# Technical Reference

# BUMBLEBEE® X

## *STEREO VISION CAMERAS*


GiGE VISION
POE ENABLED

**Version 1.4**
**Revised 2/27/2025**

2/27/2025


TELEDYNE

## FCC Compliance

This device complies with Part 15 of the FCC rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesirable operation.

## Korean EMC Certification

The KCC symbol indicates that this product complies with Korea's Electrical Communication Basic Law regarding EMC testing for electromagnetic interference (EMI) and susceptibility (EMS).

## Hardware Warranty

The warranty for the camera is 3 years. For detailed information on how to repair or replace your camera, please contact our Technical Support team.

## WEEE

The symbol indicates that this product may not be treated as household waste. Please ensure this product is properly disposed as inappropriate waste handling of this product may cause potential hazards to the environment and human health. For more detailed information about recycling of this product, please contact us.

## Trademarks

Names and marks appearing on the products herein are either registered trademarks or trademarks of FLIR Integrated Imaging Solutions, Inc. and/or its subsidiaries.

## Licensing

To view the licenses of open source packages used in this product please see What open source packages does Teledyne FLIR use?

# Table of Contents

# About This Manual

This manual provides you with a detailed specification of the Bumblebee X camera system. You should be aware that the camera system is complex and dynamic – if any errors or omissions are found during experimentation, please contact us. This document is subject to change without notice.

**Note:** All model-specific information presented in this manual reflects functionality available in the model's firmware version. For more information see Camera Firmware.

## Where to Find Information

| Chapter | What You Will Find |
|---|---|
| **Welcome to the Bumblebee X Camera** | General camera specifications and overview of stereo image processing |
| **Installing the Bumblebee X Camera** | Instructions for installing the software and camera |
| **Configuring Bumblebee X Camera Setup** | Information on configuring the camera setup, including drivers, Ethernet settings, user sets, and firmware |
| **Bumblebee X Camera Physical Interface** | Information on the mechanical properties of the camera |
| **Bumblebee X Camera Input/Output Control** | Information on input/output pins, electrical characteristics, and timing |
| **Controlling the Bumblebee X Camera** | Information on the tools available for controlling the camera |
| **Troubleshooting** | Information on how to get support, website resources, and LED status |
| **GenICam Features** | Appendix: GenICam Feature descriptions |
| **Pattern Projector Setup** | Appendix: Setting up the pattern projector with wiring configurations |

## Document Conventions

This manual uses the following to provide you with additional information:

**Note:** A note that contains information that is distinct. For example, drawing attention to a difference between models; or a reminder of a limitation.

**Warning!** A note that contains a warning to proceed with caution and care, or to indicate that the information is meant for an advanced user. For example, indicating that an action may void the camera's warranty or cause damage to the camera or other equipment.

```
Code is presented in a grey box with Courier font.
```

If there are further resources available, a link is provided either to an external website, or to the SDK.

**Related Resources**

Link to the resource

# Revision History

| Revision | Date | Notes |
|---|---|---|
| **1.0** | November 1, 2024 | Initial Release |
| **1.1** | November 25, 2024 | Support for ARM64 |
| **1.2** | December 19, 2024 | Support for firmware v1.1<br>Support for Python<br>Support for Windows (Beta) |
| **1.3** | February 3, 2025 | Power requirements updated to 12-24 V via GPIO |
| **1.4** | February 27, 2025 | Support for Windows (Full)<br>Support for Pattern Projector Kits |

# Contacting Us

For any questions, concerns or comments please contact us:

| | |
|---|---|
| **Email** | General sales questions |
| **Support Ticket** | Technical Support |
| **Support Forum** | Teledyne FLIR Community |
| **Website** | Bumblebee X page for articles, documents, firmware, CAD models |

# 1 Welcome to the Bumblebee X Camera

Welcome to the Bumblebee X camera. We offer a number of resources to assist you with your camera.

- Spinnaker SDK—software development kit that provides GenICam-compliant controls to create applications for the camera. Spinnaker is available for download. Each installation includes API documentation for C, C++, Python, and C#.
- Release Notes—information about the current firmware release including feature additions or changes, bug fixes, and known issues.
- Specifications—information about the camera model as it performs with the current firmware.
- Getting Started—quick start guide for installing the camera and software.
- Technical Reference—information about installing the camera and SDK, the physical interface and mechanical properties, supported features, troubleshooting and how to get help.
- Firmware—programming inserted into the programmable ROM of the camera that can be updated in-field. New firmware packages are available for download and include both the firmware file and documentation.

These resources as well as knowledge base articles and application notes can be found on the Bumblebee X Product page.

## 1.1 Bumblebee X Camera Care

**Warning!** Do not open the camera housing. Doing so voids the Hardware Warranty.

Avoid electrostatic charging.

The outer case of the camera can become hot to the touch when running. This is expected behavior.

Your camera is a precisely manufactured device and should be handled with care. Here are some tips on how to care for the device.

- When handling the camera unit, avoid touching the lenses. Fingerprints affect the quality of the image produced by the device.
- To clean the lenses, use a standard camera lens cleaning kit or a clean dry cotton cloth. Do not apply excessive force.
- Avoid excessive shaking, dropping or any kind of mishandling of the device.

**Note:** To replace the protective glass the camera must be returned to Teledyne for servicing. Contact Support for more details.

The Bumblebee X camera has been rated as IP-67 for protection against dust and water. To retain the IP-67 protection, an IP-rated Ethernet cable and either an IP-rated GPIO cable or the sealing plug must be used.

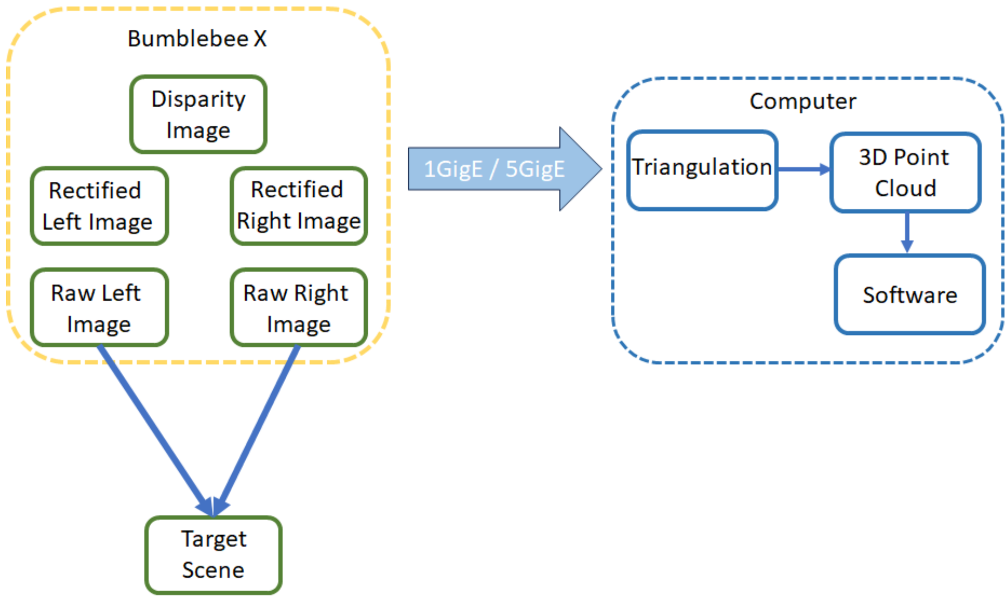
## 1.2 Bumblebee X Camera Specifications

| | BX-P5G-30C-XC3 | BX-P5G-30C-XC5 | BX-P5G-30C-XC7 |
|---|---|---|---|
| **Megapixels** | 3 MP | | |
| **Sensor** | Sony Pregius IMX265 | | |
| **Readout** | Global shutter | | |
| **Pixel Size** | 3.45 µm | | |
| **Chroma** | Color | | |
| **Interface** | 5GigE PoE | | |
| **Working Distance** | 0.5 m to 20 m | | |
| **Field of View** | 60° | 80° | 105° |
| **Focal Length** | 5.7 mm | 4.5 mm | 4.0 mm |
| **Power Requirements** | Power over Ethernet (PoE) or 12-24 V via GPIO | | |
| **Power Consumption** | 13.5 W typical | | |
| **Connector Types** | M12 X-coded 8-pin for Ethernet & Hirose LF10WBRB 12-pin for GPIO | | |
| **Mounting** | ¼”-20, M4 | | |
| **Baseline** | 24 cm | | |
| **Pre-calibrated** | Yes | | |
| **On-board Disparity Processing** | 16 FPS | | 20.8 FPS |
| **OS Support** | ROS 2, Linux, Windows, ARM64 | | |
| **I/O** | 5 Gigabit Ethernet & GPIO (4x non-isolated input/output, 1x isolated input, 1x isolated output) | | |
| **Synchronization** | IEEE 1588 PTP | | |
| **Machine Vision Standard** | GigE Vision v2.0 | | |
| **Dimensions** | 304 x 64 x 45 mm | 304 x 64 x 52 mm | 304 x 64 x 42 mm |
| **Mass** | 860 g | 905 g | 840 g |
| **Protection** | IP67 | | |
| **Compliance** | CE, FCC, RoHS | | |
| **Temperature** | Operating: -10° to 50°C / Storage: -30° to 60°C | | |
| **Humidity** | Operating: 20 to 80% (no condensation) / Storage: 20 to 95% (no condensation) | | |
| **Warranty** | 3 years | | |

## 1.3 Stereo Image Processing

Stereo vision is similar to the 3D perception of human vision in that a scene is observed from two viewpoints. The difference in the distance of an object between the two viewpoints forms the disparity. The closer an object is to the lenses, the greater the difference; the further away, the smaller the difference. The disparity is used to map the object's location to render the image in 3D and determine the depth of the scene.

The Bumblebee X stereo camera is pre-calibrated and offers on-board stereo processing including rectification and stereo matching. The calibration information is used to rectify the raw left and right images and the rectified images are passed to the stereo matching module to generate the disparity image. The on-board stereo matching is based on the Semi-Global Block Matching (SGBM) algorithm, which offers a great compromise between run-time performance and quality. On the host side, the triangulation step then converts the disparity image into a color 3D point cloud.



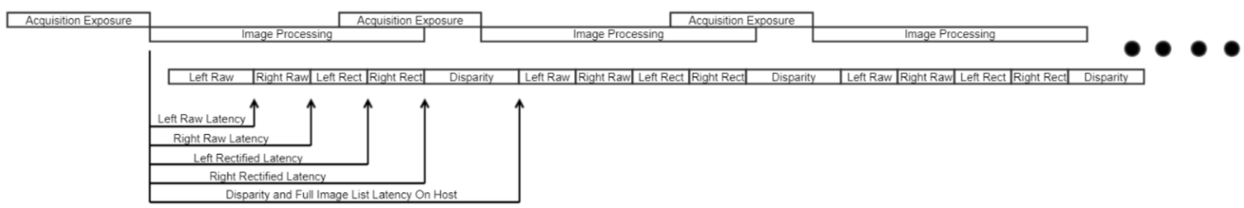

| | Description |
|---|---|
| **Raw Images** | Each of the sensors produces voltage signals in each pixel from the optical input. Raw images refer to the images after the left and right sensor data has been processed by the Image Signal Processing (ISP) pipeline. This is distinct from machine vision cameras. |
| **Rectified Images** | Stereo rectification refers to the process of projecting the raw image planes onto a common plane parallel to the line between camera centers. After rectification, corresponding points lie on the same row, which greatly simplifies the matching of points between the images to be able to calculate the difference between them. |
| **Disparity Image** | The disparity image is a visual representation of the differences between the objects in the scene. The closer the objects are to the camera the brighter they show in the disparity image. |
| **Triangulation** | Triangulation refers to the process of determining a point in 3D space given its projection onto the two images. This converts the disparity image to a 3D point cloud. |
| **3D Point Cloud** | The 3D point cloud can output to software, such as ROS, for application-specific purposes. Or, libraries such as OpenCV in C++ or Python can be used to write code for 3D point clouds. |

## 1.4 Image Transmission

The Bumblebee X camera supports transmission of up to 5 images per image acquisition. They are separated into 3 categories: Raw images (Left and Right), Rectified images (Left and Right) and the Disparity image calculated from the rectified images of the current image acquisition. You may select to transmit any of the 5 images while the camera is streaming. The default image transmission is the left rectified image and the disparity image. Note that the selected image transmission can affect what frame rate the camera can acquire images as given in Frame Rates and Latency.

The Bumblebee X camera supports a form of image transmission called multistream. Images are transmitted sequentially on separate stream ports so that they can be received on the host and presented to you as a group of images. The image streaming is done in a priority order that minimizes the latency of the images being received on the host computer. The order of streaming is as follows (only image streams that are enabled are transmitted):

1. Raw Left
2. Raw Right
3. Rectified Left
4. Rectified Right
5. Disparity




In the example diagram above , all 5 image streams have been enabled and are transmitted after image acquisition exposure. See Image Transmission Control for details on how to enable streams.

## 1.5 Frame Rates and Latency

The tables below show the preliminary frame rate and latency measurements (subject to change).

The frame rate and latency depend on:

- **Selected Stream**—Rectified left + Disparity (default), Rectified left + Rectified right, Rectified left + Rectified right + Disparity, or Disparity
- **Selected Stereo Resolution**—Full, Quarter
- **Pixel Format**—RGB8, YUV422
- **Link Speed**—5GigE, 2.5GigE, or 1GigE

The default selected stream is rectified left and disparity image which allows color point cloud generation on the host side.

Stereo resolution only refers to the rectified and disparity images. Raw images remain at full resolution.

Raw and rectified images can be output in YUV422 format, reducing the bytes required by 33% from the standard RGB8 format. This allows for a higher frame rate at the same resolution. The disparity image is unaffected.

Image latency is measured from the end of exposure until the last image component is transmitted. This is the earliest the image can be presented. Occasionally, depending on the quality of the host computer, images may take longer if they require packet resends to complete. Packet resends extend the time it takes to transmit the image.

### 1.5.1 XC3 60° and XC5 80° FOV Models

The XC3 60° and XC5 80° FOV models have a 4:3 aspect ratio. Full resolution is 2048 x 1536 and Quarter resolution is 1024 x 768.

| RGB8 Format | | 5GigE Link | | 2.5GigE Link | | 1GigE Link | |
|---|---|---|---|---|---|---|---|
| **Selected Stream** | **Selected Resolution** | **Frame Rate (FPS)** | **Latency (ms)** | **Frame Rate (FPS)** | **Latency (ms)** | **Frame Rate (FPS)** | **Latency (ms)** |
| **Rectified Left + Disparity** | Full | 16 | 85 | 16 | 85 | 7.7 | 130 |
| | Quarter | 38 | 41 | 38 | 41 | 30 | 41 |
| **Rectified Left + Rectified Right** | Full | 30 | 42 | 16 | 64 | 6.4 | 155 |
| | Quarter | 38 | 30 | 38 | 34 | 25 | 45 |
| **Rectified Left + Rectified Right + Disparity** | Full | 16 | 85 | 12 | 85 | 4.8 | 207 |
| | Quarter | 38 | 41 | 38 | 41 | 19 | 58 |
| **Disparity** | Full | 16 | 85 | 16 | 85 | 16 | 85 |
| | Quarter | 38 | 41 | 38 | 41 | 38 | 41 |

| YUV422 Format | | 5GigE Link | | 2.5GigE Link | | 1GigE Link | |
|---|---|---|---|---|---|---|---|
| **Selected Stream** | **Selected Resolution** | **Frame Rate (FPS)** | **Latency (ms)** | **Frame Rate (FPS)** | **Latency (ms)** | **Frame Rate (FPS)** | **Latency (ms)** |
| **Rectified Left + Disparity** | Full | 16 | 85 | 16 | 85 | 9 | 104 |
| | Quarter | 38 | 41 | 38 | 41 | 37 | 41 |
| **Rectified Left + Rectified Right** | Full | 38 | 37 | 23 | 47 | 9 | 104 |
| | Quarter | 38 | 29 | 38 | 31 | 37 | 39 |
| **Rectified Left + Rectified Right + Disparity** | Full | 16 | 85 | 16 | 85 | 6 | 155 |
| | Quarter | 38 | 41 | 38 | 41 | 25 | 52 |
| **Disparity** | Full | 16 | 85 | 16 | 85 | 16 | 85 |
| | Quarter | 38 | 41 | 38 | 41 | 38 | 41 |

### 1.5.2 XC7 105° FOV Models

The XC7 105° FOV models have a 16:9 aspect ratio. Full resolution is 2048 x 1152 and Quarter resolution is 1024 x 576.

| RGB8 Format | | 5GigE Link | | 2.5GigE Link | | 1GigE Link | |
|---|---|---|---|---|---|---|---|
| Selected Stream | Selected Resolution | Frame Rate (FPS) | Latency (ms) | Frame Rate (FPS) | Latency (ms) | Frame Rate (FPS) | Latency (ms) |
| Rectified Left + Disparity | Full | 20.8 | 70 | 20.8 | 70 | 10.3 | 100 |
| | Quarter | 38 | 37 | 38 | 37 | 38 | 37 |
| Rectified Left + Rectified Right | Full | 38 | 38 | 21 | 54 | 8.6 | 121 |
| | Quarter | 38 | 29 | 38 | 32 | 33 | 39 |
| Rectified Left + Rectified Right + Disparity | Full | 20.8 | 70 | 15.7 | 70 | 6.4 | 161 |
| | Quarter | 38 | 37 | 38 | 37 | 25 | 50 |
| Disparity | Full | 20.8 | 70 | 20.8 | 70 | 20.8 | 70 |
| | Quarter | 38 | 37 | 38 | 37 | 38 | 37 |

| YUV422 Format | | 5GigE Link | | 2.5GigE Link | | 1GigE Link | |
|---|---|---|---|---|---|---|---|
| Selected Stream | Selected Resolution | Frame Rate (FPS) | Latency (ms) | Frame Rate (FPS) | Latency (ms) | Frame Rate (FPS) | Latency (ms) |
| Rectified Left + Disparity | Full | 20.8 | 70 | 20.8 | 70 | 12.8 | 81 |
| | Quarter | 38 | 37 | 38 | 37 | 38 | 37 |
| Rectified Left + Rectified Right | Full | 38 | 34 | 31 | 41 | 12.8 | 81 |
| | Quarter | 38 | 28 | 38 | 28 | 38 | 37 |
| Rectified Left + Rectified Right + Disparity | Full | 20.8 | 70 | 20.8 | 70 | 8.6 | 122 |
| | Quarter | 38 | 37 | 38 | 37 | 33 | 45 |
| Disparity | Full | 20.8 | 70 | 20.8 | 70 | 20.8 | 70 |
| | Quarter | 38 | 37 | 38 | 37 | 38 | 37 |

# 2 Installing the Bumblebee X Camera

## 2.1 Preparing for Installation

### 2.1.1 Will your system support the camera?

Recommended desktop configuration:

- **OS**—Ubuntu Linux 22.04 (64-bit) / Windows 10 64-bit
- **CPU**—Intel® i7 10th gen or greater
- **RAM**—16 GB dual channel
- **Software**—ROS 2 Humble (Ubuntu Linux 22.04)

Tested **ARM** configuration:

- NVIDIA Jetson AGX Orin 64 GB Developer Kit

### 2.1.2 Do you have all the parts you need?

To install your camera you need the following components:

- Ethernet power injector
- IP-rated M12 Ethernet cable (from camera to power injector)
- Standard RJ45 Ethernet cable (from power injector to host adapter)
- Ethernet host adapter with 1G or 5G (preferred) Full Duplex support
- IP-rated GPIO cable with Hirose 12-pin connector
- Pattern projector (optional)

Teledyne FLIR sells a number of the additional parts required for installation. To purchase, visit the Accessories page.

### 2.1.3 Have you visited our website?

A downloads account is required to download software and firmware.

1. Go to teledynevisionsolutions.com.
2. Enter your email address and click Continue.
3. Complete the Create an account form and click Continue.
4. You will receive an email with a link to activate your account.
5. Once activated, you can login using your credentials.

The Bumblebee X product page has many resources, including:

- Spinnaker® SDK software, including drivers (login required)
- Firmware updates and release notes (login required)
- Dimensional drawings / CAD models and Documentation

# 2.2 Installing your Software—Linux Users

**1. Install the Spinnaker® SDK Software**

**Note:** Linux users of the Bumblebee X camera require Spinnaker version 4.1.0.338 or later.

a. Go to the Spinnaker download page. If you are not already logged in, you are prompted to login.

b. Select Spinnaker version 4.1.0.338 (or later) for Ubuntu 22.04.

c. Install the Ubuntu dependencies:

```
$ sudo apt-get install libavcodec58 libavformat58 \
 libswscale5 libswresample3 libavutil56 libusb-1.0-0 \
 libpcre2-16-0 libdouble-conversion3 libxcb-xinput0 \
 libxcb-xinerama0 qtbase5-dev qtchooser qt5-qmake \
 qtbase5-dev-tools
```

d. Install Spinnaker deb files:

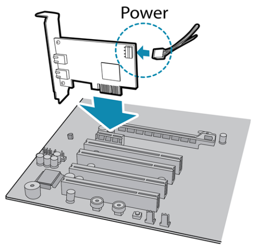
```
$ sudo sh install_spinnaker.sh
```

**2. Restart your computer.**

See the Spinnaker README file for additional information.

# 2.3 Installing your Host Adapter—Linux Users

**1. Install your Host Adapter**




Ensure the card is installed per the manufacturer's instructions.

Alternatively, use your PC's built-in host adapter, if equipped.

**2. Maximize Network Settings**

To maximize the successful usage of the camera it is important to optimize some network settings.

> **Note:** Administrator privileges are required.

A network tuning script provided with the Spinnaker SDK optimizes certain network settings using the standard tool: ethtool. Note that depending on your network interface and architecture, not all parameters set by the script are supported. The gev_nettweak tuning script is located in: /opt/spinnaker/bin/

a. Install ethtool:

```
$ sudo apt install ethtool
```

b. To show name of your host adapter:

```
$ ip addr show
```

c. Adjust <your host adapter> using the network tuning script:

```
$ sudo ./gev_nettweak <your host adapter>
```

The gev_nettweak script adjusts the following parameters:

| Parameter | Function |
|---|---|
| **MTU** | Maximizes the Maximal Transmission Unit (MTU) size on the host adapter. This is the maximum packet size for image data. |
| **net.ipv4.udp_rmem_min** | Adjusts the receive memory allocation size in the network stack. |
| **net.core.netdev_max_backlog** | Adjusts the network packet backlog queue size. |
| **net.unix.max_dgram_qlen** | Adjusts the network queue length and computes the amount of memory for UDP packets. |
| **net.core.rmem_default**<br>**net.core.rmem_max** | Adjusts the default and maximum memory for receiving network packets. |
| **rx_jumbo** | Adjusts the setting of the network device drivers to optimize the rx_ ring and the rx jumbo packet queue for maximum throughput and to disable the rx pause operation. This improves reception of image data packets from the cameras. |

> **Note:** Optimizations made by the tuning script are temporary settings that revert to default when the computer is rebooted. To make the changes permanent, adjust the parameters independently from the script.

**3. Disable Reverse Path Filtering (RPF)**

To ensure the camera enumerates properly, RPF needs to be disabled.

To disable RPF:

a. Run the following:

```
$ sudo gedit /etc/sysctl.d/10-network-security.conf
```

b. In the file, comment out the lines:

```
# Turn on Source Address Verification in all interfaces to
# in order to prevent some spoofing attacks.
## net.ipv4.conf.default.rp_filter=1
## net.ipv4.conf.all.rp_filter=1
```

c. Restart the computer.

**4. Set 5GigE Link Speed**

To use the full potential of 5GigE, we recommend setting the auto-negotiation speed and duplex of your host adapter to 5GBASE-T.

a. Verify your supported link modes:

```
$ sudo ethtool <your host adapter>
```

b. If supported, **temporarily** set the auto-negotiation speed and duplex to 5GBASE-T and full duplex:

```
$ sudo ethtool -s <your host adapter> advertise 0x1000000000000
```

Or,

c. To **permanently** set it, navigate to /etc/rc.local and edit that file with a text editor to copy in:

```
sudo ethtool -s <your host adapter> advertise 0x1000000000000
```

## 2.3.1 Permanently Changing Parameters

Running the optimization tuning script above temporarily changes parameters. If the optimizations work for your system, follow instructions below to set the parameters permanently.

### 2.3.1.1 Increase Receive Buffer Size

To **permanently** update the receive buffer size:

1. Run the following command:

```
$ sudo gedit /etc/sysctl.conf
```

2. Add the following lines to the bottom of the /etc/sysctl.conf file:

```
net.core.rmem_max=10485760
net.core.rmem_default=10485760
```

3. Reload the changes for them to take effect:

```
$ sudo sysctl -p
```

#### 2.3.1.2 Enable Jumbo Packets

To **permanently** enable Jumbo packets:

1. Open your netplan YAML configuration (for example, 01-network-manager-all.yaml) in /etc/netplan/:

```
$ sudo gedit /etc/netplan/01-network-manager-all.yaml
```

2. Set the MTU of the network adapter to the maximum allowable value for your interface:

```
network:
  ethernets:
   <your host adapter>:
    mtu: 9000
    addresses: [169.254.0.64/16]
    dhcp4: no
```

3. Restart the network:

```
$ sudo netplan apply
```

# 2.4 Installing your Software—ARM Users

**1. Install the Spinnaker® SDK Software**

**Note:** ARM users of the Bumblebee X camera require Spinnaker version 4.2.0.21 or later for ARM64.

a. Go to the Spinnaker download page. If you are not already logged in, you are prompted to login.

b. Select Spinnaker version 4.2.0.21 (or later) for Ubuntu 22.04.

c. Install the Ubuntu dependencies:

```
$ sudo apt-get install libusb-1.0-0 qtbase5-dev \
 qtchooser qt5-qmake qtbase5-dev-tools
```

d. Install Spinnaker deb files:

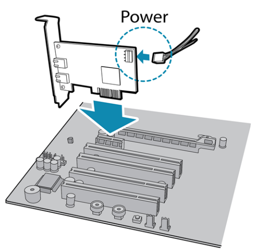
```
$ sudo sh install_spinnaker_arm.sh
```

**2. Restart your computer.**

See the Spinnaker README_ARM file for additional information.

# 2.5 Installing your Host Adapter—ARM Users

**1. Install your Host Adapter**

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2. Add the following lines to the bottom of the /etc/sysctl.conf file:

```
net.core.rmem_max=10485760
net.core.rmem_default=10485760
```

3. Reload the changes for them to take effect:

```
$ sudo sysctl -p
```

### 2.5.1.2 Enable Jumbo Packets

To **permanently** enable Jumbo packets:

1. Open your netplan YAML configuration (for example, 01-network-manager-all.yaml) in /etc/netplan/:

```
$ sudo gedit /etc/netplan/01-network-manager-all.yaml
```

2. Set the MTU of the network adapter to the maximum allowable value for your interface:

```
network:
  ethernets:
   <your host adapter>:
    mtu: 9000
    addresses: [169.254.0.64/16]
    dhcp4: no
```

3. Restart the network:

```
$ sudo netplan apply
```

# 2.6 Installing your Software—Windows Users

**1. Install the Spinnaker® SDK Software**

> **Note:** Windows users of the Bumblebee X camera require Spinnaker version 4.2.0.83 or later.

a. Go to the Spinnaker SDK Download page. If you are not already logged in, you are prompted to login.

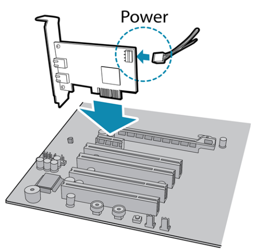
b. Select Spinnaker version 4.2.0.83 or later for Windows.

c. Run the install file and follow the installation instructions.

