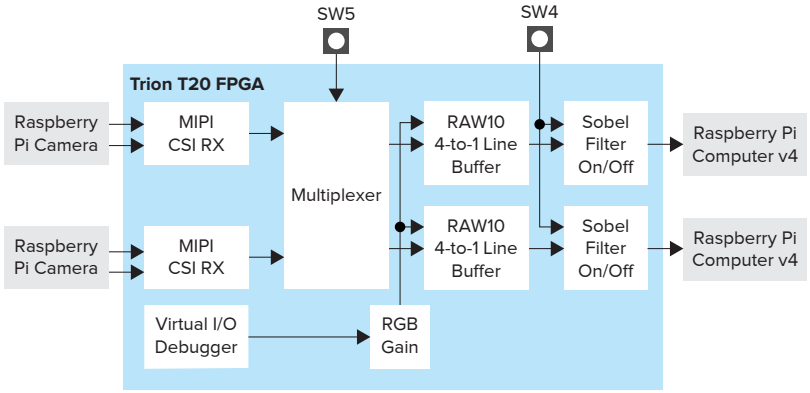


When you press SW4, the T20 FPGA runs a Sobel filter that performs edge detection on the video. Sobel filtering is a technique used to describe a large data set accurately with minimal resources. When you press pushbutton SW5, the T20 FPGA switches the camera video feed from one monitor to the other.

[1] This photo illustrates the design set up with Raspberry Pi 7" touch screen displays instead of monitors.

The example design also includes the Virtual I/O debugger core. With the Efinity® Debugger, the Virtual I/O core lets you monitor changes in the design and adjust the red gain shown on the monitors.

Figure 3: Dual-Camera MIPI CSI-2 Example Design Block Diagram



The number of pixels the MIPI RX controller sends each clock cycle depends on the data type. The example design uses the RAW10 data type, therefore, the MIPI RX controller provides four 10-bit pixels each clock cycle. Because the Sobel filter only uses grayscale data, the design converts the RAW10 data to YUV, uses the Y component for the filter, and then converts back to RAW10. Finally, because the MIPI TX controller wants six 10-bit pixels each clock cycle, the design packs the pixels by six before sending them to the controller.

Required Hardware

The design uses the following hardware:

- Trion® T20 MIPI Development Board
- 4 Raspberry Pi Camera Connector Daughter Cards
- 2 Raspberry Pi 4 boards
- 2 Raspberry Pi V2 cameras
- 4 15-pin flat cables
- 2 HDMI cables, micro-HDMI to HDMI cable (or, HDMI to HDMI cable and micro-HDMI to HDMI adapter)
- 2 monitors with an HDMI input[(2)]
- 2 USB type C cables
- 3 micro-USB cables
- USB keyboard and mouse (one set is required; 2 sets are helpful)
- 2 5-V power supplies
- 4 jumper wires
- Laptop or personal computer with the Efinity® software installed

Tip: You may want to use Raspberry Pi kits that contain extra cables and hardware.

[(2)] You can use Raspberry Pi 7" touchscreen displays instead of monitors.

