



AN 016: Connecting MIPI CSI-2 Cameras to Trion[®] FPGAs

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Introduction

Today's marketplace contains a wide variety of cameras and sensors with a MIPI CSI-2 interface. Trion® FPGAs have a dedicated MIPI CSI-2 interface to connect with these cameras seamlessly. However, because vendors have some leeway when implementing the MIPI CSI-2 specification, different cameras may require different settings to communicate with Trion® FPGAs. This application note describes the general process for bringing up a MIPI-CSI-2 capable camera to work with the Trion® CSI-2 RX interface, and gives examples for several commonly used cameras.

Required Hardware

The example designs that go along with this application note use the following hardware:

- Trion® T20 MIPI Development Board
- Camera setup for Raspberry Pi v2 camera
 - Raspberry Pi v2 camera module (with Sony IMX219 sensor)
 - Raspberry Pi Camera Connector Daughter Card
 - 15-pin flat cable
 - 3 jumper wires
- Camera setup for Leopard Imaging camera
 - LI-IMX185-MIPI-CS camera (with Sony IMX185 sensor)
 - Leopard Imaging Camera Connector Daughter Card
 - 30-pin micro-coax cable
- Camera setup for Firefly compatible camera
 - Firefly compatible camera module (with OV13850 sensor)⁽¹⁾
 - Firefly Compatible Camera Connector Daughter Card
 - 30-pin flat cable
- USB keyboard and mouse
- Micro-USB cable
- 5-V power supply with 4 A output current
- Laptop or personal computer with the Efinity® software installed

⁽¹⁾ Several vendors make camera modules that are compatible.

General Flow for Connecting Cameras

Connecting MIPI CSI-2 cameras to Trion® FPGAs involves these general steps:

1. Choose a camera; get the specifications such as the speed, resolution, number of MIPI lanes, maximum supported frame rate, supported data types, etc. from the camera data sheet.



Note: Trion FPGAs require a 60 Hz frame rate for full HD.

2. Use the [MIPI Utility](#) and [AN 015: Designing with the Trion MIPI Interface](#) to determine a combination of parameters that will work with the Trion MIPI interface.
3. Use the Efinity® Interface Designer to set up the MIPI RX interface to receive the camera data.
4. Build the rest of your RTL design and compile.



Note: You may want to add a one or more hardware debug cores to help you monitor the MIPI RX error registers.

5. Download the bitstream into the FPGA.

Typical Camera Signals

MIPI-enabled sensors have several types of signals as shown in the following table.

Table 1: Typical MIPI Camera Signals

Signal	Description
Power and ground	The camera has signals for analog power (2.8, 3.3, or 5.0 V), I/O power (3.3 or 1.8 V), and MIPI power (1.2 V).
MIPI lanes	1 clock lane and 1, 2, or 4 pairs of data lanes.
Camera control interface (CCI)	Clock (SCL) and data (SDA).
Reset	Reset pin.
Reference clock	Reference clock pin.
Enable	Enable pin.

The MIPI CSI-2 specification defines the dedicated camera control interface (CCI). The CCI is a two-wire, bi-directional, half duplex, serial interface that controls the transmitter; it is compatible with the I²C fast mode interface and uses a subset of the protocols defined in the I²C specification.

The MIPI Alliance does not define the control messages, frame timing, or latency requirements; they leave that up to the individual vendors. Therefore, cameras can have differing register settings that determine how they want to communicate with other peripherals. You should check the data sheet for the camera you want to use to find any register settings you need to communicate with the camera.

About the Camera Example Designs

To help you integrate cameras into your RTL design, Efinix has created several camera connection example designs for the Trion® T20 MIPI Development Board. These simple designs receive data from a camera via the MIPI RX interface and turn on an LED if the board is receiving the data correctly.