See the Spinnaker README file for additional information.

# 2.7 Installing your Host Adapter—Windows Users

**1. Install your Host Adapter**




Ensure the card is installed per the manufacturer's instructions.

Alternatively, use your PC's built-in host adapter, if equipped.

**2. Maximize Network Settings**

To maximize the successful usage of the camera it is important to optimize some network settings.

> **Note:** Administrator privileges are required.

In **Start→Teledyne Spinnaker SDK→SpinView**, right click on the Network Adapter and select Adapter Configuration. The Adapter Config Utility lists your network adapters and allows you to access the following:

- Adapter IP address
- Subnet mask
- Default gateway
- Receive buffers
- Transmit buffers
- Jumbo packets
- RSS
- Media optimization
- CPU affinity

**Note:** See How to Optimize GigE Network Adapter Settings for more information on configuring for best performance.

**3. Set 5GigE Link Speed**

To use the full potential of 5GigE, we recommend setting the auto-negotiation speed and duplex of your host adapter to 5GBASE-T.

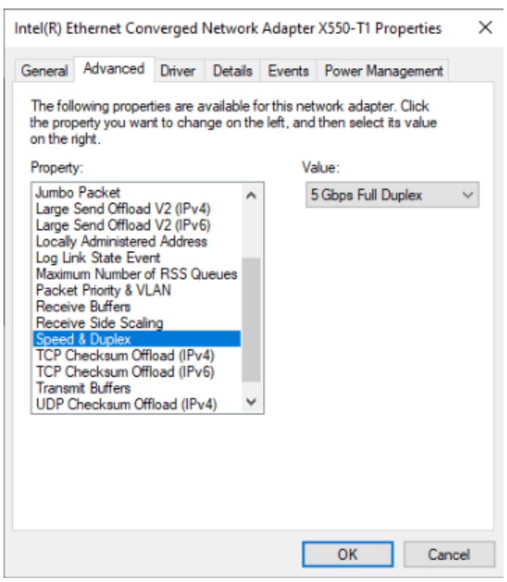
a. If necessary, update the driver to the latest to access the 5G Full Duplex option.

b. In Windows go to Control Panel\Network and Internet\Network Connections, right-click on your network adapter and select Properties.

c. Click Configure.

d. On the Advanced tab, from the Property box select Speed & Duplex and from the Value drop-down select 5Gbps Full Duplex.

e. Click OK.



## 2.8 Installing your Bumblebee X Camera

**1. Mount the Camera**

a. Calculate the distance required for your model's stereo field of view (see Determining your Stereo Field of View).

b. If using a pattern projector, mount the projector to the camera (see Using a Pattern Projector).

c. Mount the camera using the mounting holes on the top, bottom, or back of the case (see Mounting your Bumblebee X Camera).

**2. Connect the Camera**

a. Connect the host adapter to the Ethernet power injector using an RJ45 Ethernet cable.

b. Connect the camera to the injector using an M12 Ethernet cable.

**3. Connect the GPIO**

a. Connect the IP-rated GPIO cable, or;

b. Ensure the plug is secure in the GPIO connector on the back of the camera.

**4. Confirm Successful Installation**

a. Launch SpinView to connect to the camera for streaming.

b. Refer to the ROS Wrapper README file for using the camera in ROS and SDK examples.

c. Test and adjust the mounting position as necessary.

## 2.9 Powering the Bumblebee X Camera

The power requirements are: Power over Ethernet (PoE) or 12-24 V via GPIO. Power consumption is: 13.5 W typical.

Power can be provided over the Ethernet interface (PoE). To use PoE, you must also have a powered Ethernet card, a powered Ethernet switch, or an Ethernet power injector.

Power can also be provided externally through the GPIO interface.

If both power sources are connected the camera always uses external power over the GPIO connector.

The camera does not transmit images for the first 100 ms after power-up. The auto-exposure and auto-white balance algorithms do not run while the camera is powered down. It may therefore take several (*n*) images to get a satisfactory image, where *n* is undefined.

When the camera is power cycled (power disengaged then re-engaged), the camera reverts to its default factory settings, or if applicable, the last saved user set. For more information, see Working with User Sets.

# 3 Configuring Bumblebee X Camera Setup

After successful installation of your camera and interface card, you can make changes to the setup. Use the tools described below to change the driver for your interface card or configure the Ethernet settings. Some configuration and camera settings can be saved in User Sets.

For information on updating your camera's firmware post installation, see Camera Firmware.

## 3.1 Configuring Camera Drivers—Windows Users

The driver is installed automatically by the Spinnaker SDK installer for Camera Evaluation or for Application Development if the Drivers checkbox is selected (default). A restart is required.

> **Note:** For optimal driver performance, install Spinnaker version 4.2.0.83 or later.

Alternatively, you can manually install the driver. The driver files are in:

C:\Program Files\Teledyne\GigE Vision Interface\x64

## 3.2 Configuring the IP Address

When a new GigE camera is first powered and initialized, a dynamic IP address is assigned to the camera according to the DHCP protocol. If DHCP addressing fails, a link-local address is assigned. You can configure the IP address using the GenICam Features Transport Layer Control.

Alternatively, SpinView is a tool included with the Spinnaker SDK that allows you to set the internet protocol (IP) configuration for any GigE interface cards or Teledyne FLIR GigE Vision cameras connected to your system. Using SpinView, you can:

- Set the IP address for the current connection.
- Program a persistent IP address for the camera.
- Configure the default IP addressing behavior of the camera on startup using a persistent IP, DHCP or LLA.
- Enable Jumbo Frames on the GigE NIC.

Both your camera and host adapter must have an IP address on the same subnet. This can be assigned in three ways:

- **Persistent**—The camera has a fixed IP address that does not change. Generally the address is within a closed network range of 192.168.X.X.
- **Dynamic (DHCP)**—The camera is set to automatically obtain an IP address. This means that the IP address may change (within a range) every time the camera or computer is restarted. It may take up to one minute for the IP

address to resolve and the camera to enumerate.

- **Default (LLA)**—The camera uses an IP address from the link-local address block 169.254.x.x.

The camera assigns its current IP address in the following sequence:

1. **Persistent**—Uses the defined IP address. If not available, then;
2. **DHCP**—Attempts to find a dynamic IP address. If not available, then;
3. **LLA**—Uses an LLA IP address.

SpinView can automatically force an IP address refresh. This detects the IP address of the Network Interface card and automatically sets the camera's IP address relative to the card.

To open SpinView:

**Start→Teledyne Spinnaker SDK→SpinView**

# 3.3 Configuring Other Ethernet Settings

## 3.3.1 Stream Channel Destination Address

The stream channel destination address (SCDA) register is used to specify the streaming destination IP address. The default SCDA is the IP address of the network or computer to which the camera is connected. It can be set within a range so that the camera sends data as a multicast. As long as switches in the path between the sender and receivers support and are configured for multicasting, multiple receivers can listen to the data stream from the camera.

Multicast addresses are between 224.0.0.0 and 239.255.255.255.

> **Note:** For more information on multicast address assignments, see http://tools.ietf.org/html/rfc3171

To control SCDA use:

- GenICam—GevSCDA in the Transport Layer Control

## 3.3.2 Heartbeat

The heartbeat is a mandatory GigE Vision feature to monitor the connection between an application and the camera. The application must continually communicate with the camera so that it resets its heartbeat timer, or the camera assumes an error has occurred and shuts down the connection. This is to allow a host that has stopped working to be able to take control of the camera once it is restarted or to allow a different host to take control of the camera.

The Spinnaker API manages the heartbeat communication of the camera at a low level so you do not need to continuously communicate with the camera after enumeration. However, the following two features are user-controllable: Heartbeat Timeout and Heartbeat Disable. You may consider using these settings when you never want to lose connection with the camera such as a scenario where Ethernet communication may be removed from time to time. Also, the heartbeat timeout could be increased in situations where there is network congestion on a switch, preventing packets from being received on the host or device for a period of time. Generally, the default settings provide a stable method for connecting to the Bumblebee X camera.

### Heartbeat Timeout

Heartbeat timeout is the time, in milliseconds, that the camera waits before closing the connection. Heartbeat timeout can be set between 500 ms and 10 seconds. The default setting is 3000 ms (3 seconds). If there is no communication between the camera and the application for longer than the timeout value, the connection is shut down.

To control Heartbeat Timeout use:

- GenICam—Under Transport Layer Control, GevHeartbeatTimeout.
- Spinnaker API—The Spinnaker SDK supports configuring heartbeat timeout.

### Heartbeat Disable

The heartbeat is enabled by default.

To disable Heartbeat use:

- GenICam—Under Transport Layer Control GevGVCPHeartbeatDisable.
- Spinnaker API—The Spinnaker SDK supports disabling heartbeat.

# 3.4 Working with User Sets

The camera can save and restore settings and imaging parameters via on-board user configuration sets, also known as user sets. This is useful for saving default power-up settings, such as stream components, gain, exposure, and frame rate, and others that are different from the factory defaults.

## 3.4.1 Types of User Sets

You can select which user set to configure, save, or load with the UserSetSelector feature. There are two classes of user sets.

- User-defined settings
- Factory-defined settings. A factory-defined Default user set is always available. It represents a typical use case for the camera.

If the factory-defined settings are not ideal, they can be used as a starting point. From there, only a few features may need to be modified to achieve the desired configuration. The UserSetSave feature saves the current camera settings so that they can be recreated later. Once saved, these new custom settings can be loaded at any time.

The UserSetLoad feature loads the specified user set. Note that one can load a set without first saving. In this situation, the user set contents are the factory-defined default settings.

## 3.4.2 Start-up User Set

The UserSetDefault feature is used to configure a camera automatically at start-up. This loads the selected user set at start-up time. By default, it applies the factory-defined Default settings. However, you can change it to any user set so that the next time the camera restarts, it comes up with the selected user set.

### 3.4.3 User Set Managed Features

Due to limited on-board non-volatile memory, not all features are supported by user sets. See UserSetFeatureSelector for the list of all features that are supported. Features that are not listed are either of single session nature or are managed explicitly via other features, such as Defect Table Save.

### 3.4.4 User Set Conversion

The exact list of features managed by user sets may change between different versions of firmware. Consequently, there may not be a perfect match between the set of features saved to non-volatile memory and the set of features handled by the current version of firmware. In this situation, the camera performs any necessary conversions on all saved user sets. This happens automatically the first time the camera is restarted after a firmware update. The conversion performed depends on the nature of the feature discrepancy:

- Obsolete features - Saved features that are no longer supported in the current firmware. These features are ignored and removed from all subsequently saved user sets.
- Missing features - Saved user sets do not have features that are supported in the current firmware. These missing feature values are filled in using one of the factory-defined sets. If UserSetDefault points to a user-defined set, then the missing feature values are copied from the factory-defined Default set.

## 3.5 Non-Volatile Flash Memory

The Bumblebee X camera has 6 MB for you to store data.

The storage is accessed through the file I/O nodes in the camera. SpinView also provides a File Access tab to allow you to easily access files located on the camera's internal storage. You can access files related to user sets, stereo calibration and the data file mentioned above.

| Knowledge Base Article |
| --- |
| **Storing Data in On-Camera Flash Memory** |

## 3.6 Camera Firmware

Firmware is programming that is inserted into the programmable read-only memory (programmable ROM) of most cameras. Firmware is created and tested like software. When ready, it can be distributed like other software and you can install it in the programmable read-only memory.

The latest firmware versions often include significant bug fixes and feature enhancements. To determine the changes made in a specific firmware version, consult the Release Notes.

Firmware is identified by a version number, a build date, and a description. As well, the Device Version shows the progression of firmware versions for a product, starting with 1.0.

### 3.6.1 Determining Firmware Version

To determine the firmware version number of your camera:

- Query the GenICam Device Control feature DeviceFirmwareVersion.

## 3.6.2 Upgrading Firmware

Firmware can be upgraded or downgraded to later or earlier versions using SpinView, part of the Spinnaker SDK, or Console.

Before upgrading firmware:

- Install the Spinnaker SDK, available from the Spinnaker page.
- Download the latest model package zip file for the product, available from the Bumblebee X product page.

To upgrade the firmware using Console (Linux users):

1. Open terminal or command prompt and navigate to the Spinnaker installation directory.
2. Navigate to the Spinnaker installation SpinView application subdirectory.
3. From this directory, run the firmware update application SpinUpdateConsole, with the following arguments:

```
-R{Camera Serial Number} -UU -B {Full path to file ending in .ez2 extension}
```

For example:

```
SpinUpdateConsole -R24330007 -UU -B /home/xb6_5g_imx265.ez2
```

4. If the update is successful, a "Success. No issues." message is displayed.

To upgrade the firmware via SpinView (Windows users):

1. Launch the SpinView application.
2. From the Device list, right click the camera and select Update Device Firmware. If you get a Device is Active warning, close the Display pane or click the Disconnect button and right click the camera again.
3. Browse to select the firmware file and click Open.
4. Click Yes to continue.

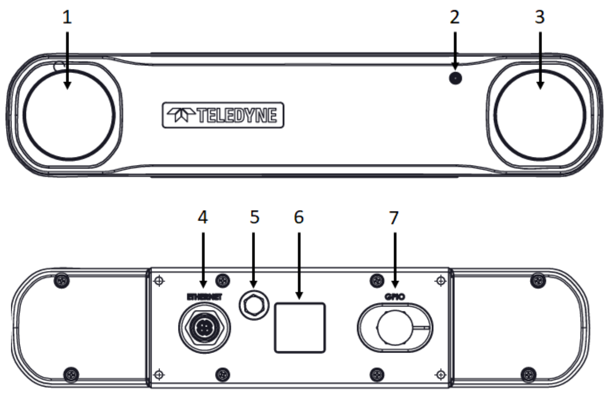
**Warning!** Do not disconnect the camera during the firmware update process.

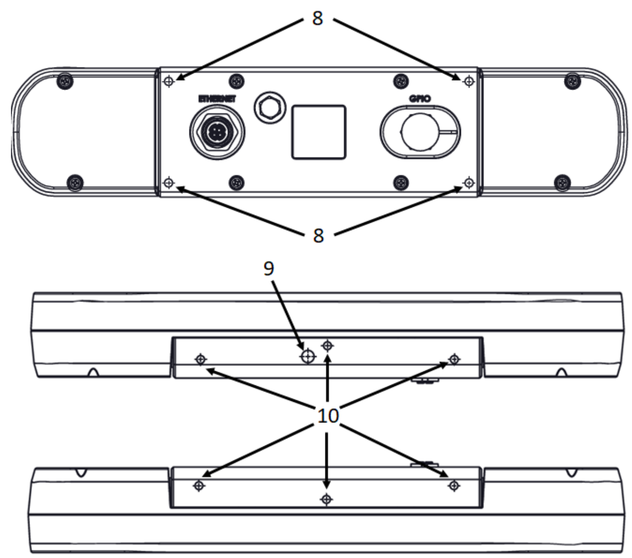
**Related Knowledge Base Articles**

| |
|---|
| Teledyne FLIR software and firmware version numbering systems |
| Determining my camera's firmware version |
| Should I upgrade my camera firmware or software? |

# 4 Bumblebee X Camera Physical Interface

## 4.1 Physical Description




**1** - Sensor 2

**2** - Status Indicator **LED** (see Status Indicator LED)

**3** - Sensor 1

**4** - **Ethernet** Connector (see Bumblebee X Camera Interface and Connectors)

**5** - **Vent**

**6** - **Label** Contains camera information such as model name, serial number and required compliance.

**7** - **GPIO** Connector (see Bumblebee X Camera Input/Output Control)

**Mounting Holes** (see Mounting your Bumblebee X Camera)

**8** - M4x0.7 holes 5.5 mm deep—4 on the back

**9** - 1/4-20 UNC hole 3.8 mm deep—1 on the bottom

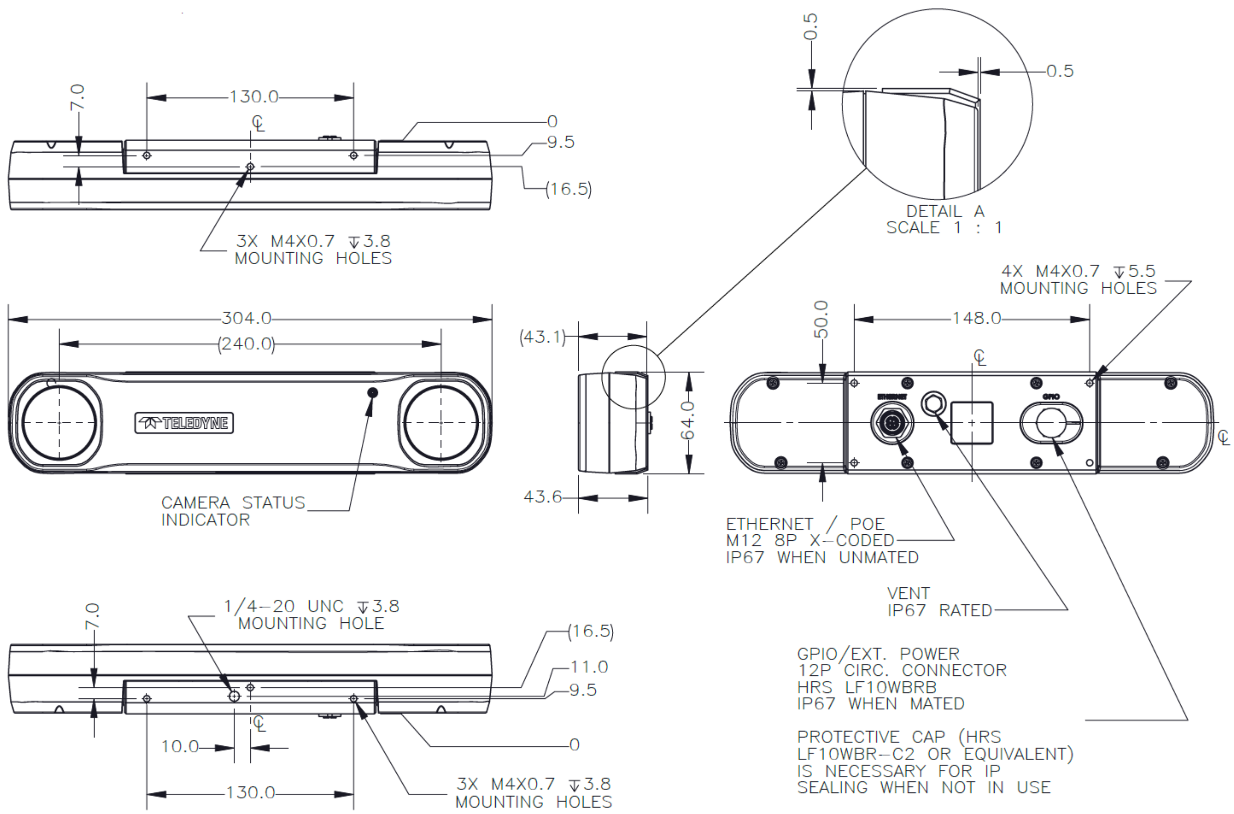
**10** - M4x0.7 holes 3.8 mm deep—3 on the top of the case and 3 on the bottom

# 4.2 Camera Drawings

## 4.2.1 Camera Dimensions BX-P5G-30C-XC3

Download CAD Models from our website:

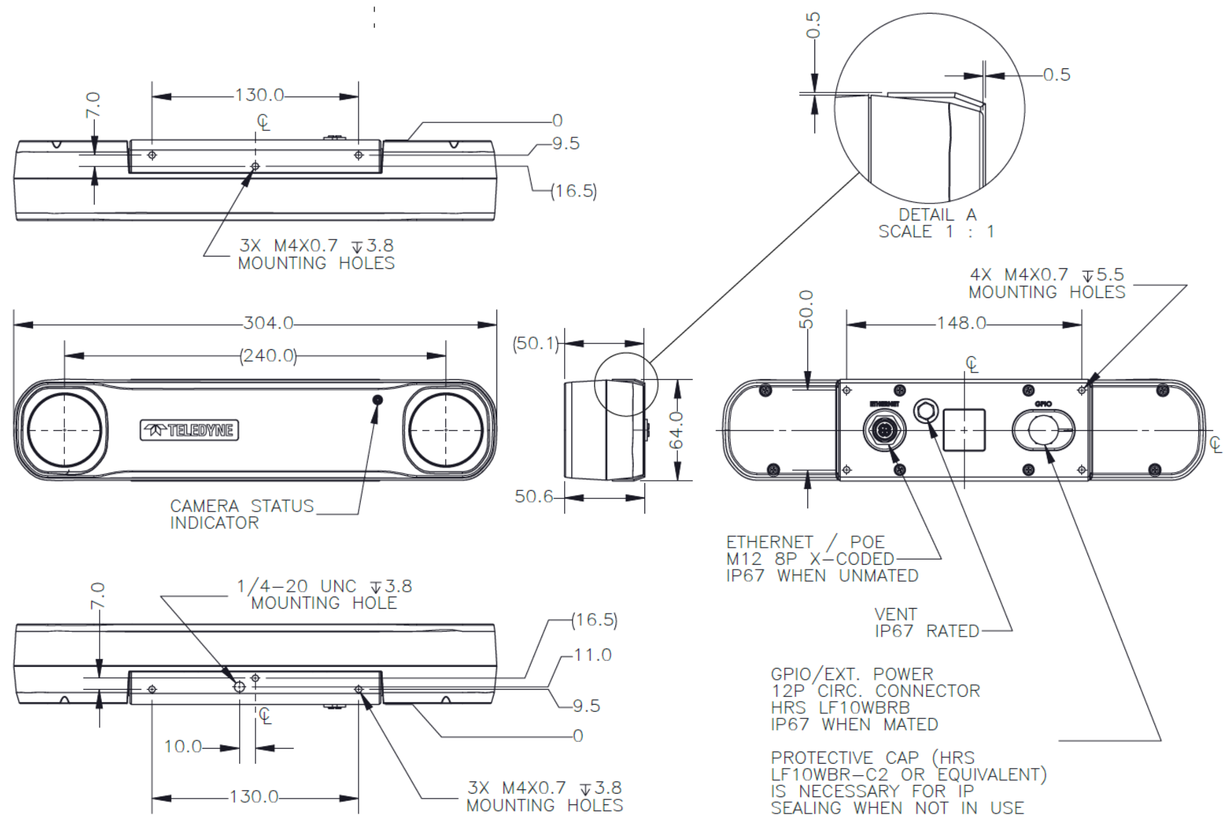
[BX-P5G-30C-XC3]



## 4.2.2 Camera Dimensions BX-P5G-30C-XC5

Download CAD Models from our website:

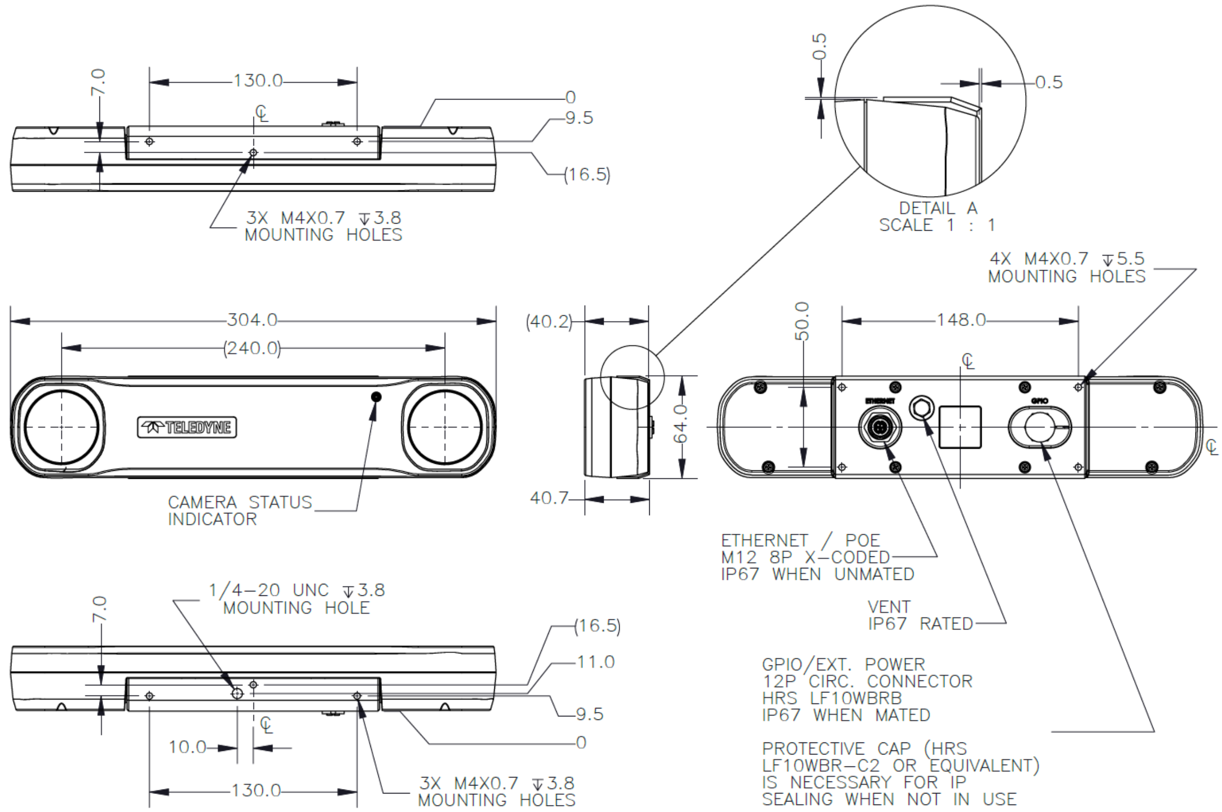
BX-P5G-30C-XC5



### 4.2.3 Camera Dimensions BX-P5G-30C-XC7

Download CAD Models from our website:

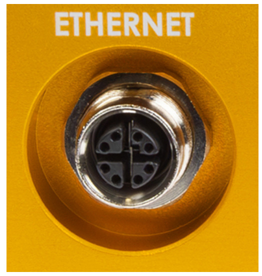
BX-P5G-30C-XC7



# 4.3 Bumblebee X Camera Interface and Connectors

## 4.3.1 Ethernet Connector

The Bumblebee X camera is equipped with a M12 X-code 8-pin Ethernet connector which can be connected to the RJ45 Ethernet jack on the Ethernet power injector using an IP-rated cable. Pin assignments conform to the Ethernet standard.




> **Note:** To retain the IP rating of the camera, an IP-rated cable must be securely attached to the camera's connector.

### 4.3.1.1 Power over Ethernet (PoE)

To use PoE, an Ethernet power injector or a powered Ethernet switch must be connected to the camera. The PoE conforms to the IEEE 802.3af-2003 standard.

## 4.3.2 Ethernet Cables

To purchase a recommended cable from Teledyne FLIR, visit the Products Accessories page.

Category 5e cables up to 40 meters in length can be used with 5GigE. For cable lengths greater than 40 meters, Category 6a cables should be used.

> **Note:** For optimal ESD protection, we recommend using a shielded Ethernet cable or connecting the camera housing to chassis ground (earth).

### 4.3.3 Host Adapter

The camera must connect to an interface card on the computer. This is sometimes called a host adapter, a bus controller, or a network interface card (NIC).

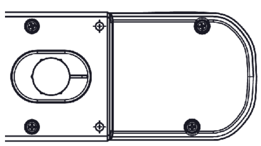
> **Note:** For optimal video streaming and camera control performance, we recommend an Intel Pro chipset on a PCIe interface.

See Installing your Host Adapter—Linux Users or Installing your Host Adapter—Windows Users for optimizing the host adapter to maximize the potential of the Bumblebee X camera.