Set Up the Hardware

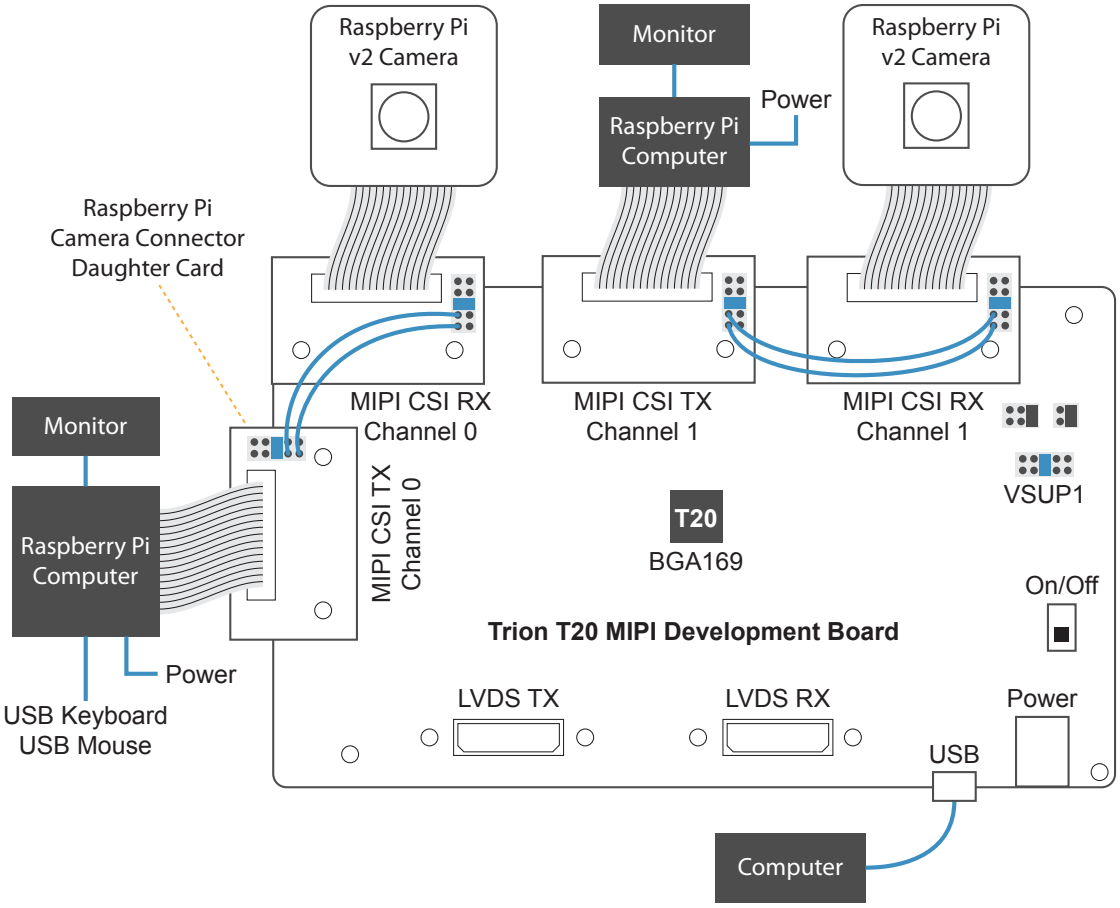
Setting up the hardware involves these general steps:

1. Attach the daughters cards, jumpers, and cables.
2. Connect the 2 Raspberry Pi boards and monitors.
3. Set up the 2 Raspberry Pi cameras.

After you set up the hardware, you program the design into the development board and then run the example.

Note: The order in which you connect and power up the boards and Raspberry Pi computers is important for the design to function correctly; essentially, the Raspberry Pi computers need to sync up with the cameras before you turn on the development board.