Figure 1: Camera Connection Example Design Block Diagram

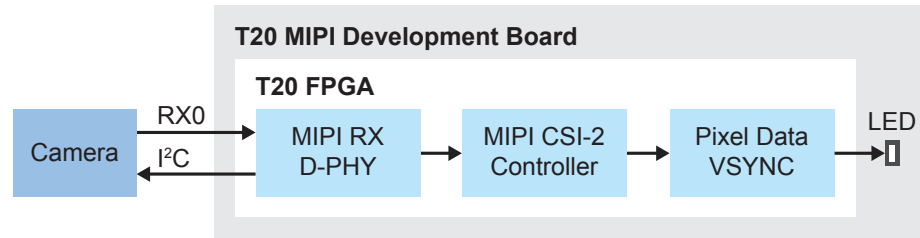


Table 2: Camera Connection Example Design Features

Design Feature	IMX185	IMX185	Raspberry Pi v2	Raspberry Pi v2	OV13850
Resolution	1920 x 1080	1280 x 720	1920 x 1080	1280 x 720	1920 x 1080
MIPI Lanes	4	4	2	2	4
Frame rate (fps)	60 Hz	60 Hz	30 Hz	60 Hz	30 Hz
Data Type	RAW 12	RAW 12	RAW 10	RAW 10	RAW 10
Scan mode	All pixels	All pixels	Partial	Partial	Windows mode

Connect Cameras

Connect the LI-IMX185-MIPI-M12 Camera

The LI-IMX185-MIPI-M12 camera module has a Sony IMX185 sensor; the module can operate as either a master or slave on the CCI interface. In this example, the camera is in master mode and triggers the FPGA to respond. Refer to the data sheet for your camera for information on setting master or slave mode.

Figure 2: IMX185 Camera Hardware Setup

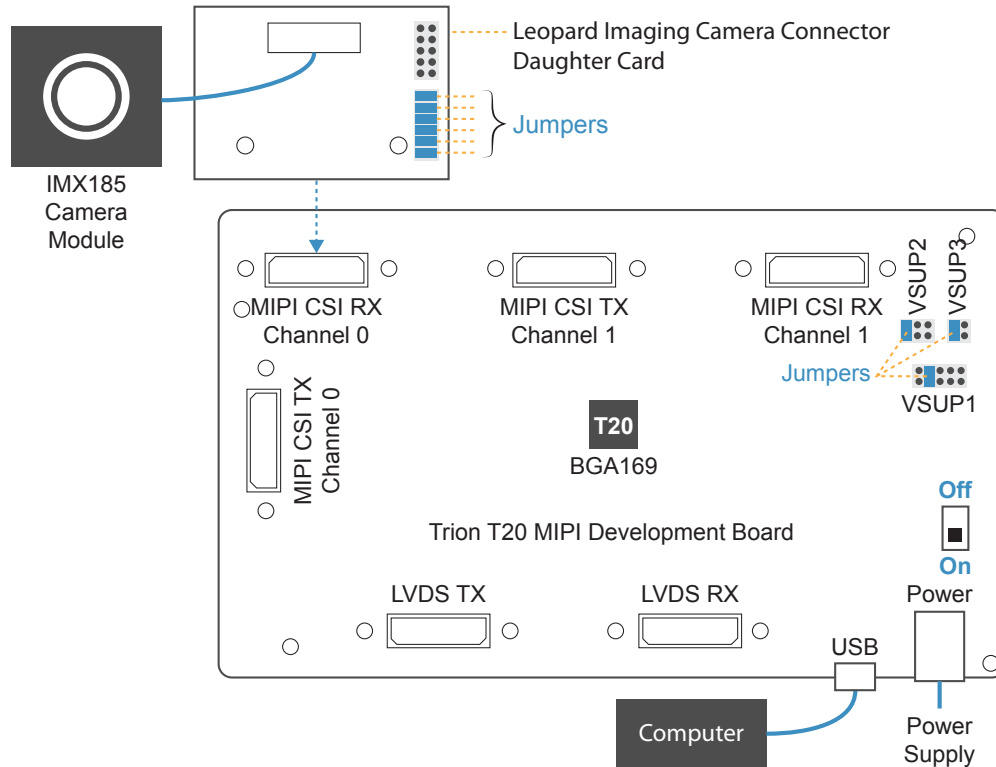
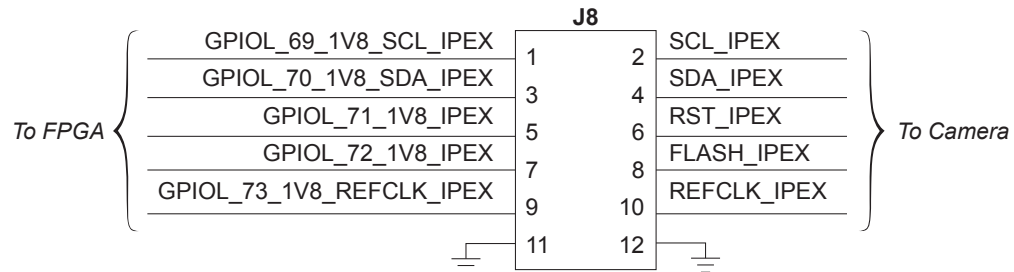


