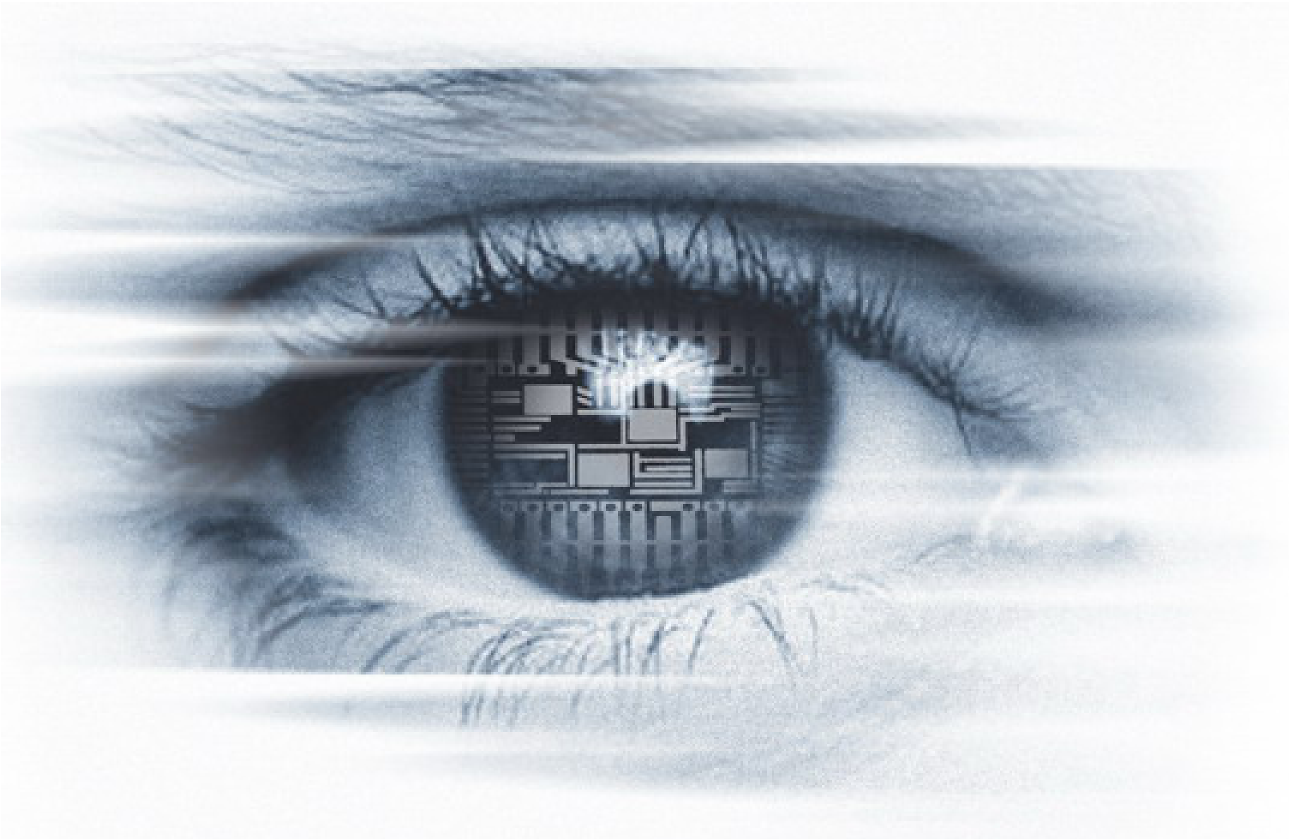
User Manual

MV1-D2048-3D03/3D04 Camera Series

3D CMOS camera with GigE interface



MAN052 06/2014 V2.5

Contents

1 Preface

1.1 About Photonfocus

The Swiss company Photonfocus is one of the leading specialists in the development of CMOS image sensors and corresponding industrial cameras for machine vision, security & surveillance and automotive markets.

Photonfocus is dedicated to making the latest generation of CMOS technology commercially available. Active Pixel Sensor (APS) and global shutter technologies enable high speed and high dynamic range (120 dB) applications, while avoiding disadvantages like image lag, blooming and smear.

Photonfocus has proven that the image quality of modern CMOS sensors is now appropriate for demanding applications. Photonfocus' product range is complemented by custom design solutions in the area of camera electronics and CMOS image sensors.

Photonfocus is ISO 9001 certified. All products are produced with the latest techniques in order to ensure the highest degree of quality.

1.2 Contact

Photonfocus AG, Bahnhofplatz 10, CH-8853 Lachen SZ, Switzerland

Sales	Phone: +41 55 451 00 00	Email: sales@photonfocus.com
Support	Phone: +41 55 451 00 00	Email: support@photonfocus.com

Table 1.1: Photonfocus Contact

1.3 Sales Offices

Photonfocus products are available through an extensive international distribution network and through our key account managers. Details of the distributor nearest you and contacts to our key account managers can be found at www.photonfocus.com.

1.4 Further information

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Photonfocus can not be held responsible for any technical or typographical errors.

1.5 Legend

In this documentation the reader's attention is drawn to the following icons:

Important note

Alerts and additional information

Attention, critical warning

Notification, user guide

2 Introduction

This manual describes the Photonfocus 3D camera series that have a Gigabit Ethernet (GigE) interface and are based on the image sensors CMV2000 or CMV4000 sensors from CMOSIS.

A list of all cameras covered in this manual is shown in Table 4.2. The term `MV1-D2048-3D03/04` is used in this manual to denote all available cameras of this series.

2.1 Camera Naming convention

The naming convention of the MV1-D2048-3D03/04 camera series is summarized in Fig. 2.1.

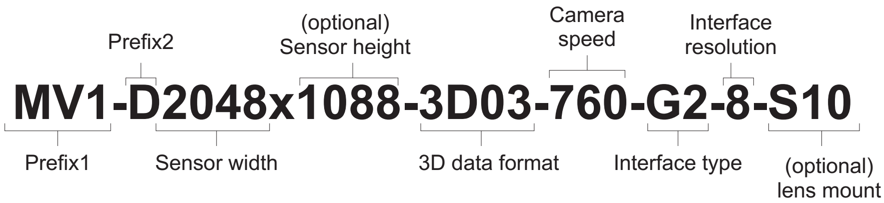

Figure 2.1: Camera naming convention

Prefix1 All cameras have `MV1` as Prefix1.

Prefix2 All cameras have `D` as Prefix2.

Sensor width All cameras covered in this manual use sensors with a width of 2048 pixels.

Sensor height This indication is optional to avoid ambiguity. The cameras that use the 2 MPix CMV2000 sensor have a height indicator of "1088". The cameras that use the 4 MPix CMV4000 sensor don’t have a height indication.

3D coordinate data format Available 3D coordinate data formats are: "3D03": integer part 10 digits, fractional part 6 digits (see also Section 5.2.9); "3D04": integer part 12 digits, fractional part 4 digits

Camera speed The camera speed is specified as the product of the camera data clock in MHz and the number of parallel data channels (taps).

Interface type Available interface type options: "G2": Gigabit Ethernet with RS-422 interface for a shaft (rotary) encoder; "H2": Gigabit Ethernet with HTL (High Threshold Logic) interface (instead of RS-422) for a shaft (rotary) encoder

Interface resolution Maximal resolution (bit width) of the camera interface.

Lens mount Cameras with no lens mount specifier have a standard (straight) C-Mount lens mount. Cameras with the "S10" lens mount option have a 10 degree Scheimpflug (C-Mount) lens mount.

3

How to get started (3D GigE G2)

3.1 Introduction

This guide shows you:

- How to install the required hardware (see Section 3.2)
- How to install the required software (see Section 3.3) and configure the Network Adapter Card (see Section 3.4 and Section 3.5)
- How to acquire your first images and how to modify camera settings (see Section 3.6)

A GigE Starter Guide [MAN051] can be downloaded from the Photonfocus support page. It describes how to access Photonfocus GigE cameras from various third-party tools.

To start with the laser detection it is recommended to use the PF 3D Suite which can be downloaded from the software section of the Photonfocus web page. The PF 3D Suite is a free GUI for an easy system set up and visualisation of 3D scan. To get started, please read the manual [MAN053] which can be downloaded from the Photonfocus web page.

Prior to running the PF 3D Suite, the GigE system should be configured as indicated in this chapter.

3.2 Hardware Installation

The hardware installation that is required for this guide is described in this section.

The following hardware is required:

- PC with Microsoft Windows OS (XP, Vista, Windows 7)
- A Gigabit Ethernet network interface card (NIC) must be installed in the PC. The NIC should support jumbo frames of at least 9014 bytes. In this guide the Intel PRO/1000 GT desktop adapter is used. The descriptions in the following chapters assume that such a network interface card (NIC) is installed. The latest drivers for this NIC must be installed.
- Photonfocus GigE camera.
- Suitable power supply for the camera (see in the camera manual for specification) which can be ordered from your Photonfocus dealership.
- GigE cable of at least Cat 5E or 6.

Photonfocus GigE cameras can also be used under Linux.

Photonfocus GigE cameras work also with network adapters other than the Intel PRO/1000 GT. The GigE network adapter should support Jumbo frames.

Do not bend GigE cables too much. Excess stress on the cable results in transmission errors. In robots applications, the stress that is applied to the GigE cable is especially high due to the fast movement of the robot arm. For such applications, special drag chain capable cables are available.

The following list describes the connection of the camera to the PC (see in the camera manual for more information):

1. Remove the Photonfocus GigE camera from its packaging. Please make sure the following items are included with your camera:

   - Power supply connector
   - Camera body cap

   If any items are missing or damaged, please contact your dealership.

2. Connect the camera to the GigE interface of your PC with a GigE cable of at least Cat 5E or 6.

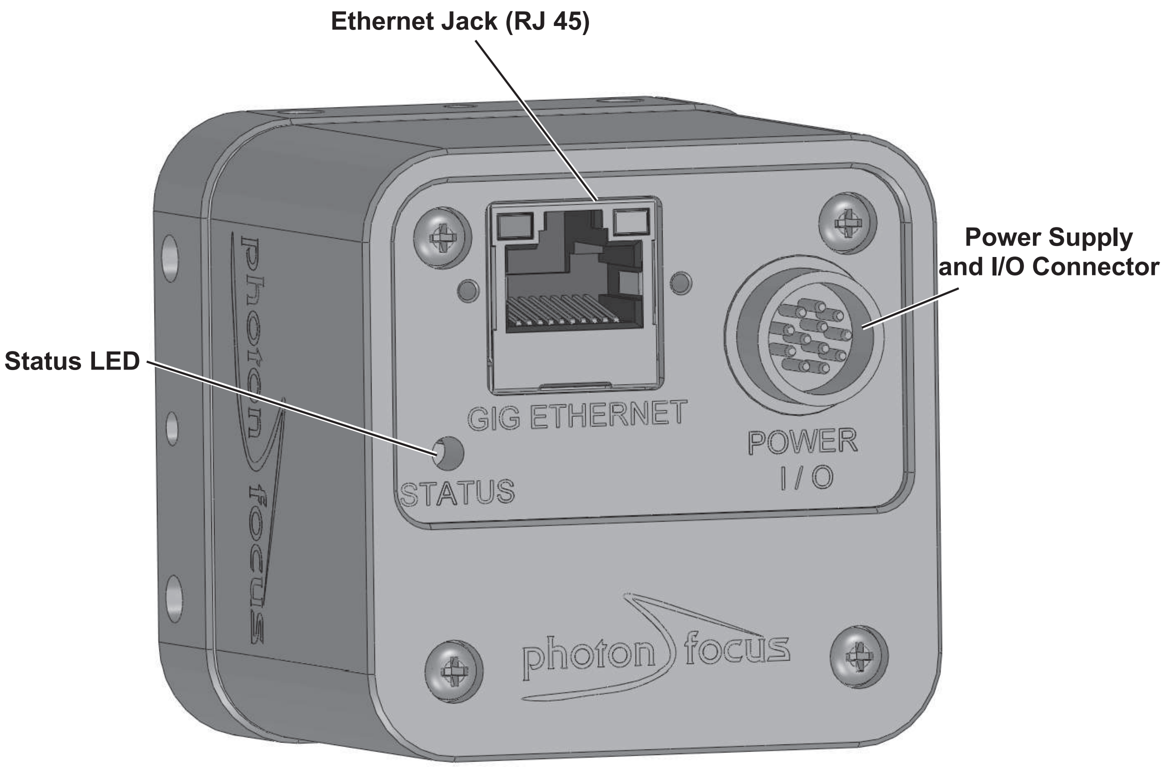

Figure 3.1: Rear view of the Photonfocus 2048 GigE camera series with power supply and I/O connector, Ethernet jack (RJ45) and status LED

3. Connect a suitable power supply to the power plug. The pin out of the connector is shown in the camera manual.

   Check the correct supply voltage and polarity! Do not exceed the operating voltage range of the camera.

A suitable power supply can be ordered from your Photonfocus dealership.

4. Connect the power supply to the camera (see Fig. 3.1).

3.3 Software Installation

This section describes the installation of the required software to accomplish the tasks described in this chapter.

1. Install the latest drivers for your GigE network interface card.
2. Download the latest eBUS SDK installation file from the Photonfocus server.

   You can find the latest version of the eBUS SDK on the support (Software Download) page at www.photonfocus.com.

3. Install the eBUS SDK software by double-clicking on the installation file. Please follow the instructions of the installation wizard. A window might be displayed warning that the software has not passed Windows Logo testing. You can safely ignore this warning and click on `Continue Anyway`. If at the end of the installation you are asked to restart the computer, please click on `Yes` to restart the computer before proceeding.
4. After the computer has been restarted, open the eBUS Driver Installation tool (`Start -> All Programs -> eBUS SDK -> Tools -> Driver Installation Tool`) (see Fig. 3.2). If there is more than one Ethernet network card installed then select the network card where your Photonfocus GigE camera is connected. In the Action drop-down list select `Install eBUS Universal Pro Driver` and start the installation by clicking on the `Install` button. Close the eBUS Driver Installation Tool after the installation has been completed. Please restart the computer if the program asks you to do so.

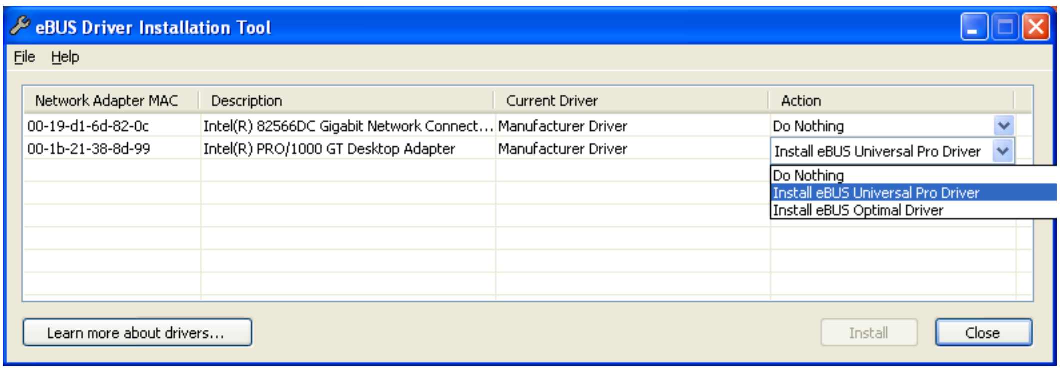

Figure 3.2: eBUS Driver Installation Tool

5. Download the latest PFInstaller from the Photonfocus server.
6. Install the PFInstaller by double-clicking on the file. In the `Select Components` (see Fig. 3.3) dialog check `PF_GEVPlayer and doc for GigE cameras`. For DR1 cameras select additionally `DR1 support and 3rd Party Tools`. For 3D cameras additionally select `PF3DSuite2 and SDK`.

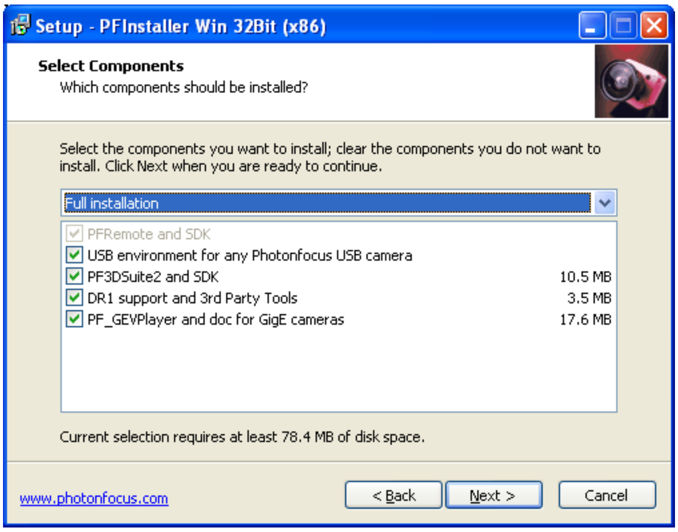

Figure 3.3: PFInstaller components choice

3.4 Network Adapter Configuration

This section describes recommended network adapter card (NIC) settings that enhance the performance for GigEVision. Additional tool-specific settings are described in the tool chapter.

1. Open the Network Connections window (`Control Panel -> Network and Internet Connections -> Network Connections`), right click on the name of the network adapter where the Photonfocus camera is connected and select `Properties` from the drop down menu that appears.

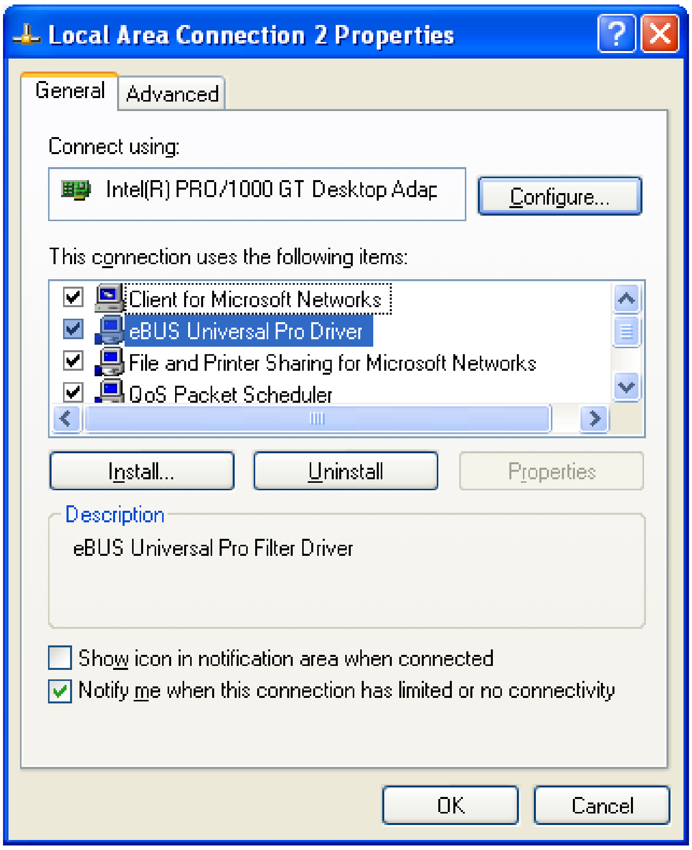

Figure 3.4: Local Area Connection Properties

2. By default, Photonfocus GigE Vision cameras are configured to obtain an IP address automatically. For this quick start guide it is recommended to configure the network adapter to obtain an IP address automatically. To do this, select `Internet Protocol (TCP/IP)` (see Fig. 3.4), click the `Properties` button and select `Obtain an IP address automatically` (see Fig. 3.5).

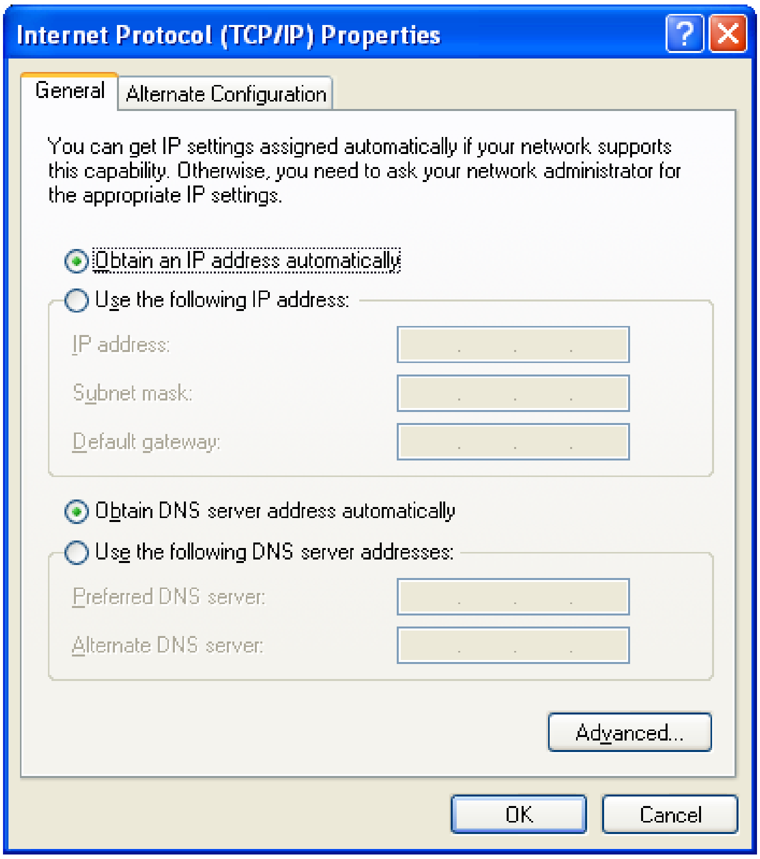

Figure 3.5: TCP/IP Properties

3. Open again the `Local Area Connection Properties` window (see Fig. 3.4) and click on the Configure button. In the window that appears click on the `Advanced` tab and click on `Jumbo Frames` in the Settings list (see Fig. 3.6). The highest number gives the best performance. Some tools however don't support the value 16128. For this guide it is recommended to select `9014 Bytes` in the Value list.