Figure 4: Completed Hardware Setup

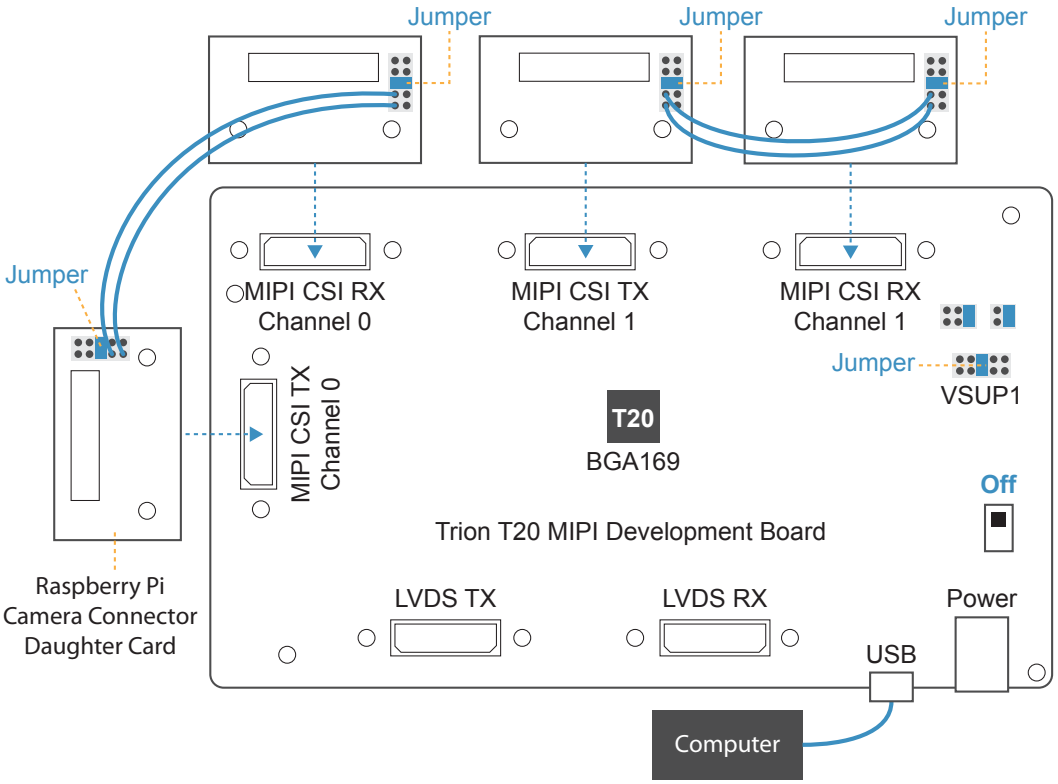


Learn more: Refer to the T20 MIPI Development Kit User Guide for information on the components available on the Trion® T20 MIPI Development Board.

Attach Daughter Cards, Jumpers, and Cables

In this step you connect the 4 Raspberry Pi Camera Connector Daughter Cards to the Trion® T20 MIPI Development Board and attach cables and jumpers. The following figure provides a reference to help you make the correct connections.

Figure 5: Connecting Daughter Cards and Cables



Important: Make sure that the Trion® T20 MIPI Development Board is turned off before connecting any cards or cables.

1. If you have not already done so, attach standoffs to the Trion® T20 MIPI Development Board and Raspberry Pi Camera Connector Daughter Cards.
2. On header VSUP1 (J2), connect pins 5 and 6 with a jumper. This connection sets voltage power supply 1 to 3.3 V with power-up sequence. Leave the jumpers on J3 and J4 at the defaults (connect pins 5 and 6 on J3 and pins 3 and 4 on J4).
3. Attach 4 Raspberry Pi Camera Connector Daughter Cards to the MIPI connectors.
4. On all 4 daughters cards, use a jumper to connect pins 5 and 6, which turns on the camera enable.
5. Use jumper wires to connect pins on the daughter cards. These connections bridge the I^2C communication between the RX and TX.

Connect RX	To TX
Channel 0 pin 2	Channel 0 pin 2
Channel 0 pin 4	Channel 0 pin 4
Channel 1 pin 2	Channel 1 pin 2
Channel 1 pin 4	Channel 1 pin 4