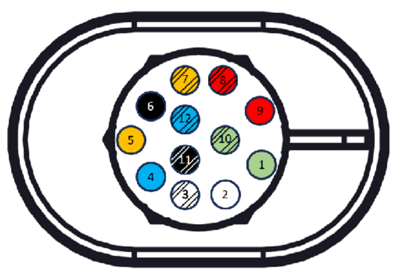
### 4.3.4 General Purpose Input/Output (GPIO)

GPIO can be used for power, trigger (both camera and pattern projector), and strobe.

The Bumblebee X camera is equipped with a 12-pin GPIO connector on the back of the case. The connector is a Hirose LF10WBRB, the mating connector is a Hirose LF10WBP-12P.



Connector orientation on back of case





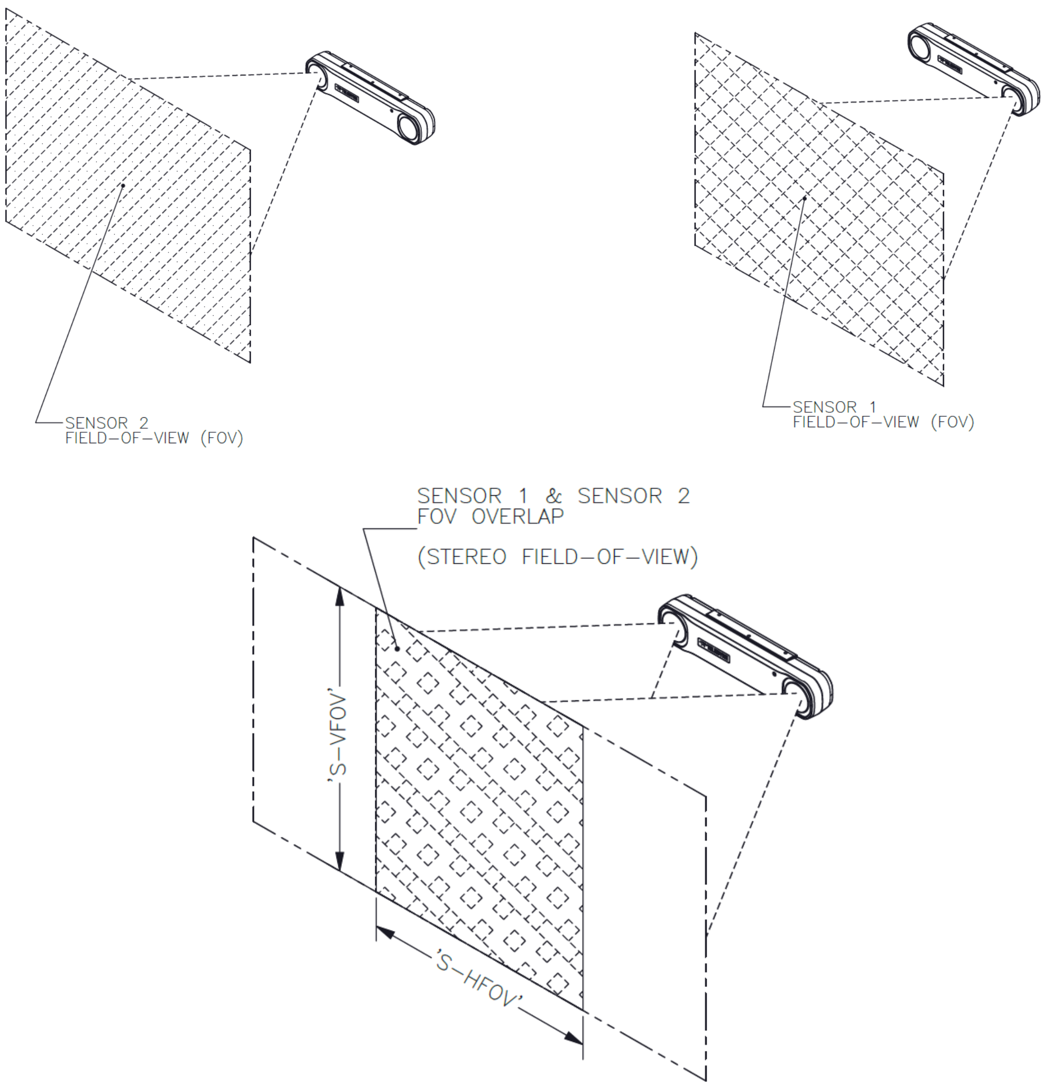
Connector with pins

> **Note:** To retain the IP rating of the camera, an IP-rated GPIO cable must be securely attached to the camera's connector. If not using GPIO, the sealing plug must be in place.

See Input/Output Control for details on pin assignments and electrical characteristics.

## 4.4 Determining your Stereo Field of View

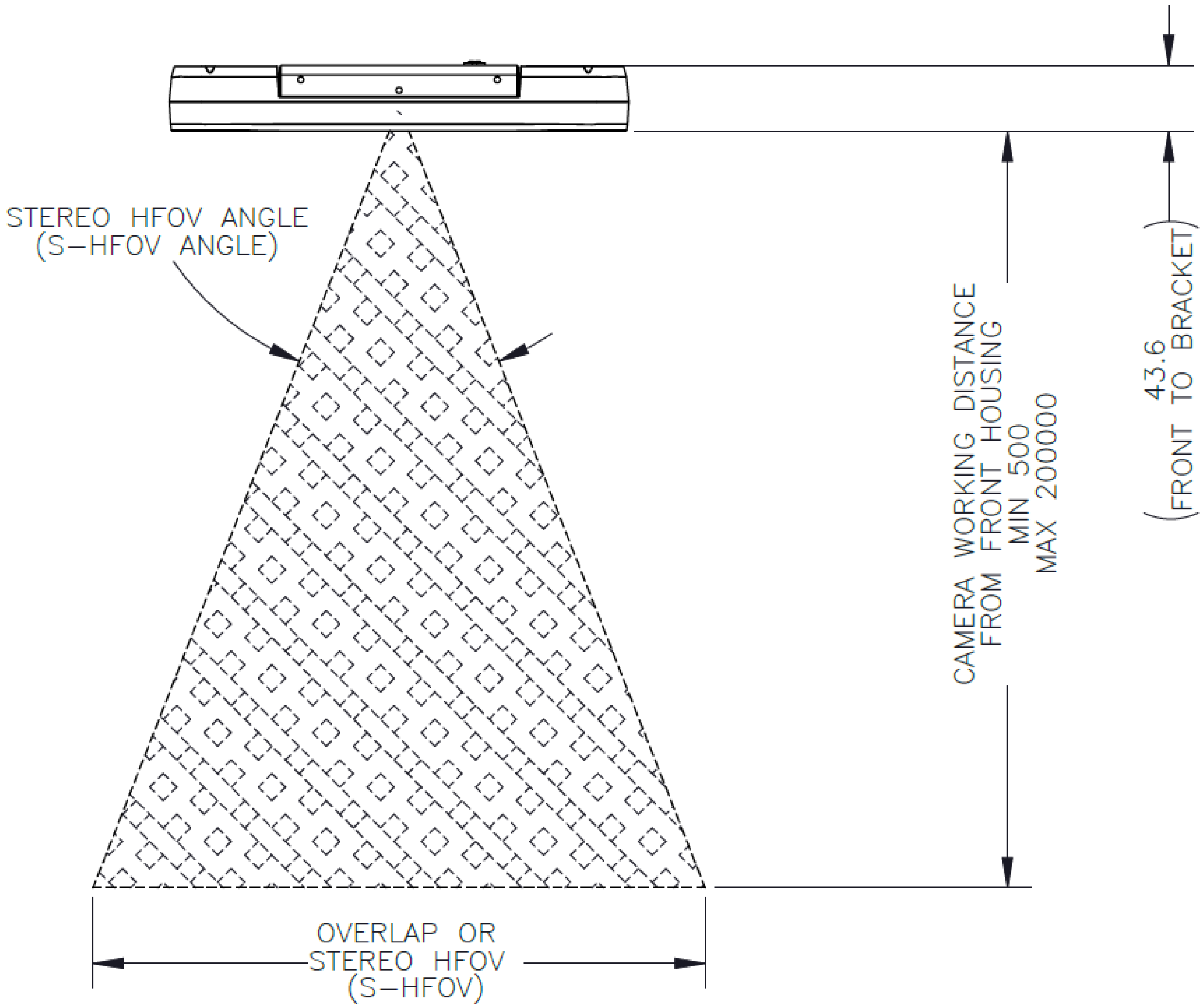
The Bumblebee X camera's stereo field of view (FOV) is determined by the overlap of the FOV from sensor 1 and sensor 2.




The stereo vertical field of view (S-VFOV) is based on the lens and the sensor's vertical FOV.

> **Note:** Teledyne FLIR recommends you use between 80 and 90% of the S-HFOV and S-VFOV values as image rectification may reduce the overall S-FOV. Stereo FOV values provided are approximate only. Test and adjust accordingly.

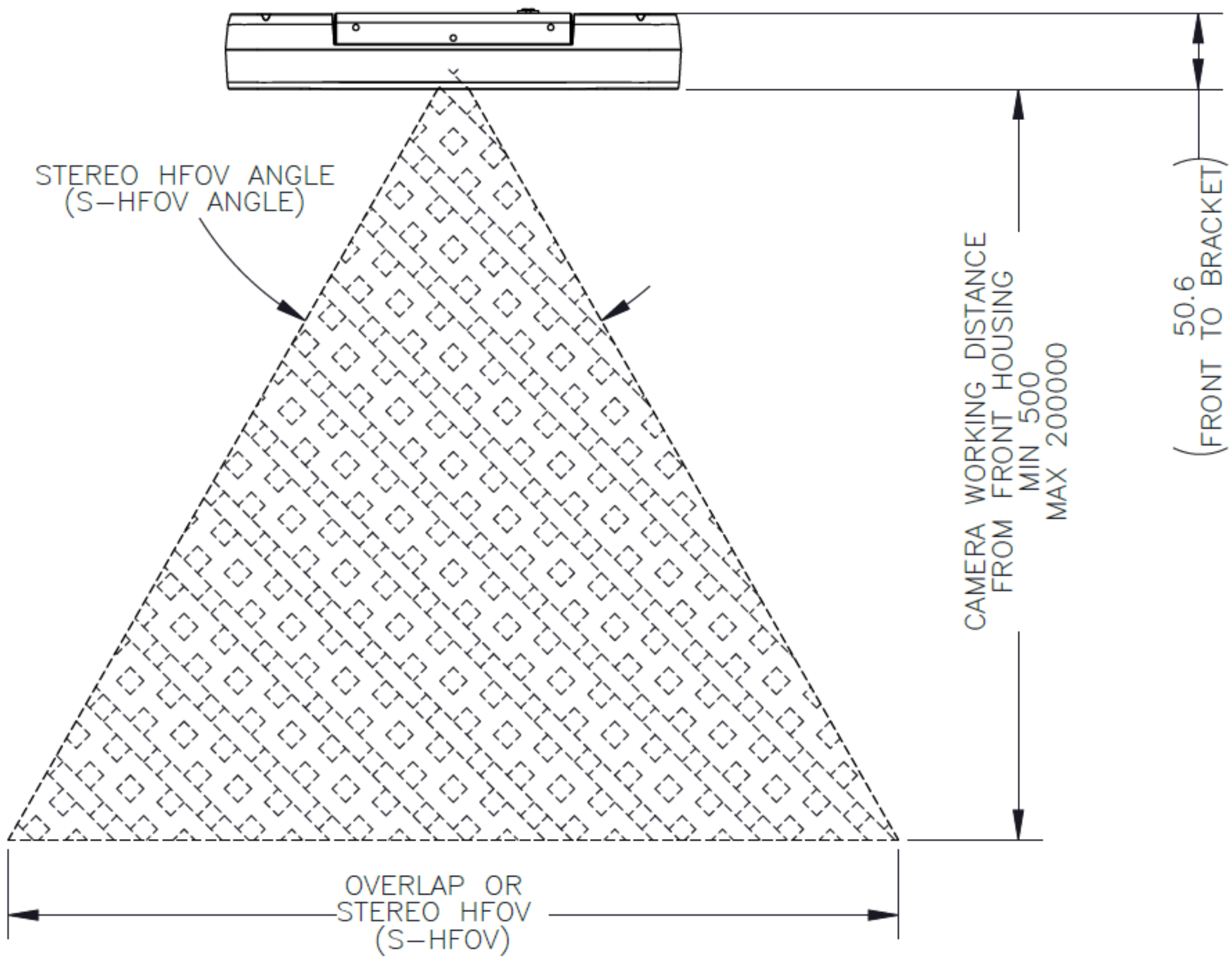
### 4.4.1 BX-P5G-30C-XC3 S-FOV




**BX-P5G-30C-XC3 S-FOV**

| Working Distance (mm) | S-HFOV Angle (degrees) | S-HFOV (mm) | S-VFOV (mm) | Expected Depth Accuracy (mm) |
|---|---|---|---|---|
| 500 (minimum) | 43 | 405 | 485 | 0.3 |
| 1000 | 54 | 1030 | 955 | 1.2 |
| 2000 | 59 | 2279 | 1895 | 4.7 |
| 2500 | 60 | 2904 | 2364 | 7.4 |
| 5000 | 62 | 6029 | 4714 | 30 |
| 10000 | 63 | 12277 | 9412 | 119 |
| 20000 (maximum) | 64 | 24775 | 18808 | 481 |

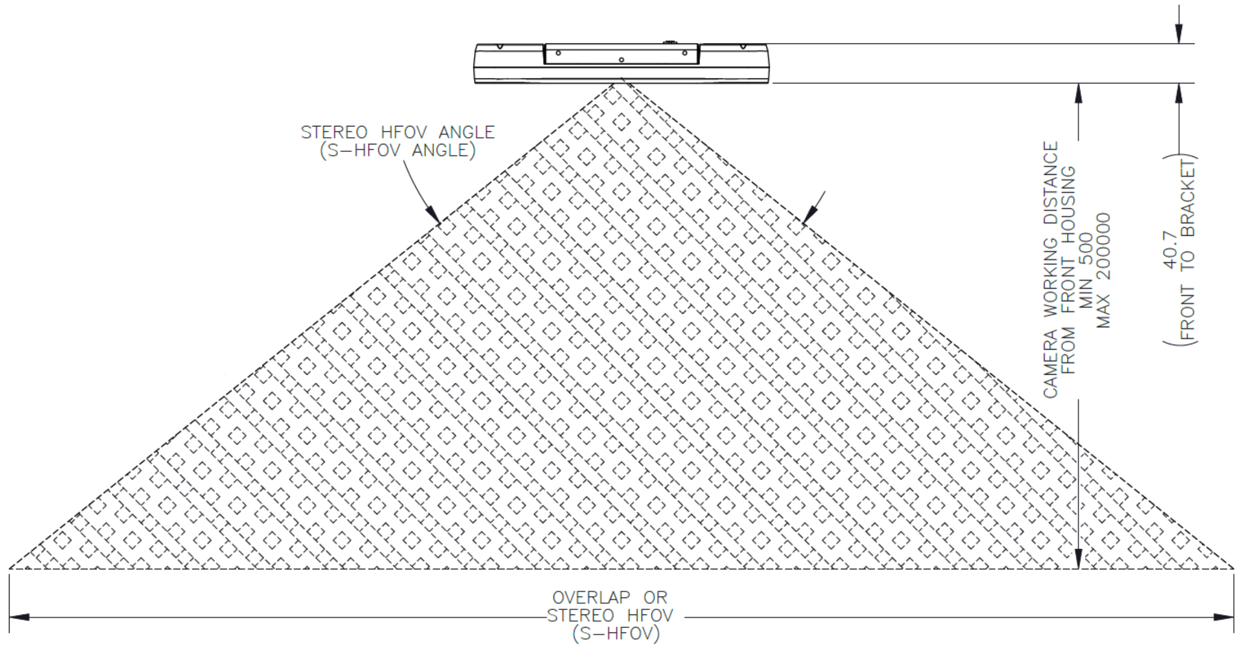
### 4.4.2 BX-P5G-30C-XC5 S-FOV




**BX-P5G-30C-XC5 S-FOV**

| Working Distance (mm) | S-HFOV Angle (degrees) | S-HFOV (mm) | S-VFOV (mm) | Expected Depth Accuracy (mm) |
|---|---|---|---|---|
| 500 (minimum) | 60 | 594 | 622 | 0.4 |
| 1000 | 69 | 1401 | 1223 | 1.7 |
| 2000 | 74 | 3015 | 2425 | 6.9 |
| 2500 | 74 | 3821 | 3025 | 11 |
| 5000 | 76 | 7856 | 6030 | 43 |
| 10000 | 77 | 15925 | 12038 | 174 |
| 20000 (maximum) | 77 | 32063 | 24056 | 707 |

### 4.4.3 BX-P5G-30C-XC7 S-FOV

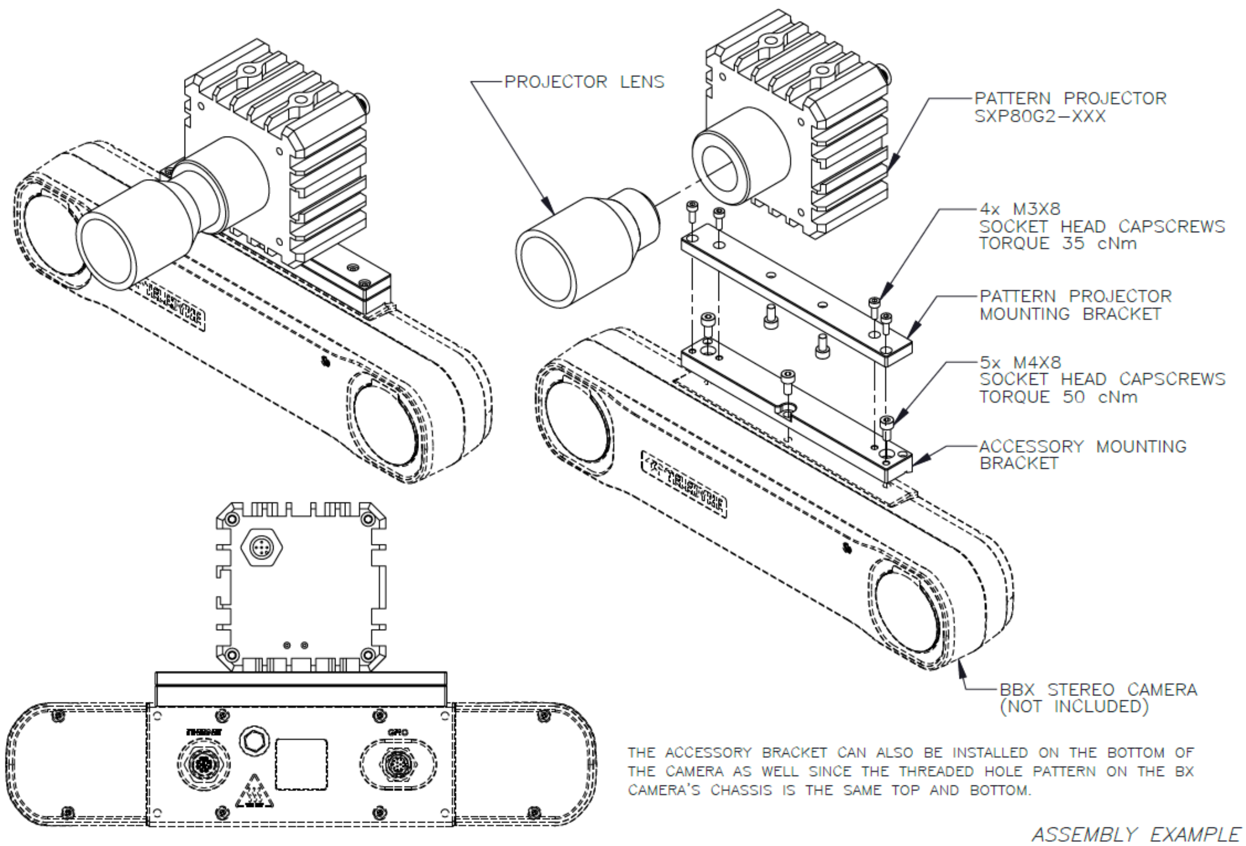



**BX-P5G-30C-XC7 S-FOV**

| Working Distance (mm) | S-HFOV Angle (degrees) | S-HFOV (mm) | S-VFOV (mm) | Expected Depth Accuracy (mm) |
|---|---|---|---|---|
| 500 (minimum) | 102 | 1258 | 835 | 0.9 |
| 1000 | 107 | 2741 | 1660 | 3.5 |
| 2000 | 110 | 5706 | 3308 | 14 |
| 2500 | 110 | 7188 | 4133 | 22 |
| 5000 | 111 | 14601 | 8254 | 90 |
| 10000 | 112 | 29427 | 16498 | 365 |
| 20000 (maximum) | 112 | 59078 | 32984 | 1520 |

# 4.5 Using a Pattern Projector

For low texture indoor scenes, a random dot pattern projector is available as an optional accessory. It can be mounted on top of the Bumblebee X camera using a bracket, and can be connected to the camera via GPIO for synchronization. Refer to Pattern Projector Setup for more information on the wiring and configuration.




# 4.6 Mounting your Bumblebee X Camera

The case is equipped with mounting holes on the back, top and bottom of the case that can be used to attach the camera to a custom mount.

- On the back of the case are four M4x0.7 holes 5.5 mm deep.
- On the top of the case are three M4x0.7 holes 3.8 mm deep.
- On the bottom of the case are three M4x0.7 holes 3.8 mm deep and one 1/4-20 UNC hole 3.8 mm deep.

# 4.7 Water and Dust Protection

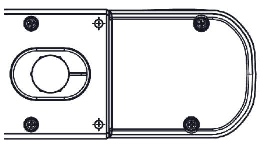
The Bumblebee X camera has passed IP67 environmental protection testing which means it is completely protected from dust ingress and protected from water ingress up when submerged up to 1 meter in depth for 30 minutes.

**Warning!** To retain the IP rating of the camera, IP-rated Ethernet and GPIO cables must be securely attached to the camera's connectors. If not using GPIO, a sealing plug must be in place.

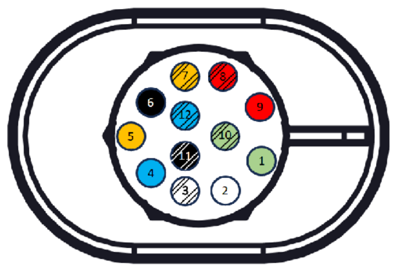
# 5 Bumblebee X Camera Input/Output Control

## 5.1 General Purpose Input/Output (GPIO)

The Bumblebee X camera is equipped with a 12-pin GPIO connector on the back of the case. The connector is a Hirose LF10WBRB, the mating connector is a Hirose LF10WBP-12P.



Connector orientation on back of case




Connector with pins


> **Note:** To retain the IP rating of the camera, an IP-rated GPIO cable must be securely attached to the camera's connector. If not using GPIO, the sealing plug must be in place.

### Notes

- No external pull-up resistor or bias voltage used on non-isolated GPIO measurements below. The internal 4k7 pull-up resistor and 3.3 V voltage source was used.
- External 4k7 pull-up resistor and external 5 V voltage source used on isolated GPIO output tests.
- Minimum and maximum output voltage on GPIO lines dependent on the pull-up resistor value and bias voltage.
- All GPIO outputs tested using common-emitter/source configuration to GND. Outputs derived from the collector/drain of the transistor/FET.
- All GPIO outputs can safely handle steady state current of 25 mA and up to 700 mA pulse (Pulse width ≤10 ms, Duty ≤1 %).
- Extended voltage range for Vext is 8 V to 30 V for short period of time. Input voltage below 8 V might not power up the camera. Input voltage above 30 V might damage the camera.
- All GPIO lines can handle maximum voltage of 30 V but the over-current protection may not work properly.
- Measurements taken at 25°C ambient and camera back case temperature at about 50°C. Measured values are for reference only and could vary depending on the test conditions (temperature, resistor value and external bias voltage).
- External power input (Vext) to the camera must have a minimum current rating of 2 A when the output voltage is 12 V or lower. Power source should be able to deliver at least 20 W.

| Color | Pin | Line | Function | Description | Parameter | Value |
|---|---|---|---|---|---|---|
| Green | 1 | N/A | Opto GND | Ground for opto-isolated IO | | |
| White | 2 | Line0 | IO | Opto-isolated input (default trigger in) | Voltage Range | 0 - 24 V |
| | | | | | Input Low Level Threshold | 1.6 V |
| | | | | | Input High Level Threshold | 1.7 V |
| | | | | | Input Current | 6 mA |
| White/Black | 3 | Line1 | O1 | Opto-isolated output | Voltage Range | 0 - 24 V |
| | | | | | Output Current (active low) | 35 mA max |
| Blue | 4 | Line2 | IO2 | Input/Output | Voltage Range | 0 - 24 V |
| | | | | | Input Low Level Threshold | 1.5 V |
| | | | | | Input High Level Threshold | 2.2 V |
| | | | | | Input Current | 700 µA |
| | | | | | Output Current (active low) | 35 mA max |
| Orange | 5 | N/A | Aux Vout | a. Adjustable output V (10 mA) | Voltage Range | 0.2 - 10.5 V |
| | | | | b. 3.3 V (400 mA) | Switched Output Voltage | 3.3 V |
| | | | | c. 5 V (400 mA) | Switched Output Voltage | 5 V |
| Black | 6 | N/A | GND | Ground for Vext, Aux Vout, and Non-isolated GPIO | | |
| Orange/Black | 7 | Line4 | IO4 | Input/Output | Voltage Range | 0 - 24 V |
| | | | | | Input Low Level Threshold | 1.5 V |
| | | | | | Input High Level Threshold | 2.2 V |
| | | | | | Input Current | 700 µA |
| | | | | | Output Current (active low) | 35 mA max |
| Red/Black | 8 | N/A | Vext | External power input to the camera | Voltage Range | 10 - 24 V<br>12 V typical |
| Red | 9 | | | | Current Capacity | 2 A min |
| Green/Black | 10 | Line5 | IO5 | Input/Output | Voltage Range | 0 - 24 V |
| | | | | | Input Low Level Threshold | 1.5 V |
| | | | | | Input High Level Threshold | 2.2 V |
| | | | | | Input Current | 700 µA |
| | | | | | Output Current (active low) | 35 mA max |
| Black/White | 11 | Line3 | IO3 | Input/Output | Voltage Range | 0 - 24 V |
| | | | | | Input Low Level Threshold | 1.5 V |
| | | | | | Input High Level Threshold | 2.2 V |
| | | | | | Input Current | 700 µA |
| | | | | | Output Current (active low) | 35 mA max |
| Blue/Black | 12 | N/A | GND | Ground for Vext, Aux Vout, and Non-isolated GPIO | | |

## 5.2 GPIO Electrical Characteristics

Both the opto-isolated input and output have over current protection as long as the voltage on these lines is within 24 V.

The output is open collector and thus requires a pull- up resistor to operate. The rise time and bias current is determined by the resistor value chosen. If the camera is generating an output signal that approaches the rise time plus the fall time of the circuit, care must be taken to optimize the pull-up resistor chosen to minimize the rise time while still remaining within the current limits of the output circuit.

The opto-isolated minimum output voltage increases at higher load current or when the pull-up resistor value on the output is decreased.

The Aux Vout has three configurable outputs. Each output is selectable via the Spinnaker software. When adjustable output is selected, the output can be adjusted to any voltage between 0.5 V to 10 V.