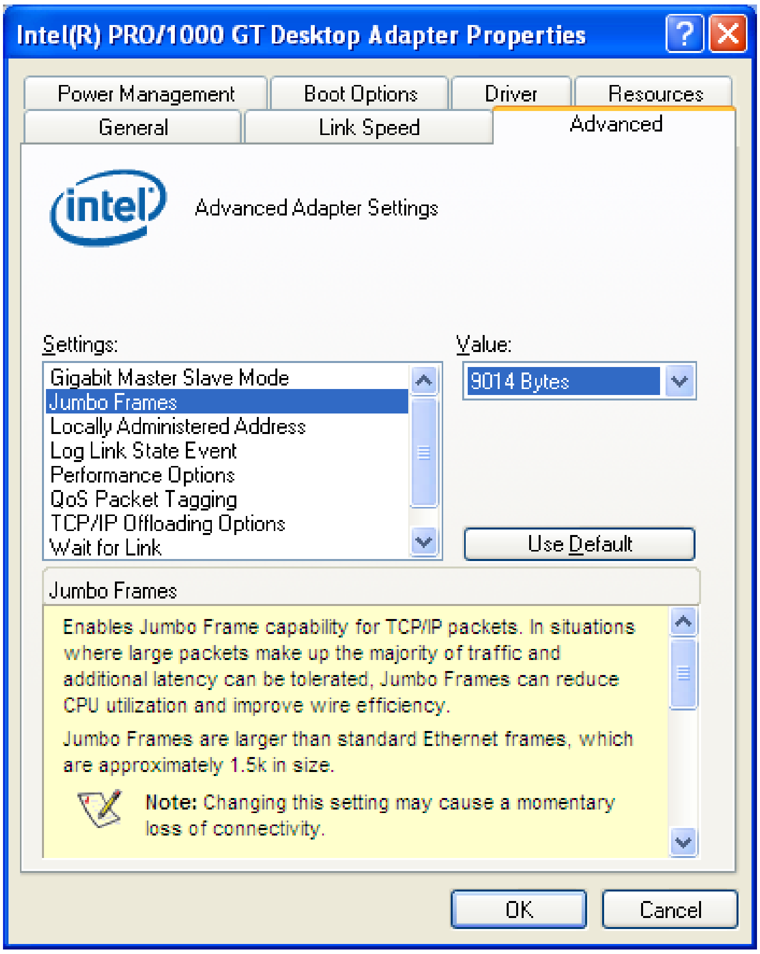

Figure 3.6: Advanced Network Adapter Properties

4. No firewall should be active on the network adapter where the Photonfocus GigE camera is connected. If the Windows Firewall is used then it can be switched off like this: Open the Windows Firewall configuration (`Start -> Control Panel -> Network and Internet Connections -> Windows Firewall`) and click on the Advanced tab. Uncheck the network where your camera is connected in the `Network Connection Settings` (see Fig. 3.7).

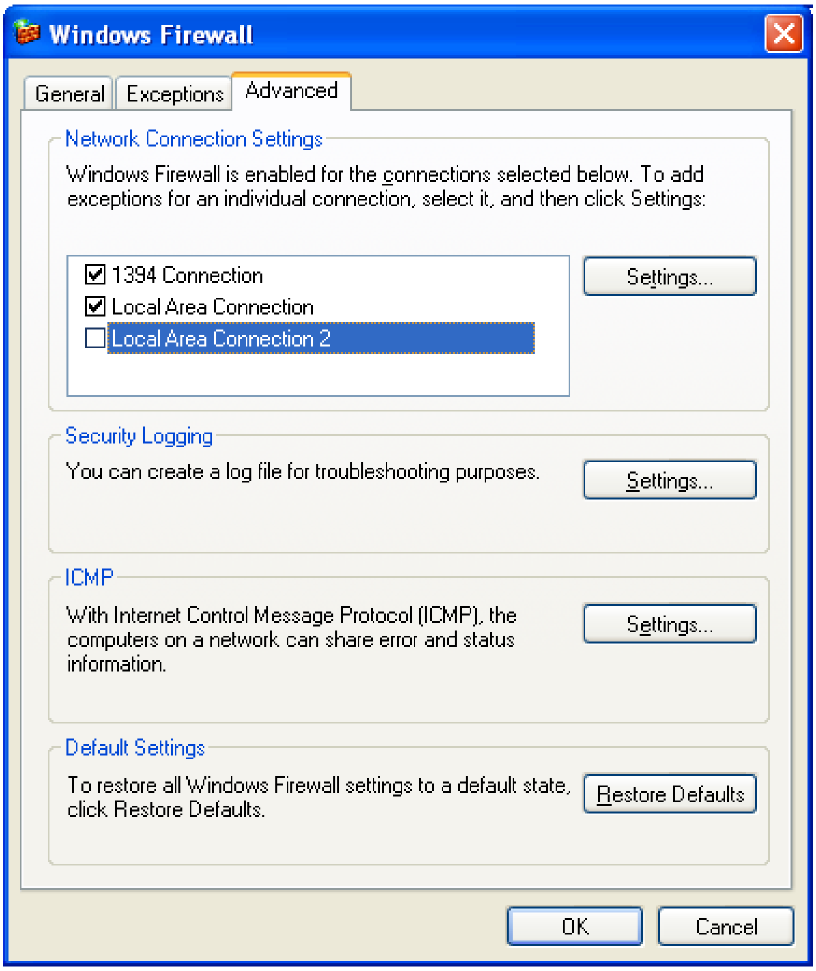

Figure 3.7: Windows Firewall Configuration

3.5 Network Adapter Configuration for Pleora eBUS SDK

Open the Network Connections window (`Control Panel -> Network and Internet Connections -> Network Connections`), right click on the name of the network adapter where the Photonfocus camera is connected and select `Properties` from the drop down menu that appears. A Properties window will open. Check the `eBUS Universal Pro Driver` (see Fig. 3.8) for maximal performance. Recommended settings for the Network Adapter Card are described in Section 3.4.

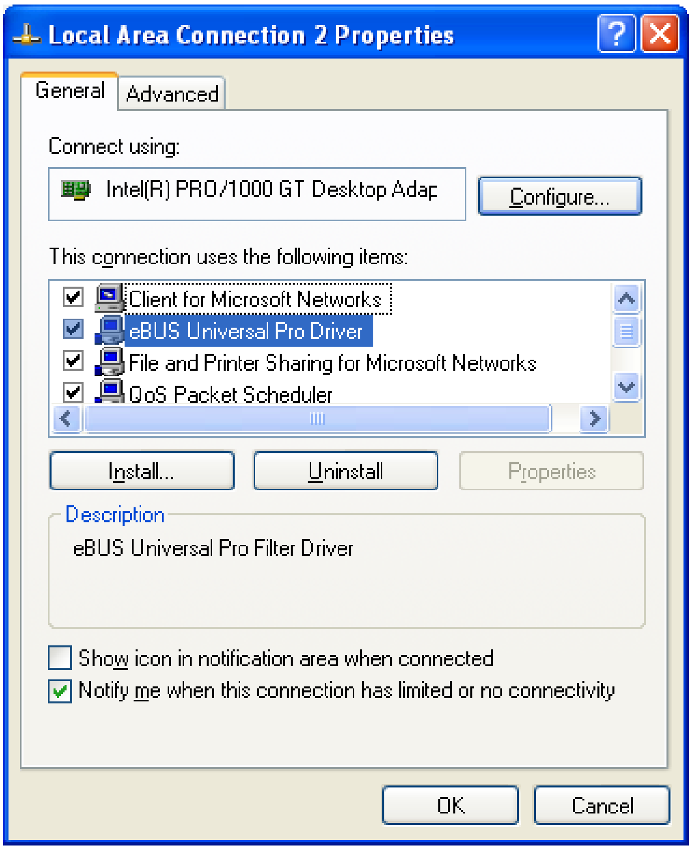

Figure 3.8: Local Area Connection Properties

3.6 Getting started

This section describes how to acquire images from the camera and how to modify camera settings.

1. Open the PF_GEVPlayer software (Start -> All Programs -> Photonfocus -> GigE_Tools -> PF_GEVPlayer) which is a GUI to set camera parameters and to see the grabbed images (see Fig. 3.9).

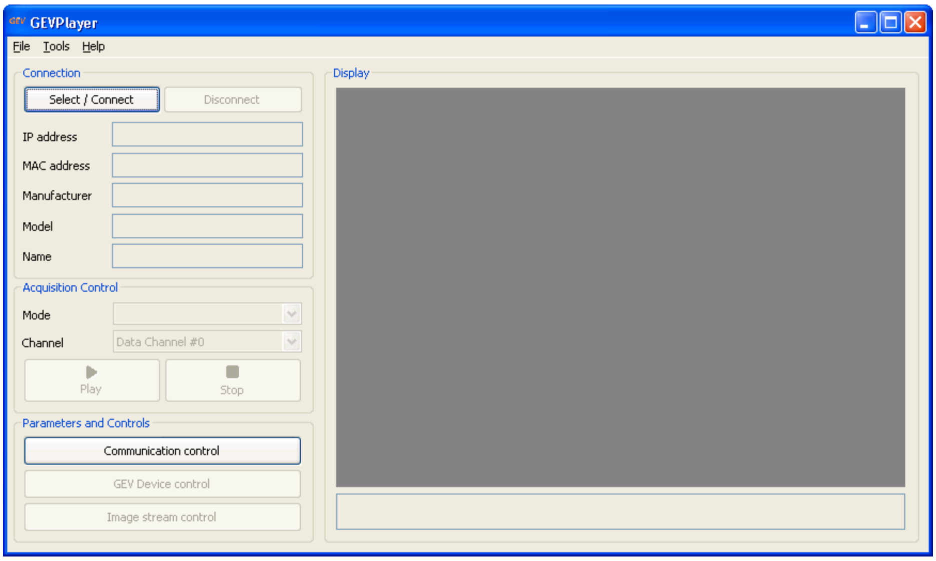

Figure 3.9: PF_GEVPlayer start screen

2. Click on the `Select / Connect` button in the PF_GEVPlayer . A window with all detected devices appears (see Fig. 3.10). If your camera is not listed then select the box `Show unreachable GigE Vision Devices`.

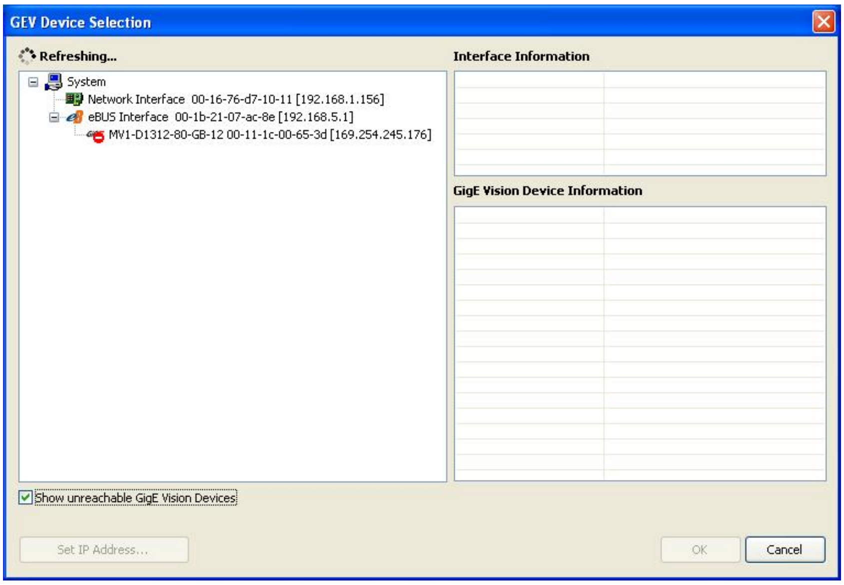

Figure 3.10: GEV Device Selection Procedure displaying the selected camera

3. Select camera model to configure and click on `Set IP Address...`.

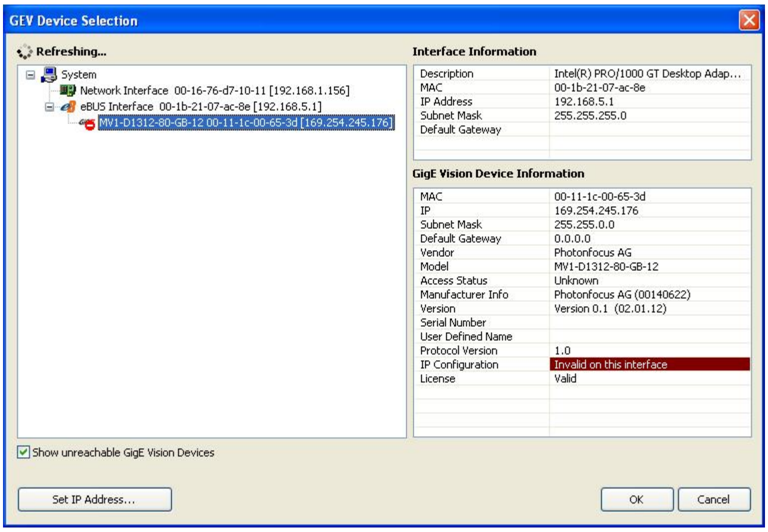

Figure 3.11: GEV Device Selection Procedure displaying GigE Vision Device Information

4. Select a valid IP address for selected camera (see Fig. 3.12). There should be no exclamation mark on the right side of the IP address. Click on `Ok` in the `Set IP Address` dialog. Select the camera in the `GEV Device Selection` dialog and click on `Ok`.

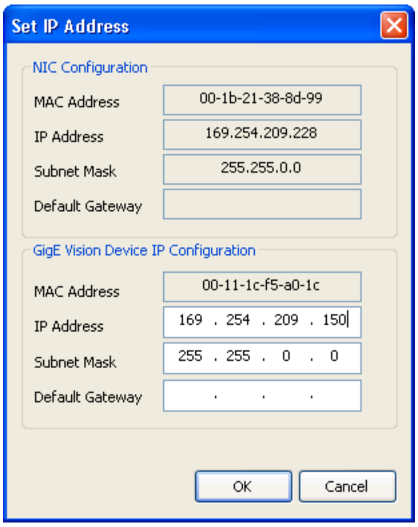

Figure 3.12: Setting IP address

5. Finish the configuration process and connect the camera to PF_GEVPlayer .
6. The camera is now connected to the PF_GEVPlayer . Click on the `Play` button to grab images.

An additional check box `DR1` appears for DR1 cameras. The camera is in double rate mode if this check box is checked. The demodulation is done in the PF_GEVPlayer software. If the check box is not checked, then the camera outputs an unmodulated image and the frame rate will be lower than in double rate mode.

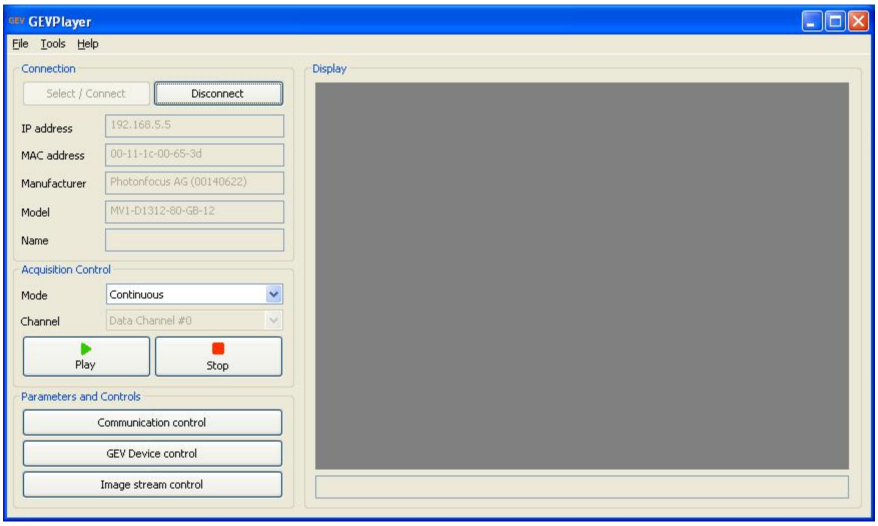

Figure 3.13: PF_GEVPlayer is readily configured

If no images can be grabbed, close the PF_GEVPlayer and adjust the Jumbo Frame parameter (see Section 3.3) to a lower value and try again.

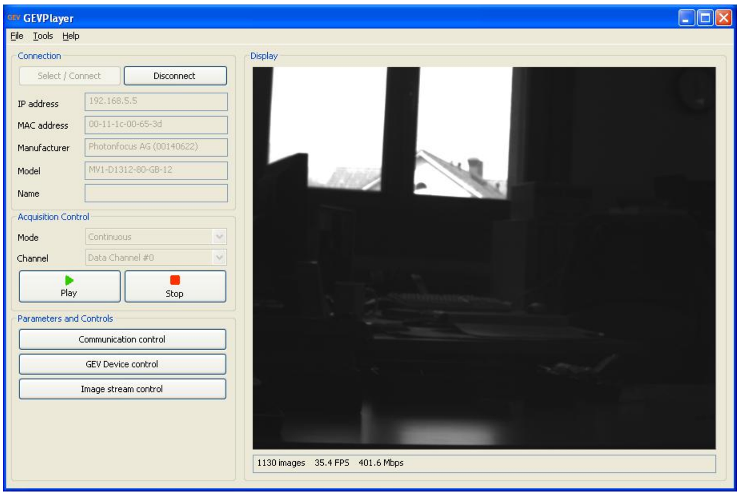

Figure 3.14: PF_GEVPlayer displaying live image stream

7. Check the status LED on the rear of the camera.

   The status LED light is green when an image is being acquired, and it is red when serial communication is active.

8. Camera parameters can be modified by clicking on `GEV Device control` (see Fig. 3.15). The visibility option Beginner shows most the basic parameters and hides the more advanced parameters. If you don't have previous experience with Photonfocus GigE cameras, it is recommended to use `Beginner` level.

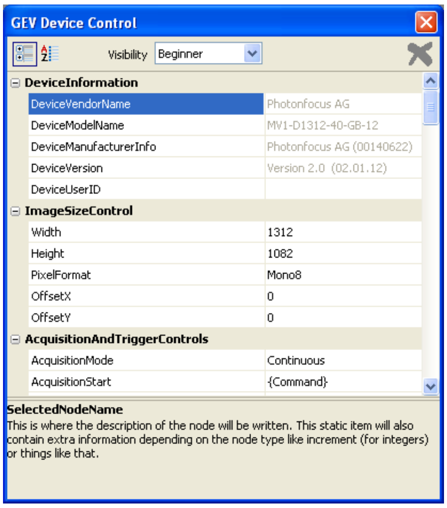

Figure 3.15: Control settings on the camera

9. To modify the exposure time scroll down to the `AcquisitionControl` control category (bold title) and modify the value of the `ExposureTime` property.

4

Product Specification

4.1 Introduction

This manual describes the Photonfocus MV1-D2048-3D03/04 camera series. The cameras have a Gigabit Ethernet interface and are optimized for high speed laser triangulation applications with up to 10200 profiles/s. The MV1-D2048x1088-3D03 camera contains a 2.2 megapixel CMOS image sensor and the MV1-D2048-3D04 a 4 megapixel sensor. The cameras includes the detection of up to two laser lines. The laser line detection algorithm (Peak Detector) is able to compute the peak position of a laser line with sub-pixel accuracy. Thus, the height profile of an object gets computed within the camera, making additional calculations in the PC needless.

The cameras are built around the monochrome CMOS image sensors CMV2000 (2.2 MP) and CMV4000 (4 MP), developed by CMOSIS. The principal advantages are:

- Up to 10200 profiles/s @ 2048 x 23 resolution
- High reliability and accuracy of 3D reconstruction, due to the non-linear interpolation technique used in the laser line (peak) detection algorithm
- Laser line (peak) detection with up to 1/64 sub pixel accuracy (3D03) (1/16 in 3D04)
- Dual Peak eliminates the need of a second camera for various setups
- 2D single line for 2D surface inspection and image overlay (at full frame rate)
- High Speed Mode available: higher speed at lower accuracy
- Gigabit Ethernet interface with GigE Vision and GenICam compliance
- Combined 2D/3D applications can be realized in the 2D/3D mode of the camera (at a reduced frame rate)
- Global shutter
- Image sensor with high sensitivity
- Region of interest (ROI) freely selectable in x and y direction
- Column Fixed Pattern Noise Correction for improved image quality.
- Advanced I/O capabilities: 2 isolated trigger inputs, 2 differential isolated inputs (RS-422 or HTL) and 2 isolated outputs
- A/B shaft encoder interface: RS-422 (G2 models) or HTL (H2 models). HTL is recommended for noisy environments.
- Model variant S10 with Scheimpflug 10 degree (C-Mount) lens mount available
- Programmable Logic Controller (PLC) for powerful operations on input and output signals
- Wide power input range from 12 V (-10 %) to 24 V (+10 %)
- The compact size of only 55 x 55 x 51.5 mm^3 makes the Photonfocus MV1-D2048-3D03/04 cameras the perfect solution for applications in which space is at a premium
- Free GUI available (PF 3D Suite) for an easy system set up and visualisation of 3D scans

The basic components for 3D imaging consist of a laser line and a high speed CMOS camera in a triangular arrangement to capture images (profiles) from objects that are moved on a conveyor belt or in a similar setup (see Fig. 4.1 and Section 5.2.2).

☞ You can find more information on the basics of laser triangulation and on the principles of 3D image acquisition technique in the user manual "PF 3D Suite" available in the support area at www.photonfocus.com.

☞ This manual describes version 2.0 of the camera. A list with the functionality changes is available in Appendix B.

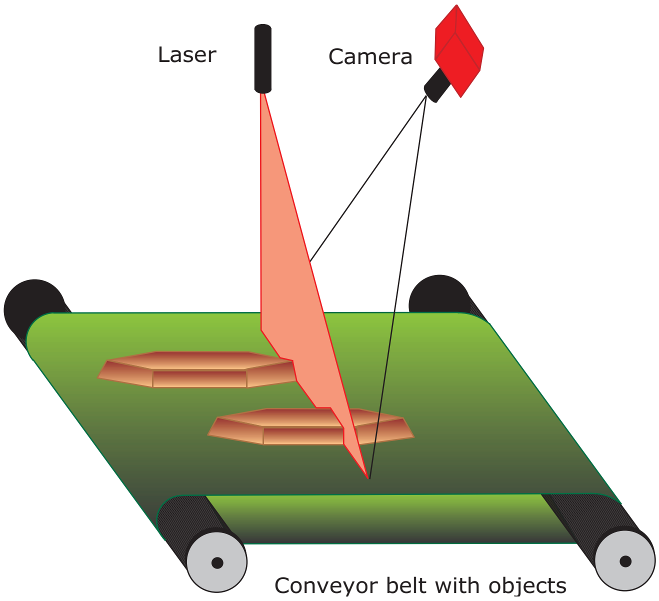

Figure 4.1: Triangulation principle with objects moved on a conveyor belt

Figure 4.2: Photonfocus MV1-D2048-3D03/04 camera series

4.2 Feature Overview

The general specification and features of the camera are listed in the following sections. The detailed description of the camera features is given in Chapter 5.