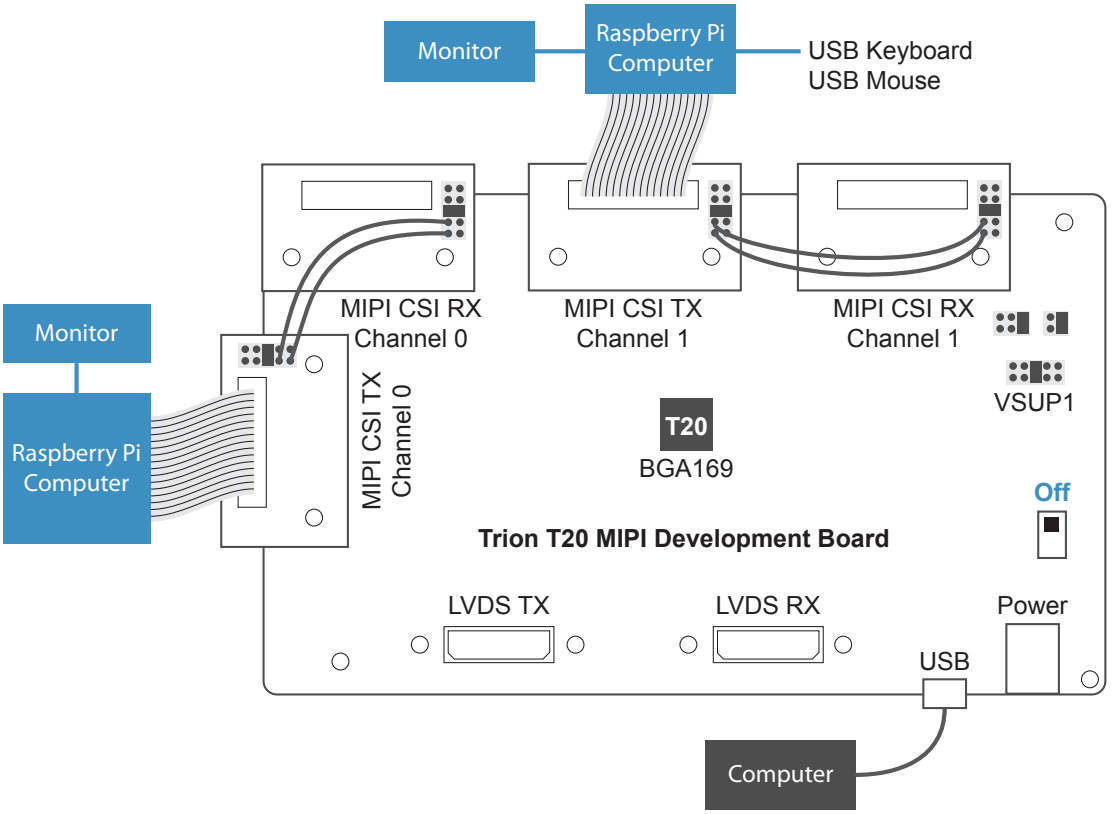
6. Connect a USB cable to the Trion® T20 MIPI Development Board and to your computer. The board receives power through the USB cable.

> **Important: Leave the board turned off.** You will turn it on later after you have set up the Raspberry Pi cameras and computers.

Connect Raspberry Pi Computers and Monitors

In this step you connect the Raspberry Pi computers and the monitors. **Do not connect the power cables to the Raspberry Pi computers**, you will do that in the next section.

Figure 6: Connect Raspberry Pi Computers and Monitors



1. Perform the following steps for the MIPI channel 1 TX:
   a. Attach a 15-pin flat cable to the daughter card and to a Raspberry Pi computer.
   b. Connect an HDMI cable to the Raspberry Pi computer's HDMI0 jack and to a monitor.
   c. Turn on the monitor.
2. Repeat step 1 for the MIPI channel 0 TX.
3. Connect a USB mouse and USB keyboard to the USB jacks on the channel 1 Raspberry Pi computer.

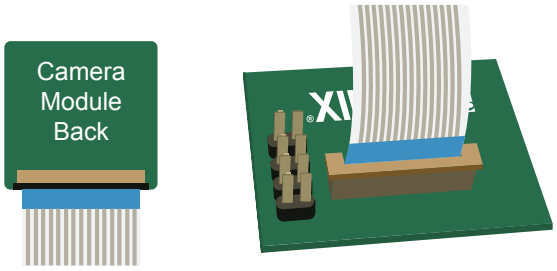
> **Note:** If you have a second USB keyboard and mouse, attach them to the channel 0 Raspberry Pi computer. If you only have 1 set, you will need to switch the keyboard and mouse between the Raspberry Pi computers to enter commands and control the video.