Figure 3: Leopard Imaging Camera Connector Daughter Card J8 Header



1. Connect the camera to the Leopard Imaging Camera Connector Daughter Card using a 30-pin I-Pex micro-coaxial cable.
2. On the daughter card header J8, connect pins 1-2, 3-4, 5-6, 7-8, 9-10, and 11-12. These jumpers allow the FPGA to control the camera's SCL, SDA, reset, flash, and reference clock pins. If you want to control those pins with other hardware, remove the jumper(s) and attach jumper wire(s) from the even pin(s) to your hardware.
3. Connect the daughter card to the MIPI RX channel 0 connector.
4. Connect pins 2-3 on VSUP1 (3.3 V) with a jumper.
5. Connect pins 1-2 on VSUP2 (3.3 V) and VSUP3 (1.2 V).
6. Connect a USB cable to the board and to your computer.
7. Turn on the power to the board.

Connect the Raspberry Pi v2 (IMX219) Camera

The Raspberry Pi v2 camera module has a Sony IMX219 sensor on it. Follow these instructions to connect the camera.

Figure 4: Raspberry Pi Camera Hardware Setup

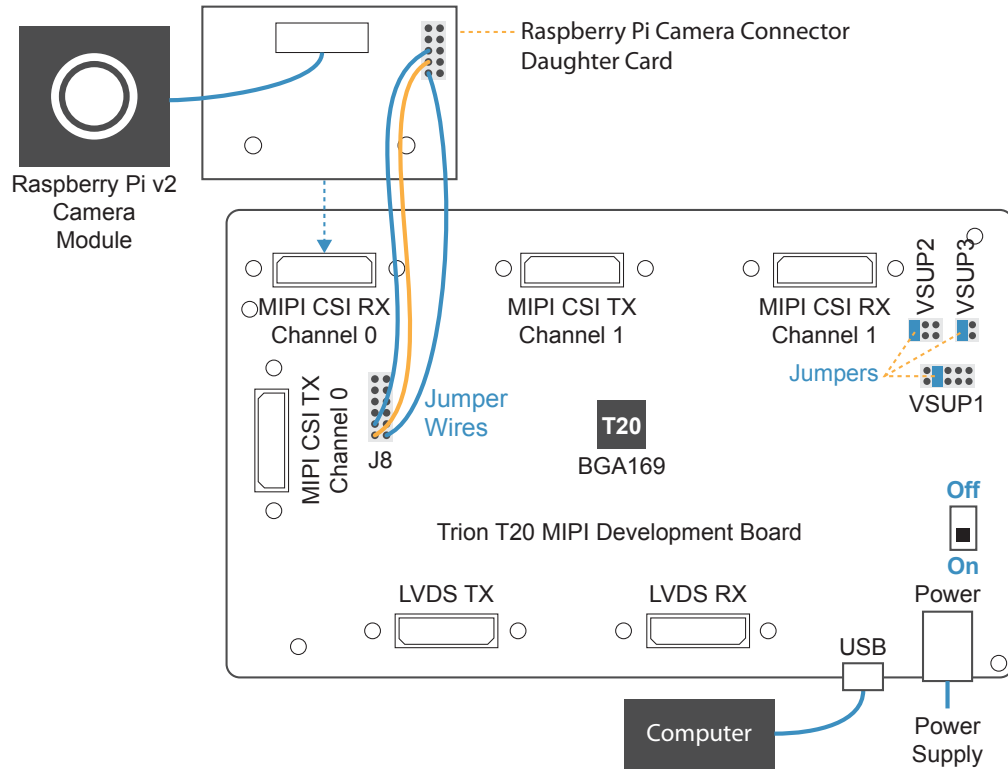
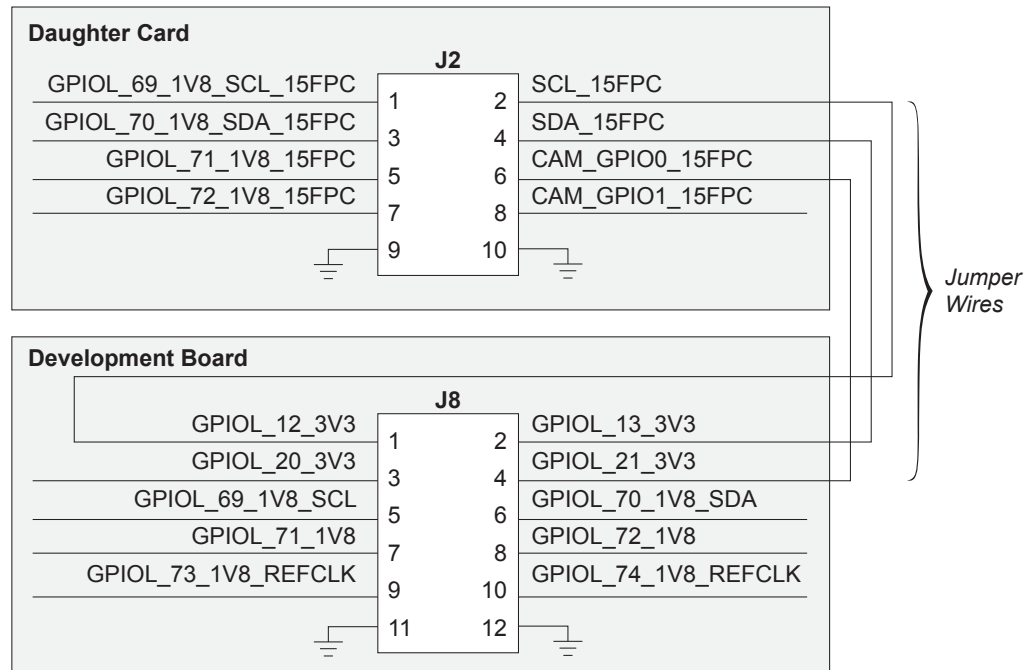


Figure 5: Raspberry Pi Camera Connector Daughter Card J2 and J8 Headers



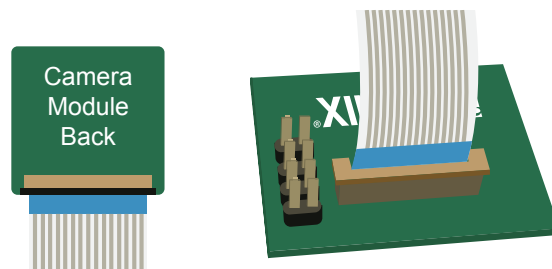
1. Connect the camera to the Raspberry Pi Camera Connector Daughter Card using a 15-pin flat/FPC cable.
2. Connect the daughter card to the MIPI RX channel 0 connector.
3. Connect a jumper wire from pin 2 on J2 (daughter card) to pin 1 on J8 (development board).
4. Connect a jumper wire from pin 4 on J2 (daughter card) to pin 2 on J8 (development board).
5. Connect a jumper wire from pin 6 on J2 (daughter card) to pin 4 on J8 (development board).
6. Connect pins 2-3 on VSUP1 (3.3 V) with a jumper.
7. Connect pins 1-2 on VSUP2 (3.3 V) and VSUP3 (1.2 V).
8. Connect a USB cable to the board and to your computer.
9. Turn on the power to the board.