	MV1-D2048x1088-3D03-760 / MV1-D2048-3D04-760
Interface	Gigabit Ethernet, GigE Vision, GenICam
Camera Control	GigE Vision Suite / PF 3D Suite
Trigger Modes	External isolated trigger inputs / Software Trigger / PLC Trigger / AB Trigger
Features	Detection of up to 2 laser lines (peak detector)
	Linear Mode / multiple slope (High Dynamic Range)
	2D single line for 2D surface inspection and image overlay
	Grey level resolution 8 bit
	Region of Interest (ROI)
	Column Fixed Pattern Noise Correction for improved image quality
	Isolated inputs (2 single ended, 2 differential) and outputs (2 single ended)
	Trigger input / Strobe output with programmable delay
	A/B shaft encoder interface (RS-422 or HTL, depending on model)

Table 4.1: Feature overview (see Chapter 5 for more information)

4.3 Available Camera Models

☞ Please check the availability of a specific camera model on our website www.photonfocus.com.

Name	Sensor Resolution	Encoder Interface	Lens mount
MV1-D2048x1088-3D03-760-G2-8	2048 x 1088	RS-422	standard
MV1-D2048x1088-3D03-760-H2-8	2048 x 1088	HTL	standard
MV1-D2048x1088-3D03-760-G2-8-S10	2048 x 1088	RS-422	Scheimpflug 10°
MV1-D2048x1088-3D03-760-H2-8-S10	2048 x 1088	HTL	Scheimpflug 10°
MV1-D2048-3D04-760-G2-8	2048 x 2048	RS-422	standard
MV1-D2048-3D04-760-H2-8	2048 x 2048	HTL	standard
MV1-D2048-3D04-760-G2-8-S10	2048 x 2048	RS-422	Scheimpflug 10°
MV1-D2048-3D04-760-H2-8-S10	2048 x 2048	HTL	Scheimpflug 10°

Table 4.2: Available Photonfocus MV1-D2048-3D03/04 camera models (all with C-Mount)

4.4 Technical Specification

	MV1-D2048x1088-3D03-760	MV1-D2048-3D04-760
Sensor	CMOSIS CMV2000	CMOSIS CMV4000
Technology	CMOS active pixel	
Scanning system	progressive scan	
Optical format / diagonal	2/3” (12.75 mm diagonal)	1” (15.92 mm diagonal)
Sensor resolution	2048 x 1088 pixels	2048 x 2048 pixels
Pixel size	5.5 μm x 5.5 μm	
Active optical area	11.26 mm x 5.98 mm	11.26 mm x 11.26 mm
Full well capacity	11 ke$^-$	
Spectral range standard sensor	< 350 to 900 nm (to 10 % of peak responsivity)	
Spectral range of (I) models	< 350 to 970 nm (to 10 % of peak responsivity)	
Spectral range of colour models	390 to 670 nm (to 10 % of peak responsivity)	
Conversion gain	0.075 LSB/e$^-$	
Sensitivity	5.56 V / lux.s (with micro lenses @ 550 nm)	
Optical fill factor	42 % (without micro lenses)	
Dark current	125 e$^-$/s @ 25°C	
Dynamic range	60 dB	
Micro lenses	Yes	
Colour format	monochrome	
Characteristic curve	Linear, Piecewise linear (multiple slope)	
Shutter mode	global shutter	
Bit depth	8 bit	
Maximal frame rate	see Section 5.3	
Digital Gain	0.1 to 15.99 (Fine Gain)	
Exposure Time	13 μs ... 0.349 s / 20.8 ns steps	26 μs ... 0.349 s / 20.8 ns steps

Table 4.3: General specification of the MV1-D2048-3D03/04 cameras

Fig. 4.3 shows the quantum efficiency curve of the CMV2000/4000 sensor from CMOSIS measured in the wavelength range from 400 nm to 1000 nm.

	MV1-D2048-3D03/04 cameras
Operating temperature	0°C ... 40°C
Camera power supply	+12 V DC (- 10 %) ... +24 V DC (+ 10 %)
Trigger signal input range	+5 .. +30 V DC
Typical power consumption	< 6 W
Lens mount	C-Mount
Dimensions	55 x 55 x 51.5 mm^3
Mass	260 g
Conformity	CE, RoHS, WEEE

Table 4.4: Physical characteristics and operating ranges

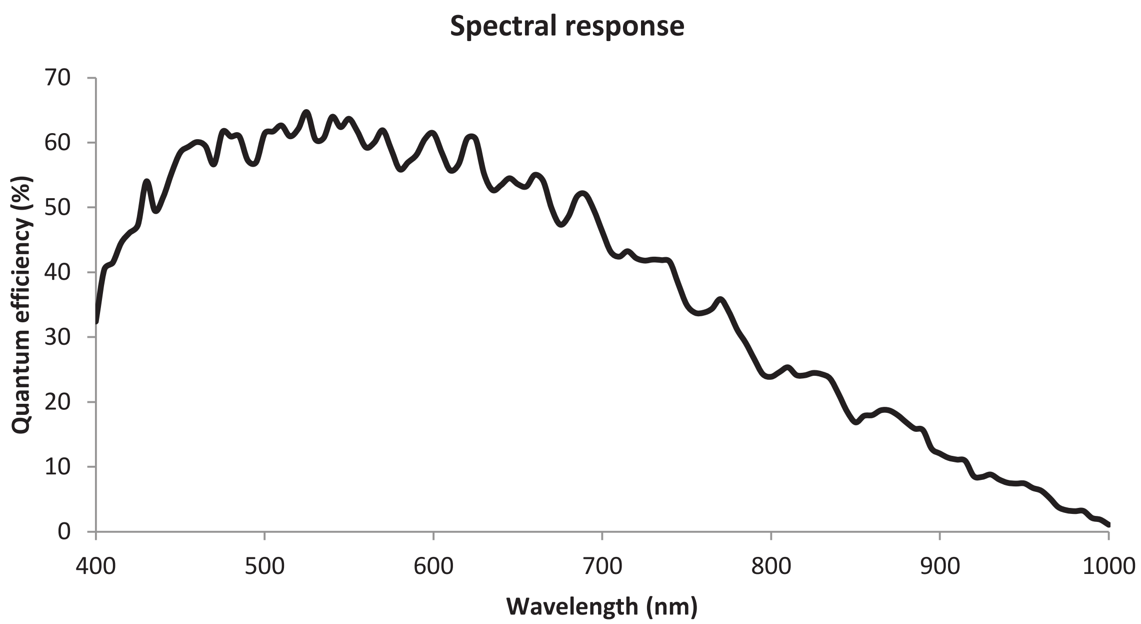

Figure 4.3: Spectral response of the CMV2000/4000 CMOS image sensor (with micro lenses)

5 Functionality

5.1 Introduction

This chapter serves as an overview of the camera configuration modes and explains camera features. The goal is to describe what can be done with the camera. The setup of the MV1-D2048-3D03/04 cameras is explained in later chapters.

5.2 3D Features

5.2.1 Overview

The MV1-D2048-3D03/04 cameras contain a very accurate laser line detector for laser triangulation (measurement of 3D profiles) that extracts 3D information in real time. For more details see Section 5.2.4.

The camera should be placed so that the laser line is located in horizontal direction. The outputs of the laser detector (peak detector) are the location coordinate of the laser line, the width of the laser line and the grey value of the highest grey value inside the laser line (see Section 5.2.3).

The camera has a special mode (see 2D&3D mode in Section 5.2.5) for setup and debugging purposes that allows to view the image and the detected laser line in the same image.

It is possible to detect one or two laser lines on different parts of the image sensor. This allows to handle some setups with only one camera where normally two cameras are required (see Triangulation setups 5 to 7 in Section 5.2.2).

For every laser peak, one complete image row is transmitted in high speed (3Donly) mode. This image row can be used for surface inspection or to produce a 2D overlay image.

5.2.2 Measuring Principle

For a triangulation setup a laser line generator and a camera is used. There are several configurations which are used in the laser triangulation applications. Which setup is used in an application is determined by the scattering of the material to be inspected. There are setups for highly scattering materials and others for nearly reflecting surfaces.

In addition the penetration depth of light depends on the wavelength of light. The longer the wavelength the deeper is the penetration of the light. Historically red line lasers with a wavelength around 630 nm were used. With the modern high power semiconductor line laser in blue (405 nm), green and also in the near infrared there is the possibility to adapt the wavelengths due to the inspection needs.

But not only the penetration depth affects the choice of the wavelength of the line laser. For an accurate measurement other disturbing effects as radiation or fluorescence of the object or strong light from neighbourhood processes have to be suppressed by optical filtering and an appropriate selection of the laser wavelength. Hot steel slabs for instance are best inspected with blue line laser because of the possibility to separate the laser line with optical filters from temperature radiation (Planck radiation) which occurs in red and NIR.

The accuracy of the triangulation system is determinate by the line extracting algorithm, the optical setup, the quality parameters of the laser line generator and the parameters of the lens which makes optical engineering necessary.

Triangulation Setup 1

In this setup the camera looks with the viewing angle α on the laser line projected from the top. A larger angle leads to a higher resolution. With larger angles the range of height is reduced. Small angles have the benefit of little occlusions.

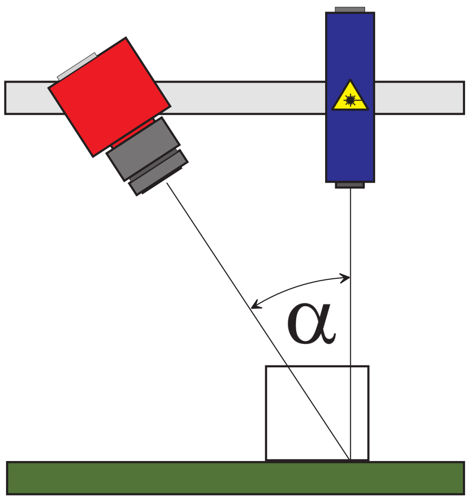

Figure 5.1: Triangulation setup 1

Triangulation Setup 2

This setup shows an opposite configuration of the laser line and the camera. The resolution at same triangulation angle is slightly higher but artifacts which occur during the measurement at borders of the object have to be suppressed by software.

Triangulation Setup 3

In this setup the laser line generator and the camera are placed in a more reflecting configuration. This gives more signal and could be used for dark or matte surfaces. In case of reflecting surfaces there is only a little amount of scattering which can be used as signal for triangulation. Also in this case this triangulation setup helps to get results.

Triangulation Setup 4

In contrast to the setup before this setup is used for high scattering material or for application where strong reflections of the object have to be suppressed. The resolution is reduced due to the relations of the angles α and β.

Triangulation Setup 5a

The 3D03 camera has the possibility to detect and determine two laser lines. This gives the possibility to build up a triangulation setup with two laser lines and one camera to avoid

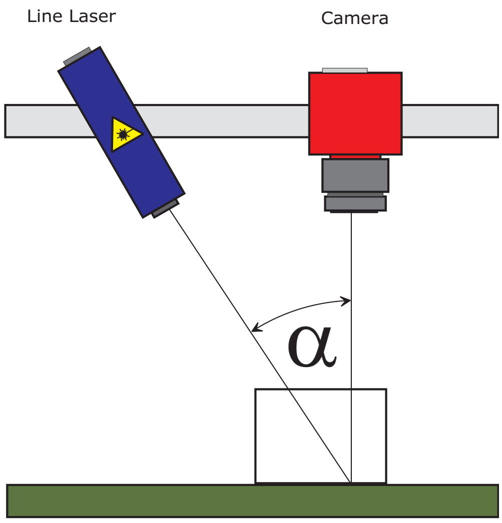

Figure 5.2: Triangulation setup 2

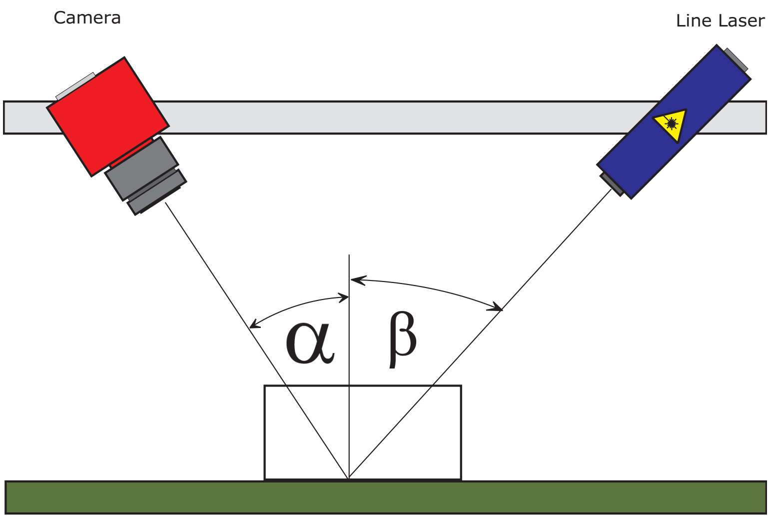

Figure 5.3: Triangulation setup 3

occlusions. To reduce the calibration effort a setup with equal angles for the laser lines is beneficial but not mandatory.

Triangulation Setup 5b

Similar setup to Triangulation Setup 5a, but the angles of the camera and the laser are not equal.

Triangulation Setup 6

The possibility to examine two lines gives the possibility to use the MV1-D2048-3D03/3D04 camera in setups to measure the thickness of glasses or other transparent materials. Additional reflexes which occur in such setups could be suppressed by appropriate ROI settings and geometric arrangements.

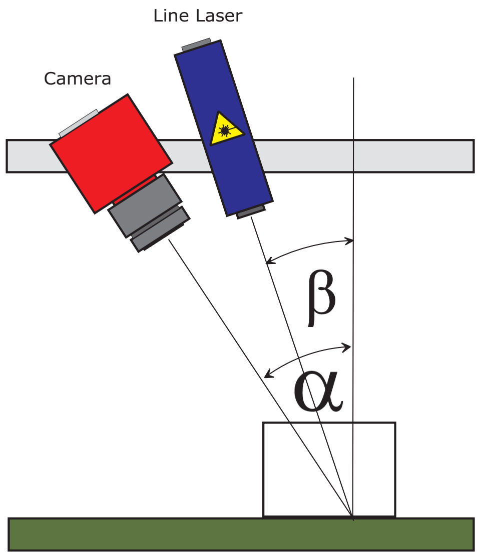

Figure 5.4: Triangulation setup 4

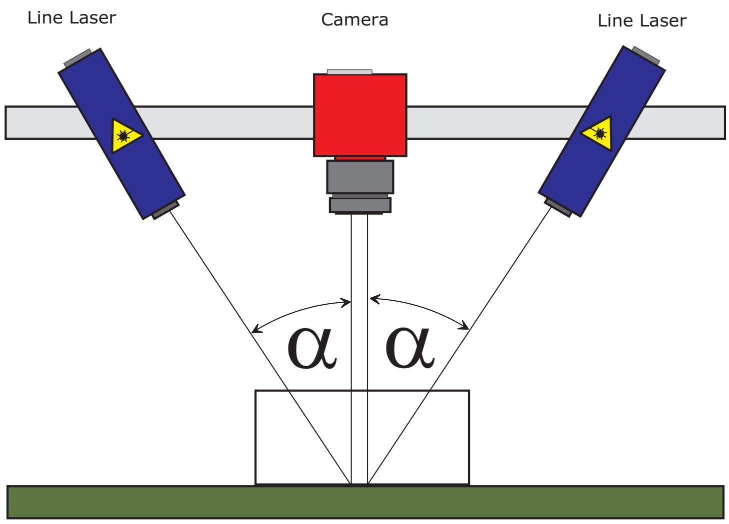

Figure 5.5: Triangulation setup 5a

Triangulation Setup 7

The two line detection could also be used to eliminate vibrations and elastic deformations of the inspected work piece. This is often used in fast profile scanners where the profile guidance is on the limits. Vibrations and elastic deformations could be detected by interpreting the local height gradients of the two laser lines during inspection. A change in the 3D profile, for instance a shape defect, always gives a change in the local gradient, whereas a vibration or elastic deformations does not. This fact can be used in software algorithms to compensate vibration effects and increase the accuracy of the measurements.

5.2.3 Laser Line Detection

The laser line detector takes a threshold value as its input. The threshold has two purposes:

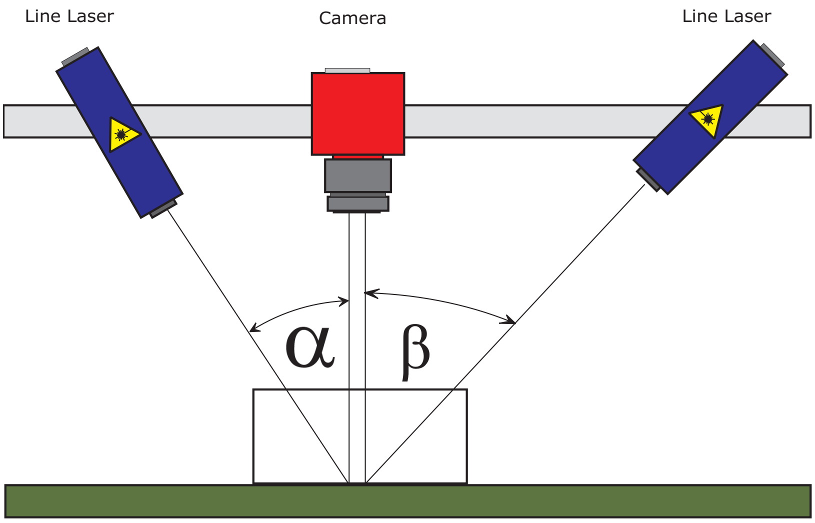

Figure 5.6: Triangulation setup 5b

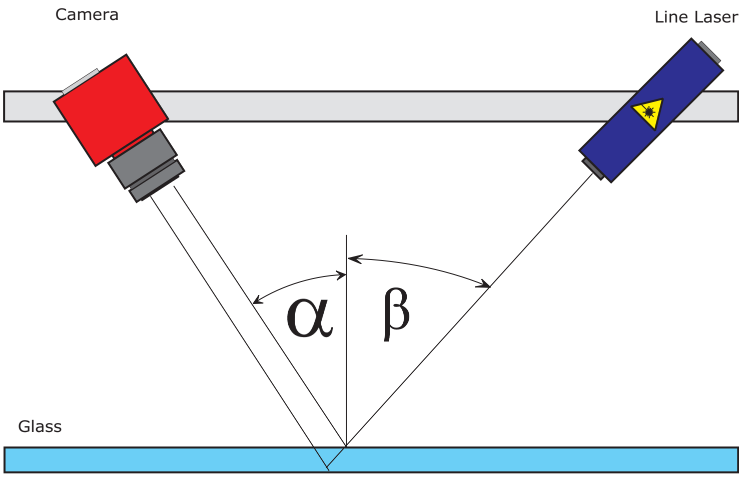

Figure 5.7: Triangulation setup 6

- All pixels with grey value below the threshold value will be ignored. This filters out the image background.
- The value 2*threshold is used in the calculation of the laser line width and height (see below).

The output values are calculated column wise (see also Fig. 5.9):

Peak coordinate Vertical coordinate of the laser line peak

Laser line width The laser line width is the number of pixels that have a grey value above 2*threshold around the laser peak. If there are no pixels inside the laser line that have a grey level above 2*threshold, then the laser line width is 0. In this case the threshold value should be changed.

Laser line height The laser line height is the highest grey value of the detected laser line. If there are no pixels inside the laser line that have a grey level above 2*threshold, then the height is set to threshold. In this case the threshold value should be changed.

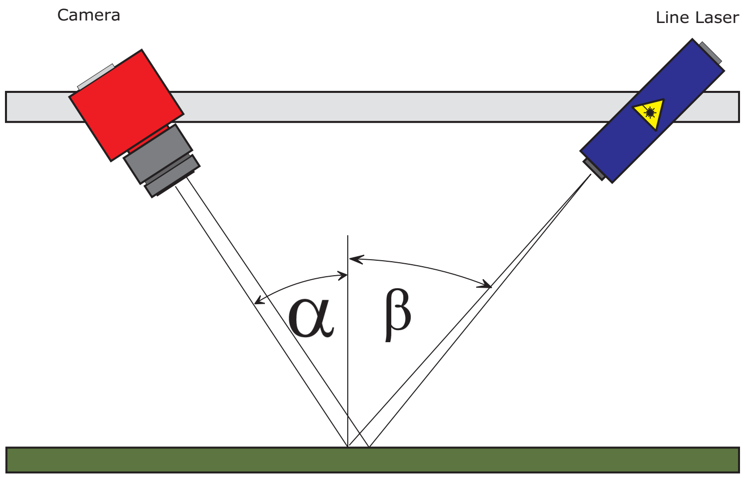

Figure 5.8: Triangulation setup 7

The value of the threshold should be set slightly above the grey level of the image background. However, the value 2*threshold should be smaller than the highest grey level inside the laser line, otherwise the laser line width and height are not correctly calculated.

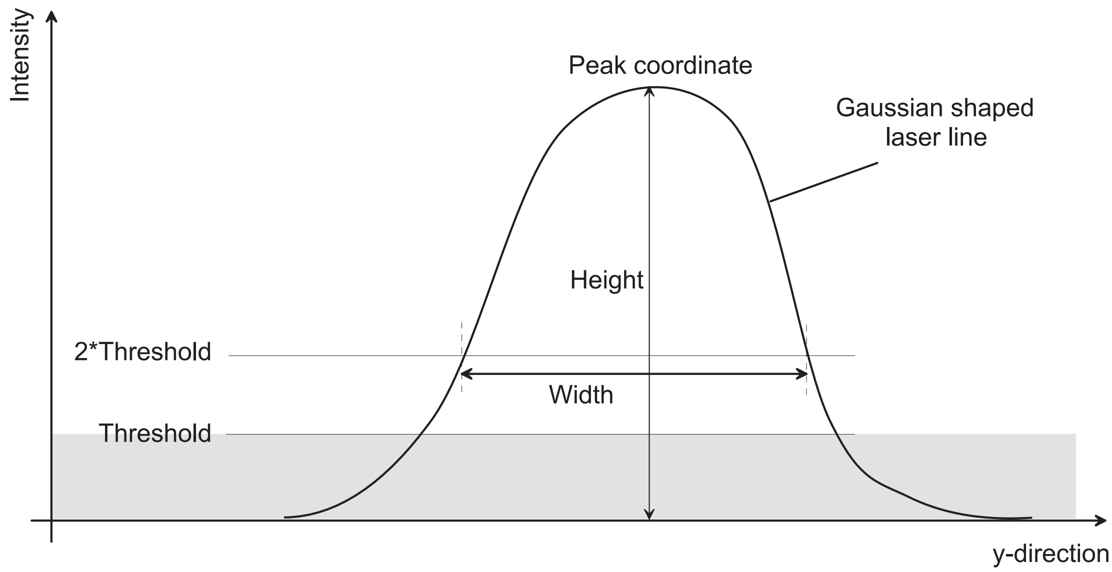

Figure 5.9: Schematic of laser line

5.2.4 Interpolation Technique

Structured light based systems crucially rely on an accurate determination of the peak position of the Gaussian shaped laser line. The Peak Detector algorithm in the MV1-D2048-3D03/04 cameras applies nonlinear interpolation techniques, where 64 data points are calculated between two pixels within the Gaussian shaped laser line. This technique is superior to other commonly used detection techniques, such as the detection of peak pixel intensity across the laser line (resulting in pixel accuracy) or the thresholding of the Gaussian and calculation of the average (resulting in sub pixel accuracy).