Connecting the Raspberry Pi Cable

The 15-pin flat cable for the Raspberry Pi camera has a blue stripe on one side.

- When connecting to the camera, the stripe faces away from the camera.
- When connecting to the Raspberry Pi Camera Connector Daughter Card, the stripe faces away from the Efinix® logo.

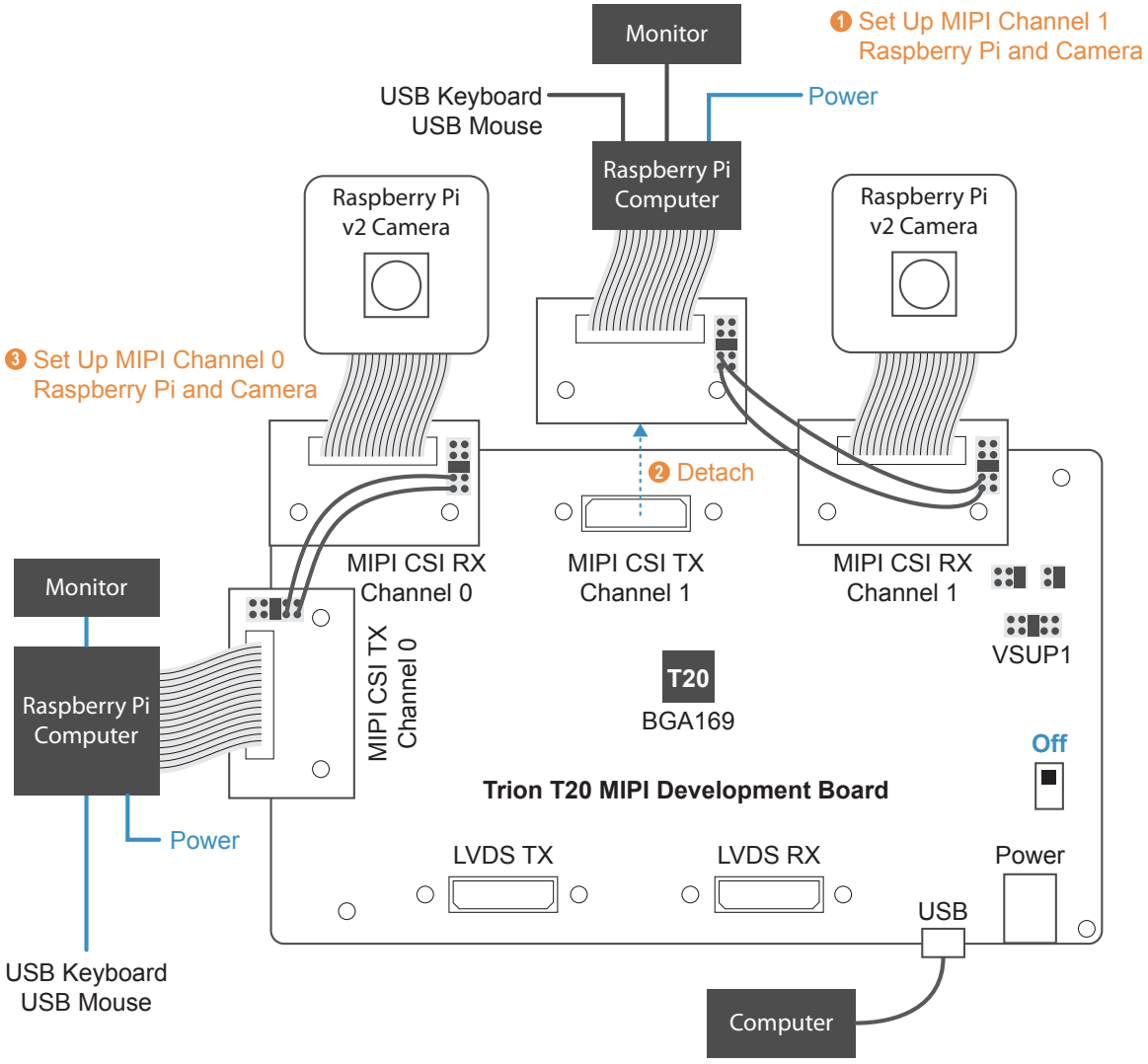
Figure 7: Connecting Raspberry Pi Cable



Set Up the Raspberry Pi Cameras

In this step you connect the cameras and enable them. After you connect the cameras, you power the Raspberry Pi computers up one at a time and enable their connection to the respective cameras.

Figure 8: Setting Up Cameras



Note: These instructions assume that you have already set up your Raspberry Pi computer. If this is the first time you are using them, **follow the instructions on the Raspberry Pi web site to set up the board.**

1. Connect the Raspberry Pi cameras to the MIPI RX channel 0 and 1 connectors.
2. Connect a power cable to the TX 1 Raspberry Pi computer. The Raspberry Pi boots to the Raspbian desktop.

3. Enable the camera attached to MIPI channel 1:

   Note: The Raspberry Pi camera is disabled by default.

   a. Go to the Raspbian Desktop.
   b. Choose **Raspberry Pi > Preferences > Raspberry Pi Configuration**.
   c. Click the **Interfaces** tab.
   d. Set the camera to **Enable** and click **OK**.
   e. Reboot the Raspberry Pi.
4. Test the camera connection:

   a. Open a command prompt.
   b. Type the command `vcgencmd get_camera` and press return. The system should respond `supported=1 detected=1`.

      If the system does not detect the camera, check that you have set up the hardware correctly.
5. Leaving all of the cables connected, detach the channel 1 TX daughter card from the Trion® T20 MIPI Development Board.