The adjustable output load current should be limited to 10 mA max. The output voltage accuracy or regulation is dependent on the load current. The adjustable output has current-limit protection from overload for short periods of time. However, prolonged overload or a short circuit condition might damage the output drive circuit. The output load current for the 3.3 V or the 5 V fixed output should be limited to 400 mA. If the load current is more than 400 mA, the output shuts down to protect the drive circuit. The fixed outputs (3.3 V and 5 V) are derived from the main power source of the camera (PoE or Vext). High inrush current on Aux Vout could disrupt the PoE or Vext voltage and cause the camera to reset. Care must be taken to reduce the inrush current when the 400 mA fixed outputs (3.3 V or 5 V) are used to power external devices, so as not to affect the operation of the camera.

**Note:** Measured values are for reference only.
The logic high input current for non-isolated input measures 0 A because there is a diode on the input circuit that is reverse-biased when the input voltage is higher than 3.3 V.

**Opto-isolated Input**

| External Input Voltage | Input Current (Logic High) | Input Current (Logic Low) | Input Resistor |
|---|---|---|---|
| 3.3 V | 4.7 mA | 0 A | 0 Ω |
| 5 V | 5.7 mA | 0 A | 0 Ω |
| 12 V | 6 mA | 0 A | 0 Ω |
| 24 V | 6.2 mA | 0 A | 0 Ω |

**Opto-isolated Output**

| External Bias Voltage | External Pull-up Resistor | Opto_Out Low Voltage | Output_Out High Voltage |
|---|---|---|---|
| 3.3 V | 330 Ω | 1.20 V | 3.299 V |
| 5 V | 330 Ω | 1.35 V | 4.975 V |
| | 1k Ω | 735 mV | 4.990 V |
| | 4k7 Ω | 220 mV | 4.999 V |

**Non-isolated GPIO Input**

| External Input Voltage | Input Current (Logic High) | Input Current (Logic Low) | Input Resistor |
|---|---|---|---|
| 3.3 V | 0 A | 700 µA | 0 Ω |
| 5 V | 0 A | 700 µA | 0 Ω |
| 12 V | 0 A | 700 µA | 0 Ω |
| 24 V | 0 A | 700 µA | 0 Ω |

**Non-isolated GPIO Output**

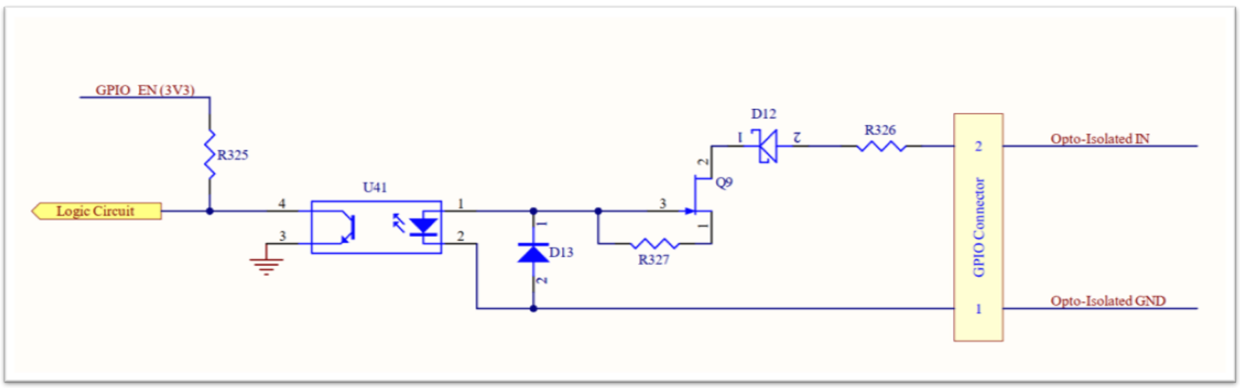
| External Bias Voltage | External Pull-up Resistor | Output Low Voltage | Output High Voltage |
|---|---|---|---|
| 3.3 V (internal) | 4k7 (internal) | 22 mV | 3.29 V |
| 3.3 V | 330 Ω | 300 mV | 3.29 V |
| 5 V | 1k Ω | 160 mV | 4.99 V |
| 12 V | 4k7 | 84 mV | 11.99 V |
| 24 V | 10k | 80 mV | 23.96 V |

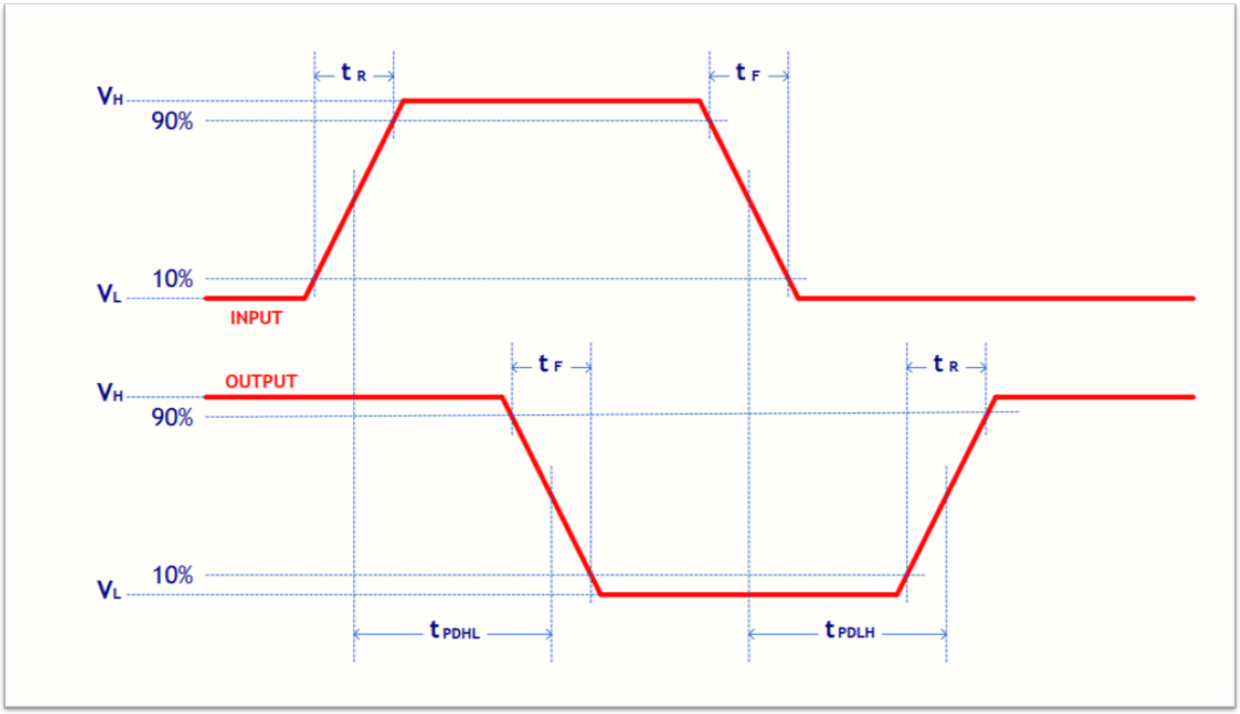
# 5.3 Input Timing Characteristics

## 5.3.1 Timing for Opto-isolated Input

### Notes

- Input pulses used are square waveform from a signal generator with maximum voltage of 3.3 V.
- The output voltage goes to the FPGA's logic input pin. The threshold voltage for logic high and logic low is about 1.2 V.
- Input threshold voltage is observed/measured when the output voltage crosses the 1.2 V logic level.
- Internal pull-up resistor is 4k7 Ω.
- Internal bias voltage (GPIO_EN) is 3.3 V.
- Timing diagram, schematic, and measured values are for reference only.



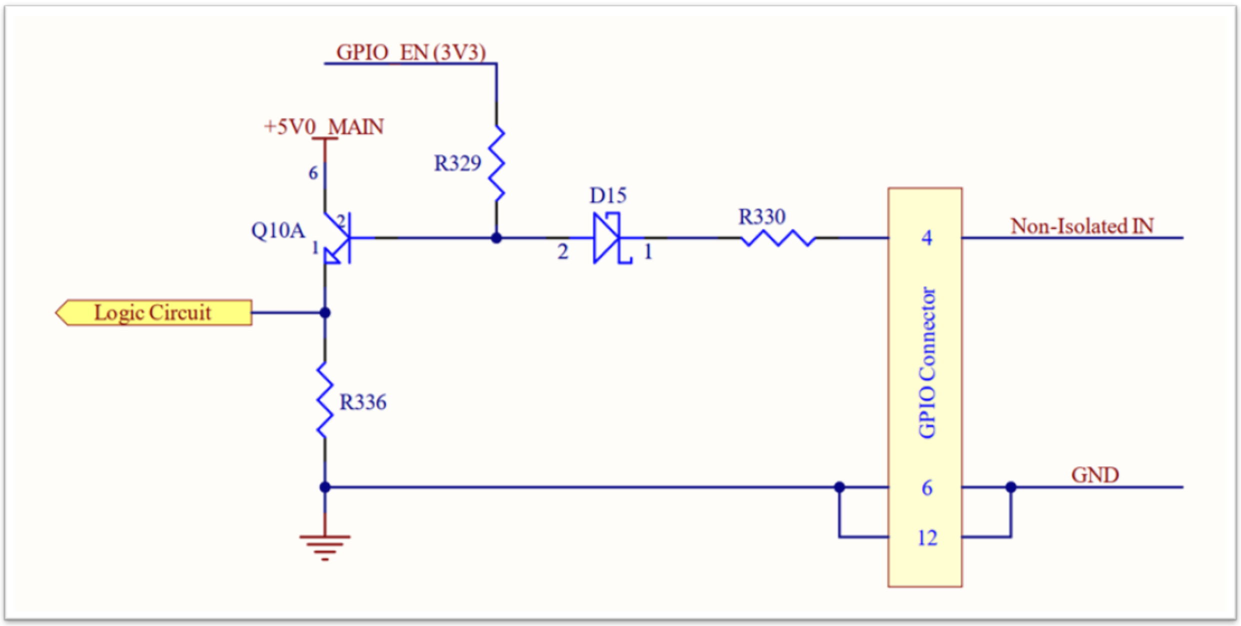


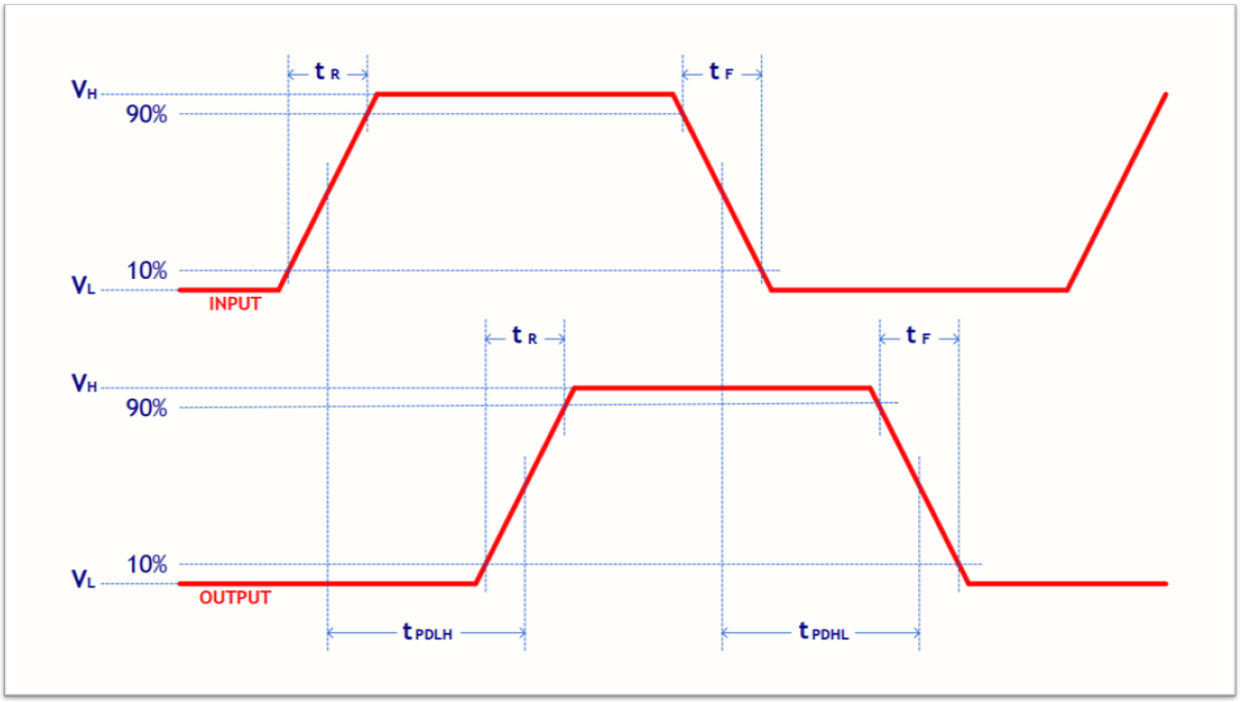

| Parameter | Symbol | Measured Value |
|---|---|---|
| **Output Rise Time** | tR | 26 µs |
| **Output Fall Time** | tF | 0.5 µs |
| **Propagation Delay (Low-to-High)** | tPDLH | 14.5 µs |
| **Propagation Delay (High-to-Low)** | tPDHL | 2.96 µs |

## 5.3.2 Timing for Non-isolated Input

### Notes

- Input pulses used are square waveform from a signal generator with maximum voltage of 3.3 V
- The output voltage goes to the logic driver circuit. The threshold voltage for logic high and logic low is about 1.2 V.
- Input threshold voltage is observed/measured when the output voltage crosses the 1.2 V logic level.
- Internal pull-up resistor is 4k7 Ω.
- Internal bias voltage (GPIO_EN) is 3.3 V.
- Timing diagram, schematic, and measured values are for reference only.





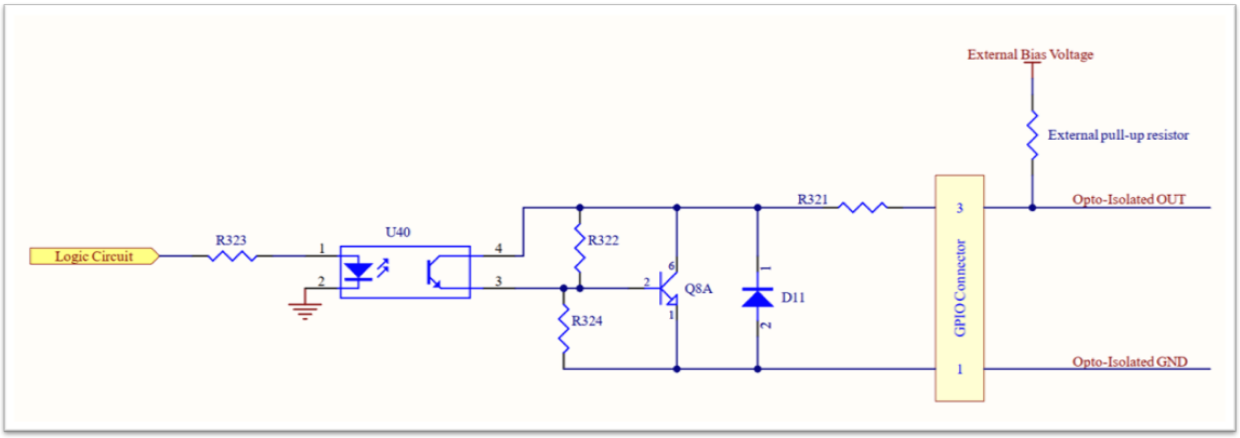

| Parameter | Symbol | Measured Value |
|---|---|---|
| **Output Rise Time** | tR | 25 ns |
| **Output Fall Time** | tF | 23 ns |
| **Propagation Delay (Low-to-High)** | tPDLH | 74 ns |
| **Propagation Delay (High-to-Low)** | tPDHL | 63 ns |

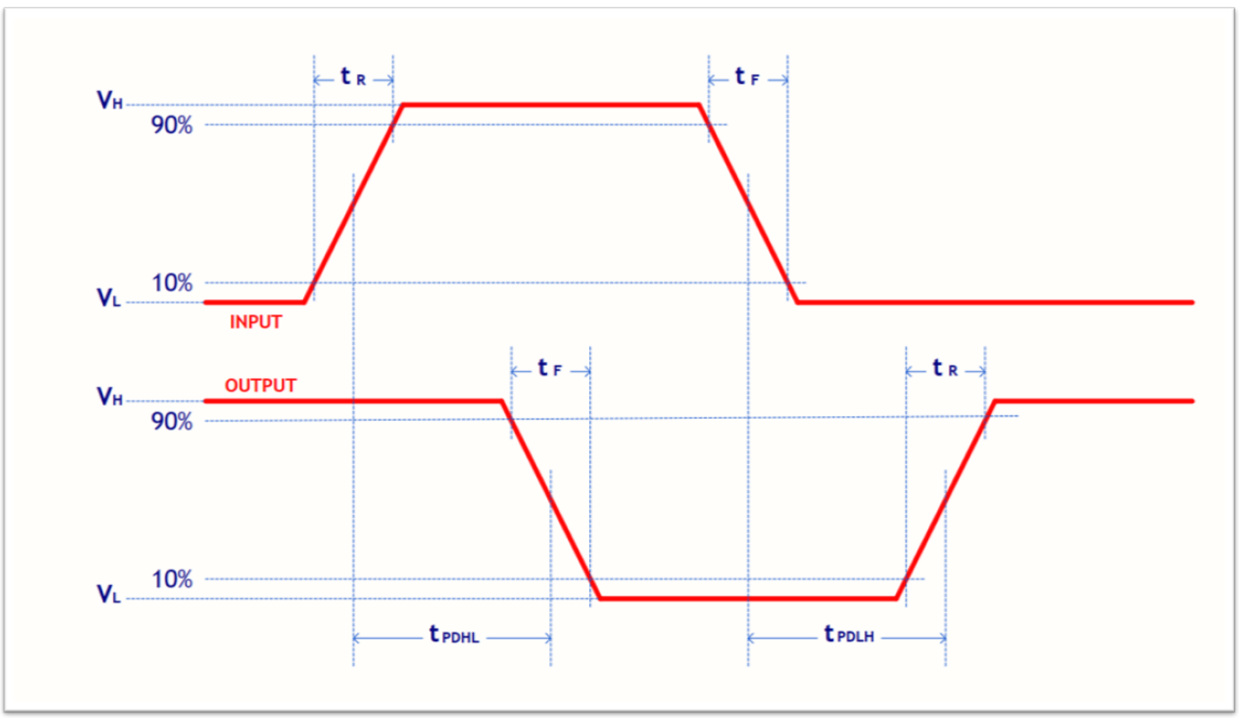
# 5.4 Output Timing Characteristics

## 5.4.1 Timing for Opto-isolated Output

### Notes

- Input pulses are square wave from the FPGA with maximum voltage of 3.3 V
- The output voltage threshold between logic high and logic low is between 1.2 V to 2.4 V.
- Input threshold voltage is observed/measured when the output voltage changes logic level.
- Timing diagram, schematic, and measure values are for reference only.



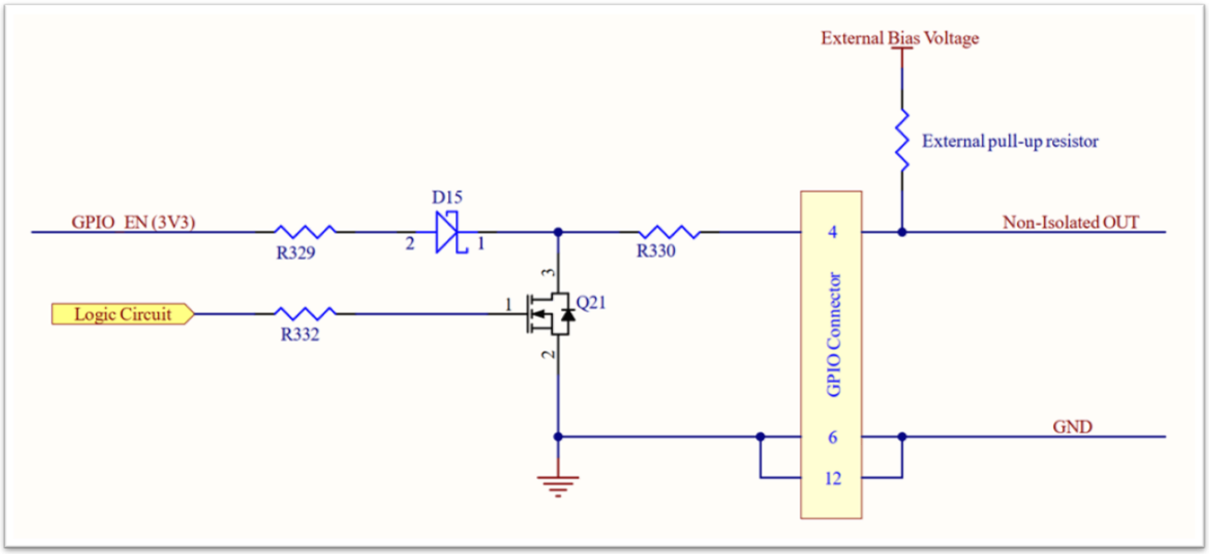



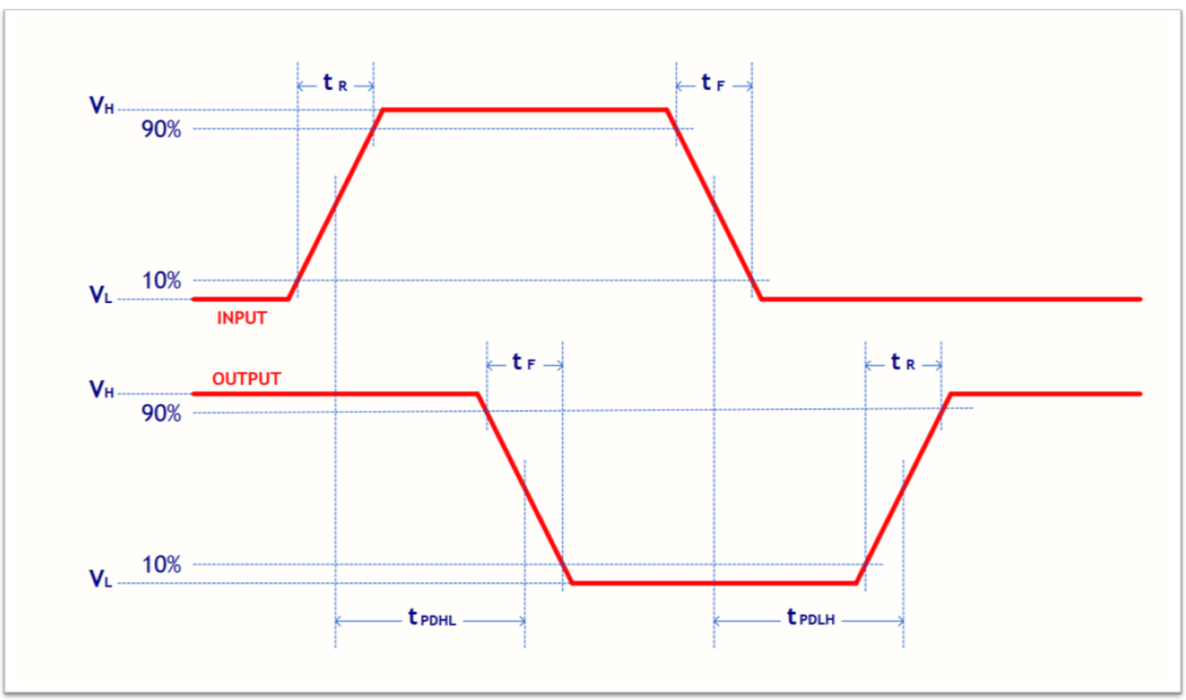
| External Bias Voltage | External pull-up resistor | Parameter | Symbol | Measured Values |
|---|---|---|---|---|
| 3.3 V | 330 Ω | Output Rise Time | tR | 1 µs |
| | | Output Fall Time | tF | 1.5 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |
| | 1k Ω | Output Rise Time | tR | 7.8 µs |
| | | Output Fall Time | tF | 660 ns |
| | | Propagation Delay (Low-to-High) | tPDLH | 15 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.4 µs |
| | 4k7 Ω | Output Rise Time | tR | 27 µs |
| | | Output Fall Time | tF | 600 ns |
| | | Propagation Delay (Low-to-High) | tPDLH | 16 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |
| 5 V | 330 Ω | Output Rise Time | tR | 1.25 µs |
| | | Output Fall Time | tF | 1.75 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |
| | 1k Ω | Output Rise Time | tR | 8.2 µs |
| | | Output Fall Time | tF | 880 ns |
| | | Propagation Delay (Low-to-High) | tPDLH | 15 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.45 µs |
| | 4k7 Ω | Output Rise Time | tR | 25 µs |
| | | Output Fall Time | tF | 750 ns |
| | | Propagation Delay (Low-to-High) | tPDLH | 15.7 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.3 µs |
| 24 V | 4k7 Ω | Output Rise Time | tR | 14 µs |
| | | Output Fall Time | tF | 2.2 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 15 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.4 µs |

### 5.4.2 Timing for Non-isolated Output

**Notes**

- Input pulses are square wave from the FPGA with maximum voltage of 3.3 V
- The output voltage threshold between logic high and logic low is between 1.2 V to 2.4 V.
- Input threshold voltage is observed/measured when the output voltage changes logic level.
- Timing diagram, schematic. and measure values are for reference only.



| External Bias Voltage | External pull-up resistor | Parameter | Symbol | Measured Values |
|---|---|---|---|---|
| 3.3 V | 330 Ω | Output Rise Time | tR | 1 µs |
| | | Output Fall Time | tF | 1.5 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1.1 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.65 µs |
| | 1k Ω | Output Rise Time | tR | 1.2 µs |
| | | Output Fall Time | tF | 1.2 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1.2 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |
| | 4k7 Ω | Output Rise Time | tR | 3.3 µs |
| | | Output Fall Time | tF | 1 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1.3 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |
| 5 V | 330 Ω | Output Rise Time | tR | 1.2 µs |
| | | Output Fall Time | tF | 1.7 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |
| | 1k Ω | Output Rise Time | tR | 1.7 µs |
| | | Output Fall Time | tF | 1.6 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1.2 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |
| | 4k7 Ω | Output Rise Time | tR | 5 µs |
| | | Output Fall Time | tF | 1.3 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1.4 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |
| 24 V | 4k7 Ω | Output Rise Time | tR | 5.5 µs |
| | | Output Fall Time | tF | 2.5 µs |
| | | Propagation Delay (Low-to-High) | tPDLH | 1.3 µs |
| | | Propagation Delay (High-to-Low) | tPDHL | 1.5 µs |

# 6 Controlling the Bumblebee X Camera

The Bumblebee X camera's features can be accessed using various controls, including:

- Spinnaker SDK including:
  - The SpinView camera evaluation application, included in the Spinnaker SDK installation
  - API examples
- Robot Operating System (ROS)

Examples of the controls are provided throughout this document.

## 6.1 Using the Spinnaker® SDK

You can monitor or control features of the camera through Spinnaker API examples provided in the Spinnaker SDK, or through the SpinView camera evaluation application. A *Programmer's Guide and API Reference* is included in the installation.

The Spinnaker SDK is available for download from the Spinnaker page.