The nonlinear interpolation technique used in the Peak Detector algorithm results in a better estimate of the maximum intensity of the laser line. The data mapping for the 3D data block is shown in Section 5.2.9 and the basics of the interpolation principle are illustrated in Fig. 5.10.

The line position (PEAK) is split into a coarse position and a fine position (sub-pixel). The coarse position is based on the pixel pitch and is transferred in PEAK [15:6] (PEAK[15:4] in 3D04). The sub-pixel position that was calculated from the Peak Detector algorithm (6 bit sub-pixel information in 3D03, 4 bit sub-pixel in 3D04) is mapped to PEAK [5:0] (PEAK[3:0] in 3D04) (see also Section 5.2.9).

Fig. 5.11 shows a comparison of the peak detector algorithm of the MV1-D2048-3D03/04 cameras against the Center Of Gravity (COG) algorithm that is used in most triangulation systems. It can clearly be observed that the Peak Detector algorithm gives more accurate results.

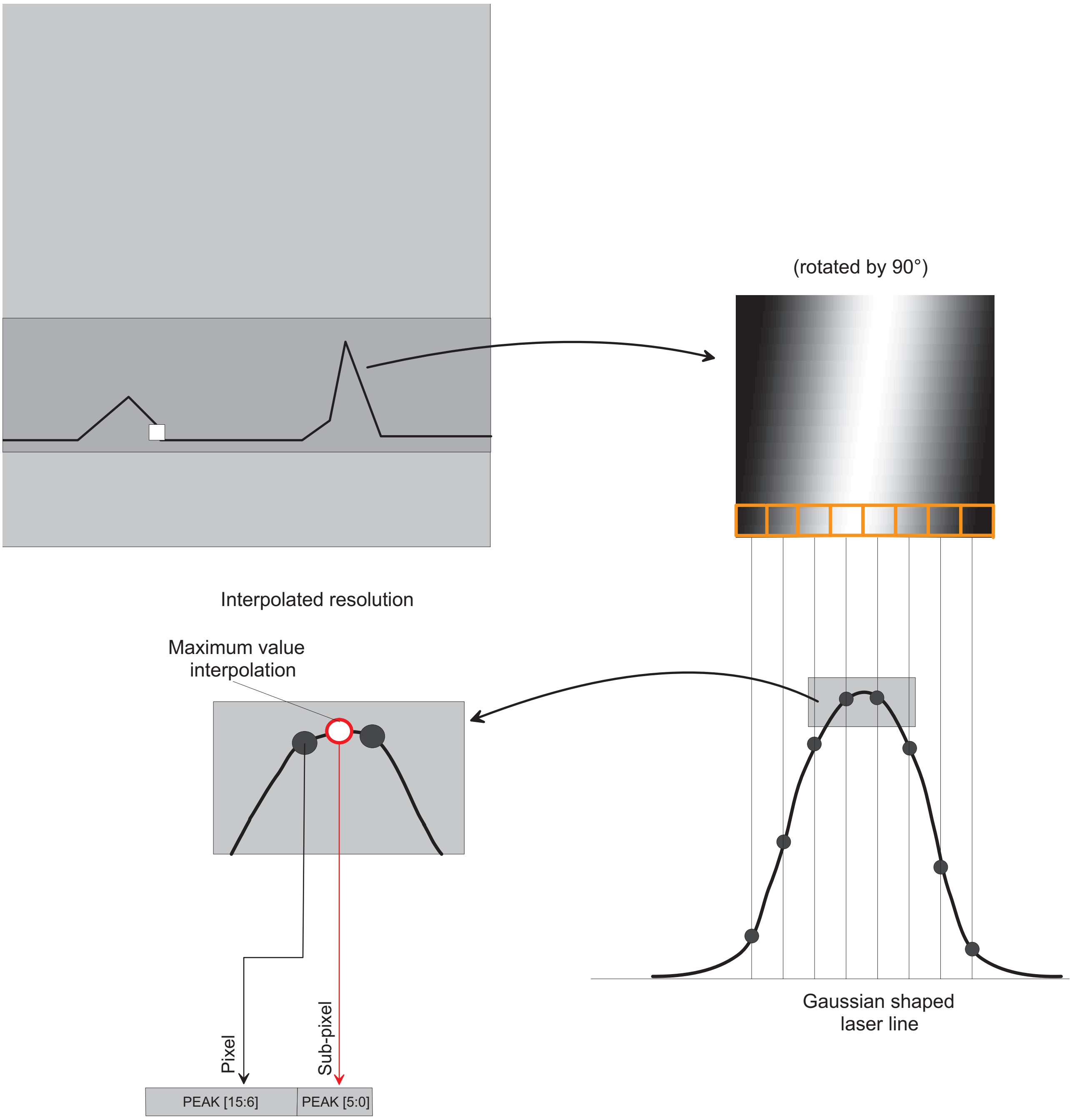

Figure 5.10: Interpolation technique provides sub-pixel accuracy in the detection of the laser peak by interpolating up to 64 data points between two pixels.

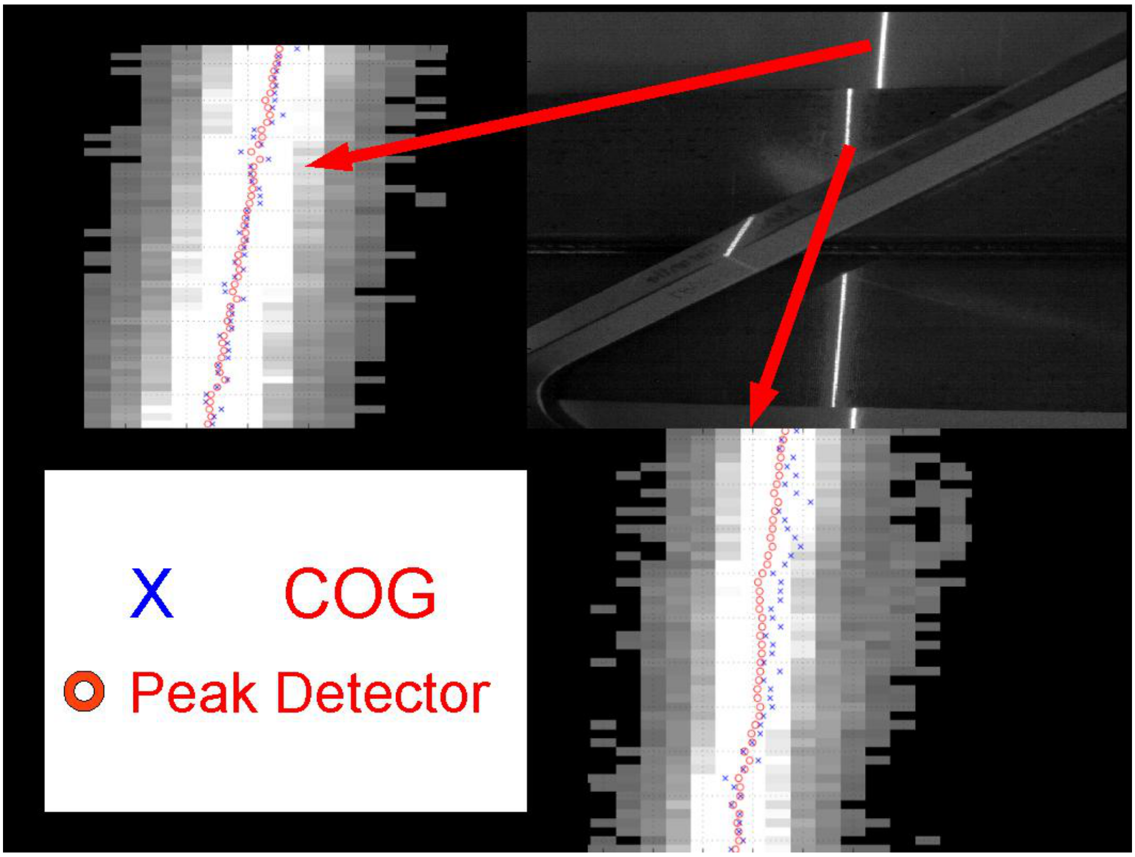

Figure 5.11: Comparison of peak detector algorithm against COG algorithm

5.2.5 3D modes

The camera has three modes that determine which data is transmitted to the user:

2Donly Laser detection is turned off and camera behaves as a normal area scan camera. This mode serves as a preview mode in the setup and debugging phase.

2D&3D Laser line detection is turned on. The sensor image (2D image) is transmitted together with the 3D data. In the PF 3D Suite, the detected laser line is shown as a coloured line in the 2D image. This mode serves as a preview mode in the setup and debugging phase of the triangulation system.

3Donly Laser line detection is turned on and only 3D data plus an additional image row is transmitted. The scan rate of this mode is considerably faster than the 2D&3D mode.

☞ The 3Donly mode must be used to achieve the highest scan rate.

5.2.6 Peak Mirror

The property `Peak[i]_Mirror` modifies the output coordinates of peak [i] to Peak[i]_3DH-p[i]-1, where Peak[i]_3DH=height of scan area for peak [i] and p[i] detected laser position for peak [i]. PeakMirror can be enabled for each of the 2 peaks individually.

In single peak mode, PeakMirror has roughly the same effect regarding the detected 3D positions as rotating the camera by 180°.

In dual peak mode, depending geometrical setup of the camera and the lasers, the orientation of the positions can be different on each peak scan area: e.g. in peak scan area 0, a bigger position value might indicate a bigger object height, whereas in peak scan area 1, a smaller position value might indicate a bigger height. The PeakMirror property can be set for one peak to obtain the same orientation for both scan areas.

5.2.7 Single / Dual Peak

It is possible to detect one or two laser lines on different parts of the image sensor (parameter PeakDetector_NrOfPeaks). In dual peak mode (PeakDetector_NrOfPeaks=2) the image sensor can be divided in two scan areas (see Fig. 5.12). The first laser line (laser line 0) must be located in the scan area 0 and the second laser line in the scan area 1. The location and size of the scan areas can be chosen by the user (see also Section 5.3.2).

5.2.8 2D Line

For many tasks it is required or beneficial to have a 2D image of the scanned object. The MV1-D2048-3D03/04 cameras transmit one image row for every laser peak (see Fig. 5.12). A complete 2D image can be obtained by joining the 2D lines. The vertical position of the 2D lines can be set by the user (property `Peak[i]_2DY`, replace [i] by 0 or 1).

The illumination outside the laser scan area is normally low. A digital gain (property `Peak[i]_Gain`) and offset (property `Peak[i]_DigitalOffset`) can be set for the 2D lines to have an image with enough light intensity.

The 2D lines must not be placed inside a laser peak scan area, otherwise the peak detection will be seriously affected.

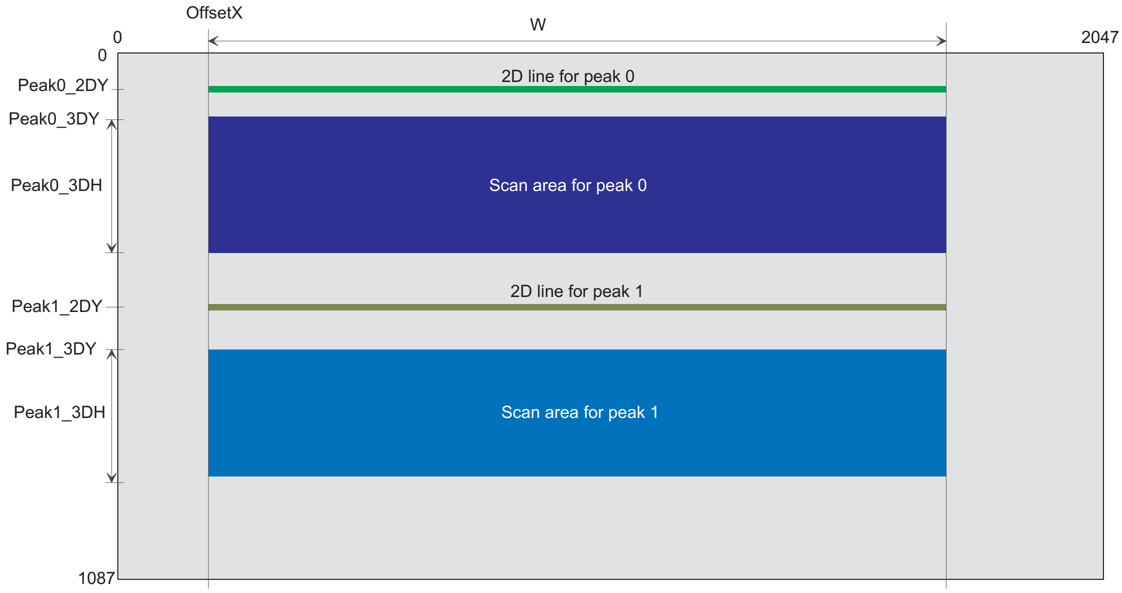

Figure 5.12: ROI definition in 3D modes

5.2.9 3D data format

Cameras with version 2.1 and later have an additional property `DataFormat3D` which has an effect on the organisation of the 3D data. Camera prior to this version have always `DataFormat3D`=0, although this property is not available.

For every peak there are 4 additional lines that contain the 3D data. Every pixel contains 8 bits of 3D data which are always placed in the 8 LSB. A table with the bit assignment of the 3D data for `DataFormat3D`=0 is shown in Fig. 5.13 and with `DataFormat3D`=1 in Fig. 5.14. The peak position coordinate (PEAK) is relative to the scan area of the peak. To get the absolute position on the image sensor, the value Peak0_3DY must be added for peak 0 (Peak1_3DY must be added for peak 1).

LL_HEIGHT and LL_WIDTH values are explained in Fig. 5.13 and in Fig. 5.14.

STAT value: the status (value) of some parameters and internal registers are placed here. The status information is described in Section 5.10.2. In every pixel (column) 4 bits of this status information send, starting with the LSB in the first column.

3D row	Bits								Description
	7	6	5	4	3	2	1	0	
0	PEAK[15:8]								Peak detector (laser line) coordinate. 3D03 cameras: PEAK[15:6]: integer part, PEAK[5:0]: fractional part. 3D04 cameras: PEAK[15:4]: integer part, PEAK[3:0]: fractional part
1	PEAK[7:0]								
2	'0'	'0'	LL_WIDTH[5:0]						LL_WIDTH: laser line width
3	LL_HEIGHT[3:0]				STAT				LL_HEIGHT: highest grey value inside the laser line (4 MSB). STAT: Status information

Figure 5.13: 3D data format, DataFormat3D=0

3D row	Bits								Description
	7	6	5	4	3	2	1	0	
0	PEAK[15:8]								Peak detector (laser line) coordinate. 3D03 cameras: PEAK[15:6]: integer part, PEAK[5:0]: fractional part. 3D04 cameras: PEAK[15:4]: integer part, PEAK[3:0]: fractional part
1	PEAK[7:0]								
2	LL_HEIGHT[7:0]								LL_HEIGHT: highest grey value inside the laser line (8 bit).
3	LL_WIDTH[3:0]				STAT				LL_WIDTH: laser line width (4 MSB). Width of laser line is 4*LL_WIDTH STAT: Status information

Figure 5.14: 3D data format. DataFormat3D=1

Calculation example (DataFormat3D=0, 3D03 models): Suppose that the 3D data of image column n has the following data: 14 / 176 / 10 / 128 (see also Fig. 5.15).

The position of the laser line is in this case 58.75: integer part is calculated from the 8 bits of 3D row 0 followed by the 2 MSB of 3D row 1: 0b0000111010 = 0x03a = dec 58. The fractional part is calculated from the 6 LSB of 3D row 1: 0b110000 = 0x30. This value must be divided by 64: 0x30 / 64 = 0.75.

The laser line width is 10 pixels (6 LSB of 3D row 2).

The LL_HEIGHT value is in this case 8 (=4 MSB of 3D row 3). This means that the 4 MSB of the highest gray value have the value 8. At 12 bit resolution, the highest gray value lies between 0x800 (=2048) and 0x8ff (=2303).

3D row	Bits								
	7	**6**	**5**	**4**	**3**	**2**	**1**	**0**	
0	0	0	0	0	1	1	1	0	Position integral part
1	1	0	1	1	0	0	0	0	Position fractional part
2	0	0	0	0	1	0	1	0	Laser line width
3	1	0	0	0	0	0	0	0	

LL_HEIGHT

Figure 5.15: 3D data calculation example (3D03 models)

5.2.10 Transmitted data in 2D&3D mode

The transmitted image in 2D&3D mode is shown in Fig. 5.16. The data is transmitted in the following order:

- Scan area for peak 0
- Scan area for peak 1 (omitted if PeakDetector_NrOfPeaks=1)
- 2D line for peak 0
- 3D data for peak 0
- 2D line for peak 1 (omitted if PeakDetector_NrOfPeaks=1)
- 3D data for peak 1 (omitted if PeakDetector_NrOfPeaks=1)

Resulting height in 2D&3D mode is:

Hres = Peak0_3DH + 5 (if PeakDetector_NrOfPeaks=1), or

Hres = Peak0_3DH + Peak1_3DH + 10 (if PeakDetector_NrOfPeaks=2)

5.2.11 Transmitted data in 3Donly mode

In 3Donly mode only the 2D lines and the 3D data is transmitted. The FrameCombine feature (see Section 5.2.12) was added to lower the transmitted frame rate. For FrameCombine = f, the data for f images are combined into one image.

Resulting height in 3Donly mode is therefore:

Hres = f * 5 (if PeakDetector_NrOfPeaks=1), or

Hres = f * 10 (if PeakDetector_NrOfPeaks=2)

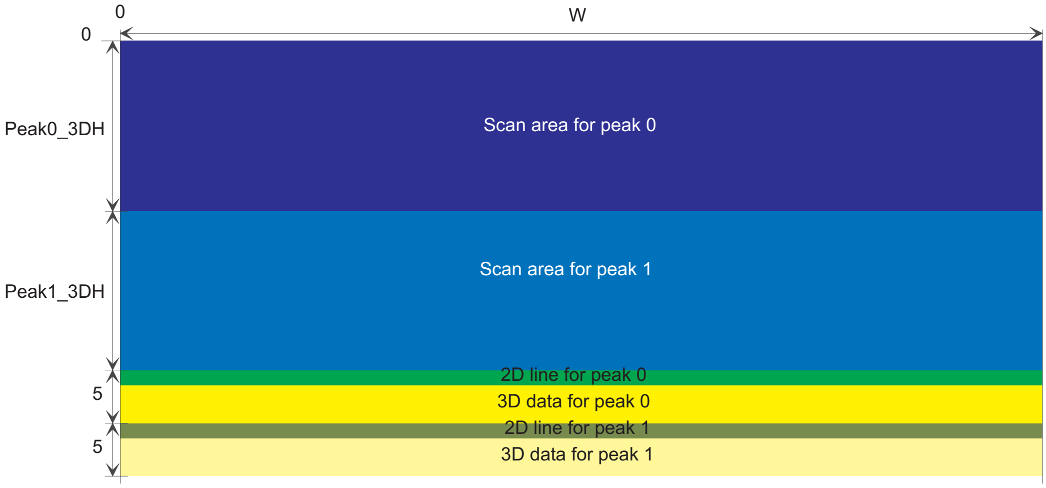

Figure 5.16: Transmitted image in 2D&3D mode

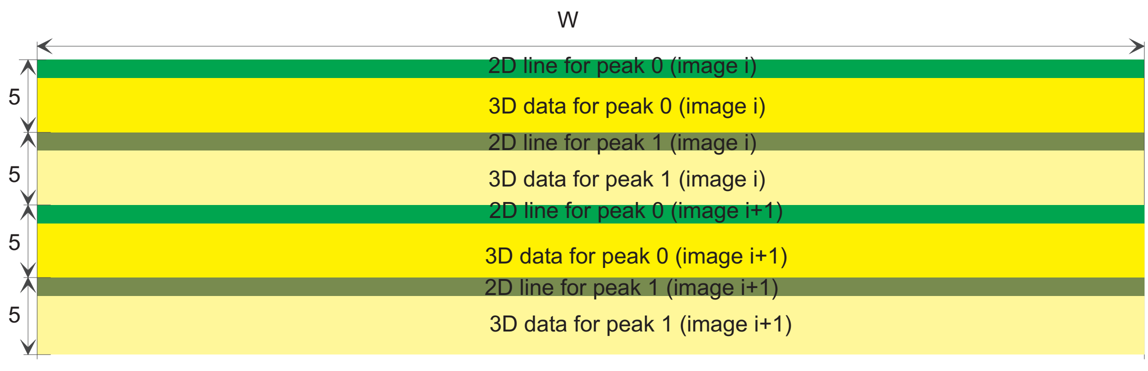

Figure 5.17: Transmitted image in 3Donly mode with FrameCombine=2

5.2.12 Frame Combine

Very high frame rates, that are well over 1000 fps, can be achieved in 3Donly mode. Every frame (image) activates an interrupt in the GigE software which will issue a high CPU load or the frame rate can not be handled at all by an overload of interrupts.