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 6: Connecting Raspberry Pi Cable



Connect the Firefly Compatible Camera

The Firefly compatible cameras have an OmniVision OV13850 sensor. Follow these instructions to connect the camera module.

Figure 7: Firefly Compatible Camera Hardware Setup

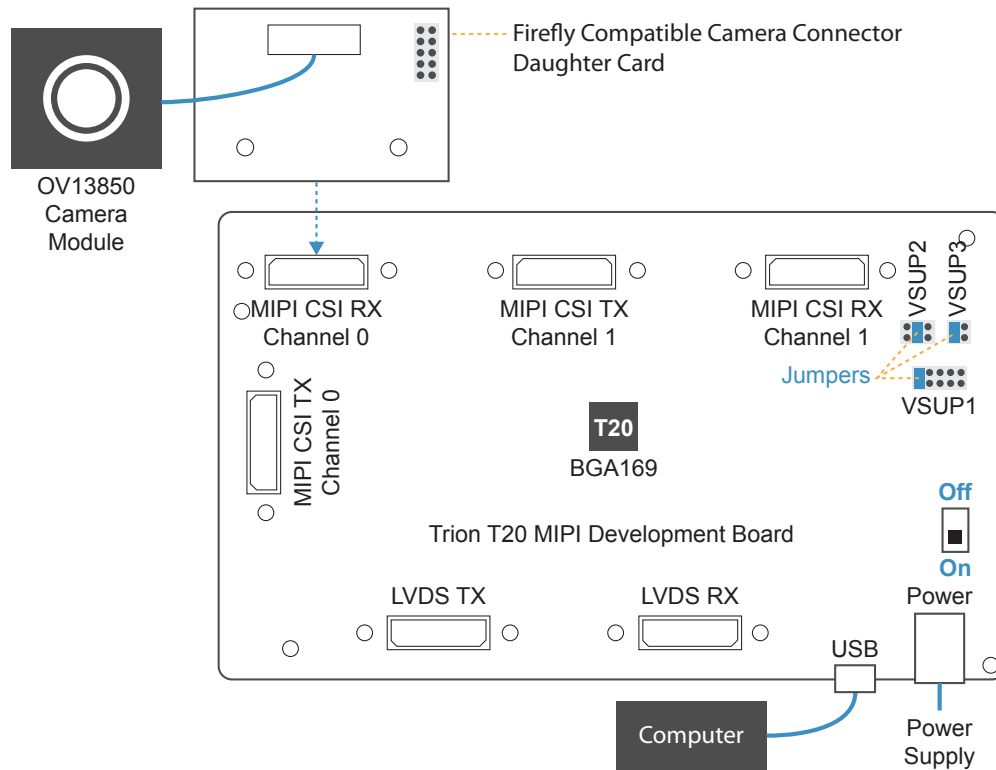
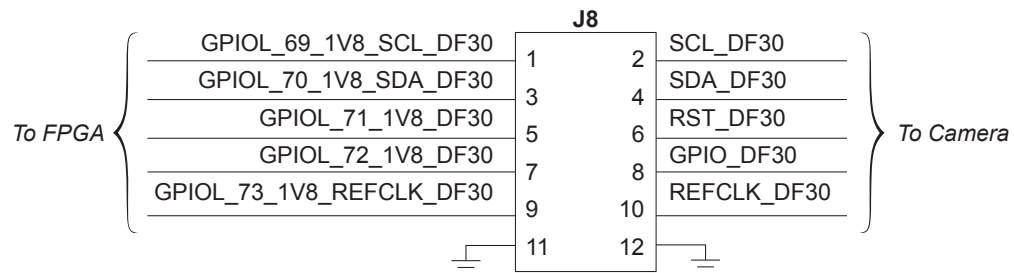