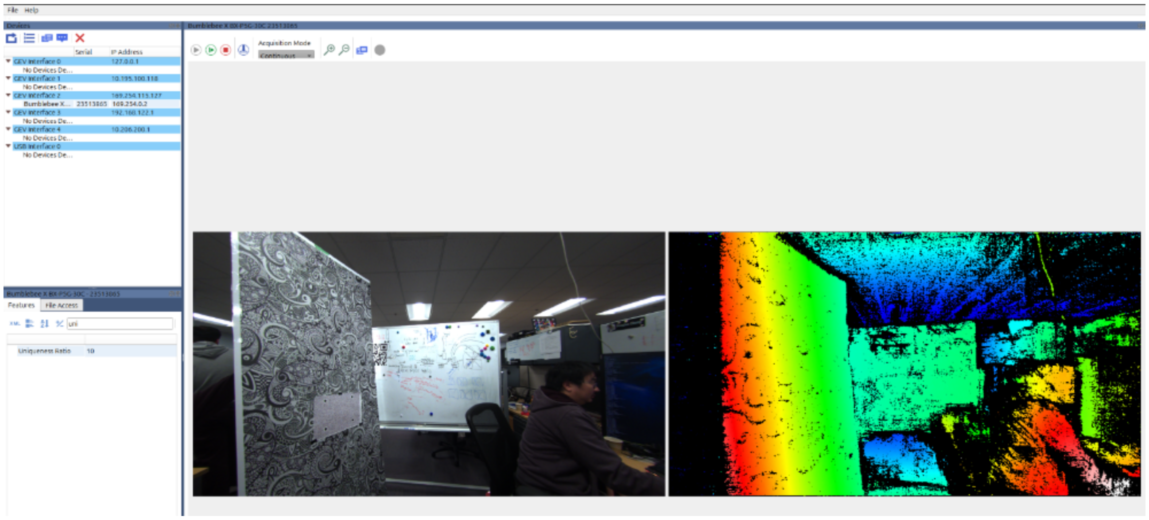
### 6.1.1 SpinView Camera Evaluation Application

The SpinView application is a generic, easy-to-use streaming image viewer included with the Spinnaker SDK that can be used to test many of the capabilities of your camera. It allows you to view a live video stream from the camera, save individual images, adjust the various attributes, frame rates, features and settings of the camera. It includes tools for updating firmware, managing drivers, IP addressing, and activity logging.

#### 6.1.1.1 SpinView in Linux

In Linux, SpinView is implemented using the QT platform. The SpinView_QT implementation can display 2D information in single stream view or multistream view. It does not display the 3D information.

The following image shows the SpinView application while the Bumblebee X camera is streaming in multistream view. In this case, all active streams are shown side-by-side: the left rectified image and the disparity image (with heatmap enabled).



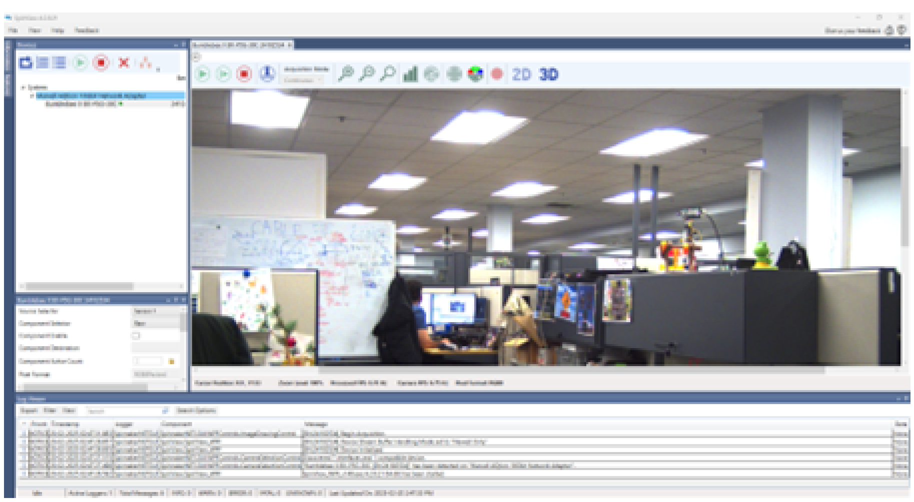
### 6.1.1.2 SpinView in Windows

In Windows, SpinView is implemented using the Windows Presentation Foundation (WPF) platform. The SpinView_WPF implementation displays 2D information or 3D information in single stream view. It does not display the multistream view. The 2D and 3D buttons switch between the views.

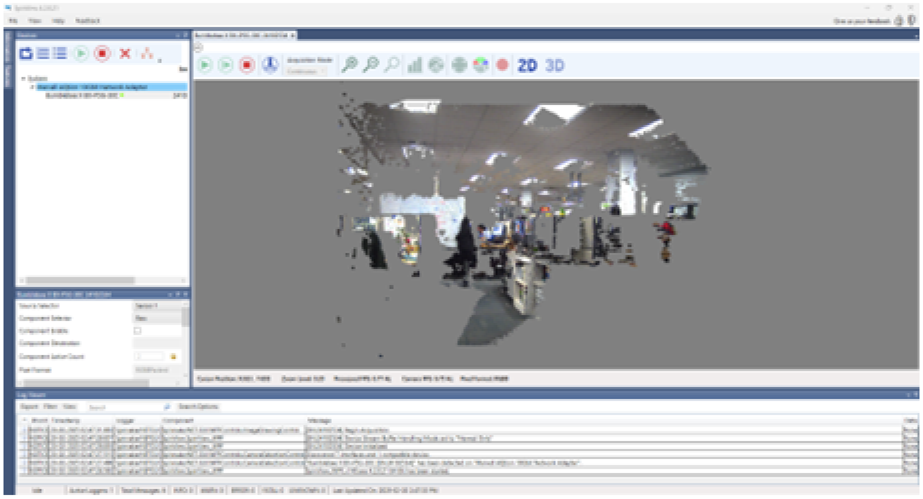
In the 3D view, you can use the mouse or keyboard to interact with the 3D point cloud.

| | Rotate | Translate | Zoom |
|---|---|---|---|
| Mouse | Left click + drag | Right click + drag<br>Center click + drag | Wheel |
| Keyboard | | A = translate camera to the left<br>D = translate camera to the right | W = Zoom in<br>S = Zoom out |

The following images show the SpinView application while the Bumblebee X camera is streaming.



**SpinView Windows 2D View**



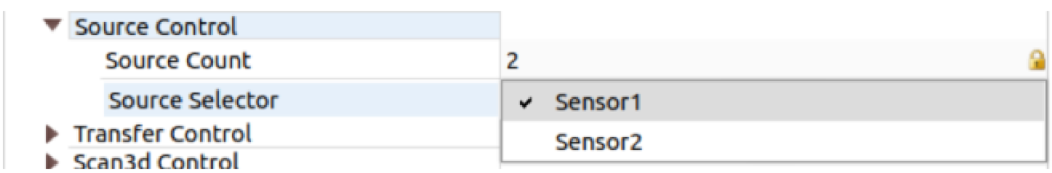

**SpinView Windows 3D View**

## 6.1.2 Image Transmission Control

### 6.1.2.1 Enabling Multistream in Linux

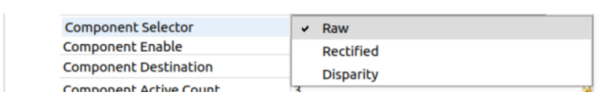
In SpinView_QT the multistream image transmission is controlled using the Component Enable node.

1. From the Source Selector, select the source, either Sensor 1 (Left) or Sensor 2 (Right).

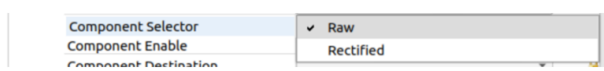



2. From the Component Select, select the component: either Raw, Rectified, or Disparity for Sensor 1 or either Raw or Rectified for Sensor 2.

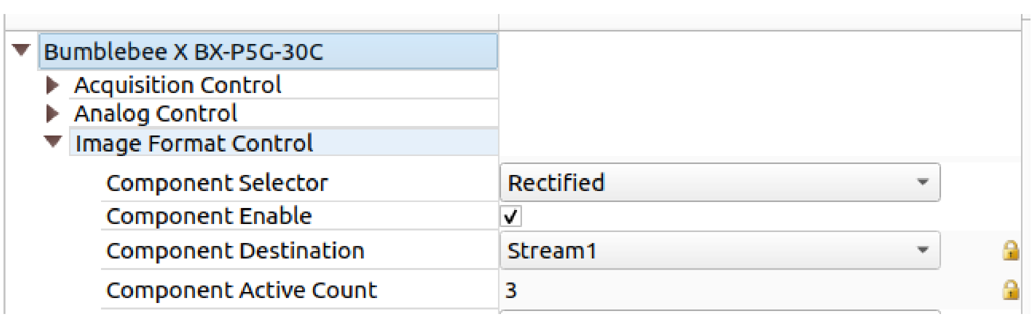
Sensor 1




Sensor 2




3. Click Component Enable to enable the selected component.

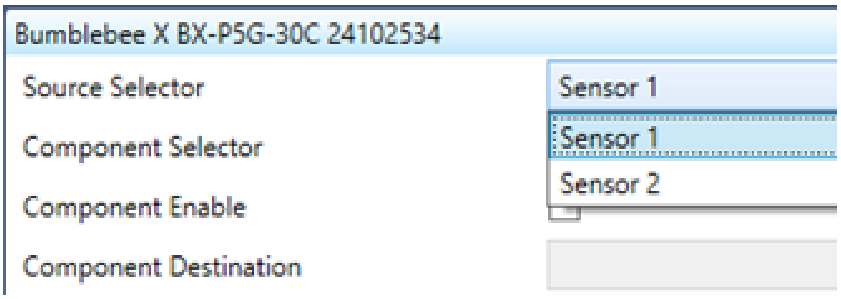


Component Destination indicates the component destination stream. This updates as more components are enabled. The Component Active Count indicates the number of components that have been activated. Activate the components you need in the image transmission and then observe each components destination to determine which stream is assigned to which component before entering acquisition mode.

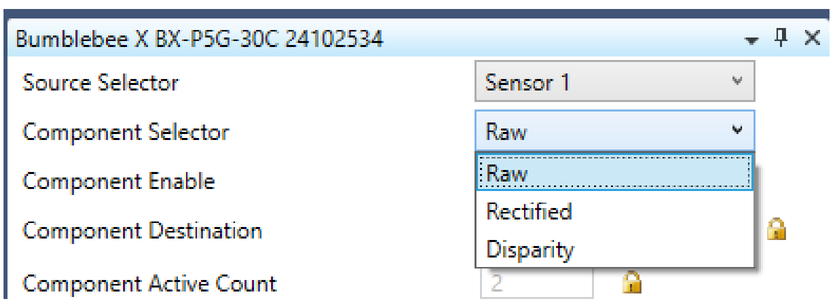
### 6.1.2.2 Enabling Multistream in Windows

In SpinView_WPF the multistream image transmision is controlled using the Component Enable node.

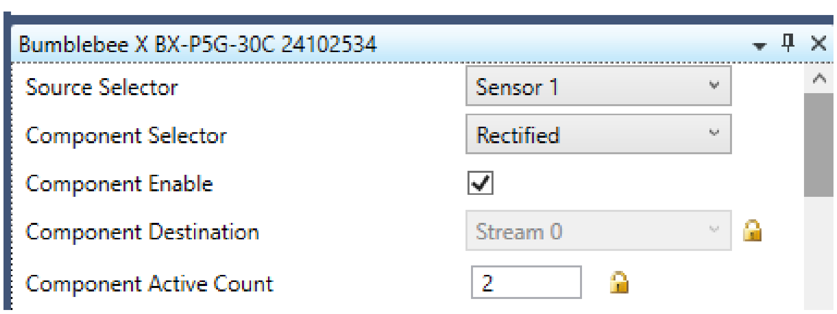
1. From the Source Selector, select the source, either Sensor 1 (Left) or Sensor 2 (Right).




2. From the Component Select, select the component: either Raw, Rectified, or Disparity for Sensor 1 or either Raw or Rectified for Sensor 2.




3. Click Component Enable to enable the selected component.



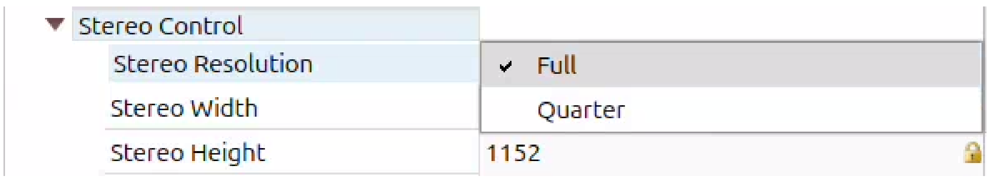

Component Destination indicates the component destination stream. This updates as more components are enabled. The Component Active Count indicates the number of components that have been activated. Activate the components you need in the image transmission and then observe each components destination to determine which stream is assigned to which component before entering acquisition mode.

### 6.1.2.3 Additional Multistream Parameters

There are pixel format options for the raw and rectified images: RGB8 or YUV422.


Raw and rectified images can be output in YUV422 format, reducing the bytes required by 33% from the standard RGB8 format. This allows for a higher frame rate at the same resolution. The disparity image is unaffected.

There are stereo resolution options: Full and Quarter.

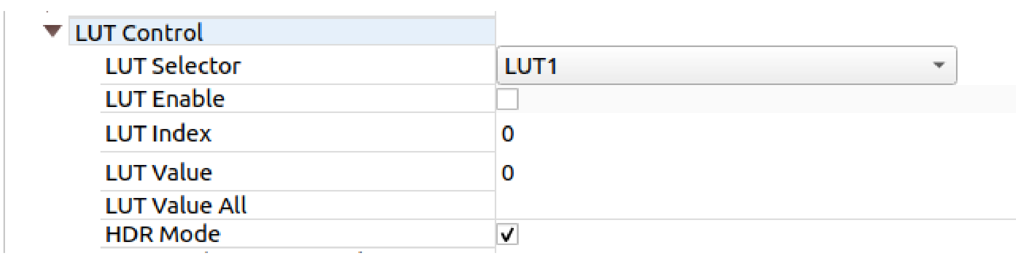



Stereo resolution only refers to the rectified and disparity images. Raw images remain at full resolution.

The XC3 60° and XC5 80° FOV models have a 4:3 aspect ratio. Full resolution is 2048 x 1536 and Quarter resolution is 1024 x 768.

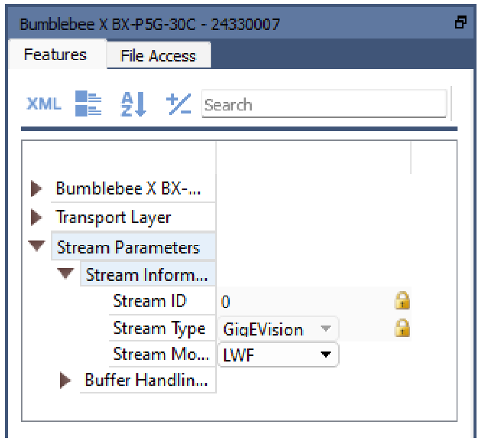
The XC7 105° FOV models have a 16:9 aspect ratio. Full resolution is 2048 x 1152 and Quarter resolution is 1024 x 576.

Under LUT Control, there is an HDR mode feature which is enabled by default. It applies a customized compression curve to integrate the full dynamic range of the 12-bit sensor into 8-bits. This helps in scenes with shadows and highlights. Note that the HDR mode feature cannot be enabled simulatneously with the LUT feature.



### 6.1.2.4 Features - Stream Parameters

Stream information about GenTL data streams is displayed in the Features tab, under the Stream Parameters heading - as shown in the screenshot below.




For multistream image transmission in SpinView, the information listed here refers to the data stream with index 0:

1. Under the **Stream Information** sub-heading, StreamID displays 0.
2. Under the **Buffer Handling Control** sub-heading, counts and controls refer to data stream 0.

When using the Spinnaker API, stream information for each data stream is retrieved through the GentL Stream Nodemap. By default, the function:

```
GetTLStreamNodeMap()
```

returns the node map associated with data stream 0.

Pass in a stream index to get nodes from a specific data stream, for example:

```
GetTLStreamNodeMap(4)
```

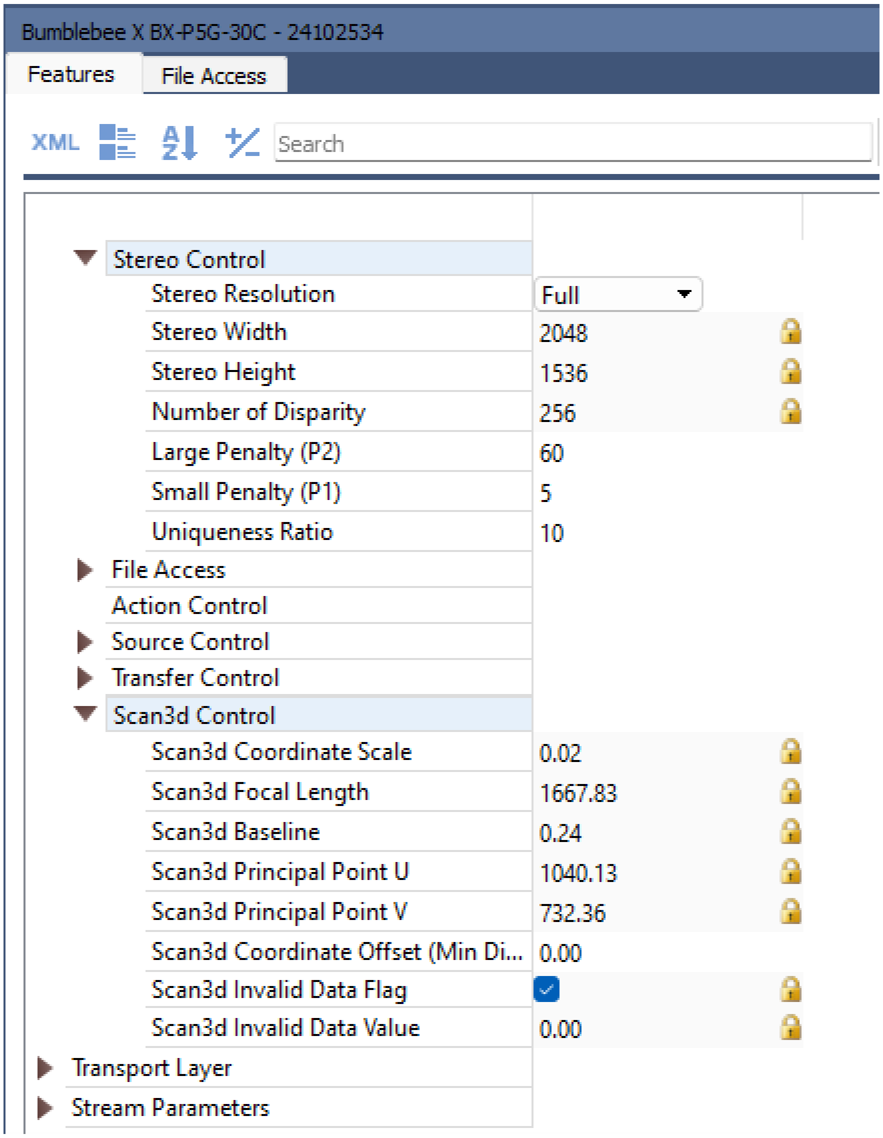
## 6.1.3 Stereo Processing Control

All the parameters of stereo processing can be controlled while the camera is streaming except the stereo resolution which must be changed before entering acquisition mode.

When making changes to disparity parameters, the changes are reflected on the next viable disparity image after the command has been acknowledged. Properties that affect frames are applied to both (Left and Right) sides at the same time. Auto Exposure and Auto White Balance are based on Sensor 1 (Left sensor).

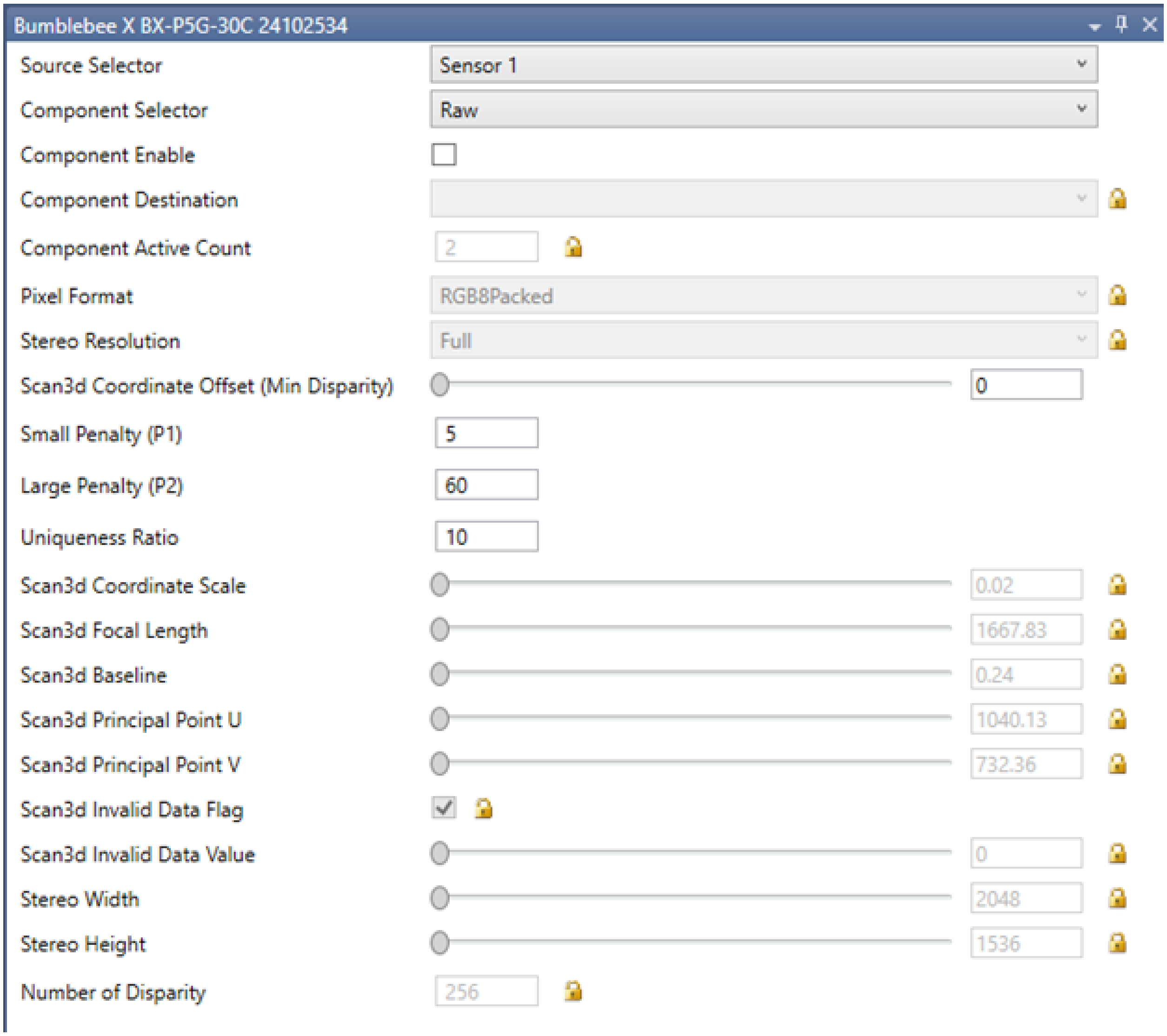
### 6.1.3.1 Stereo Processing Control in Linux

In the SpinView_QT features panel, there is a section on Stereo Control settings and a section on Scan3d Control parameters.



### 6.1.3.2 Stereo Processing Control in Windows

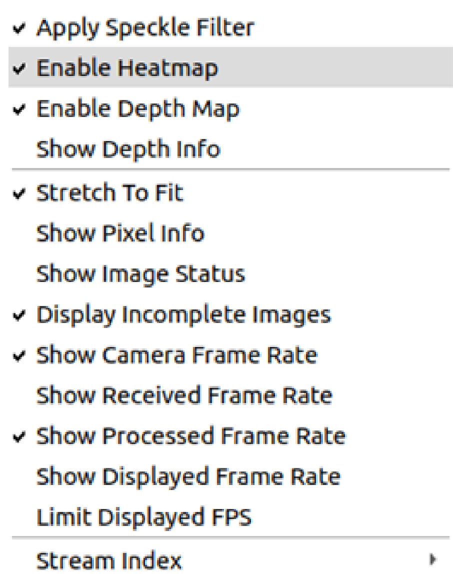
In the SpinView_WPF features pane there is a pane for Stereo and Scan3d Control settings. This is opened from the top menu: View→Dynamic Dialogs→Stereo



### 6.1.3.3 User-controlled parameters

| Parameter | Description | Possible Values | Recommended Value |
|---|---|---|---|
| **Stereo Resolution** | Selects the resolution output of the stereo engine. Stereo resolution can be viewed through Stereo Width and Stereo Height. | Full<br>Quarter | |
| **Large Penalty (P2)** | Penalty for disparity changes greater than 1 pixel between neighbor pixels. Decreasing this parameter helps object boundaries. Large Penalty should be larger than Small Penalty. Also called P2. | 1 - 255 | 60 |
| **Small Penalty (P1)** | Penalty for disparity changes of 1 pixel between neighbor pixels. Decreasing this parameter helps slanted surfaces. Also called P1. | 1 - 255 | 5 |
| **Uniqueness Ratio** | The margin by which the best cost must win over the next best to be considered valid. Increasing this ratio removes noisy points, resulting in fewer 3D points. | 0 - 100 | 10 |
| **Scan 3D Coordinate Offset (minimum disparity)** | Offset when transforming a pixel from relative coordinates to world coordinates. It is equivalent to minimum disparity.<br>Increasing this value allows for distance calculation on nearer objects. | 0 - 768 | 0 |

Right-click on the disparity image to access the shortcut menu, which offers display choices:




If you enable the Depth Map and Show Depth Info, you can hover your mouse over the depth map to see depth values.

To help with noise reduction, there is an option to apply a speckle filter on the host side. It has the following configurable parameters:

| Parameter | Description | Range | Recommended Value |
|---|---|---|---|
| **Max Speckle Size** | Maximum size of disparity region to consider their noise speckles and invalidate | 1 - N/A | 40 |
| **Speckle Threshold** | Maximum disparity variation allowed within a connected component during speckle filtering | 0 - 255 | 4 |

### 6.1.4 Custom Applications Built with the Spinnaker API

The Spinnaker SDK includes a full Application Programming Interface that allows you to create custom applications to control your camera. Included with the SDK are a number of source code examples to help you get started.

Spinnaker API examples are provided for C++ and Python languages. The C++ examples are precompiled for your convenience.

Two stereo-specific examples are included:

- **StereoAcquisition**—This example shows how to acquire image sets from the camera. The image sets are then saved to file and/or used to compute 3D point cloud and saved as a PLY file.
- **StereoGPIO**—This example shows how to set the GPIO of the camera, which can be used to trigger the camera, trigger the pattern projector, synchronize with another camera, and other features.

#### 6.1.4.1 Examples using Open Source Libraries

The Spinnaker SDK includes an OpenCV example:

- **StereoOpenCV** (C++)—This example shows how to acquire image sets from the camera using the Spinnaker SDK, then use OpenCV to process and display the image sets.

Two Python examples are available at our Github repository:

- **StereoOpenCV** (Python)—This example shows how to acquire image sets from the camera using PySpin, then use OpenCV to process and display the image sets.
- **StereoOpen3D** (Python)—This example shows how to acquire images sets from the camera, convert the disparity image to a point cloud using PySpin, and then use Open3D to process and display the point cloud.

The Github examples respository is available at: [github.com/Teledyne-MV/Spinnaker-Examples](github.com/Teledyne-MV/Spinnaker-Examples)

# 6.2 Using the Robot Operating System (ROS)

## 6.2.1 ROS 2

The ROS2 wrapper is available at https://github.com/Teledyne-MV/Stereo-BX-ROS2.