To solve this issue, the FrameCombine mode has been implemented in the MV1-D2048-3D03/04 camera. In this mode, the data of f images are bundled into one frame. In the example shown in Fig. 5.18 4 frames are combined into one frame (`FrameCombineNrFrames`=4). In this case there are 4 times less software interrupts that indicate a new frame than without FrameCombine and the CPU load is significantly reduced. Instead of receiving 4 images with 5 rows, only one image with 20 rows is received which reduces the frame rate that sees the computer. Without FrameCombine, the CPU load on the computer might be too high to receive all images and images might be dropped. The value f (=FrameCombineNrFrames) can be set by the user. This value should be set so that the resulting frame rate is well below 1000 fps (e.g. at 100 fps). E.g. if the camera shows a maximal frame rate of 4000 (property `AcquisitionFrameRateMax`), then `FrameCombineNrFrames` could be set to 40 to have a resulting frame rate of 100 fps. Another example of FrameCombineNrFrames=2 is shown in Fig. 5.17. The PF 3D Suite supports this mode.

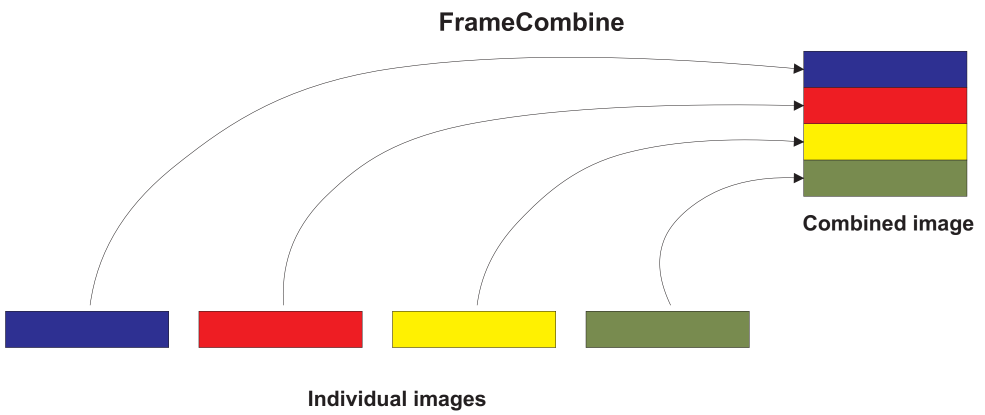

Figure 5.18: Example for FrameCombine with 4 frames

Frame Combine Timeout

There exist possibilities to transmit the combined frame even if there is not enough data to fill it. E.g. It can be desirable to get the 3D data immediately after an item on the conveyor belt has passed.

FrameCombine_Timeout A timeout can be specified after which the combined frame will be transmitted, regardless if there was enough data to fill it. The timeout counter is reset after each frame and counts until a new trigger has been detected or until the timeout is reached.

☞ A FrameCombine_Timeout value of 0 disables the FrameCombine timeout feature.

FrameCombine_ForceTimeout The transmission of the combined frame is forced by writing to the `FrameCombine_ForceTimeout` property.

When the FrameCombine is finished by a timeout, then the remaining data in the combined frame will be filled with filler data: the first two pixels of every filler row have the values 0xBB (decimal 187) and 0x44 (decimal 68). The remaining pixels of the filler rows have the value 0. If looking at the 3D data, the filler rows seem to have the following values (applying the filler values to the 3D data format): the peak positions of the first column is 750.921875, of the second column 243.0625 and of the remaining columns 0. The laser line width of the first column is 59, of the second column 4 and of the remaining columns 0. LL_HEIGHT is 11 for the first column, 4 for the second column and 0 for the remaining columns. Status information: the image counter is 75 and the remaining status information is 0.

☞ The FrameCombine mode is only available in 3Donly mode.

☞ When acquisition is stopped, then a pending combined frame will be discarded. To get the pending combined frame, a `FrameCombine_ForceTimeout` command must be sent prior to stopping the acquisition.

5.2.13 Peak Filter

Peaks that are detected by the PeakDetector algorithm can be filtered by applying the parameters described in this section. A filtered peak appears as all 3D data set to 0, which is the same as if no peak occurred.

Filtering peaks might increase the robustness of the 3D application by filtering peaks that were caused by unwanted effects, such as reflections of the laser beam. The PeakFilter parameters can be set for each of the two peaks individually.

PeakFilter parameters (replace [i] by 0 or 1):

Peak[i]_EnPeakFilter Enable peak filtering for peak [i]. If set to False, the PeakFilter settings are ignored.

Peak[i]_PeakFilterHeightMin Filters all peaks (columns) where 256*LL_HEIGHT < Peak[i]_PeakFilterHeightMin (see Fig. 5.13 and Fig. 5.19).

Peak[i]_PeakFilterHeightMax Filters all peaks (columns) where 256*LL_HEIGHT > Peak[i]_PeakFilterHeightMax (see Fig. 5.13 and Fig. 5.19).

Peak[i]_PeakFilterWidthMin Filters all peaks (columns) where LL_WIDTH < Peak[i]_PeakFilterWidthMin (see Fig. 5.13 and Fig. 5.20).

Peak[i]_PeakFilterWidthMax Filters all peaks (columns) where LL_WIDTH > Peak[i]_PeakFilterWidthMax (see Fig. 5.13 and Fig. 5.20).

An illustration of the PeakFilterHeight parameters is shown in Fig. 5.19. The red line denotes a situation where the laser peak is filtered because the height is too big or too small. An illustration of the PeakFilterWidth parameters is shown in Fig. 5.20. The red line denotes a situation where the laser peak is filtered because the width is too big or too small.

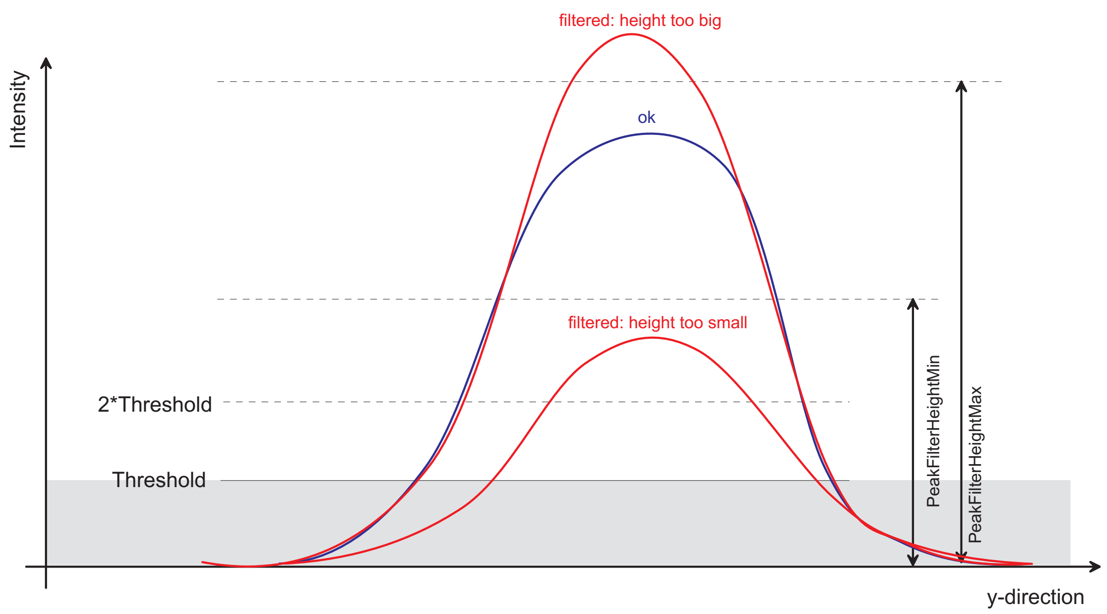

Figure 5.19: Illustration of the PeakFilterHeight parameters

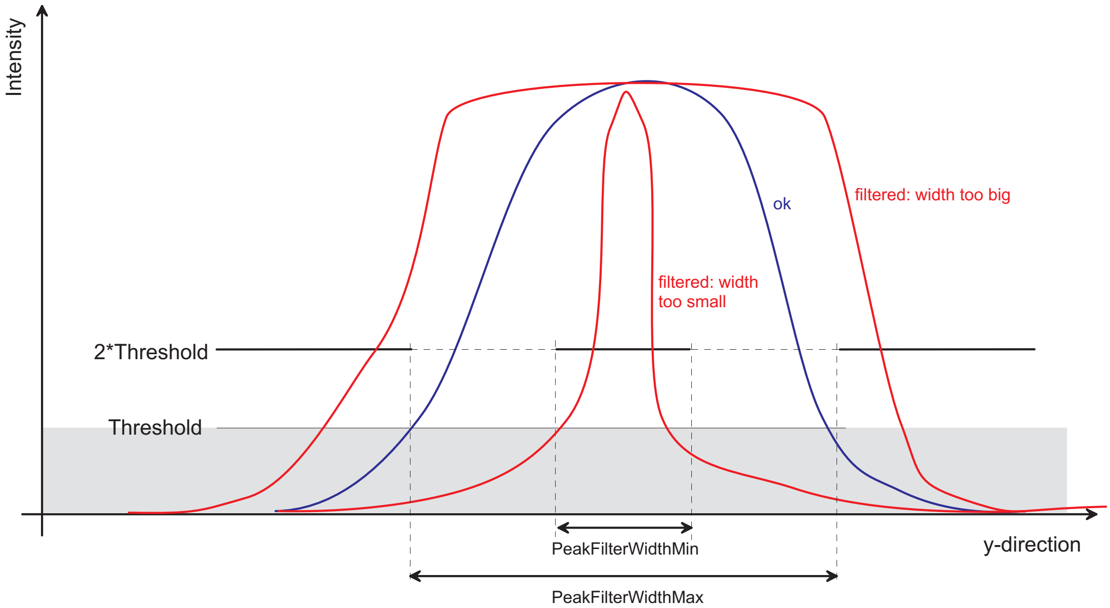

Figure 5.20: Illustration of the PeakFilterWidth parameters

5.2.14 Absolute Coordinates

☞ The "absolute coordinates" feature is available in camera revision 2.2 and later.

The 3D coordinates are given relative to the start of the 3D ROI as a default.

When the property `Peak[i]_EnAbsCoordinate` is set to True for peak i then the 3D coordinates are given relative to the value of the property `Peak[i]_AbsCoordinateBase`. This is useful if the 3D-ROI is not kept constant.

Example: `Peak0_EnAbsCoordinate` = True, `Peak0_AbsCoordinateBase` = 0, `Peak0_3DY`=200: If the peak is detected in row 50 of the ROI, the value 250 (50+Peak0_3DY) would be given as resulting 3D coordinate.

☞ The value of `Peak[i]_AbsCoordinateBase` must fulfill the following conditions: (`Peak[i]_AbsCoordinateBase` <= `Peak[i]_3DY`) and (`Peak[i]_AbsCoordinateBase` + 1024 >= `Peak[i]_3DY` + `Peak[i]_3DH`).

MirrorPeak and absolute coordinates

If`Peak[i]_Mirror` =True and `Peak[i]_EnAbsCoordinate` = True then the formula to calculate the 3D coordinate is:

c’ = `MAX_H` + `Peak[i]_AbsCoordinateBase` - `Peak[i]_3DY` - c - 1,

where `c` is the original (relative) coordinate without mirroring. `MAX_H`=1024 for 3D03 and `MAX_H`=2048 for 3D04. This is the same as mirroring in a ROI with Y=`Peak[i]_AbsCoordinateBase` and H=`MAX_H`.

5.2.15 High speed mode

The High Speed Mode provides higher scanning speed at the cost of reduced data accuracy (see also Section 5.3.2 for a list of frame rates). The average loss in data accuracy is +/- 0.5 pixel.

☞ High speed mode is only available in 3Donly mode

☞ The High Speed feature is not available in all camera revisions (see Appendix B).

5.3 Reduction of Image Size

5.3.1 Region of Interest (ROI) (2Donly mode)

This section describes the ROI features in the 2Donly mode where the camera behaves as a standard area scan camera.

The maximal frame rate of the 2Donly mode is considerably lower than in the 3Donly mode.

Some applications do not need full image resolution. By reducing the image size to a certain region of interest (ROI), the frame rate can be drastically increased. A region of interest can be almost any rectangular window and is specified by its position within the full frame and its width and height. Table 5.1 shows some numerical examples of how the frame rate can be increased by reducing the ROI.

The ROI is determined by the following properties: OffsetX, Width, OffsetY, Height

Only reductions in height result in a higher frame rate.

ROI Dimension	MV1-D2048-3D03/04
2048 x 2048 [1)]	22 fps
2048 x 1088	42 fps
1280 x 1024 (SXGA)	45 fps
1280 x 768 (WXGA)	60 fps
800 x 600 (SVGA)	77 fps
640 x 480 (VGA)	96 fps
2048 x 256	178 fps

Table 5.1: Frame rates of different ROI settings in 2Donly mode (minimal exposure time) (Footnotes: [1)] MV1-D2048-3D04 models only)

5.3.2 Region of Interest (ROI) in 3D modes

The ROI definition in the 3Donly and 2D&3D modes is tailored to laser line detection.

The ROI is determined by the following properties: OffsetX, Width, Peak0_2DY, Peak0_3DY, Peak0_3DH and additionally if PeakDetector_NrOfPeaks=2, Peak1_2DY, Peak1_3DY and Peak1_3DH.

There is a high speed mode that provides higher scanning speed at the cost of reduced data accuracy (not available in all revisions, see Appendix B).

For every peak (laser line) there are two areas (see Fig. 5.12):

One row with 2D data from the image sensor (Peak<n>_2DY) and one area for the detection of the laser line <n> (n= 1 or 2) defined by the parameters Peak<n>_3DY, Peak<n>_3DH. These values can be freely set within the following limits:

1. All regions (2D lines and laser triangulation regions) must not overlap, i.e. no row should be read out more than once.
2. The minimal height of the laser triangulation region (Peak<n>_3DH) is 23 if one peak is used and 29 if two peaks are used.
3. The maximal height of the laser triangulation regions (Peak<n>_3DH) is 1024 for 3D03 cameras and 2016 for 3D04 cameras.

The maximal frame rates for the MV1-D2048x1088-3D03 camera series are shown in Table 5.2 (single peak mode) and in Table 5.3 (dual peak mode). The corresponding tables for the MV1-D2048-3D04 camera series are Table 5.4 and Table 5.5. "HS" refers to the HighSpeed mode (see also Section 5.2.15). The image (profile) width can be set by the user and does not impact the maximal frame rate.

Peak0_3DH	2D&3D mode	3Donly mode [1)]	3Donly mode HS [1)]
23	1440 fps	10200 fps	10200 fps
32	1130 fps	8180 fps	10200 fps
64	635 fps	4800 fps	8180 fps
128	338 fps	2630 fps	4800 fps
256	175 fps	1380 fps	2630 fps
512	90 fps	710 fps	1380 fps
1024	45 fps	360 fps	710 fps

Table 5.2: MV1-D2048x1088-3D03 Frame rates of different ROI settings in 3D single peak modes (minimal exposure time) (Footnotes: [1)] includes 1 user-selectable image row)

Peak0_3DH	Peak1_3DH	2D&3D mode	3Donly mode [1)]	3Donly mode HS [1)]
29	29	634 fps	5130 fps	5130 fps
32	32	586 fps	4740 fps	5130 fps
64	64	324 fps	2610 fps	4740 fps
128	128	171 fps	1370 fps	2610 fps
256	256	88 fps	700 fps	1370 fps
512	512	44 fps	358 fps	700 fps

Table 5.3: MV1-D2048x1088-3D03 Frame rates of different ROI settings in 3D dual peak modes (minimal exposure time) (Footnotes: [1)] includes 1 user-selectable image row for each peak)

Peak0_3DH	2D&3D mode	3Donly mode [1]	3Donly mode HS [1]
23	1340 fps	7730 fps	7730 fps
32	1060 fps	6510 fps	7730 fps
64	615 fps	4170 fps	6510 fps
128	330 fps	2430 fps	4220 fps
256	173 fps	1320 fps	2430 fps
512	88 fps	690 fps	1320 fps
1024	44 fps	360 fps	690 fps
2016	22 fps	180 fps	360 fps

Table 5.4: MV1-D2048-3D04 Frame rates of different ROI settings in 3D single peak modes (minimal exposure time) (Footnotes: [1] includes 1 user-selectable image row)

Peak0_3DH	Peak1_3DH	2D&3D mode	3Donly mode [1]	3Donly mode HS [1]
29	29	610 fps	4420 fps	4420 fps
32	32	570 fps	4130 fps	4420 fps
64	64	320 fps	2410 fps	4130 fps
128	128	170 fps	1320 fps	2410 fps
256	256	87 fps	690 fps	1320 fps
512	512	44 fps	350 fps	690 fps
1024	1024	22 fps	180 fps	350 fps

Table 5.5: MV1-D2048-3D04 Frame rates of different ROI settings in 3D dual peak modes 3D04(minimal exposure time) (Footnotes: [1] includes 1 user-selectable image row for each peak)

5.4 Trigger and Strobe

5.4.1 Trigger Source

The trigger signal can be configured to be active high or active low by the `TriggerActivation` (category `AcquisitionControl`) property. One of the following trigger sources can be used:

Free running The trigger is generated internally by the camera. Exposure starts immediately after the camera is ready and the maximal possible frame rate is attained, if `AcquisitionFrameRateEnable` is disabled. Settings for free running trigger mode: `TriggerMode` = Off. In Constant Frame Rate mode (`AcquisitionFrameRateEnable` = True), exposure starts after a user-specified time has elapsed from the previous exposure start so that the resulting frame rate is equal to the value of `AcquisitionFrameRate`.

Software Trigger The trigger signal is applied through a software command (`TriggerSoftware` in category `AcquisitionControl`). Settings for Software Trigger mode: `TriggerMode` = On and `TriggerSource` = Software.

Line1 Trigger The trigger signal is applied directly to the camera by the power supply connector through pin ISO_IN1 (see also Section A.1). A setup of this mode is shown in Fig. 5.21 and Fig. 5.22. The electrical interface of the trigger input and the strobe output is described in Section 6.6. Settings for Line1 Trigger mode: `TriggerMode` = On and `TriggerSource` = Line1.

PLC_Q4 Trigger The trigger signal is applied by the Q4 output of the PLC (see also Section 6.7). Settings for PLC_Q4 Trigger mode: `TriggerMode` = On and `TriggerSource` = PLC_Q4.

ABTrigger Trigger from incremental encoder (see Section 5.4.8).

☞ Some trigger signals are inverted. A schematic drawing is shown in Fig. 7.4.

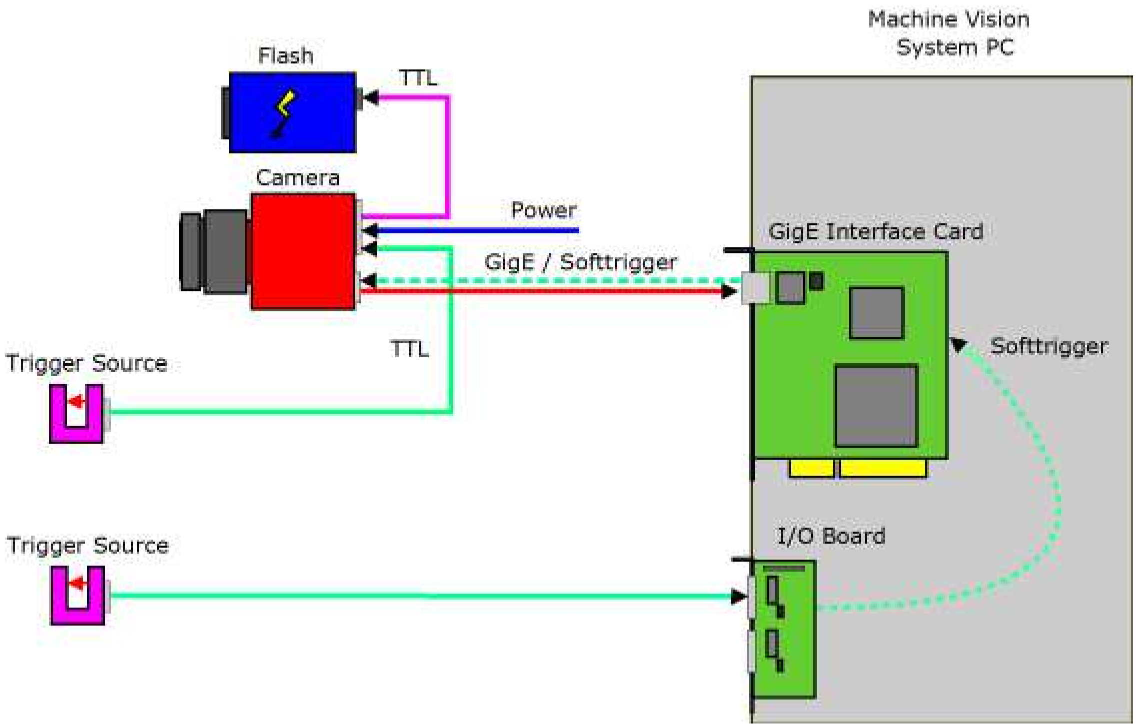

Figure 5.21: Trigger source

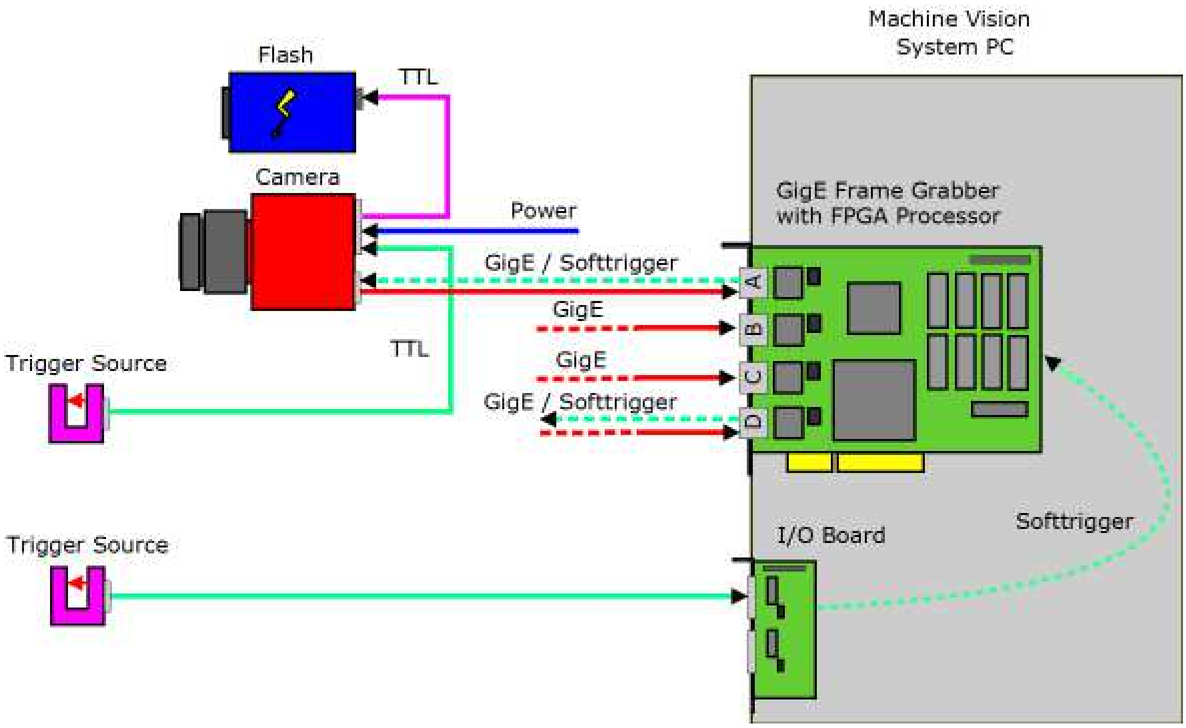

Figure 5.22: Trigger Inputs - Multiple GigE solution

5.4.2 Trigger and AcquisitionMode

The relationship between AcquisitionMode and TriggerMode is shown in Table 5.6. When `TriggerMode`=Off, then the frame rate depends on the `AcquisitionFrameRateEnable` property (see also under Free running in Section 5.4.1).