   Note: If you do not detach the daughter card, the system will experience a power differential problem that will cause the second Raspberry Pi computer to not boot.
6. Remove the USB keyboard and mouse from the Raspberry Pi computer attached to TX channel 1 and connect them to the computer attached to TX channel 0.
7. Connect a power cable to the TX 1 Raspberry Pi computer. The Raspberry Pi boots to the Raspbian desktop.
8. Enable the camera attached to MIPI channel 0 as described in step 3.
9. Test the camera as described in step 4.
10. Re-attach the channel 1 TX daughter card to the Trion® T20 MIPI Development Board.

Program the Trion® T20 MIPI Development Board

The Trion® T20 MIPI Development Board ships pre-loaded with a loopback design. To use the dual-camera MIPI CSI-2 example design, you must program the design into the board.

Note: You can use active, passive, or JTAG programming.

1. Turn on the Trion® T20 MIPI Development Board.
2. Download the example design file, **mipi_dual_camera_example_t20f169_devkit-v<version>.zip**, from the Support Center.
3. Unzip the file into your working directory.
4. Open the project (**pi4_demo_top.xml**) in the Efinity software and review it.
5. Use the Efinity® Programmer to download the bitstream file to your board. The example includes a bitstream file, **pi4_demo_top.hex**.

Learn more: Instructions on how to use the Efinity® software is available in the Support Center.

Run the Example Design

With the hardware set up and the Trion® T20 MIPI Development Board programmed you are ready to run the dual-camera video processing application.

1. Open a command prompt on the Raspbian Desktop.

   Note: The USB keyboard and mouse should still be connected to the TX channel 1 Raspberry Pi computer.

2. Type the command to capture data:[3]

   ```
   raspivid -t 0 -md 5 -fps 30 -p 300,20,480,270
   ```

   `raspivid` captures video with a video encoding component.