The stereo_image_publisher ROS 2 package enables publishing of stereo images, disparity maps, and point clouds from the Bumblebee X camera using the Spinnaker SDK. This wrapper provides five image streams (raw and rectified images from the two sensors, and the computed disparity image), along with a point cloud. You can configure various stereo parameters and camera settings dynamically using RQT.

Key features include:

- Publication of 5 image streams: raw and rectified images from each camera, and the disparity image.
- Point cloud generation with configurable decimation factor and generation bounds.
- Real-time stereo camera parameter tuning (for example: smallPenalty, largePenalty, uniquenessRatio, minDisparity).
- Camera-specific configuration options (for example: exposure, gain, frame rate, auto white balance).
- Selectable image streams for optimized performance based on your requirements.

### Published Topics

The following image topics are available to be published:

- BumbleBee_X/serial_name/raw_left
- BumbleBee_X/serial_name/raw_right
- BumbleBee_X/serial_name/rectified_left
- BumbleBee_X/serial_name/rectified_right
- BumbleBee_X/serial_name/disparity

Additionally, the generated point cloud is published on:

- BumbleBee_X/serial_name/point_cloud

### Usage

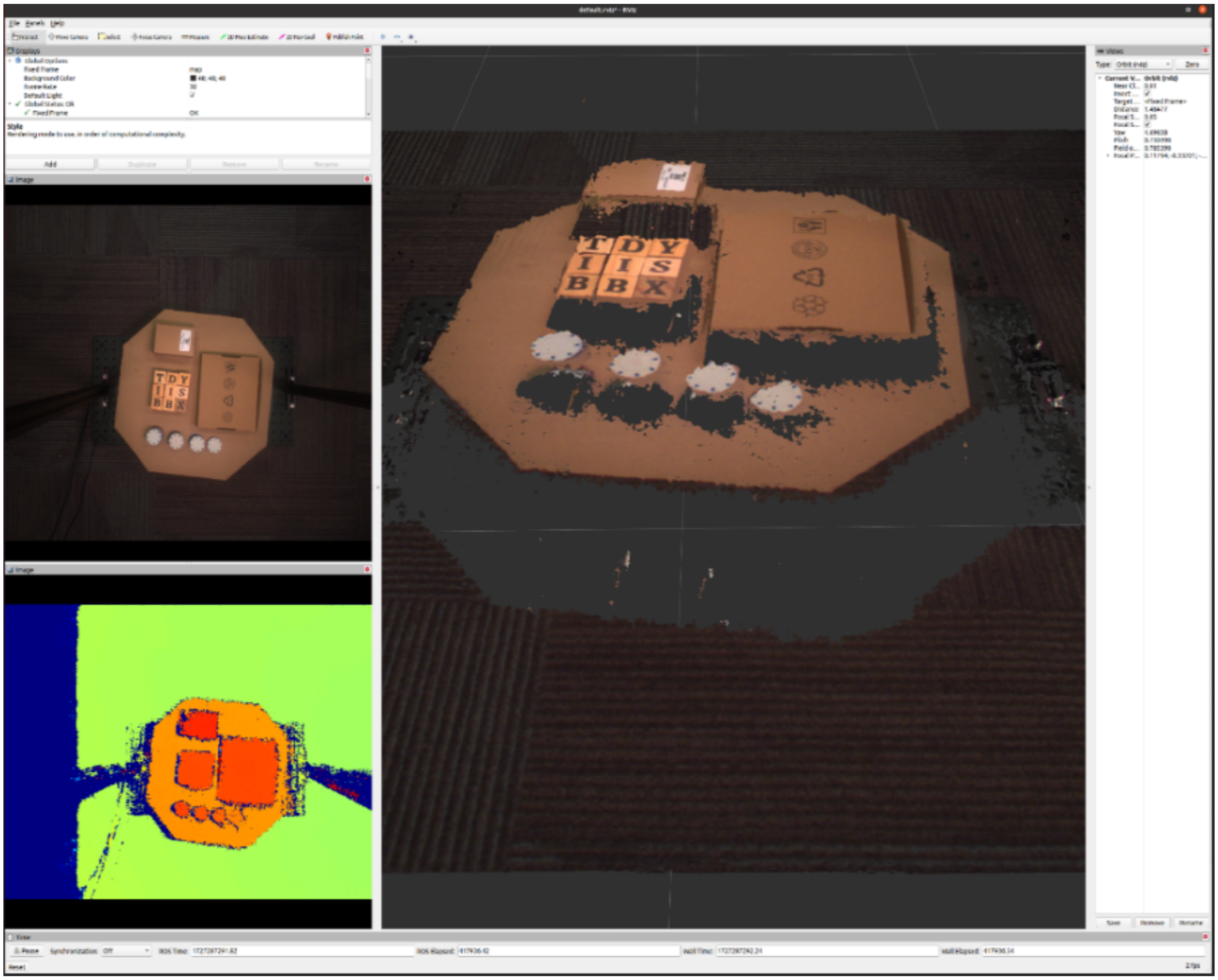
After sourcing ROS2 and the wrapper, execute by using:

```
ros2 run bumblebee_ros stereo_image_publisher
```

For details, please refer to the usage instructions documented in https://github.com/Teledyne-MV/Stereo-BX-ROS2.

## RViz2

You are able to view the published image and point cloud topics in RViz. An example scene is shown below:



## RQT

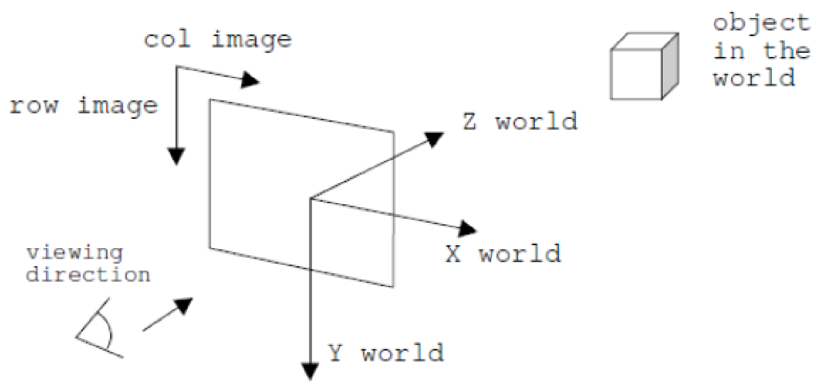
We recommend using RQT for dynamically changing parameters related to generating point cloud, selecting streams, and changing the camera settings.

# 6.3 Converting to a 3D Point Cloud

The Bumblebee X camera outputs the disparity image which can be converted into 3D point cloud on the host. Disparity image computation is the most computationally intensive step of the stereo processing pipeline and is done on-board the camera. Point cloud generation is based on a simple conversion and can be done on the host quickly.

## 6.3.1 3D Coordinate Frame

The disparity image uses the left image as the reference; therefore, the XYZ coordinate frame for the resulting 3D point cloud is at the left camera, as shown in the following diagram:




## 6.3.2 Point Cloud Conversion

Point cloud conversion can be done via a Spinnaker API call or implemented as described below by making use of the camera calibration parameters. There are a number of read-only stereo-related parameters from the camera, most of which are based on the GenICam Standard Features Naming Convention (SFNC).

| Parameters | Description |
|---|---|
| **Scan3d Coordinate Scale** | The scale factor that needs to be applied to the disparity values. Since the last 6 bits are used for sub-pixel accuracy, the scale factor is 1/64 = 0.015625 |
| **Scan3d Focal Length** | The focal length in pixels |
| **Scan3d Baseline** | The stereo baseline in meter, i.e., distance between the two sensors |
| **Scan3d Principal Point U** | The horizontal position of the principal point in pixels |
| **Scan3d Principal Point V** | The vertical position of the principal point in pixels |
| **Scan3d Invalid Data Flag** | Enable the definition of a non-valid disparity pixel (always enabled) |
| **Scan3d Invalid Data Value** | Value that identifies a non-valid disparity pixel (set to 0) |
| **Stereo Width** | The rectified and disparity image width |
| **Stereo Height** | The rectified and disparity image height |
| **Number of Disparity** | Disparity search range for on-board Semi-Global Block Matching (SGBM) stereo algorithm, which is fixed at 256 pixels. |

A disparity value of 0 indicates an invalid disparity and should not be used for point cloud conversion. For a non-zero disparity value at (col, row) coordinates in the disparity image, the camera disparity needs to be scaled followed by adding an offset to obtain the actual disparity with subpixel accuracy. The actual disparity can be used to compute Z, and then X and Y can be computed accordingly:

disparity_actual = disparity_camera * Scan3d Coordinate Scale + Scan3d Coordinate Offset

Z = Scan3d Focal Length * Scan3d Baseline / disparity_actual

X = (col – Scan3d Principal Point U) * Z / Scan3d Focal Length

Y = (row – Scan3d Principal Point V) * Z / Scan3d Focal Length

### 6.3.3 Range of Point Cloud

While the camera can work between 0.5 m to 20 m, the disparity search range determines the working distance where it can compute depth. The default search range is 0 to 255, which can be adjusted via the Scan3d Coordinate Offset (minimum disparity). For example, by setting it to 100, the disparity search range becomes 100 to 355, which affects the minimum and maximum point cloud range according to the Z formula in the previous section. Increasing the Scan3d Coordinate Offset allows closer objects to be seen, but it also reduces how far objects can be observed. Determining the optimum setting is highly dependent on the scene.

Some examples are shown in the following table:

**Point Cloud Range (at Full Resolution)**

| | Minimum Disparity = 0 | | Minimum Disparity = 50 | | Minimum Disparity = 100 | |
|---|---|---|---|---|---|---|
| | Minimum Z | Maximum Z | Minimum Z | Maximum Z | Minimum Z | Maximum Z |
| XC3 60° FOV Models | 1.6 m | 20+ m | 1.3 m | 8 m | 1.1 m | 4 m |
| XC5 80° FOV Models | 1.2 m | 20+ m | 1 m | 6.2 m | 0.9 m | 3.1 m |
| XC7 105° FOV Models | 0.7 m | 20+ m | 0.6 m | 3.4 m | 0.5 m | 1.7 m |

Stereo resolution can be set to full (default) or Quarter. When it is set to Quarter, the camera streams at higher frame rate with lower latency, but there are fewer 3D points with lower accuracy. The point cloud range depends on the stereo resolution. The following table shows the point cloud range for Quarter resolution:

**Point Cloud Range (at Quarter Resolution)**

| | Minimum Disparity = 0 | | Minimum Disparity = 25 | | Minimum Disparity = 50 | |
|---|---|---|---|---|---|---|
| | Minimum Z | Maximum Z | Minimum Z | Maximum Z | Minimum Z | Maximum Z |
| XC3 60° FOV Models | 0.8 m | 20+ m | 0.7 m | 8 m | 0.7 m | 4 m |
| XC5 80° FOV Models | 0.6 m | 20+ m | 0.6 m | 6 m | 0.5 m | 3.1 m |
| XC7 105° FOV Models | 0.33 m | 20+ m | 0.3 m | 3.4 m | 0.3 m | 1.7 m |

# 7 Troubleshooting

## 7.1 Support

Teledyne FLIR endeavors to provide the highest level of technical support possible to you. Most support resources can be accessed through the Bumblebee X camera resources.

The **Resources and Support** section contains links to:

**Knowledge Base**

- Application Notes
- System Requirements
- Technical Guidance
- Troubleshooting
- White papers

**Documents and Drawings**

- Datasheets
- Getting Started Manual
- Technical References
- Drawings
- Product Change Notifications (PCN)

**Software and Firmware**

- Spinnaker SDK
- Firmware

**Contacting Technical Support**

Before contacting Technical Support, have you:

1. Read the product documentation?
2. Searched the Product Support page?
3. Downloaded and installed the latest version of software and/or firmware?
4. Checked out our support community forum?

If you have done all the above and still can't find an answer to your question, contact our Technical Support team.

## 7.2 Status Indicator LED

| LED | 1GigE / 5GigE |
|---|---|
| **Blinking Green (1 blink)** | Link-Local Address (LLA) |
| **Blinking Green (2 blinks)** | DHCP IP Address |
| **Blinking Green (3 blinks)** | Persistent IP Address |
| **Solid Green** | Acquisition Started |
| **Solid Red** | Link is down |
| **Rapidly Flashing Green** | Firmware updating |
| **Flashing Green and Red** | General Error |

# A GenICam Features

This section contains information on standard GenICam features and nodes that control the Bumblebee X camera.

## A.1 Acquisition Control

### A.1.1 Acquisition and Frame Rate

There are three acquisition modes:

- **Continuous**—acquires images continuously. This is the default mode.
- **Multi Frame**—acquires a specified number of images (AcquisitionFrameCount) before stopping acquisition.
- **Single Frame**—acquires 1 image before stopping acquisition.

Use AcquisitionMode to select your mode.

Use AcquistionStart and AcquisitionStop to start and stop acquiring images with the selected mode.

The Acquisition Frame Rate can be manually or automatically controlled. Use AcquisitionFrameRateEnable to set this On (manual control) or Off (automatic control). By default, this is Off. If you select manual control, use AcquisitionFrameRate to specify a frame rate.

The ResultingFrameRate reports the actual frame rate at which the camera is streaming. If this does not equal the Acquisition Frame Rate it is because the Exposure Time is greater than the frame time.

### A.1.2 Exposure Time Modes

There are two exposure time modes:

- **Timed**—exposure time is a specified value. This is the default mode.
- **TriggerWidth**—exposure time is controlled by the trigger signal.

Use ExposureMode to make a selection.

When ExposureMode is set to Timed, exposure time can be manually or automatically controlled.

- For manual control, set ExposureAuto to Off. Use the ExposureTime control to set the exposure time in microseconds.
- For automatic control, set ExposureAuto to Once or Continuous. The camera automatically adjusts the exposure to maximize the dynamic range. Once briefly enables automatic exposure to adapt the device and then sets exposure to manual control (Off). Continuous constantly adapts the device. Continuous is the default setting.

**Note:** For the Auto Exposure feature, gain and/or exposure time must be set to Once or Continuous.

### A.1.2.1 Trigger Features

Triggering allows you to acquire images at specific times when an event occurs. Triggering works with the acquisition modes and settings. By default, triggering is set to Off. To enable triggering, set TriggerMode to On.

| Trigger Selector Option | Description | Result | | |
|---|---|---|---|---|
| | | Single Frame Mode | Multi Frame Mode | Continuous Mode |
| **Acquisition Start** | A trigger starts acquisition in the selected AcquisitionMode | Trigger acquires one image | Trigger acquires the specified number of images | Trigger acquires images until you stop acquisition |
| **Frame Start** | A trigger is required for each individual image that is acquired | Trigger acquires one image<br>For each subsequent trigger you first must use AcquisitionStart to receive more images | Trigger acquires the specified number of images<br>For each subsequent trigger you first must use AcquisitionStart to receive more images | Trigger acquires one image<br>You do not have to start acquisition again for subsequent triggers |
| **Frame Burst Start** | A trigger acquires a specified number of images. You do not have to start acquisition again for subsequent triggers. This mode is primarily used in Continuous mode, as Single Frame and Multi Frame settings overwrite the burst count. | Trigger acquires one image | Trigger acquires the number of images specified in AcquisitionFrameCount | Trigger acquires the number of images specified in AcquisitionBurstFrameCount |

### A.1.2.2 Trigger Options

| Trigger | Specifies | Options |
|---|---|---|
| **Trigger Source** | The source that can signal the acquisition to acquire images | Physical Line Inputs<br>User Outputs<br>Counters<br>Logic Blocks<br>Software |
| **Tigger Activation** | What voltage level or transition that activates a trigger | Level Low<br>Level High<br>Falling Edge<br>Rising Edge<br>Any Edge |
| **Trigger Overlap** | Whether a trigger responds while the readout of a previously acquired image is still occurring | When Off—a trigger is disregarded during readout<br>When ReadOut—a trigger acquires another image during readout |
| **Trigger Delay** | The time in microseconds between when the camera receives a trigger and when exposure begins for the image | |
| **Trigger Software** | Use TriggerSoftware to perform a software trigger | |

# A.2 Analog Control

## A.2.1 Gain

Gain is the amount of amplification that is applied to a pixel by the A/D converter. An increase in gain can result in a brighter image but also an increase in noise.

Gain can be manually or automatically controlled.

Use the Gain Selector to choose which gain to control. The All selection is a total amplification across all channels (or taps).

For manual control, set GainAuto to Off. Use the Gain control to set the amplification in dB.

For automatic control, set GainAuto to Once or Continuous. The camera automatically adjusts the gain to maximize the dynamic range. Once briefly enables automatic gain to adapt the device and then sets gain back to manual control (Off). Continuous constantly adapts the device.

> **Note:** For the Auto Exposure feature, gain and/or exposure time must be set to Once or Continuous.

## A.2.2 Black Level

The Black Level feature controls the offset applied to the video signal. It determines the image average when there is no light reaching the sensor.

There are two methods of applying black level: **Analog** and **Digital**. The analog black level controls the offset applied during analog-to-digital (A/D) conversion. The digital black level is an offset applied after the image has been digitized.

The sum of the analog and digital black levels can be set and read by setting Black Level Selector to **All** and then using the Black Level feature to enter or view the percentage offset.

Only the total black level (All) can be set by the user. Based on the value of black level All, the analog and digital black levels are automatically set to achieve the requested total black level.

## A.2.3 White Balance

White balance compensates for color shifts caused by different lighting conditions. White balance is specified as the gains of the **Red** and **Blue** channels relative to **Green**. For example, if the blue balance ratio is set to 1.5 then 50% more gain is applied to the blue channel than the green channel. White balance can be manually or automatically controlled.

For manual control, set White Balance Auto to Off. Use the Balance Ratio Selector to select either the Red or Blue channel. Use the Balance Ratio to specify a value for that channel. To disable white balance, set both red and blue balance ratios to 1.0.

For automatic control, set White Balance Auto to Once or Continuous. The camera automatically adjusts the red and blue balance ratios to achieve good color balance. Once runs for a number of iterations and then sets White Balance Auto to Off. Continuous adjusts the values continually if the algorithm determines that the colors are imbalanced. A number of parameters that affect automatic white balance are available in the AutoAlgorithmControl category.

## A.2.4 Gamma

The Gamma feature controls the gamma correction applied to pixel intensity. The equation used is:

$$P' = P^{\mathrm{Gamma}}$$

where *P* is the input pixel value and *P'* is the pixel value after gamma correction. Note that the value for Gamma is defined as the power applied to the pixel value, and not the gamma of the display. If a display with a gamma of 2.0 is used, the image gamma can be set to 0.5 to compensate. For sRGB output, Gamma should be set to 0.4545 (1/2.2).

If linear output data is required, disable gamma by setting GammaEnable to 0.

Gamma and the Pixel Lookup Table (LUT) can both be used at once. Gamma is applied before the Pixel LUT.

# A.3 Auto Algorithm Control

## A.3.1 Auto Exposure (AE)

Auto exposure (AE) control is designed to automatically determine the exposure time and gain of the camera so that the resulting image looks as bright as expected. In general, the camera supports various auto exposure features, and these features produce different results in the final image. In addition, the camera allows you to control how fast the exposure and gain get settled.

> **Note:** For the Auto Exposure feature, gain and/or exposure time must be set to Once or Continuous.

### A.3.1.1 Auto Exposure Features

To enable AE, Exposure Auto and/or Gain Auto must be set to Once or Continuous. AE automatically determines the exposure time and/or gain according to the target image average.

The target image average can be manually or automatically controlled.

| Control | |
|---|---|
| **Manual** | 1. Set Target Grey Value Auto to Continuous.<br>2. Set the desired image average in Target Grey Value.<br>This value is a percentage of the maximum pixel value. |
| **Automatic** | ▪ Set Target Grey Value Auto to Off.<br>The target image average is then automatically determined according to user-defined AE modes and other AE features. |

By default, AE uses the full range of exposure time and/or gain and target grey value, but these can be limited.

| Lower Limit / Upper Limit | Description | Unit of Measure |
|---|---|---|
| **Exposure Time** | Range when exposure is Once or Continuous | Microseconds (µs) |
| **Gain** | Range when gain is Once or Continuous | Decibels (dB) |
| **Target Grey Value** | Range of target image average | Percent (%) |

**Auto Exposure Damping** controls how fast the exposure and gain get settled. A small damping value may result in the system being unstable. The range is from 0.0 - 1.0. The default value is 0.5.

If both exposure time and gain are set to Once or Continuous AE determines which to adjust first by the **Auto Exposure Control Priority**.

| Priority | Description |
|---|---|
| **Gain** | The camera sets the gain to 0 dB, and the exposure is adjusted according to the target grey level. If the maximum exposure is reached before the target grey level is hit, the gain starts to change to meet the target. This mode is used to have the minimum noise. |
| **Exposure** | The camera sets the exposure to a small value (default is 5 ms). The gain is adjusted according to the target grey level. If maximum gain is reached before the target grey level is hit, the exposure starts to change to meet the target. This mode is used to capture fast motion. |

### A.3.1.2 Lighting Modes

**AE Lighting Mode** can compensate for strong light sources in front or behind an object. The options are: Backlight, Frontlight, or Normal. The default lighting mode is Normal. Use the Lighting Mode feature to select depending on your conditions.

| Lighting Mode | Description |
|---|---|
| **Backlight Compensation** | The backlight compensation mode is used when a strong light is coming from the back of the object. For example, people standing in the shade with the bright sky at the back. A regular auto exposure algorithm makes the object underexposed in such lighting conditions. Backlight compensation is able to properly expose the object when a strong backlight occurs, regardless of the locations of the object relative to the frame. |
| **Excessive Frontlight Compensation** | The excessive frontlight compensation mode is used when a strong light is shining in the front of the object while the background is dark. For example, a parking spot that has lights on at night while its surrounding areas are very dark. A regular auto exposure algorithm makes the object overexposed in such lighting conditions. Frontlight compensation is able to properly expose the object when a strong front light and a dark background appear, regardless of the locations of the object relative to the frame. |
| **Normal Lighting (Default)** | If the object of interest in the frame is not under backlight or frontlight conditions, then normal lighting should be used. Select Normal lighting mode to make Metering Mode available. |

### A.3.1.3 Metering Modes

**AE Metering Mode** is available only if Lighting Mode is set to Normal. The options are: Average, Spot, and Partial. The default AE metering mode is Average. Use the Metering Mode feature to select depending on your conditions.

| Metering Mode | Description |
|---|---|
| **Average Metering** | This mode measures the light from the entire scene uniformly to determine the final exposure value. Every portion of the exposed area has the same contribution. |
| **Spot Metering** | This mode measures the light from a small area (about 3%) in the center of the scene while the rest of the scene is ignored. This mode is used when the scene has a high contrast and the object of interest is relatively small. |
| **Partial Metering** | This mode measures the light from a larger area (about 11%) in the center of the scene. This mode is used when very dark or bright regions appear at the edge of the frame. |

### A.3.1.4 Region of Interest

A **region of interest** (ROI) can be applied to the auto exposure features. This AE ROI can be equal to or smaller than the area of the captured ROI. To use AE ROI:

1. Set the ROI Selector to Auto Exposure.
2. Turn on ROI Enable.
3. Set the horizontal and vertical offsets (relative to the ROI being captured) with ROI Offset X and ROI Offset Y.
4. Set the width and height with ROI Width and ROI Height.

### A.3.1.5 EV Compensation

EV Compensation allows you to adjust the resultant image intensity with one control. Positive EV compensation makes the image brighter while negative EV compensation makes the image darker. The range is from -3 to 3 with a step of 1/3. The default value is 0.

## A.3.2 Auto White Balance

When White Balance Auto is set to Continuous or Once the camera automatically adjusts the values of Balance Ratio Red and Blue to achieve good color balance. It is used to compensate for color shifts in the image caused by different lighting conditions.

There are two profiles of auto white balance: Indoor and Outdoor. These are selected with White Balance Auto Profile.

| Profile | Description |
|---|---|
| **Outdoor** | The values of the red and blue balance ratios are restricted to a set of expected values for normal outdoor lighting conditions (i.e., daylight). |
| **Indoor** | The values of the red and blue balance ratios can take any values within specified limits. This allows auto white balance to compensate for artificial lighting such as fluorescent lights that are more greenish than daylight. The Indoor profile can also be used for outdoor conditions, since it does not place restrictions on the white balance solution. |

By default, auto white balance uses the full range of balance ratios, but these can be limited.

- White Balance Auto Lower Limit / White Balance Auto Upper Limit - the lower and upper values that auto white balance can set for the red and blue balance ratios.

**White Balance Auto Damping** controls the speed at which auto white balance adjusts the values of the red and blue balance ratios. The range is from 0 to 1. Higher values of damping result in the white balance changing more gradually.

By default auto white balance examines all of the pixels in the image, but it can also use a region of interest (ROI). A common use for an auto white balance ROI is placing a white object in the image and then specifying the ROI on that object. To use ROI:

1. Set the ROI Selector to Auto White Balance.
2. Turn on ROI Enable.
3. Set the horizontal and vertical offsets (relative to the ROI being captured) with ROI Offset X and ROI Offset Y.
4. Set the width and height with ROI Width and ROI Height.

# A.4 Color Transformation Control

**Note:** To access color transformation controls, ISP must be enabled. The ISP enable feature is under the Image Format control (IspEnable).

**Related Resources**

| For more information |
| --- |
| Using Color Correction |

A color transformation is a linear operation applied to input red, green, and blue values for each pixel, which are multiplied by a 3x3 matrix and then added to an offset triplet.

The equation, taking input RGB values and producing three output channels (C0, C1 and C2) is given by:

$$\begin{bmatrix} C0_{out} \\ C1_{out} \\ C2_{out} \end{bmatrix} = \begin{bmatrix} Gain00 & Gain01 & Gain02 \\ Gain10 & Gain11 & Gain12 \\ Gain20 & Gain21 & Gain22 \end{bmatrix} \begin{bmatrix} R_{in} \\ G_{in} \\ B_{in} \end{bmatrix} + \begin{bmatrix} Offset0 \\ Offset1 \\ Offset2 \end{bmatrix}$$

There are two available color transformations, **RGB to RGB** and **RGB to YUV**.

The **RGB to RGB** transform takes input in the camera's native RGB color space, which varies based on the properties of the camera and sensor. The RGB to RGB transform is usually used to convert from the camera's native color space to sRGB (standard RGB) color space. This operation is often called a Color Correction Matrix (CCM).

The RGB to RGB transform can be enabled/disabled. Select RGB to RGB with Color Transformation Selector and then set Color Transformation Enable to 0 (disabled) or 1 (enabled).

Use the RGB Transform Light Source to select the active RGB to RGB matrix from a set of pre-calibrated matricies optimized for different lighting conditions.

To set your own RGB to RGB matrix, select Custom RGB Transform Light Source, and then use the features Color Transformation Value Selector and Color Transformation Value to set the Gain/Offset coefficients.

The **RGB to YUV** transform happens after the RGBtoRGB transform and after applying Gamma. It is only available for YUV or YCbCr pixel formats, and it cannot be enabled or disabled, except by changing Pixel Format.

For both RGB to RGB and RGB to YUV, the gain/offset values used can be queried by selecting a value with Color Transformation Value Selector and then reading its Color Transformation Value.

In addition to the RGB to RGB transform, the color of the image can also be adjusted with the Saturation control, when Saturation Enable is set to 1. Increasing Saturation makes the colors in the image more vivid.

# A.5 Counter And Timer Control

**Related Resources**

| For more information |
| --- |
| Using Counter and Timer Control |

The Counter and Timer control feature allows you to:

- Create a function generator
- Keep a count of how many times a signal has fired.

Use the CounterSelector to select a counter, either 0 or 1.