☞ The `ContinuousRecording` and `ContinousReadout` modes can be used if more than one camera is connected to the same network and need to shoot images simultaneously. If all cameras are set to Continuous mode, then all will send the packets at same time resulting in network congestion. A better way would be to set the cameras in `ContinuousRecording` mode and save the images in the memory of the IPEngine. The images can then be claimed with `ContinousReadout` from one camera at a time avoid network collisions and congestion.

AcquisitionMode	TriggerMode	After the command AcquisitionStart is executed:
Continuous	Off	Camera is in free-running mode. Acquisition can be stopped by executing `AcquisitionStop` command.
Continuous	On	Camera is ready to accept triggers according to the `TriggerSource` property. Acquisition and trigger acceptance can be stopped by executing `AcquisitionStop` command.
SingleFrame	Off	Camera acquires one frame and acquisition stops.
SingleFrame	On	Camera is ready to accept one trigger according to the `TriggerSource` property. Acquisition and trigger acceptance is stopped after one trigger has been accepted.
MultiFrame	Off	Camera acquires n=`AcquisitionFrameCount` frames and acquisition stops.
MultiFrame	On	Camera is ready to accept n=`AcquisitionFrameCount` triggers according to the `TriggerSource` property. Acquisition and trigger acceptance is stopped after n triggers have been accepted.
SingleFrameRecording	Off	Camera saves one image on the on-board memory of the IP engine.
SingleFrameRecording	On	Camera is ready to accept one trigger according to the `TriggerSource` property. Trigger acceptance is stopped after one trigger has been accepted and image is saved on the on-board memory of the IP engine.
SingleFrameReadout	don't care	One image is acquired from the IP engine's on-board memory. The image must have been saved in the `SingleFrameRecording` mode.
ContinuousRecording	Off	Camera saves images on the on-board memory of the IP engine until the memory is full.
ContinuousRecording	On	Camera is ready to accept triggers according to the `TriggerSource` property. Images are saved on the on-board memory of the IP engine until the memory is full. The available memory is 24 MB.
ContinousReadout	don't care	All Images that have been previously saved by the `ContinuousRecording` mode are acquired from the IP engine's on-board memory.

Table 5.6: AcquisitionMode and Trigger

5.4.3 Exposure Time Control

The exposure time is defined by the camera. For an active high trigger signal, the camera starts the exposure with a positive trigger edge and stops it when the programmed exposure time has elapsed.

External Trigger

In the external trigger mode with camera controlled exposure time the rising edge of the trigger pulse starts the camera states machine, which controls the sensor and optional an external strobe output. Fig. 5.23 shows the detailed timing diagram for the external trigger mode with camera controlled exposure time.

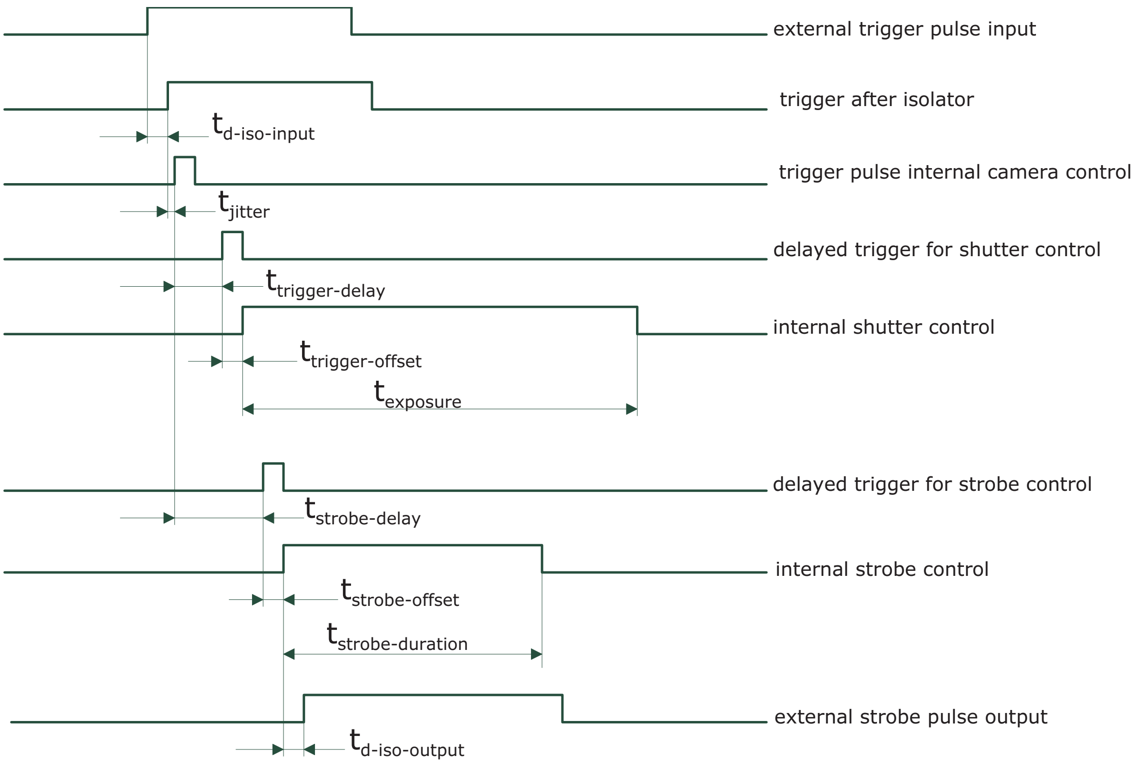

Figure 5.23: Timing diagram for the camera controlled exposure time

The rising edge of the trigger signal is detected in the camera control electronic which is implemented in an FPGA. Before the trigger signal reaches the FPGA it is isolated from the camera environment to allow robust integration of the camera into the vision system. In the signal isolator the trigger signal is delayed by time $t_{d-iso-input}$. This signal is clocked into the FPGA which leads to a jitter of t_{jitter}. The pulse can be delayed by the time $t_{trigger-delay}$ which can be configured by a user defined value via camera software. The trigger offset delay $t_{trigger-offset}$ results then from the synchronous design of the FPGA state machines. The exposure time $t_{exposure}$ is controlled with an internal exposure time controller.

The trigger pulse from the internal camera control starts also the strobe control state machines. The strobe can be delayed by $t_{strobe-delay}$ with an internal counter which can be controlled by the customer via software settings. The strobe offset delay $t_{strobe-delay}$ results then from the synchronous design of the FPGA state machines. A second counter determines the strobe duration $t_{strobe-duration}$(strobe-duration). For a robust system design the strobe output is also isolated from the camera electronic which leads to an additional delay of $t_{d-iso-output}$. Table 5.7 gives an overview over the minimum and maximum values of the parameters.

5.4.4 Trigger Delay

The trigger delay is a programmable delay in milliseconds between the incoming trigger edge and the start of the exposure. This feature may be required to synchronize the external strobe with the exposure of the camera.

5.4.5 Trigger Divider

The Trigger Divider reduces the trigger frequency that is applied to the camera. Every n-th trigger is processed for a setting of `TriggerDivider` = n. If n=1, then every trigger is processed (default behaviour). Fig. 7.4 shows the position of the TriggerDivider block.

☞ TriggerDivider is ignored if trigger mode must be set to free-running Trigger (`TriggerMode` = Off).

5.4.6 Burst Trigger

The camera includes a burst trigger engine. When enabled, it starts a predefined number of acquisitions after one single trigger pulse. The time between two acquisitions and the number of acquisitions can be configured by a user defined value via the camera software. The burst trigger feature works only in the mode "Camera controlled Exposure Time".

The burst trigger signal can be configured to be active high or active low. When the frequency of the incoming burst triggers is higher than the duration of the programmed burst sequence, then some trigger pulses will be missed. A missed burst trigger counter counts these events. This counter can be read out by the user.

The burst trigger mode is only available when `TriggerMode`=On. Trigger source is determined by the `TriggerSource` property.
The timing diagram of the burst trigger mode is shown in Fig. 5.24.

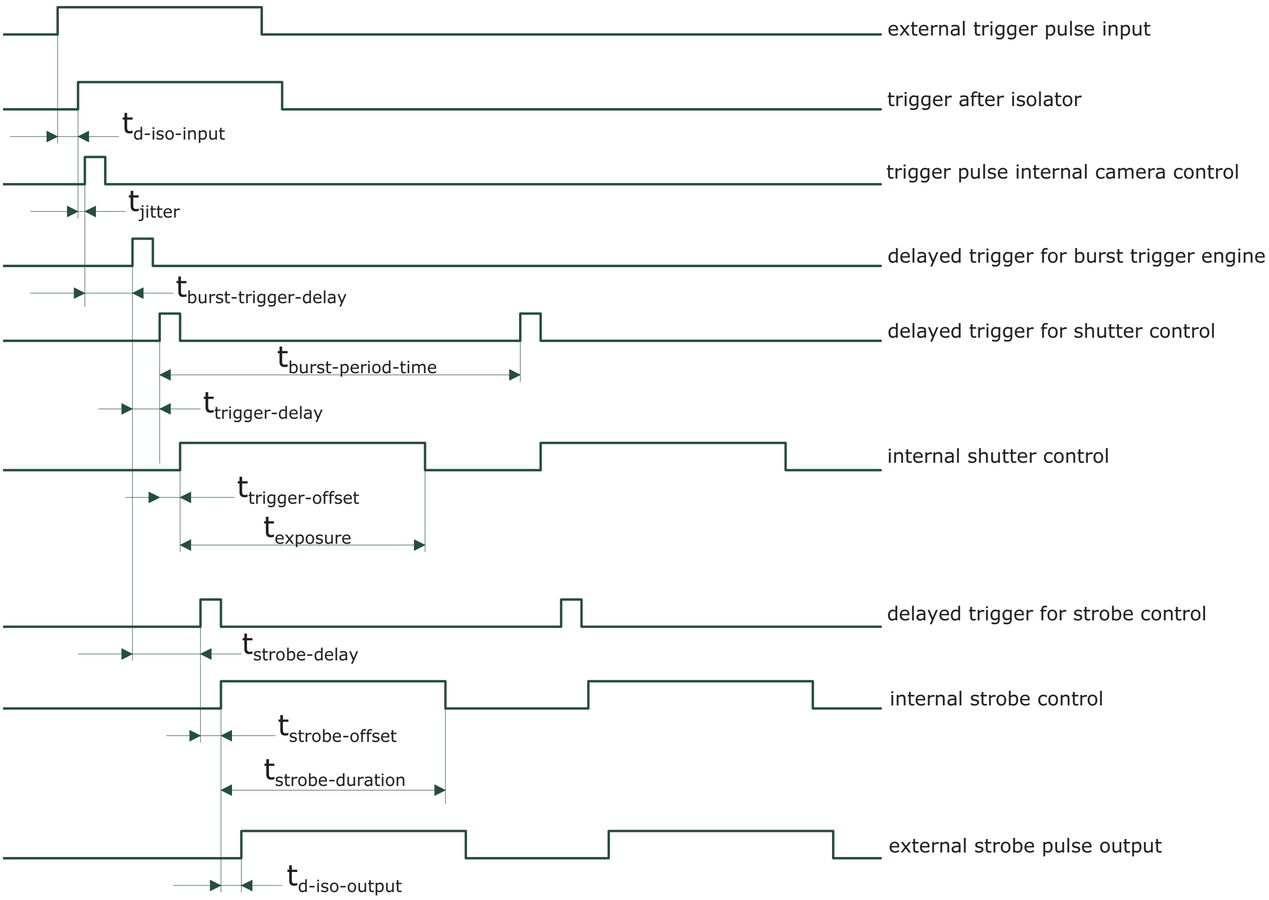

Figure 5.24: Timing diagram for the burst trigger mode

	MV1-D2048-3D03/04	MV1-D2048-3D03/04
Timing Parameter	**Minimum**	**Maximum**
$t_{d-iso-input}$	1 μs	1.5 μs
$t_{d-RS422-input}$	65 ns	185 ns
t_{jitter}	0	21 ns
$t_{trigger-delay}$	0	0.34 s
$t_{burst-trigger-delay}$	0	0.34 s
$t_{burst-period-time}$	depends on camera settings	0.34 s
$t_{trigger-offset}$ (non burst mode)	200 ns	167 ns
$t_{trigger-offset}$ (burst mode)	250 ns	188 ns
$t_{exposure}$	10 μs	0.34 s
$t_{strobe-delay}$	600 ns	0.34 s
$t_{strobe-offset}$ (non burst mode)	200 ns	167 ns
$t_{strobe-offset}$ (burst mode)	250 ns	188 ns
$t_{strobe-duration}$	200 ns	0.34 s
$t_{d-iso-output}$	150 ns	350 ns
$t_{trigger-pulsewidth}$	200 ns	n/a
Number of bursts n	1	30000

Table 5.7: Summary of timing parameters relevant in the external trigger mode using camera MV1-D2048-3D03/04

5.4.7 Software Trigger

The software trigger enables to emulate an external trigger pulse by the camera software through the serial data interface. It works with both burst mode enabled and disabled. As soon as it is performed via the camera software, it will start the image acquisition(s), depending on the usage of the burst mode and the burst configuration. The trigger mode must be set to external Trigger (`TriggerMode` = On).

5.4.8 A/B Trigger for Incremental Encoder

An incremental encoder with differential A/B outputs (G2 models: RS-422, H2 models: HTL) can be used to synchronize the camera triggers to the speed of a conveyor belt. These A/B outputs can be directly connected to the camera and appropriate triggers are generated inside the camera.

☞ The A/B Trigger feature is is not available on all camera revisions, see Appendix B for a list of available features.

In this setup, the output A is connected to the camera input ISO_INC0 (see also Section 6.6.4 and Section A.1) and the output B to ISO_INC1.

In the camera default settings the PLC is configured to connect the ISO_INC inputs to the A/B camera inputs. This setting is listed in Section 7.11.3.

The following parameters control the A/B Trigger feature:

TriggerSource Set TriggerSource to `ABTrigger` to enable this feature

ABMode Determines how many triggers should be generated. Available modes: single, double, quad (see description below)

ABTriggerDirection Determines in which direction a trigger should be generated: `fwd`: only forward movement generates a trigger; `bkwd`: only backward movement generates a trigger; `fwdBkwd`: forward and backward movement generate a trigger.

ABTriggerDeBounce Suppresses the generation of triggers when the A/B signal bounce. ABTriggerDeBounce is ignored when `ABTriggerDirection=fwdbkwd`.

ABTriggerDivider Specifies a division factor for the trigger pulses. Value 1 means that all internal triggers should be applied to the camera, value 2 means that every second internal trigger is applied to the camera.

EncoderPosition (read only) Counter (signed integer) that corresponds to the position of incremental encoder. The counter frequency depends on the ABMode. It counts up/down pulses independent of the `ABTriggerDirection`. Writing to this property resets the counter to 0.

A/B Mode

The property ABMode takes one of the following three values:

Single A trigger is generated on every A/B sequence (see Fig. 5.25). `TriggerFwd` is the trigger that would be applied if `ABTriggerDirection=fwd`, `TriggerBkwd` is the trigger that would be applied if `ABTriggerDirection=bkwd`, `TriggerFwdBkwd` is the trigger that would be applied if `ABTriggerDirection=fwdBkwd`. `GrayCounter` is the Gray-encoded BA signal that is shown as an aid to show direction of the A/B signals. `EncoderCounter` is the representation of the current position of the conveyor belt. This value is available as a camera register.

Double Two triggers are generated on every A/B sequence (see Fig. 5.26).

Quad Four triggers are generated on every A/B sequence (see Fig. 5.27).

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There is a bug in the single A/B trigger mode in some camera revisions (see Appendix B, A/B Trigger Bug). In this case when the encoder position moves back and forth by a small amount, the EncoderCounter is incremented and the decrement is sometimes omitted, leading to a wrong EncoderPosition indication in the camera. Therefore the single A/B trigger mode should not be used in the affected versions. To have the same behaviour as the single trigger mode, but without the bug, use the double A/B mode and double the value of `ABTriggerDivider`.

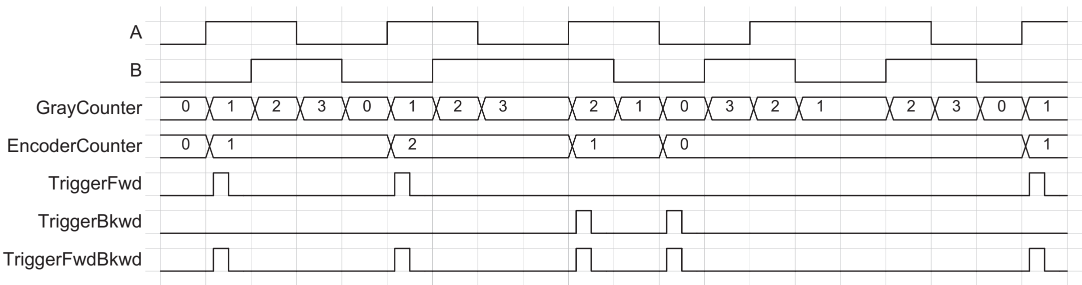

Figure 5.25: Single A/B Mode

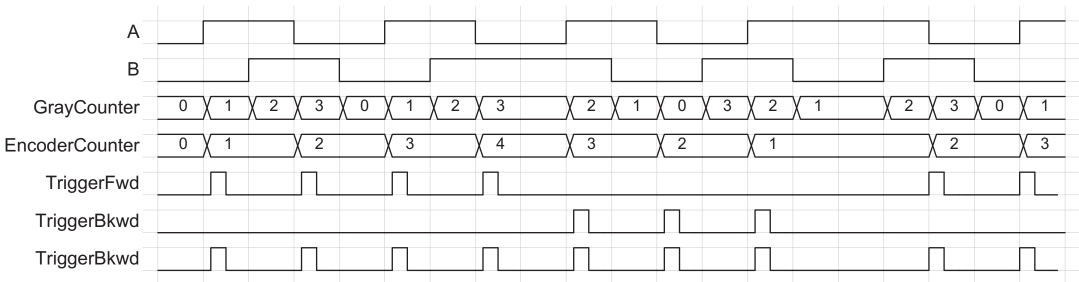

Figure 5.26: Double A/B Mode

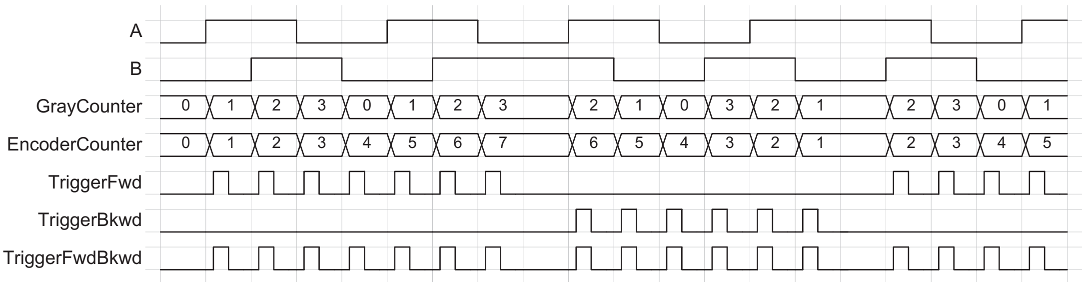

Figure 5.27: Quad A/B Mode

A/B Trigger Debounce

A debouncing logic can be enabled by setting `ABTriggerDeBounce=True`. It is implemented with a watermark value of the EncoderCounter (see Fig. 5.28). Suppose `ABTriggerDirection=fwd`, then the watermark value is increased with the increments of the EncoderCounter. If EncoderCounter decreases, e.g. Due to bouncing problems, the watermark value is hold unchanged. Triggers are then only generated when the watermark value increases.

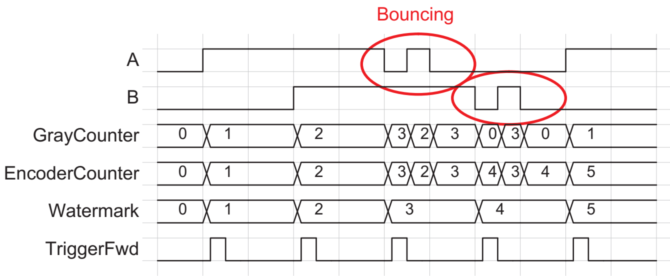

Figure 5.28: A/B Trigger Debouncing, example with ABMode=quad

The A/B Trigger Debounce mode can also be used for another issue:

In some applications the conveyor belt may stop between parts. In practice the conveyor belt stops and retraces by a small amount which may cause a misalignment in the system. If `ABTriggerDirection=fwd` is used and the Debounce mode is enabled and the conveyor belt starts again in forward direction, no triggers are generated for the amount that the conveyor belt retraced (see Fig. 5.29). The highest value of the EncoderCounter is stored as the watermark. Triggers are only generated when the EncoderCounter is at the watermark level.