   `-t 0` captures video until you stop it with a Ctrl+C command.

   `-md 5` captures video with 1640 x 922 resolution at 30 Hz

   `-p 300,20,480,270` superimposes the streamed video in a preview window onto the Raspbian Desktop.

   The monitor displays video from the camera.
3. Detach the USB keyboard and mouse from the TX channel 1 computer and connect them to the TX channel 0 computer.
4. Repeat steps 1 and 2 to begin capturing video from the TX channel 0 camera.
5. Press SW5 to switch the feed from the RX channels. After 3 seconds, the channels switch back automatically.
6. Press SW4 to toggle the Sobel filter on and off. The default is off.
7. Type Ctrl+C on the Raspberry Pi keyboard to stop streaming video on the TX channel 0 computer.
8. Detach the USB keyboard and mouse from the TX channel 0 computer and connect to the TX channel 1 computer; type Ctrl+C to stop streaming.
9. Press SW2 to reset the system.

   Important: Do not reset the system when the cameras are streaming video.

Use the Efinity Debugger to Control Video Output

The example design includes a Virtual I/O debugger core, which you can use the control the red, blue, and green gains in the video the design sends to the monitors.

1. Run the Efinity software.
2. Open the Debugger. The tool opens to the Debug perspective. The `VIO_0` debug core sources and probes displays.
3. Click Connect Debugger. The probes show the values on the MIPI signals.
4. Set the **PROBE_TRIGGER** signal to 1 (0 is the default).

[3] Refer to the Raspberry Pi web site for a complete listing of camera commands.

5. To adjust the red, green, or blue gain, enter a value from 0 to 7 in the **Value** field for the **red_gain**, **green_gain** and **blue_gain** sources. 0 is the minimum setting and 7 is the maximum setting. The default is 4.

Additionally, the Virtual I/O debugging signals are routed to the J12 header on the Trion® T20 MIPI Development Board. You can use this header to monitor the MIPI HSYNC and VSYNC signals directly.

Next Steps

Once you have demonstrated the functionality of the example design, you can use it to explore how the T20 MIPI CSI-2 interface works.

- The TX PHY speed is 1.5 Gbps to demonstrate the hardened PHY capability. You can use the Efinity Interface Designer to change the setting to any speed from 1 to 1.5 Gbps.

  Note: Do not change the lane mapping in the Interface Designer because it is mapped for the example design's hardware.

- The Interface Designer contains settings for the TX and RX interface timing. The design uses specific timing settings that work with the hardware (Raspberry Pi camera and computer). If you want to explore the effect these timing settings have on the interface functionality, use the **MIPI Utility** and **AN 015: Designing with the Trion MIPI Interface** to guide your timing choices.
- Clocking is an important part of building a MIPI CSI-2 design. The MIPI RX uses a 100 MHz clock, `mipi_cal_clk`. The RTL design uses the clock `mipi_pclk`. The example design does not have a frame buffer, therefore, it needs to process the data from the RX line buffer faster than the input data rate. You can adjust the speed of `mipi_pclk`, but it should be faster than 107 MHz to keep up with the RX controller.

Shut Down the Example Design

Wihen you are finished using the example design, use these steps to shut it down.

1. Type Ctrl+C on the Raspberry Pi keyboard to stop streaming video on the attached camera.
2. Detach the USB keyboard and mouse from the Raspberry Pi computer and connect them to the other computer.
3. Type Ctrl+C to stop streaming video on the camera.
4. Press SW2 to reset the system.

   Important: Do not reset the system when the cameras are streaming video.

5. Turn off the Trion® T20 MIPI Development Board.
6. Remove power from the Raspberry Pi computers.
7. Remove all cables.

Revision History

Table 1: Revision History

Date	Version	Description
June 2020	2.1	Added topic on conecting the Raspberry Pi cable.
May 2020	2.0	Clarified instructions for setting up the cameras.
January 2020	1.0	Initial release.