Use CounterEventSource to select the event to increment the counter. Possible counter event sources include:

- MHz Tick
- Line Inputs
- User Outputs
- Counter Starts
- Counter Ends
- Logic Block Outputs
- Exposure Start
- Exposure End
- Frame Trigger Wait

When the selected source allows for signal activation, use CounterEventActivation to specify Level Low, Level High, Falling Edge, Rising Edge, or Any Edge.

Use CounterDelay to indicate the maximum number of counts that need to occur before generating the Counter Start event.

Use CounterDuration to indicate the maximum number of counts that need to occur before generating the Counter End event.

**Note:** Only one of CounterTriggerSource or CounterResetSource can be active at a time. Selecting one disables the other.

Use CounterTriggerSource to select the event to start the counter. Possible counter trigger sources include:

- MHz Tick
- Line Inputs
- User Outputs
- Counter Starts
- Counter Ends
- Logic Block Outputs
- Exposure Start
- Exposure End
- Frame Trigger Wait

When the selected source allows for signal activation, use CounterTriggerActivation to specify Level Low, Level High, Falling Edge, Rising Edge, or Any Edge.

Use CounterResetSource to select the event to end the counter. Possible counter reset sources include:

- MHz Tick
- Line Inputs
- User Outputs
- Counter Starts
- Counter Ends
- Logic Block Outputs
- Exposure Start
- Exposure End
- Frame Trigger Wait

When the selected source allows for signal activation, use CounterResetActivation to specify Level Low, Level High, Falling Edge, Rising Edge, or Any Edge.

CounterValue indicates the current counter while CounterStatus indicates the current status. CounterValueAtReset indicates the counter's value when a reset occurred.

# A.6 Defective Pixel Correction

The camera supports table-based defective pixel correction, where a list of defective pixel coordinates is specified, and the values of those pixels are replaced based on the values of their neighbors. The camera comes with a list of defective pixels calibrated during manufacturing (the factory default table), but you can update or replace this list.

Defect Correct Static Enable turns table-based defective pixel correction On or Off.

Defect Correction Mode controls the method used for replacing the value of pixels within the table. The options are Average or Highlight. Average replaces defective pixels with the average of their neighbors. Highlight is used for debugging purposes and sets pixels within the table to the maximum possible pixel value to highlight them.

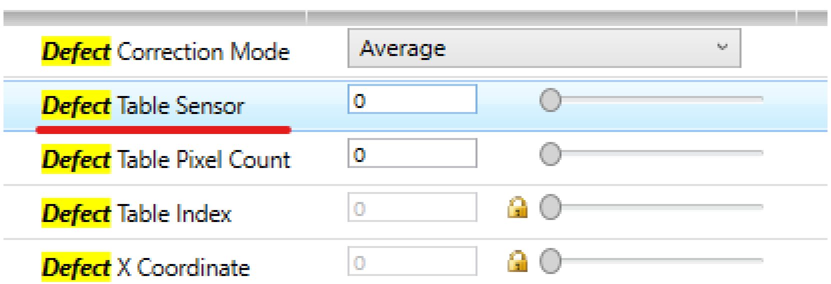
## A.6.1 Modifying the List of Defective Pixels

Defect Correct Pixel Count controls the number of defective pixels in the table.

Defect Table Index selects an individual pixel within the table. This is a zero-based index, so if there are *N* pixels in the table, the index range is from 0 to *N*-1. Defect X Coordinate and Defect Y Coordinate define the (X,Y) coordinates of the defective pixel selected by the index. These values can be changed. These (X,Y) coordinates are relative to the full image ROI, when Offset X and Offset Y are both zero.

Each sensor in the Bumblebee X camera can have its pixels corrected independently (up to 255 pixels).

In SpinView, use Defect Table Sensor to select either 0 (left - sensor 1) or 1 (right - sensor 2):




Changes made to the defective pixel table using these controls do NOT take effect immediately. When you have finished making a series of changes to the table, execute the command Defect Table Apply for the changes to affect images captured by the camera. This writes the table to volatile memory, so changes are lost if the camera loses power.

Defect Table Save saves the table to persistent storage within the camera, so that the modified table is loaded whenever the camera boots up. Saving overwrites the existing table stored in memory.

Defect Table Factory Restore resets the table to its factory default state. This completely overwrites any changes made to the table, both the active table used in images being captured by the camera and the table saved in memory.

> **Note:** Because it takes time to download a full defect table, if the camera is streaming when a table is either applied or restored to factory default, the results may appear momentarily corrupted until the complete table is written to the FPGA.

# A.7 Device Control

Device Control provides you with device information and allows you to control some device parameters.

## A.7.1 General Information

Use Device User ID to enter a unique device name. This information is retained over power cycles.

Use Device Indicator Mode to control the status LED. The LED can be active, inactive, or in error mode.

## A.7.2 Bandwidth

Information about the bandwidth usage and link speed is provided.

Use Device Link Throughput Limit to specify what bandwidth is used for the streaming of data. This affects the maximum frame rate. This must be less that the Device Max Throughput.

## A.7.3 Timestamp

Use Timestamp Latch to capture the current timestamp of the device.

## A.7.4 Power Supply

Use the Device Power Supply Selector to choose a power supply, either External or Sensor (Internal). External power can be either through the device interface or through GPIO.

## A.7.5 Device Reset

Use Device Reset to soft reboot the camera. Use Factory Reset to clear any user tables loaded and perform a soft reboot of the camera.

# A.8 Digital IO Control

This section describes how to configure the camera's general purpose digital input and outputs (sometimes referred to as GPIO).

<table>
<tr><th>Node</th><th>Description</th></tr>
<tr><td>LineSelector</td><td>To choose which of the 4 lines to configure. All the features listed beneath it are controllable on a per line basis.</td></tr>
<tr><td>Line Mode</td><td>To control the direction - either Input or Output - of the selected I/O line.</td></tr>
<tr><td>External Voltage Selector</td><td>To choose which external voltage output is used: Output 3.3 V, Output 5.0 V, or Output Adjustable.</td></tr>
<tr><td>External Voltage Value</td><td>If the External Voltage Selector is set to Output Adjustable, this controls the voltage value.</td></tr>
<tr><td>LineInverter</td><td>To control a logic inverter on the selected line.</td></tr>
<tr><td>LineStatus</td><td>This indicates the current status of the selected line. A checked status (enabled) indicates logic high. An unchecked status (disabled) indicates logic low. Since this node must be polled to get its status it should not be used as a real time control for reading internal signals.</td></tr>
<tr><td>LineStatusAll</td><td>This is a hexadecimal representation of all the line status bits (Line 0 status corresponds to bit 0, Line 1 status with bit 1, etc). This allows simultaneous reading of all line statuses at once.</td></tr>
<tr><td>LineInputFilterSelector</td><td>To choose a filter. Filters are unique per line. Use LineFilterWidth to set the width of the filter in microseconds. There are two choices of filter:<br>■ Deglitch - designed to filter out any noise or other spurious signals on the line, it does not consider the state to have transitioned until after the Filter Width time has expired. This means that Deglitch introduces a delay in the signal.<br>■ Debounce - designed to filter out rapid connecting and disconnecting common in mechanical switches. This means that Debounce considers the first edge as valid and won't allow a subsequent change of state until after the debounce time has elapsed.<br>Note: The Deglitch filter is applied before Debounce filter.</td></tr>
<tr><td>LineSource</td><td>To control what signal is output on the line when the Line Mode is set to output. The choices are:<br>■ Other Lines—creates a loop back<br>■ User Outputs—outputs user controllable internal signals<br>■ Counter Active—shows when a counter is in use<br>■ Logic Blocks—drives the lines<br>■ Exposure Active—indicates when the image sensor is exposing<br>■ Frame Trigger Wait—indicates when the camera is ready to accept a new Frame Start trigger</td></tr>
<tr><td>UserOutputSelector</td><td>To select which bit to use as internal signals within the camera if a User Output is selected as a Line Source. Use UserOutputValue to set the selected user output to logic high (enabled) or logic low (disabled).</td></tr>
</table>

| Node | Description |
|---|---|
| **UserOutputValueAll** | This is a hexadecimal representation of all the user output bits (User Output 0 corresponds to bit 0, User Output 1 with bit 1, etc). Reading or writing User Output Value All allows simultaneous setting or reading of all user outputs at once. |
| **LineFormat** | This is read only and indicates what type of circuit the selected line has. The options for Line Format are:<br>■ **Tri State**—indicates the line is not driven. This is typical for digital inputs.<br>■ **Opto Coupled**—indicates that an opto isolator is being used to isolated the external circuitry from the internal camera electronics.<br>■ **Open Drain**—indicates there is an internal MOSFET that will pull the pin low but requires an external pull up resistor to produce a logic level high signal. This is typical for digital outputs. |

# A.9 File Access

The file access interface allows access to the cameras file system.

It provides access to the cameras user set files, LUT files and a user definable file.

Usage of the file access features and registers should not be attempted directly. Instead access the file system through the file access interface of the host application.

The user set files are treated differently than the other files in the system. These file when uploaded will modify the user set setting within the camera. If the user set file is from an older version of the camera or a different model, the user sets with in the file will be converted to the appropriate user sets for the new firmware. The file will then be replaced with the updated user set file. If the file contains user sets that are not appropriate for the firmware version on the camera, they will be ignored and discarded. If the file has been modified in any way, the file will be discarded and regenerated.

While a file is open within the file access interface, the camera will not be able to start acquisition. Also, the FileAccessExecute command will be disabled when the camera is in acquisition mode. Care should be taken to not leave any file open within the camera's file system as it will disable the start acquisition register without any feedback as to why.

# A.10 Image Format Control

Features of Image Format Control include:

- Pixel Format
- ADC Bit Depth
- Test Pattern
- Reverse XReverse Y

## A.10.1 Pixel Format

**Not all formats are supported on all cameras.**

**Related Resources**

**For details on pixel formats and packing**

Understanding Pixel Formats

Use the PixelFormat feature to select from a list of supported formats. Once a format is selected, the following values are derived:

| Value | Description |
|---|---|
| **PixelSize** | The total size in bits of the image's pixel. |
| **PixelColorFilter** | The type of color filter that is applied to the image. This only applies to bayer formats. The value is None for other formats. |
| **PixelDynamicRangeMin** | The minimum value that can be returned during the digitization process. This corresponds to the darkest value of the camera. For color cameras, this returns the smallest value that each color component can take. |
| **PixelDynamicRangeMax** | The maximum value that can be returned during the digitization process. This corresponds to the brightest value of the camera. For color cameras, this returns the largest value that each color component can take. |

**Note:** On color cameras, the bayer pixel format is updated if Reverse X and Reverse Y are changed. For example, if the original pixel format is BayerRG8 and Reverse X is switched from Disabled to Enabled, then the pixel format is updated to BayerGR8.

## A.10.2 ADC Bit Depth

All camera sensors incorporate an analog to digital converter (ADC) to digitize the images.

The camera's ADC is configured to a fixed bit output. This is not the same as pixel size. If the pixel format selected has fewer bits per pixel than the ADC output, the least significant bits are dropped. If the pixel format selected has greater bits per pixel than the ADC output, the least significant bits are padded and can be discarded by the user. Image data is left-aligned across a 2-byte format.

For example, for a 12-bit output, the least significant 4 bits are padded in order to fill 2 bytes (0xFFF0).

A 10-bit conversion produces 1,024 possible values between 0 and 65,472.

A 12-bit conversion produces 4,096 possible values between 0 and 65,520.

A 14-bit conversion produces 16,384 possible values between 0 and 65,532.

Some image sensors support multiple ADC bit depths. A higher ADC bit depth results in better image quality but slower maximum frame rate. Stop acquisition then use the ADC Bit Depth control to make a selection.

## A.10.3 Test Pattern

The camera is capable of outputting continuous static images for testing and development purposes.

Use the TestPatternGeneratorSelector feature to choose which test pattern to control.

- **Sensor** produces a test pattern that varies based on the image sensor.
- **Pipeline Start** inserts a test pattern at the start of the camera's image processing pipeline.

Set the TestPattern feature to Off to disable the selected test pattern generator.

When Sensor is selected, create a test pattern by setting the TestPattern feature to Sensor Test Pattern.

When Pipeline Start is selected, create a test pattern by setting the TestPattern feature to Increment or Variable Frame Sequence. The Increment test pattern increases the pixel value by one 8-bit greyscale value at each pixel location, wrapping around to zero after it reaches 255.

The Variable Frame Sequence option generates a sequence of frames containing varying test pattern. The sequence resets at the start of acquisition.

Both test pattern generators can be enabled at the same time, however, the Pipeline Start test pattern overwrites the Sensor test pattern.

Most image processing features (such as Gamma, Balance Ratio, and others) are still available when the test pattern is on and can alter the test pattern image. Some features for controlling the sensor do not affect the test pattern image, such as Exposure Time, Gain, and analog Black Level. It is recommended to turn Exposure Auto and Gain Auto Off when using a test pattern, as those features do not function properly when the test pattern is on.

Note that the test pattern generators must be set to Off to get the actual image data from the sensor.

## A.10.4 Reverse X

> **Note:** Reverse X should only be used when using raw output to do your own rectification and disparity. The Bumblebee X camera rectification and disparity does **not** work when Reverse X is enabled.

When Reverse X is enabled, it horizontally flips the image sent by the camera. The region of interest is applied after flipping.

For color cameras, the bayer pixel format may be changed after flipping. For example, BayerRG16 is changed to BayerGR16.

## A.10.5 Reverse Y

> **Note:** Reverse Y should only be used when using raw output to do your own rectification and disparity. The Bumblebee X camera rectification and disparity does **not** work when Reverse Y is enabled.

When Reverse Y is enabled, it vertically flips the image sent by the camera. The region of interest is applied after flipping.

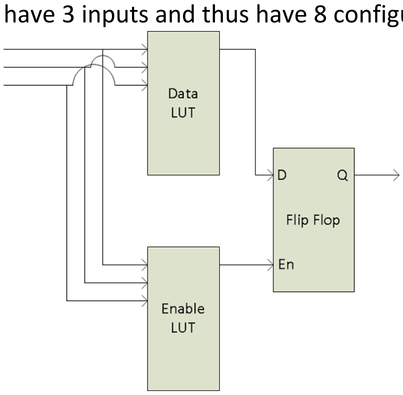
For color cameras, the bayer pixel format may be changed after flipping. For example, BayerRG16 is changed to BayerGB16.

# A.11 Logic Block Control

**Related Resources**

| **For more detail:** |
|---|
| Using Logic Blocks |

A Logic Block is a collection of combinatorial logic and latches that allows you to create new, custom signals inside the camera. Each Logic Block is comprised of 2 lookup tables (LUT) with programmable inputs, truth tables and a flip flop output. There is a LUT for both the D input (Value LUT) and the enable input (Enable LUT) of the flip flop. Both LUTs have 3 inputs and thus have 8 configuration bits for their truth table.



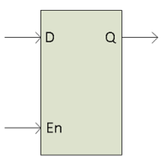

To configure the LUTs first select either the Value or Enable LUT using the LogicBlockLUTSelector, then use the LogicBlockLUTInput to configure the different inputs into the LUT - note that the Value and Enable LUT share the inputs so setting the inputs on one will affect the other. The LogicBlockLUTInputSource selects the internal signal to be used and the LogicBlockLUTInputActivation selects what level or edge to be considered a positive input into the LUT. Once the inputs to the LUT have been selected the entries in the truth table can be configure either individually using the LogicBlockLUTRowIndex and LogicBlockLUTOutput or all at once using the LogicBlockLUTOutputValueAll

The following truth table show a simple AND of Input1 and Input2 while Input0 is not considered ("DON'T CARE").

| Source | | | Output |
|---|---|---|---|
| 2 | 1 | 0 | |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 1 | 0 |
| 0 | 1 | 0 | 0 |
| 0 | 1 | 1 | 0 |
| 1 | 0 | 0 | 0 |
| 1 | 0 | 1 | 0 |
| 1 | 1 | 0 | 1 |
| 1 | 1 | 1 | 1 |

To program this function into a LUT write the value of 0xC0 (1100 0000b) to the LogicBlockLUTOutputValueAll.

The details of the output Flip Flop output are shown in the following table. The previous value of the Value LUT will remain on the output until the Enable LUT is set at which point the output will be updated to the new value of the Value LUT. This allows latching of a given signal. To effectively bypass the output latch and pass the Value LUT signal through continuously simple program the Enable LUT truth table to all 1's (LogicBlockLUTOutputValueAll = 0xFF)




| D | EN | Q (next) |
|---|---|---|
| 0 | 0 | Q (previous) |
| 0 | 1 | 0 |
| 1 | 0 | Q (previous) |
| 1 | 1 | 1 |

# A.12 Test Control

Test Control provides functionality to allow certain features to be exercised.

There are two features available in Test Control:

- **TestEventGenerate**—This feature allows you to generate test events. Executing sends a single TestEvent, which then populates the Event Test Data selector with the ID and the timestamp of when the event occurred.
- **TestPendingAck**—This feature allows you to test the device's pending acknowledge feature. When this feature is written, the device waits for the corresponding time period in milliseconds before acknowledging the write.
- **Test0001**—This feature is for internal testing only.

If a test fails, an error is produced for the log.

# A.13 Transfer Control

The Transfer Control category contains features that control the transferring of image data to the host.

An acquisition generates frames that are optionally processed and may have extra data appended (chunk data) before being placed in the transfer queue for transmission out of the device. Once the image data has gone through any processing and had the appropriate data appended it is referred to as a block. These blocks are then handed to the transfer module to be sent out of the device on data streams. The transfer module then transmits these blocks externally on stream channels.

This can be manually or automatically controlled. Use the Transfer Control Mode to select the control method. There are three options: **Basic**, **Automatic**, and **User Controlled**.

In both **Basic** and **Automatic** mode the camera starts transmitting data as soon as there is enough data to fill a link layer packet. This reduces the latency between when the image was acquired and when it is available to the user. As long as the link layer is able to transfer data blocks faster than they are being generated the camera continuously sends one image after another on the stream channel.

There is a **Transfer Queue** which starts to fill up if the link slows down.

- The Transfer Queue Max Block Count indicates the transfer queue's maximum capacity.
- The Transfer Queue Current Block Count indicates the number of blocks currently in the transfer queue.
- The Transfer Queue Overflow Count indicates the number of blocks that have been lost before being transmitted.
- The Transfer Queue Mode indicates the mechanism for transmitting and overwriting blocks in the transfer queue. It is First In First Out, which means the oldest block in the queue is always sent next on the stream channel.

Once the transfer queue is full the camera overwrites the oldest block in the queue with the new block arriving from the acquisition and processing modules that has not already begun being transmitted. At this point the Queue Overflow is incremented. Once the image that is currently being transmitted finishes, the transmission module transmits the next oldest image in the transfer queue.

In **User Controlled** mode you can directly control the transfer of blocks. Use the Transfer Operation Mode to select an operation mode. There are two options: **Continuous** and **Multi Block**.

- **Continuous** sends images without stopping in the same manner as Basic/Automatic, but you can use Transfer Start and Transfer Stop to control the streaming while acquisition runs independently.
- **Multi Block** transmits a specified number of blocks and then stops. Use the Transfer Block Count to specific the number of blocks. Use the Transfer Start command to initiate a multi block transfer.

> **Note:** Acquisition can be started and stopped without affecting the transfer queue or transfer state however closing the stream channel clears both the queue and any pending transmissions.

# A.14 Transport Layer Control

The Transport Layer control provides the following information:

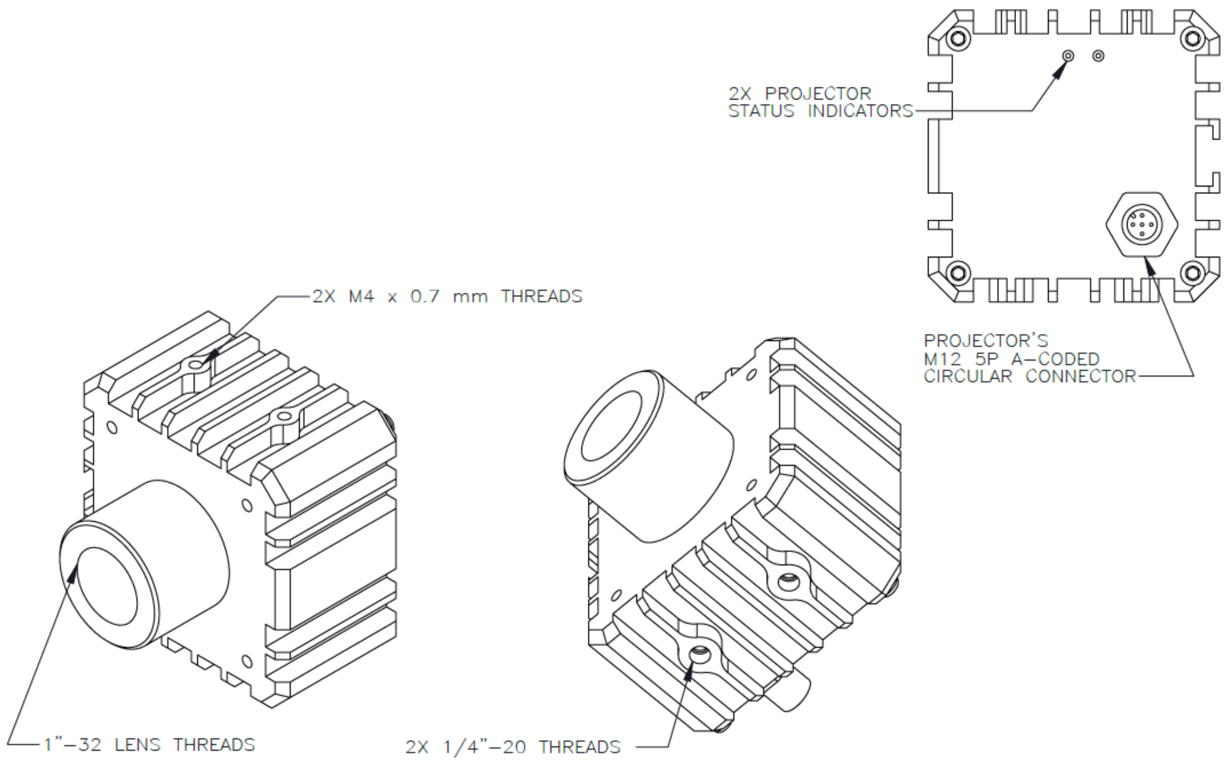
- **Gev IEEE 1588**—Enables IEEE 1588 Precision Time Protocol (PTP) to control the timestamp register.
- **Gev IEEE 1588 Clock Accuracy**—The expected accuracy of the device clock when it is the grandmaster or when it becomes the grandmaster.
- **Gev IEEE 1588 Status**—The status of the IEEE 1588 clock.
- **Gev IEEE 1588 Mode**—The mode of the IEEE 1588 clock.

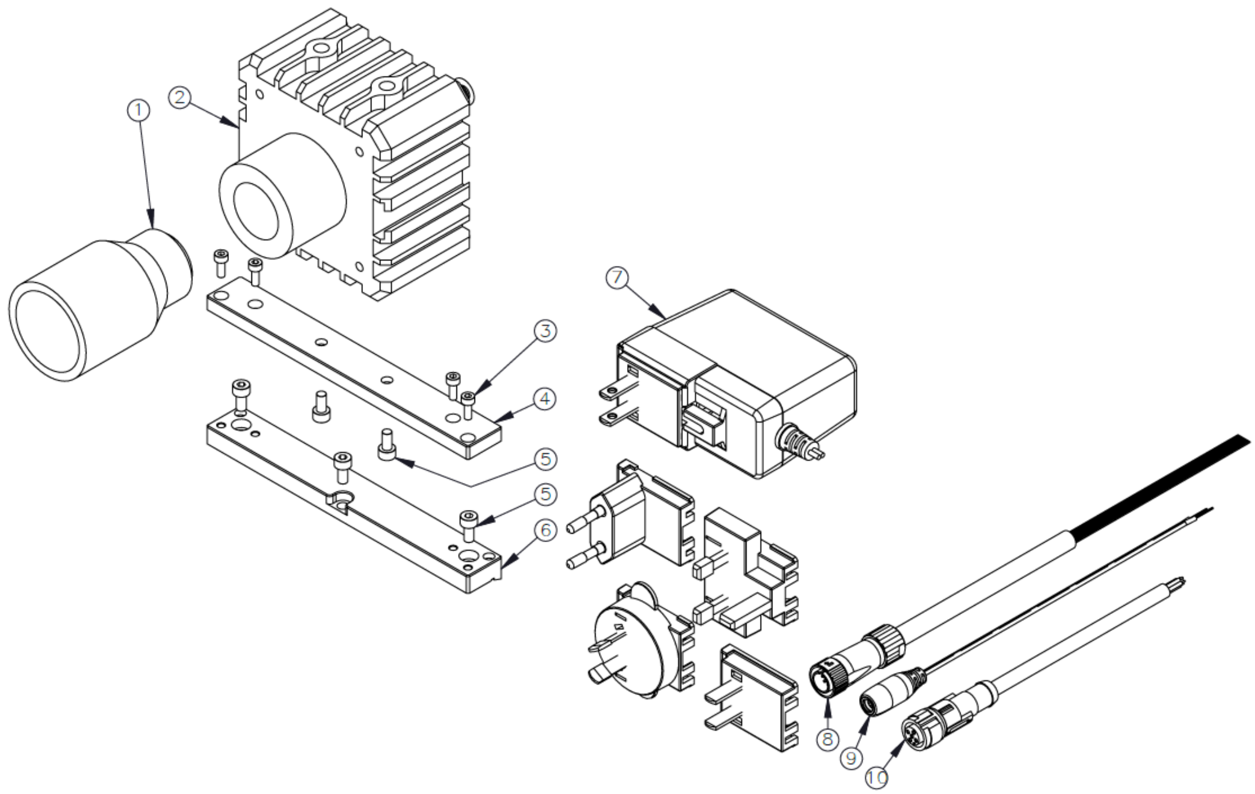
# B Pattern Projector Setup

This section contains information on how to use the Smart Vision Light pattern projector with the Bumblebee X camera as well as the wiring and configuration details.

## B.1 Pattern Projector Kit

Teledyne FLIR offers the KIT-SXP80G2-WHI and KIT-SXP80G2-850 pattern projector kits for the color and monochrome Bumblebee X cameras respectively. The kits and their contents are shown below.






| Item Number | Part Number | Item | Description | Quantity |
|---|---|---|---|---|
| 1 | 4255579 | Lens | Vari-Focal, C-Mount, AZURE 1R02812ZM | 1 |
| 2 | 4255615 | Smart Vision Light (color) | SXP80G2-WHI White Light Projector with Reticle | 1 |
| | 4255613 | Smart Vision Light (mono) | SXP80G2-850 IR Projector with Reticle | |
| 3 | 4253403 | Screws | M3 x 0.5-8, SHCS, SS A2-70/21-M43D0-8L001 | 4 |
| 4 | 4255626 | Mounting Bracket | Bumblebee X Bracket for SXP80G2 | 1 |
| 5 | 4226899 | Screws | M4 x 0.7-8, SHCS, SS/21-M44D0-08L01 | 5 |
| 6 | 4255605 | Mounting Bracket | Bumblebee X Bracket Base | 1 |
| 7 | 4255614 | Power Supply | 24 V 1.5 A, AC/DC, Global, Wall mount | 1 |
| 8 | ACC-01-3017 | GPIO Cable for Bumblebee X | Hirose LF10WBP-12 to Wire Leads, 3 m | 1 |
| 9 | 4255647 | Power Cable | DC Jack 2.1 mm to Leads, 1 m | 1 |
| 10 | 4255646 | GPIO Cable for Projector | M12 5 Pin A-coded to Wire Leads, 5 m | 1 |

The projector has two operation modes: Continuous and Overdrive, where the Overdrive mode draws higher current to provide higher intensity.