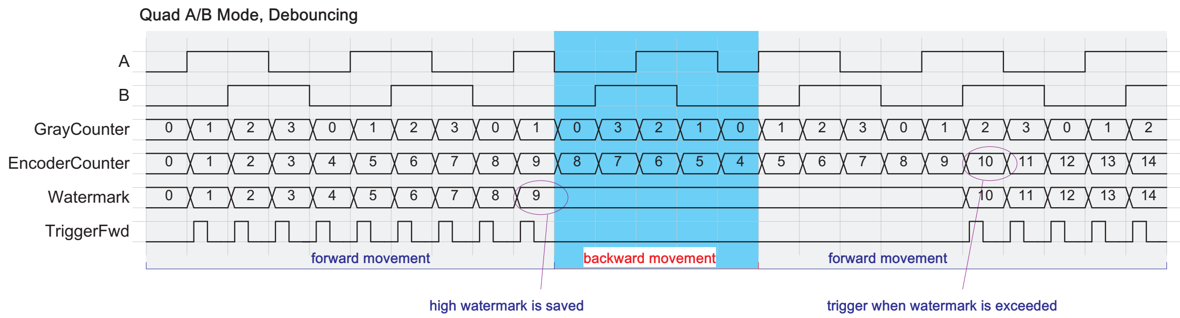

Figure 5.29: A/B Trigger Debouncing, example with ABMode=quad; example for encoder retracing

A/B Trigger Divider

if `ABTriggerDivider`>1 then not all internally generated triggers are applied to the camera logic. E.g. If ABTriggerDivider=2, then every second trigger is applied to the camera (see Fig. 5.30).

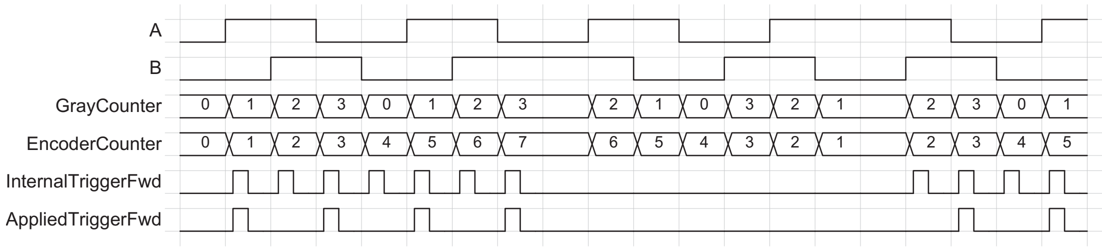

Figure 5.30: A/B Trigger Divider, example with ABTriggerDivider=1, ABMode=quad

A Only Trigger

The camera supports the use of simple incremental decoders that only provide one input, by enabling the property `ABTriggerAOnly`. The B-signal is ignored in this mode and information about direction of the object movement is not available: if `ABTriggerAOnly` is enabled then the encoder position is always incremented. Detailed diagrams are shown in Fig. 5.31 and Fig. 5.32. Note that the quad mode is not available when `ABTriggerAOnly`=true.

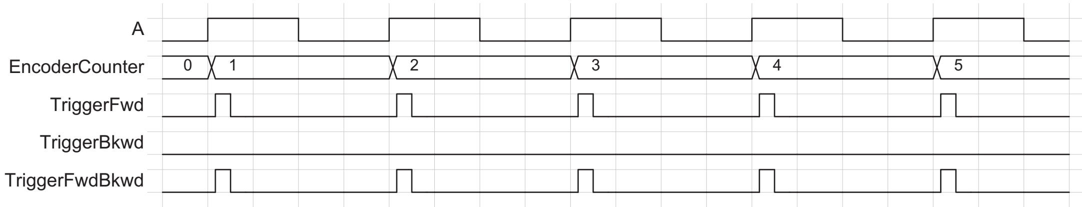

Figure 5.31: AOnly Trigger in Single A/B Mode

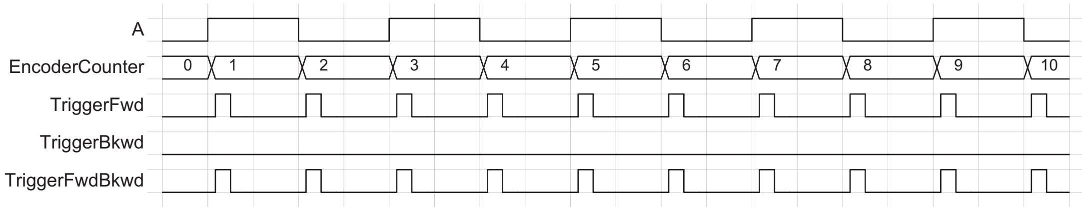

Figure 5.32: AOnly Trigger in Double A/B Mode

Encoder Position

The internal ABTrigger signal before the ABTriggerDivider is processed for the Encoder Position: every TriggerFwd pulse increments the Encoder Position and every TriggerBkwd pulse decrements its value. For details refer to the diagram of the corresponding mode.

The Encoder Position value can be accessed through the `EncoderPosition` property or through the status info that is inserted into the image (see Section 5.10).

By default the Encoder Position is only generated when TriggerMode=On and TriggerSource=ABTrigger. When the property ABTriggerCountAlways=True, then the Encoder Position is generated regardless of the trigger mode.

5.4.9 Counter Reset by an External Signal

The image counter and the real time counter (timestamp) (see Section 5.10.1) can be reset by an external signal. Both counters can be embedded into the image by the status line (see Section 5.10) or their register can be read out. These counters may be used to check that no images are lost or to ease the synchronisation of multiple cameras.

The external signal to reset the above mentionend counters is selected by the property Counter_ResetCounterSource. Available choices are PLC_Q4 to PLC_Q7 (see Section 7.11), Line1 (ISO_IN1) and ExposureStart. ExposureStart resets the counters at the start of an exposure.

The property Counter_ResetCounterMode determines how often the selected source should reset the counters. The setting Once works together with the property Counter_ResetCounterOnNextTrigger.

If Counter_ResetCounterMode=Once, then the counters are reset on the next active edge of the selected reset source (property Counter_ResetCounterSource) after the device is armed with Counter_ResetCounterOnNextTrigger=True. The register Counter_ResetCounterOnNextTrigger is reset after the resetting trigger is received.

The setting Counter_ResetCounterMode=Continuous resets the counters on every occurrence of an active edge of the reset source without the requirement to arm the device first. This setting is suited if the reset source signal is different than the camera trigger.

The active edge of the reset input can be set by the property Counter_ResetCounterSourceInvert. If set to True, then the rising edge is the active edge, else the falling edge.

Counter reset by an external signal is important if you would like to synchronize multiple cameras. One signal is applied to all cameras which resets the counters simultaneously. The timestamps of all cameras are then theoretically synchronous with each other. In practice every camera runs on its own clock source which has a precision of +/- 30 ppm and therefore the values of the timestamp (real time counter) of the cameras may diverge with time. If this is an issue, then the counters could be reset periodically by the external signal.

The counter reset by an external signal feature is not available on all camera revisions, see Appendix B for a list of available features.

5.4.10 Trigger Acquisition

The applied trigger can be enabled or disabled by one or two external signals in the TriggerAcquisition mode. This mode works with free-running (internal) trigger and external trigger.

The property `TriggerAcquisition_Enable` enables the TriggerAcquisition mode.

Level Triggered Trigger Acquisition

The Level Triggered mode is enabled by setting `TriggerAcquisition_Mode` to `Level` and `TriggerAcquisition_Enable=True`. A signal acts as a trigger enable (see Fig. 5.33). This signal is selected by `TriggerAcquisition_StartSource`. A high signal level enables the triggering of the camera and a low signal level disables all triggers.

To invert the TriggerAcquisition signal use one of the PLC_Q signal and select the inverted signal as its source. Table 5.8 shows a setting that uses ISO_IN0 as trigger enable signal: the inverted signal is used as ISO_IN0 is inverted in the input logic (see Fig. 7.4).

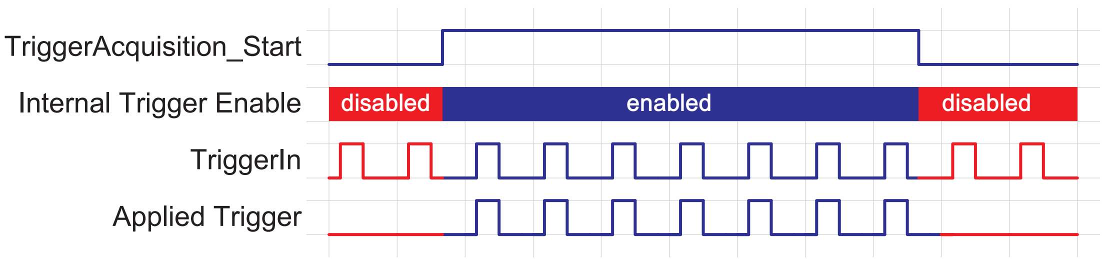

Figure 5.33: Trigger Acquisition Level triggered (TriggerAcquisition_Mode = Level)

Feature	Value	Category
TriggerAcquisition_Enable	True	Trigger/TriggerAcquisition
TriggerAcquisition_Mode	Level	Trigger/TriggerAcquisition
TriggerAcquisition_StartSource	PLC_Q5	Trigger/TriggerAcquisition
PLC_I0	Line0	<PLC>/SignalRoutingBlock
PLC_Q5_Variable0	PLC_I0_Not	<PLC>/LookupTable/Q5
PLC_Q5_Operator0	Or	<PLC>/LookupTable/Q5
PLC_Q5_Variable1	Zero	<PLC>/LookupTable/Q5
PLC_Q5_Operator1	Or	<PLC>/LookupTable/Q5
PLC_Q5_Variable2	Zero	<PLC>/LookupTable/Q5
PLC_Q5_Operator2	Or	<PLC>/LookupTable/Q5
PLC_Q5_Variable3	Zero	<PLC>/LookupTable/Q5

Table 5.8: Example of using ISO_IN0 as trigger enable in level mode

Edge Triggered Trigger Acquisition

The Edge Triggered mode is enabled by setting `TriggerAcquisition_Mode` to `Edge` and `TriggerAcquisition_Enable=True`. Two signals acts as a trigger enable (see Fig. 5.34). A rising edge on the start signal enables triggers. A rising edge on the stop signal disables all triggers. The start/stop signals are selected by `TriggerAcquisition_StartSource` and `TriggerAcquisition_StopSource`.

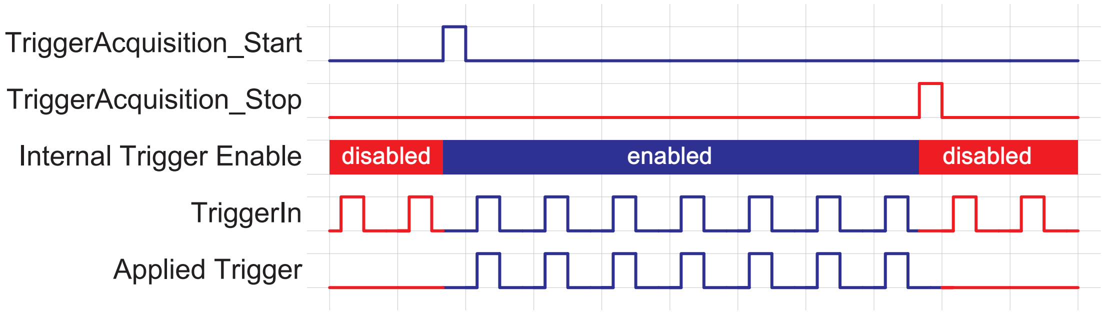

Figure 5.34: Trigger Acquisition Level triggered (TriggerAcquisition_Mode = Edge)

Trigger Acquisition and Free-Running Trigger

The `TriggerAcquisition` feature can also be used with free-running trigger (`TriggerMode=Off`). `TriggerAcquisition` enables or disables in this case the generation of the free-running trigger.

5.4.11 Strobe Output

he strobe output is an isolated output located on the power supply connector that can be used to trigger a strobe. The strobe output can be used both in free-running and in trigger mode. There is a programmable delay available to adjust the strobe pulse to your application.

☞ The strobe output needs a separate power supply. Please see Section 6.6, Fig. 5.21 and Fig. 5.22 for more information.

5.5 High Dynamic Range (multiple slope) Mode

To have an accurate laser line detection it is important that the pixels that represent the laser line, are not saturated. The High Dynamic Range (HDR) mode is a special integration mode that increases the dynamic range of the pixels, and thus avoids the saturation of the pixels in many cases. The HDR mode is also called multiple slope mode or piecewise linear mode.

The HDR (multi slope) mode clips illuminated pixels which reach a programmable voltage, while leaving the darker pixels untouched (see Fig. 5.35). The clipping level can be adjusted once (2 slopes) or twice (3 slopes) within the exposure time.

Parameters:

Multislope_Mode There are 3 predefined HDR parameter sets: `LowCompression`, `NormalCompression` and `HighCompression`. If `Multislope_Mode` is set to `UserDefined` then the individual parameters can be set to user defined values.

Multislope_NrSlopes Number of slopes. `Multislope_NrSlopes`=2: 2 slopes with only knee point B. `Multislope_NrSlopes`=3: 3 slopes with knee points A and B.

Multislope_Value1 Corresponds to Vlow1: the higher the value, the higher the compression.

Multislope_Time1 Time corresponding to knee point B. The value is the fraction (per mill) of the total exposure time.

Multislope_Value2 Corresponds to Vlow2: the higher the value, the higher the compression. This value is ignored if `Multislope_NrSlopes` =2.

Multislope_Time2 Time corresponding to knee point A. The value is the fraction (per mill) of the total exposure time. This value is ignored if `Multislope_NrSlopes` =2.

The red line in Fig. 5.35 shows a pixel with high illumination. Without the HDR (3 slopes) mode, the pixel would have reached its saturated value. With HDR mode, the pixel reaches value P1 which is below the saturation value. The resulting pixel response in this case is shown in Fig. 5.36. The blue line (P2) shows a pixel with low illumination. Its value never reaches Vlow2 or Vlow1 at the knee points and the resulting response is linear.

☞ The parameters `Multislope_Value1` and `Multislope_Value2` are only applied after a camera trigger. Note that in free-running mode the camera trigger is applied internally by the camera itself.

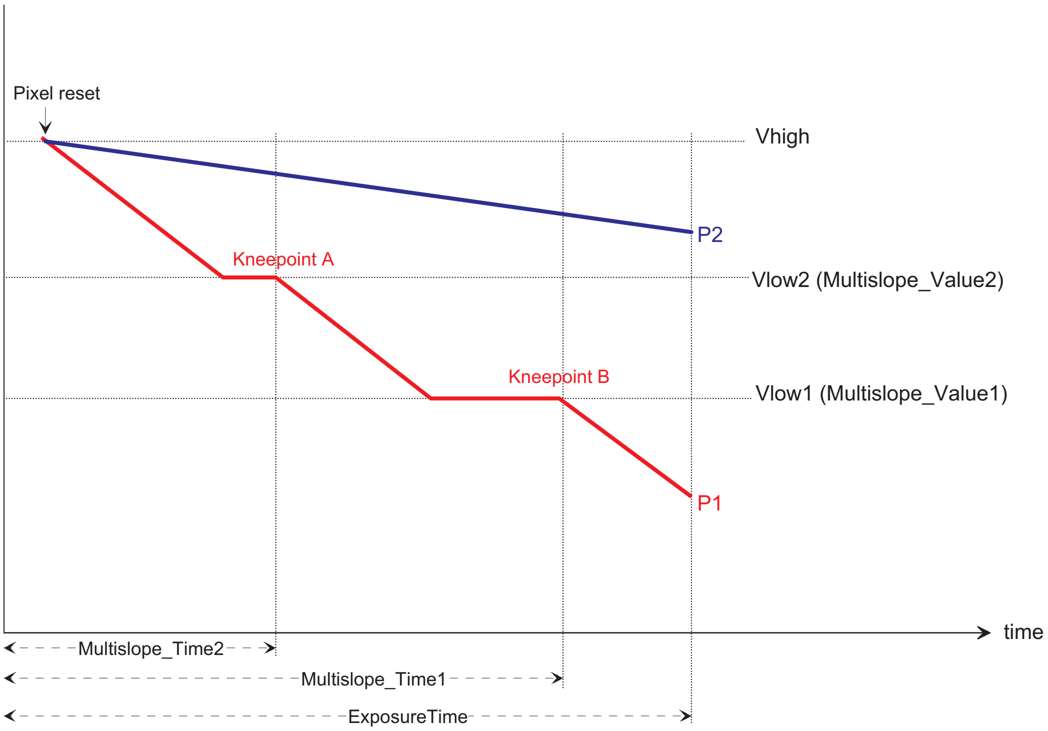

Figure 5.35: Multi Slope (HDR mode)

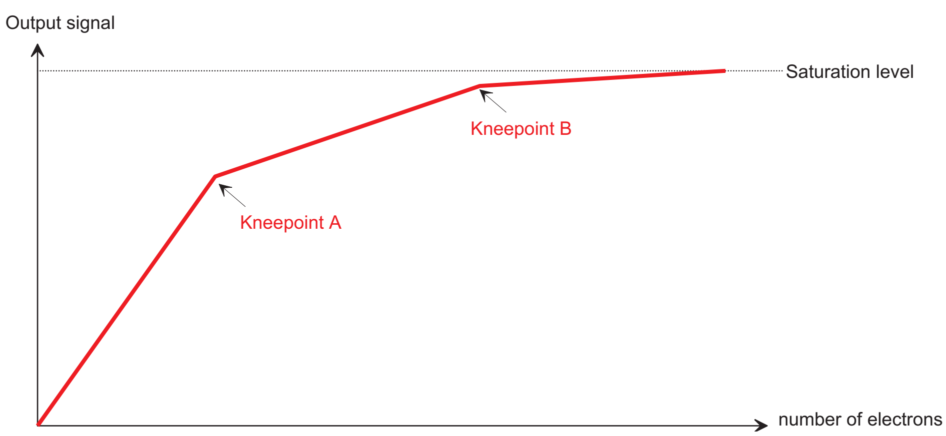

Figure 5.36: Piecewise linear response

5.6 Data Path Overview

The data path is the path of the image from the output of the image sensor to the output of the camera. The sequence of blocks is shown in figure Fig. 5.37.

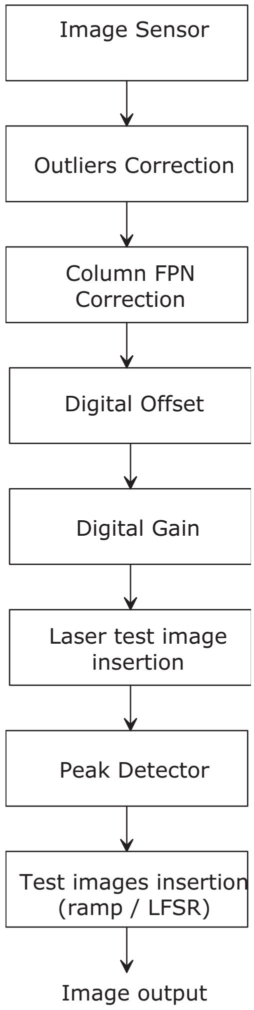

Figure 5.37: camera data path

5.7 Column FPN Correction

The camera contains a correction to decrease the Column Fixed Pattern Noise (FPN) of the sensor. By default the Column FPN Correction is enabled.

The Column FPN Correction of the camera is correctly calibrated at the Photonfocus production facility. Although a new calibration is normally not required, the user can recalibrate the Column FPN Correction. No light should be applied to the camera during calibration. The average grey value of every column of the image is calculated. The difference to the average grey value of the whole image is then calculated for every column and stored in internal camera memory. After calibration, this difference is then subtracted column-wise from every image to reduce the Column FPN. Detailed instructions on the calibration of the Column FPN Correction is given in Section 7.7.

5.8 Outliers Correction

Defective pixels of the image sensor might appear as dark or bright pixels. Although this is not common, a defective pixel correction (Outliers Correction) is implemented in the camera. By default the outliers corrections for black pixels and for white pixels are enabled.

A pixel is labeled as a black pixel if the grey value is smaller than the parameter `BlackLimit` and the grey value differences to its two neighbours on the same row exceed the value of the parameter `BlackDiff` (see Fig. 5.38). The Black Pixel Outliers correction can be enabled or disabled by a property (see also Section 7.8). If it is enabled then a black outlier pixel is replaced by the mean of the grey values of its two neighbours on the same row.

Similarly a pixel is labeled as a white pixel if the grey value is bigger than the parameter `WhiteLimit` and the grey value differences to its two neighbours on the same row exceed the value of the parameter `WhiteDiff` (see Fig. 5.38). The White Pixel Outliers correction can be enabled or disabled by a property (see also sec_gui_outliers_corr). If it is enabled then a white outlier pixel is replaced by the mean of the grey values of its two neighbours on the same row.

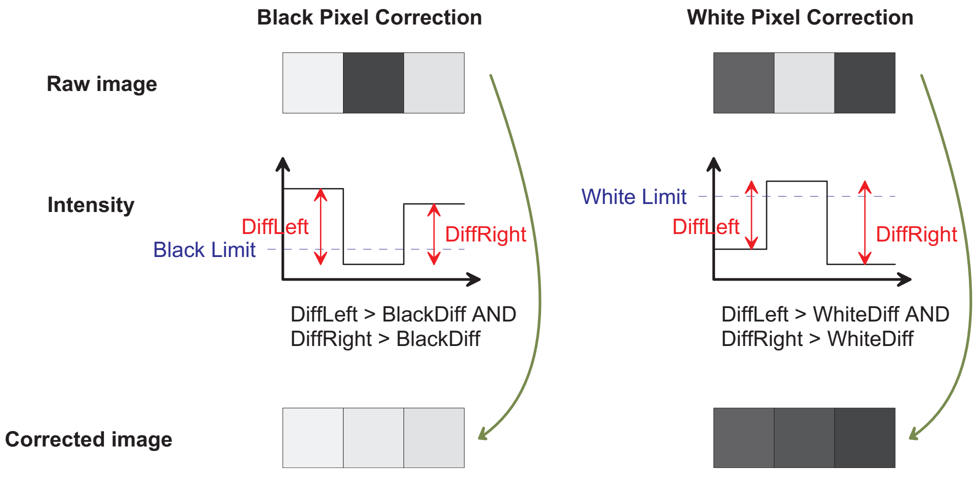

Figure 5.38: Outliers correction

5.9 Gain and Offset

There are three different gain settings on the camera:

Analog Gain Analog gain on the image sensor (only available in some models, see Appendix B). Available values: x1, x1.2, x1.4, x1.6. Note that `Digital Offset` is applied after the `Analog Gain`.