Figure 8: Firefly Compatible Camera Connector Daughter Card J8 Header



1. Connect the camera to the Firefly Compatible Camera Connector Daughter Card using a 30-pin flat/FPC cable.
2. Connect the daughter card to the MIPI RX channel 0 connector.
3. Connect pins 7-8 on VSUP1 (2.8 V) with a jumper.
4. Connect pins 3-4 on VSUP2 (1.8 V).
5. Connect pins 1-2 on VSUP3 (1.2 V).
6. Connect a USB cable to the board and to your computer.
7. Turn on the power to the board.

Program the Trion® T20 MIPI Development Board

The Trion® T20 MIPI Development Board ships pre-loaded with a loopback design. To use the camera connection example design(s), you must program the design(s) into the board.



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

Before programming, complete hardware set up for the camera you want to use and turn on power to the Trion® T20 MIPI Development Board.

1. Download the camera connection example design file from the Support Center. Efinix provides each example in a separate zip file.
2. Unzip the file into your working directory.
3. Open the project (**mipi_<camera name>_top.xml**) in the Efinity software and review it.
4. Use the Efinity® Programmer to download the bitstream file to your board.

The Leopard Imaging and Raspberry Pi examples have 2 bitstream files, one for 720p and one for 1080p.

The Firefly compatible camera example has only 1 bitstream file.

When you have finished programming, LEDs on the Trion® T20 MIPI Development Board indicate whether the camera is connecting successfully:

- *LI-IMX185-MIPI-M12 camera*—D5 turns on; if it is off, there is an error.
- *Raspberry Pi camera*—D5 turns on; if it is off, there is an error.
- *Firefly compatible camera*—D5 and D6 flash alternately; if they are off or solid on, there is an error.



Learn more: Instructions on how to use the Efinity® software [is available in the Support Center](#).

Changing the Video Resolution

The example designs have **.mem** files that contain the register mapping for the cameras for different resolutions. You change the design's target resolution by commenting out the `INITIAL_CODE` parameter setting for the file you do not want to use:

```
//-----//
// I2C settings
//-----//
parameter I2C_ID          = 7'h1A;          // I2C ID
parameter INITIAL_CODE    = "imx185_1080p_reg.mem"; // Initial code file
// parameter INITIAL_CODE = "imx185_720p_reg.mem";
parameter MEM_DEPTH       = 423;            // Initial code memory depth
parameter REGISTER_BYTE   = 2;              // Number of register bytes
//-----//
```

Table 3: Camera Register Memory Map Files

Camera Module	Resolution	Register Map File
LI-IMX185-MIPI-M12	1920 x 1080	imx185_1080p_reg.mem
LI-IMX185-MIPI-M12	1280 x 720	imx185_720p_reg.mem
Raspberry Pi v2	1920 x 1080	piv2_1080p_reg.mem
Raspberry Pi v2	1280 x 720	piv2_720p_reg.mem
Firefly compatible	1920 x 1080	ov13850_1080p_reg.mem

Modifying the Register Map

To use a different resolution, modify the register map file. Each line represents the MSB, LSB, or data.

- Line 1 is the MSB of the 8 bit register.
- Line 2 is the LSB of the 8 bit register.
- Line 3 is the data.
- Line 4 is the MSB of the next register, and so on

For example:

```
30
00
01
30
05
01
30
06
00
```

Lines 1 and 2 refer to register 3000 with line 3 data of 01.

Lines 4 and 5 refer to register 3005 with line 6 data of 01.

Lines 7 and 8 refer to register 3006 with line 9 data of 00.

Revision History

Table 4: Document Revision History

Date	Version	Description
June 2020	1.1	Added a topic on how connecting the Raspberry Pi cable.
February 2020	1.0	Initial release.