### Projector Specifications

| | Continuous Operation | Overdrive Operation |
|---|---|---|
| **Electrical Input** | 24 VDC +/- 5% | |
| **Input Current** | Maximum 840 mA | Peak 1.25 A during strobe |
| **Input Power** | Maximum 20 W | Peak 30 W during strobe |
| **PNP Trigger** | 2 mA at 5 VDC \| 8 mA at 10 VDC \| 15.4 mA at 24 VDC | |
| **NPN Trigger** | 12.5 mA at Common (0 VDC) | |
| **Trigger Input** | PNP > +4 VDC (24 VDC maximum) to activate **or** NPN ≥ 1 VDC to activate (**not both**) | |
| **Mode Control** | Connect pin 5 to 1-10 VDC (10 - 100% output); 24 VDC maximum | Connect pin 5 to GND (see wiring configuration) |
| **Strobe Duration** | Minimum 10 µs \| Maximum ∞ | Minimum 10 µs \| Maximum 50 ms |
| **Strobe Frequency** | Maximum 4 kHz or 1 / Duty Cycle as calculated, whichever is less | |
| **Strobe Trigger Latency** | 6 µs | |
| **Duty Cycle** | Not Applicable | Maximum 10% |
| **Power Indicator** | Green when powered up | |
| **Status Indicator** | Amber when on \| Red when a fault is detected | |
| **Analog Intensity** | Output adjustable from 10 - 100% of intensity limit by a 1 - 10 VDC signal. Jumpering pin 5 to pin 1 provides maximum intensity. | |
| **Connection** | 5-pin M12 connector | |
| **Operating Temperature** | -10° to 40° C (14° to 104° F) \| RH maximum 80% non-condensing humidity | |
| **Storage Temperature** | -20° to 70° C (-4° to 158° F) \| RH maximum 80% non-condensing humidity | |
| **IP Rating** | IP50 | |
| **Mass** | ~580 grams | |
| **Compliance** | CE, IEC 62471, RoHS | |
| **Warranty** | 3 years | |

# B.2 Wiring Guide

## B.2.1 NPN—Continuous Mode

The following wiring schematic illustrates how to connect the camera to the projector in continuous mode using the NPN line. This example shows the projector being triggered by the Bumblebee X camera via the camera's opto-isolated output. The projector can be externally triggered by other devices as well.

> **Note:** Power requirements are different between continuous and overdrive operations modes.

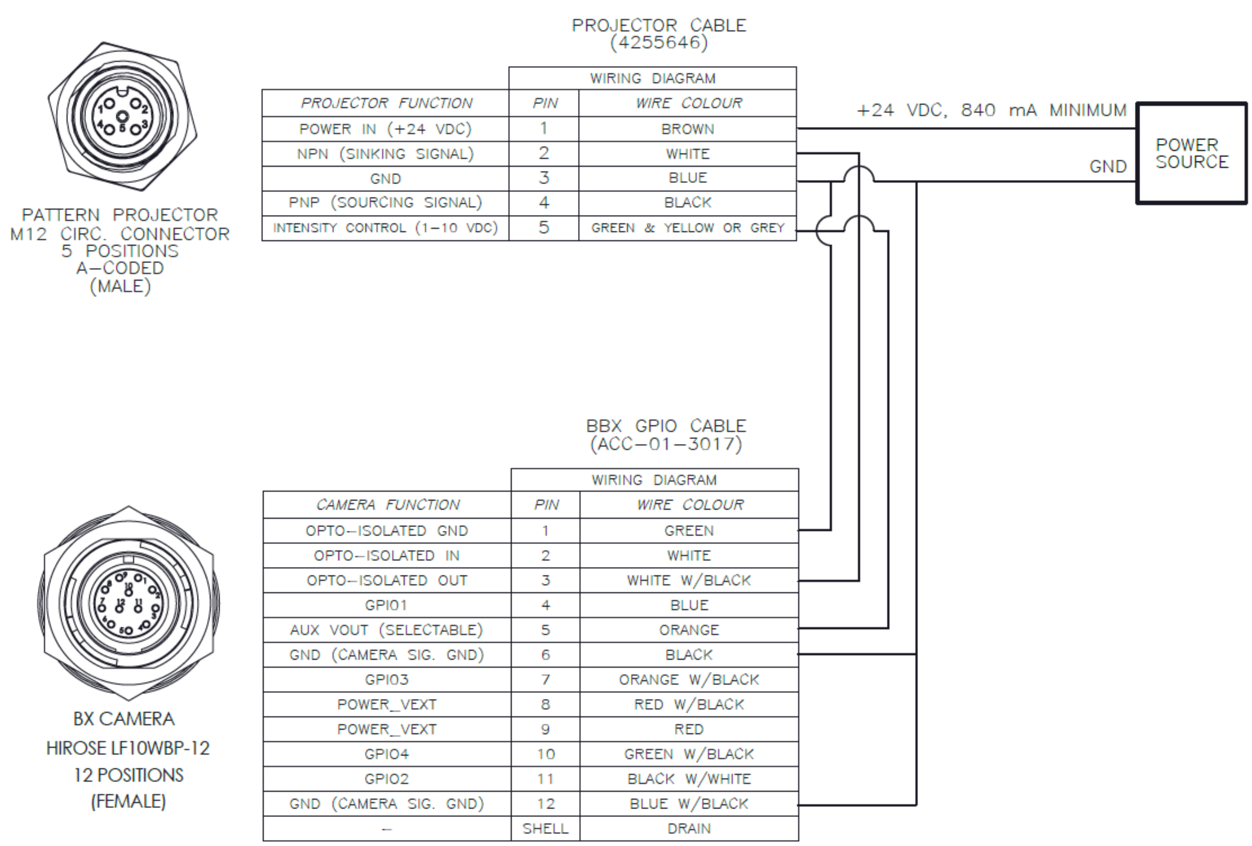
To use continuous mode, either:

- Tie Projector Pin 4 (PNP) → Projector Pin 1 (Power In)

  **OR**

- Tie Projector Pin 2 (NPN) → Projector Pin 3 (GND)

**Do NOT do both**.




PROJECTOR CABLE (4255646)

| PROJECTOR FUNCTION | PIN | WIRE COLOUR (WIRING DIAGRAM) |
|---|---|---|
| POWER IN (+24 VDC) | 1 | BROWN |
| NPN (SINKING SIGNAL) | 2 | WHITE |
| GND | 3 | BLUE |
| PNP (SOURCING SIGNAL) | 4 | BLACK |
| INTENSITY CONTROL (1–10 VDC) | 5 | GREEN & YELLOW OR GREY |

BBX GPIO CABLE (ACC–01–3017)

| CAMERA FUNCTION | PIN | WIRE COLOUR (WIRING DIAGRAM) |
|---|---|---|
| OPTO–ISOLATED GND | 1 | GREEN |
| OPTO–ISOLATED IN | 2 | WHITE |
| OPTO–ISOLATED OUT | 3 | WHITE W/BLACK |
| GPIO1 | 4 | BLUE |
| AUX VOUT (SELECTABLE) | 5 | ORANGE |
| GND (CAMERA SIG. GND) | 6 | BLACK |
| GPIO3 | 7 | ORANGE W/BLACK |
| POWER_VEXT | 8 | RED W/BLACK |
| POWER_VEXT | 9 | RED |
| GPIO4 | 10 | GREEN W/BLACK |
| GPIO2 | 11 | BLACK W/WHITE |
| GND (CAMERA SIG. GND) | 12 | BLUE W/BLACK |
| – | SHELL | DRAIN |

| For Variable Intensity | For Maximum Intensity |
|---|---|
| Tie Projector Pin 5 (Intensity Control)<br>→Bumblebee X Pin 5 (Aux Vout) | Tie Projector Pin 5 (Intensity Control)<br>→Projector Pin 1 (Power In) |

### Notes:

- An external resistor is not required to pull the voltage line when using the projector's NPN line. It is needed for wiring up the PNP line in the later examples.
- The logic on the Output pin of the Bumblebee X camera needs to be inverted so that it functions like a PNP. See SpinView Configuration.

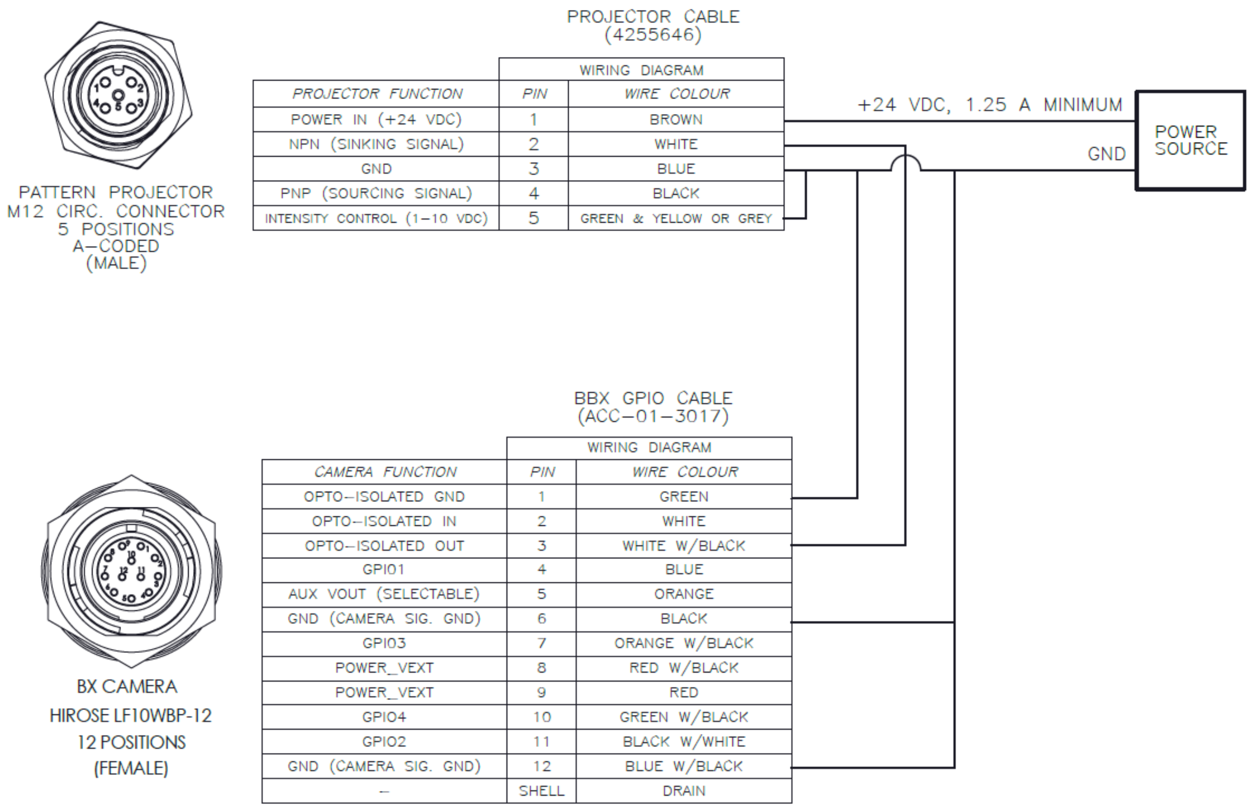
## B.2.2 NPN—Overdrive Mode

The following wiring schematic illustrates how to connect the camera to the projector in overdrive mode using the NPN line. This example shows the projector being triggered by the Bumblebee X camera via the camera's opto-isolated output. The projector can be externally triggered by other devices as well.

**Note:** Power requirements are different between continuous and overdrive operations modes.

For overdrive mode:

- Tie Projector Pin 5 (Intensity Control) → Projector Pin 3 (GND).
  There is no intensity adjustment because of this.




| PROJECTOR FUNCTION | PIN | WIRE COLOUR |
|---|---|---|
| POWER IN (+24 VDC) | 1 | BROWN |
| NPN (SINKING SIGNAL) | 2 | WHITE |
| GND | 3 | BLUE |
| PNP (SOURCING SIGNAL) | 4 | BLACK |
| INTENSITY CONTROL (1–10 VDC) | 5 | GREEN & YELLOW OR GREY |

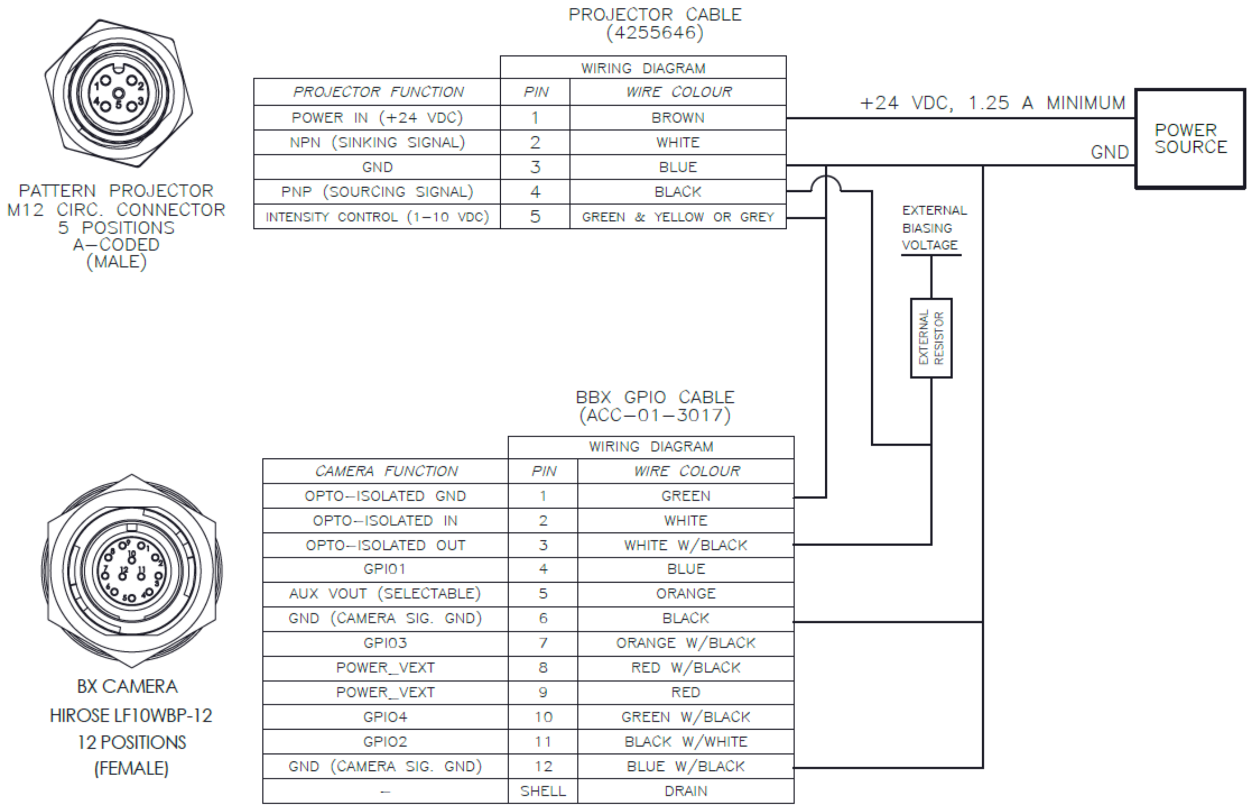
| CAMERA FUNCTION | PIN | WIRE COLOUR |
|---|---|---|
| OPTO–ISOLATED GND | 1 | GREEN |
| OPTO–ISOLATED IN | 2 | WHITE |
| OPTO–ISOLATED OUT | 3 | WHITE W/BLACK |
| GPIO1 | 4 | BLUE |
| AUX VOUT (SELECTABLE) | 5 | ORANGE |
| GND (CAMERA SIG. GND) | 6 | BLACK |
| GPIO3 | 7 | ORANGE W/BLACK |
| POWER_VEXT | 8 | RED W/BLACK |
| POWER_VEXT | 9 | RED |
| GPIO4 | 10 | GREEN W/BLACK |
| GPIO2 | 11 | BLACK W/WHITE |
| GND (CAMERA SIG. GND) | 12 | BLUE W/BLACK |
| – | SHELL | DRAIN |

### Notes:

- No external resistor is required.
- The logic on the Output pin of the Bumblebee X camera needs to be inverted so that it functions like a PNP. See SpinView Configuration.

## B.2.3 PNP—Overdrive Mode Example 1

The following wiring schematic illustrates one example of how to connect the Bumblebee X camera to the projector in overdrive mode using the PNP line.




| PROJECTOR FUNCTION | PIN | WIRE COLOUR |
|---|---|---|
| POWER IN (+24 VDC) | 1 | BROWN |
| NPN (SINKING SIGNAL) | 2 | WHITE |
| GND | 3 | BLUE |
| PNP (SOURCING SIGNAL) | 4 | BLACK |
| INTENSITY CONTROL (1–10 VDC) | 5 | GREEN & YELLOW OR GREY |

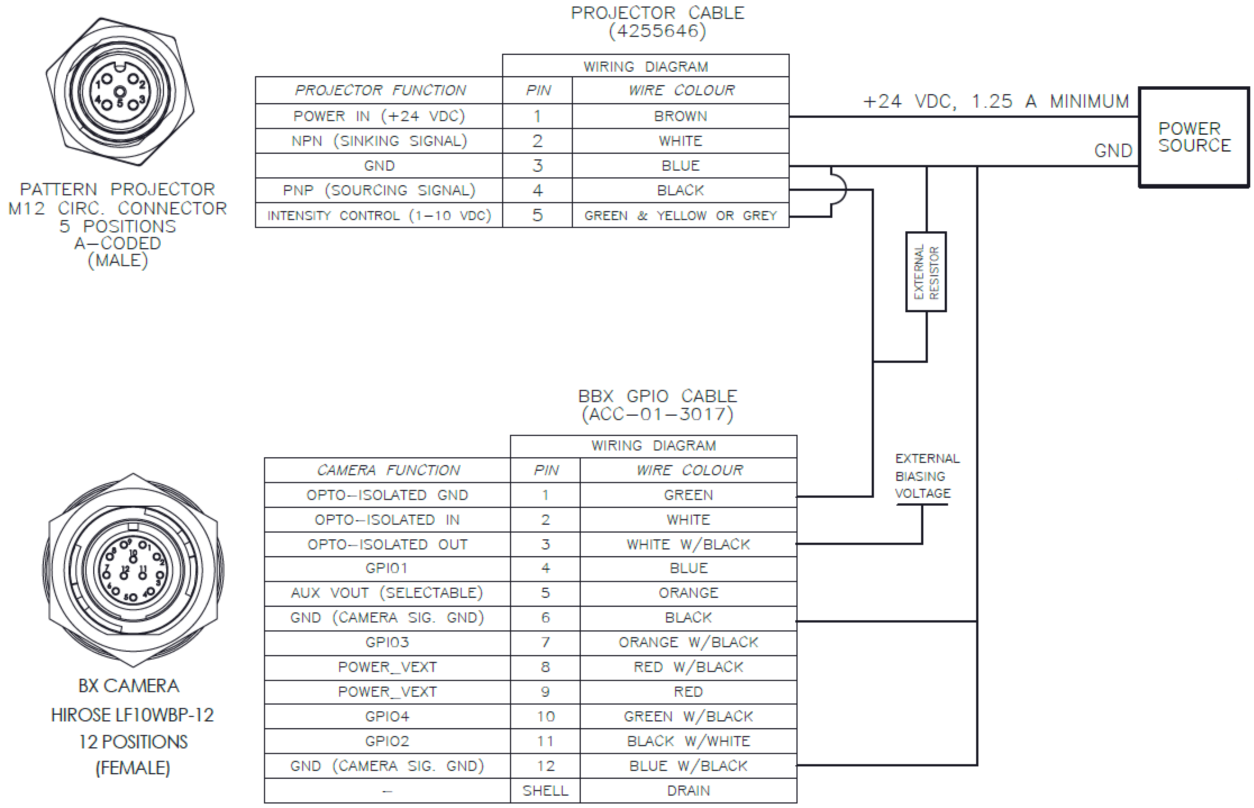
| CAMERA FUNCTION | PIN | WIRE COLOUR |
|---|---|---|
| OPTO–ISOLATED GND | 1 | GREEN |
| OPTO–ISOLATED IN | 2 | WHITE |
| OPTO–ISOLATED OUT | 3 | WHITE W/BLACK |
| GPIO1 | 4 | BLUE |
| AUX VOUT (SELECTABLE) | 5 | ORANGE |
| GND (CAMERA SIG. GND) | 6 | BLACK |
| GPIO3 | 7 | ORANGE W/BLACK |
| POWER_VEXT | 8 | RED W/BLACK |
| POWER_VEXT | 9 | RED |
| GPIO4 | 10 | GREEN W/BLACK |
| GPIO2 | 11 | BLACK W/WHITE |
| GND (CAMERA SIG. GND) | 12 | BLUE W/BLACK |
| – | SHELL | DRAIN |

**Notes:**

- An external resistor must be used to drive the PNP line on the device. The selection of the external resistor value influences the timing (changing the resistor value changes the time constant of the RLC circuit).
- Reference resistor values and minimum external bias voltages necessary to drive the projector:
  - 4k7 OHM - 9 VDC
  - 1k OHM - 5 VDC
  - 330 OHM - 4 VDC
- Do not exceed 24 VDC for the external bias voltage. **Higher voltages will cause damage to the camera.**
- The line does not need to be inverted in SpinView.
- The downside of this setup is that the minimum voltage required to drive the projector depends on the value of the external resistor.

## B.2.4 PNP—Overdrive Mode Example 2

The following wiring schematic illustrates another example on how to connect the Bumblebee X camera to the projector in overdrive mode using the PNP line.




| PROJECTOR FUNCTION | PIN | WIRE COLOUR (WIRING DIAGRAM) |
|---|---|---|
| POWER IN (+24 VDC) | 1 | BROWN |
| NPN (SINKING SIGNAL) | 2 | WHITE |
| GND | 3 | BLUE |
| PNP (SOURCING SIGNAL) | 4 | BLACK |
| INTENSITY CONTROL (1–10 VDC) | 5 | GREEN & YELLOW OR GREY |

| CAMERA FUNCTION | PIN | WIRE COLOUR (WIRING DIAGRAM) |
|---|---|---|
| OPTO-ISOLATED GND | 1 | GREEN |
| OPTO-ISOLATED IN | 2 | WHITE |
| OPTO-ISOLATED OUT | 3 | WHITE W/BLACK |
| GPIO1 | 4 | BLUE |
| AUX VOUT (SELECTABLE) | 5 | ORANGE |
| GND (CAMERA SIG. GND) | 6 | BLACK |
| GPIO3 | 7 | ORANGE W/BLACK |
| POWER_VEXT | 8 | RED W/BLACK |
| POWER_VEXT | 9 | RED |
| GPIO4 | 10 | GREEN W/BLACK |
| GPIO2 | 11 | BLACK W/WHITE |
| GND (CAMERA SIG. GND) | 12 | BLUE W/BLACK |
| -- | SHELL | DRAIN |

**Notes:**

- An external resistor must be used to drive the PNP line on the device. The selection of the external resistor value influences the timing (changing the resistor value changes the time constant of the RLC circuit).
- Reference resistor values and minimum external bias voltages necessary to drive the projector:
  - 4k7 OHM - 3.2 VDC
  - 1k OHM - 3.5 VDC
  - 330 OHM - 4.0 VDC
- Do not exceed 24 VDC for the external bias voltage. **Higher voltages will cause damage to the camera.**
- The logic on the Output pin of the Bumblebee X camera needs to be inverted so that the PNP line functions properly. See SpinView Configuration .
- The upside of this setup is that a very low minimum voltage is required to drive the projector and it is dependent on the value of the external resistor used.

# B.3 SpinView Configuration

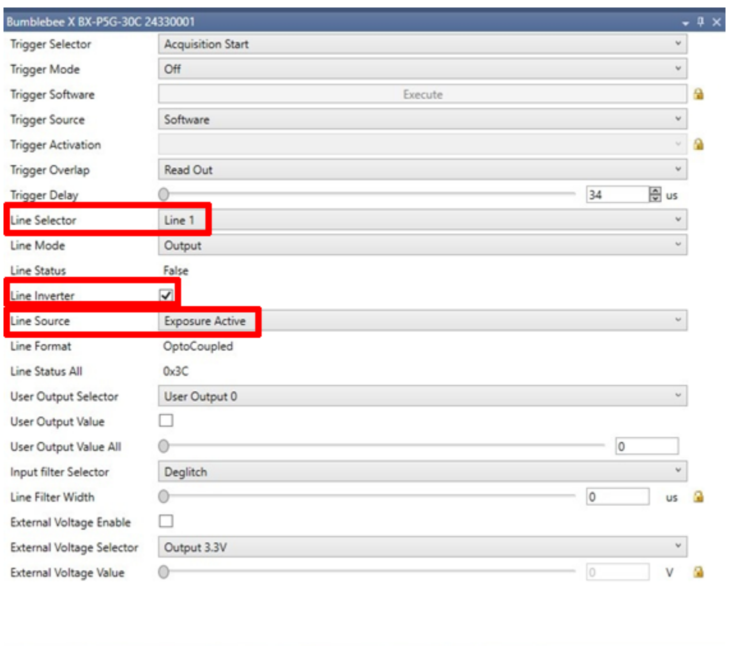
There are two ways to trigger the projector with SpinView:

1. Syncing the projector output by tying the pulses with the frame rate.
2. Using a counter at a higher pulse rate of the frame.

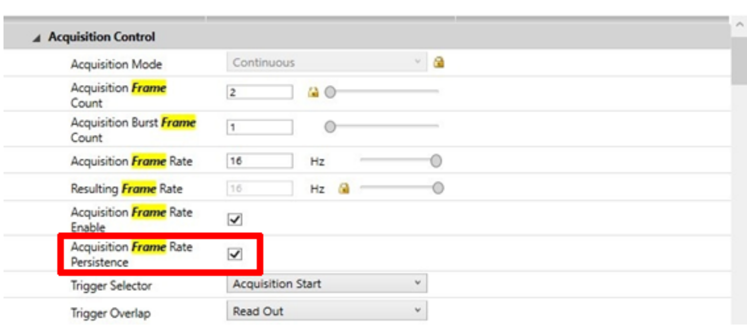
### Syncing the Output with Frame Rate

The simplest way is to tie the projector’s pulse with the frame rate resulting in the camera capturing the light output.

1. Under GPIO settings:
   a. Set **Line Selector** to the Opto-Out (Line 1 for Bumblebee X camera).
   b. Select **Line Inverter** for NPN setup or PNP Overdrive Example 2 setup.
   c. Set **Line Source** to Exposure Active.




2. Under Acquisition Control:
   - Enable **Acquisition Frame Rate Persistence**.



3. Under Settings:
    - Adjust the frame rate. Start low to allow projector to catch up with the frame. Slowly adjust while observing the image to check that projector light is seen and steady.

## Using the Counter

A counter can also be used to drive the pattern projector. The counter allows you to adjust the pulse rate of the camera.

1. Under GPIO settings:
    a. Set **Line Selector** to the Opto-Out (Line 1 for Bumblebee X camera).

    b. Select **Line Inverter** for NPN setup or PNP Overdrive Example 2 setup.

    c. Set **Line Source** to Counter 0 Active.

2. Under Counter and Timer Controls:
    - Both counter duration and counter delay control the pulse width of the projector. You can leave the counter delay to 0 and adjust the counter duration only.

      Note that if the line is inverted, a lower counter duration corresponds to a shorter pulse width, otherwise a higher counter duration corresponds to a shorter pulse width.