Gain (Digital Fine Gain) Digital fine gain accepts fractional values from 0.01 up to 15.99. It is implemented as a multiplication operation. Colour camera models only: There is additionally a gain for every RGB colour channel. The RGB channel gain is used to calibrate the white balance in an image, which has to be set according to the current lighting condition.

Digital Gain Digital Gain is a coarse gain with the settings x1, x2, x4 and x8. It is implemented as a binary shift of the image data where '0' is shifted to the LSB's of the gray values. E.g. for gain x2, the output value is shifted by 1 and bit 0 is set to '0'.

The resulting gain is the product of the three gain values, which means that the image data is multiplied in the camera by this factor.

☞ Digital Fine Gain and Digital Gain may result in missing codes in the output image data.

A user-defined value can be subtracted from the gray value in the digital offset block. If digital gain is applied and if the brightness of the image is too big then the interesting part of the output image might be saturated. By subtracting an offset from the input of the gain block it is possible to avoid the saturation.

5.10 Image Information and Status Information

There are camera properties available that give information about the acquired images, such as an image counter and the number of missed trigger signals. These properties can be queried by software.

5.10.1 Counters

Image counter The image counter provides a sequential number of every image that is output. After camera startup, the counter counts up from 0 (counter width 24 bit). The counter can be reset by the camera control software.

Real Time counter (Time stamp) The time counter starts at 0 after camera start, and counts real-time in units of 1 micro-second. The time counter can be reset by the software in the SDK (Counter width 32 bit).

Missed trigger counter The missed trigger counter counts trigger pulses that were ignored by the camera because they occurred within the exposure or read-out time of an image. In free-running mode it counts all incoming external triggers (counter width 8 bit / no wrap around).

Missed burst trigger counter The missed burst trigger counter counts trigger pulses that were ignored by the camera in the burst trigger mode because they occurred while the camera still was processing the current burst trigger sequence.

Missed FrameCombine trigger counter Counts missed triggers due to the FrameCombine feature (see also Section 5.2.12). A missed FrameCombine trigger can occur if a trigger is applied while filler rows are added to a frame due to a FrameCombine timeout.

5.10.2 Status Information

Status information is inserted in the 4 LSB in the last 3D data row (see bits labeled STAT in Fig. 5.13). LSB are transmitted first (see Table 5.9). The status information is divided in fields of 32 bits each, where every information field corresponds to one information parameter (see Table 5.10). Unused bits are set to 0.

Col 0	Col 1	Col 2	Col 3	...	Col n
STAT[3:0]	STAT[7:4]	STAT[11:8]	STAT[15:12]	...	STAT[4*n+3:4*n]

Table 5.9: STAT value

Status bits	Parameter	Description
STAT[23:0]	IMG_CNT[23:0]	Image counter (see also Section 5.10.1)
STAT[63:32]	RT_CNT[31:0]	Real time counter (time stamp) (see also Section 5.10.1)
STAT[87:64]	ENC_POS[23:0]	Encoder position (see also Section 5.4.8)
STAT[103:96]	M_TRIG[7:0]	Missed trigger counter (see also Section 5.10.1)
STAT[135:128]	M_BURST_TRIG[7:0]	Missed burst trigger counter (see also Section 5.10.1)
STAT[167:160]	M_FC_TRIG[7:0]	Missed FrameCombine trigger counter (see also Section 5.10.1)
STAT[195:192]	M_TRIG_LEVEL[3:0]	Trigger Level: signal level of the trigger input signal (only available in some models, see Appendix B). Bit 0: PLC_Q4: Bit 1: Line1; Bit 2: PLC_Q6 (A-Trigger); Bit 3: PLC_Q7 (B-Trigger).

Table 5.10: Status fields

5.11 Laser test image

A Laser Test Image has been added that resembles a moving laser line (see Fig. 5.39) and it is placed just before the peak detection. Therefore it can be used to test if the 3D data is correctly processed during application development.

5.12 Test Images

Test images are generated in the camera FPGA, independent of the image sensor. They can be used to check the transmission path from the camera to the acquisition software. Independent from the configured grey level resolution, every possible grey level appears the same number of times in a test image. Therefore, the histogram of the received image must be flat.

A test image is a useful tool to find data transmission errors or errors in the access of the image buffers by the acquisition software.

Figure 5.39: Laser test image

The analysis of the test images with a histogram tool gives a flat histogram only if the image width is a multiple of 256 (in 8 bit mode).

5.12.1 Ramp

Depending on the configured grey level resolution, the ramp test image outputs a constant pattern with increasing grey level from the left to the right side (see Fig. 5.40).

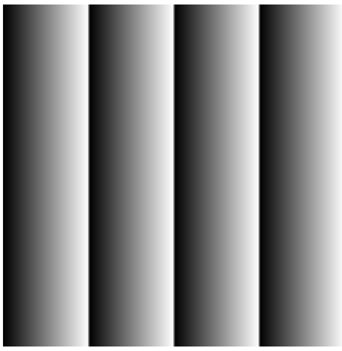

Figure 5.40: Ramp test images: 8 bit output

5.12.2 LFSR

The LFSR (linear feedback shift register) test image outputs a constant pattern with a pseudo-random grey level sequence containing every possible grey level that is repeated for every row. The LFSR test pattern was chosen because it leads to a very high data toggling rate, which stresses the interface electronic and the cable connection.

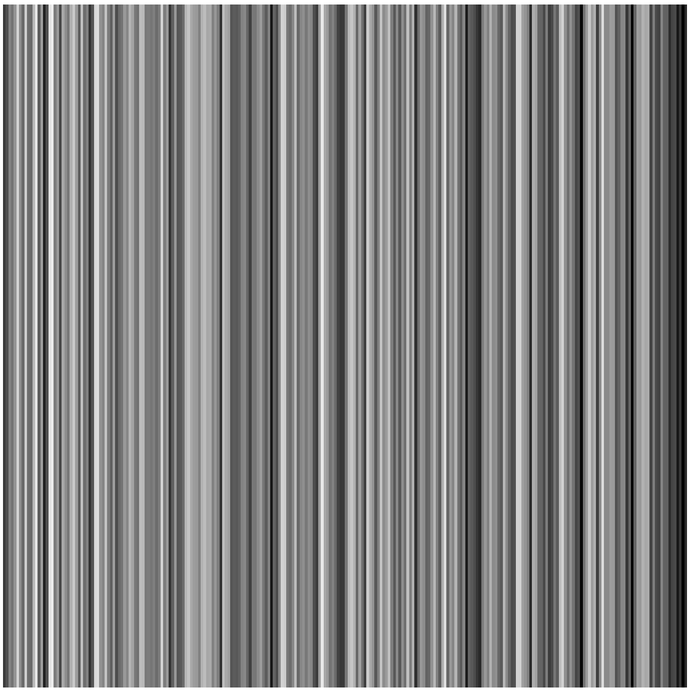

Figure 5.41: LFSR (linear feedback shift register) test image

In the histogram you can see that the number of pixels of all grey values are the same.

Please refer to application note [AN026] for the calculation and the values of the LFSR test image.

5.12.3 Troubleshooting using the LFSR

To control the quality of your complete imaging system enable the LFSR mode, set the camera window to 1024 x 1024 pixels (x=0 and y=0) and check the histogram. If your image acquisition application does not provide a real-time histogram, store the image and use a graphic software tool (e.g. ImageJ) to display the histogram.

In the LFSR (linear feedback shift register) mode the camera generates a constant pseudo-random test pattern containing all grey levels. If the data transmission is correctly received, the histogram of the image will be flat (Fig. 5.42). On the other hand, a non-flat histogram (Fig. 5.43) indicates problems, that may be caused either by a defective camera, by problems in the acquisition software or in the transmission path.

Figure 5.42: LFSR test pattern received and typical histogram for error-free data transmission

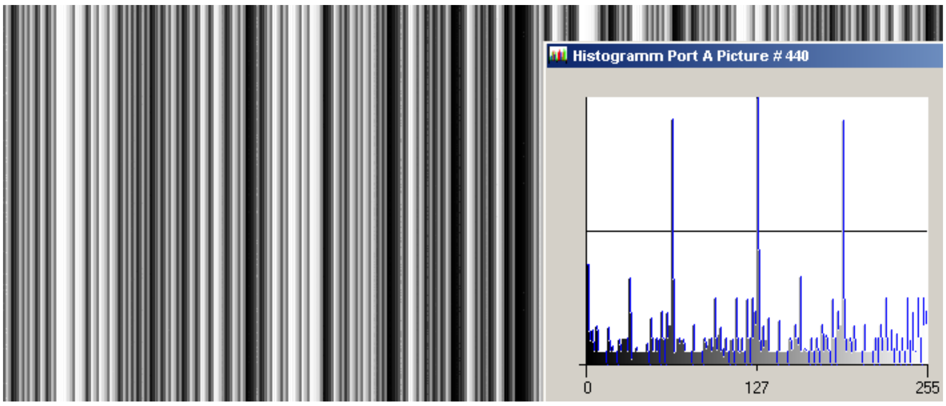

Figure 5.43: LFSR test pattern received and histogram containing transmission errors

In robots applications, the stress that is applied to the camera cable is especially high due to the fast movement of the robot arm. For such applications, special drag chain capable cables are available. Please contact the Photonfocus Support for consulting expertise.

6 Hardware Interface

6.1 GigE Connector

The GigE cameras are interfaced to external components via

- an Ethernet jack (RJ45) to transmit configuration, image data and trigger.
- a 12 pin subminiature connector for the power supply, Hirose HR10A-10P-12S (female) .

The connectors are located on the back of the camera. Fig. 6.1 shows the plugs and the status LED which indicates camera operation.

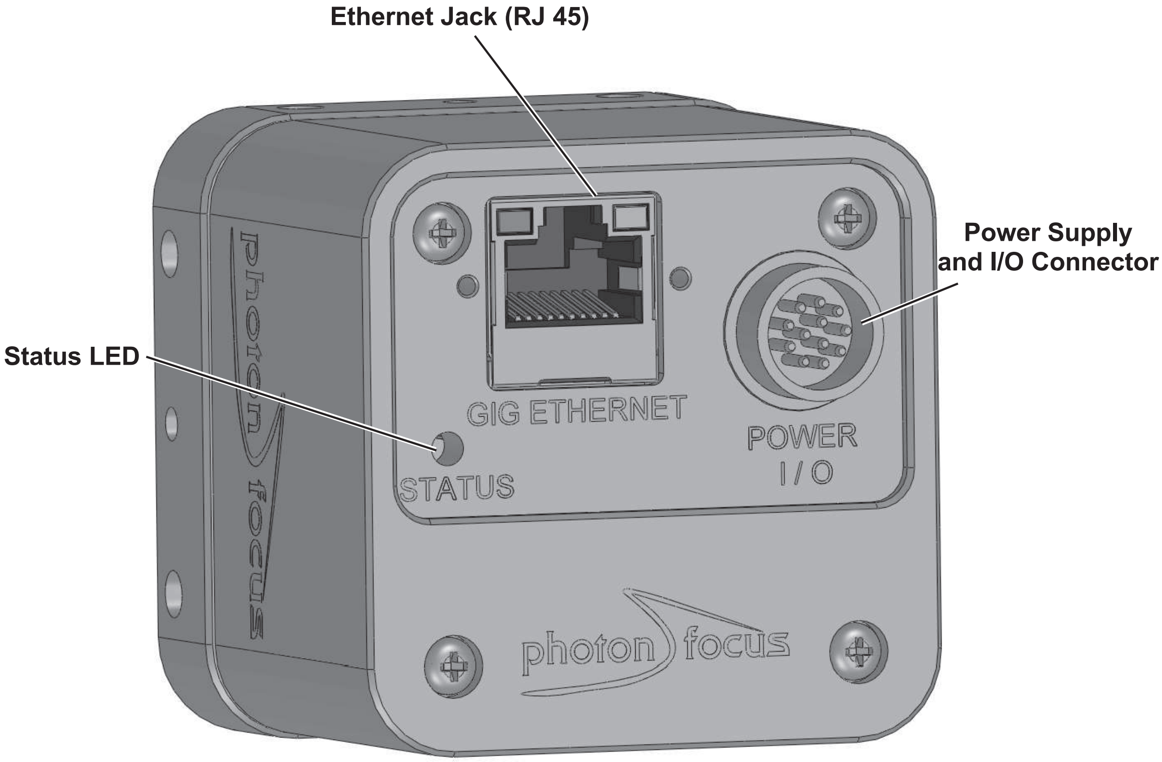

Figure 6.1: Rear view of the GigE camera

6.2 Power Supply Connector

The camera requires a single voltage input (see Table 4.4). The camera meets all performance specifications using standard switching power supplies, although well-regulated linear power supplies provide optimum performance.

It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages will damage the camera.

☞ A suitable power supply can be ordered from your Photonfocus dealership.

For further details including the pinout please refer to Appendix A.

6.3 Status Indicator (GigE cameras)

A dual-color LED on the back of the camera gives information about the current status of the GigE CMOS cameras.

LED Green	It blinks slowly when the camera is not grabbing images.When the camera is grabbing images the LED blinks at a rate equal to the frame rate. At slow frame rates, the LED blinks. At high frame rates the LED changes to an apparently continuous green light, with intensity proportional to the ratio of readout time over frame time.
LED Red	Red indicates an active serial communication with the camera.

Table 6.1: Meaning of the LED of the GigE CMOS cameras

6.4 Power and Ground Connection for GigE G2 Cameras

The interface electronics is isolated from the camera electronics and the power supply including the line filters and camera case. Fig. 6.2 shows a schematic of the power and ground connections in the G2 camera models.

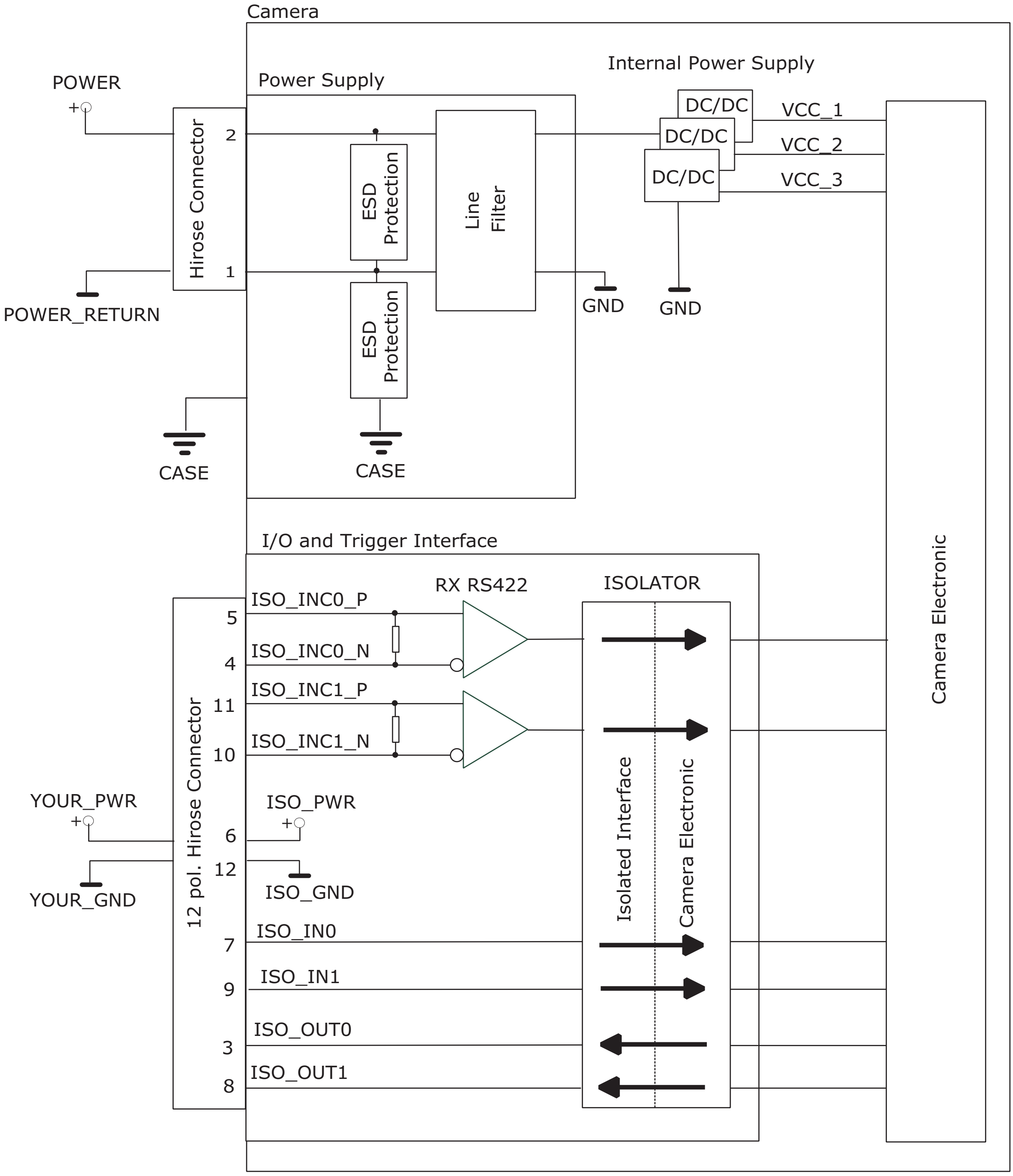

Figure 6.2: Schematic of power and ground connections in G2 camera models

6.5 Power and Ground Connection for GigE H2 Cameras

The interface electronics is isolated from the camera electronics and the power supply including the line filters and camera case. Fig. 6.3 shows a schematic of the power and ground connections in H2 camera models.

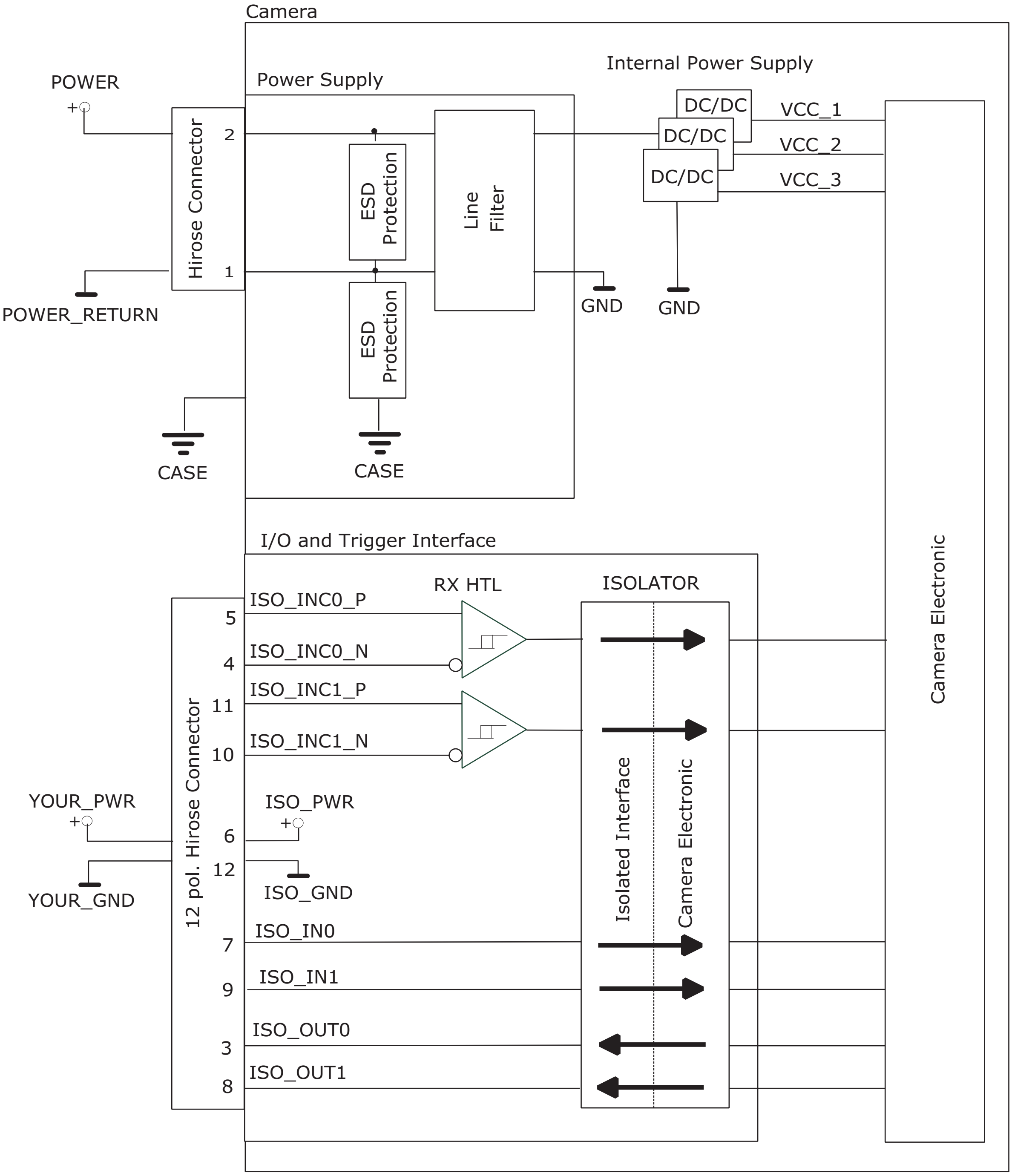

Figure 6.3: Schematic of power and ground connections in H2 camera models

6.6 Trigger and Strobe Signals for GigE Cameras

6.6.1 Overview

The 12-pol. Hirose power connector contains two external trigger inputs, two strobe outputs and two differential inputs (G2 models: RS-422, H2 models: HTL). All inputs and outputs are connected to the Programmable Logic Controller (PLC) (see also Section 6.7) that offers powerful operations.

☞ The pinout of the power connector is described in Section A.1.

☞ G2 models: ISO_INC0 and ISO_INC1 RS-422 inputs have -10 V to +13 V extended common mode range. H2 models: input voltage range of ISO_INC0 and ISO_INC1 differential HTL inputs is 10 to 30 V.

☞ ISO_OUT0 and ISO_OUT1 have different output circuits (see also Section 6.6.2).

☞ A suitable trigger breakout cable for the Hirose 12 pol. connector can be ordered from your Photonfocus dealership.

☞ Simulation with LTSpice is possible, a simulation model can be downloaded from our web site www.photonfocus.com on the software download page (in Support section). It is filed under "Third Party Tools".

⚠ Don't connect single-ended signals to the differential inputs ISO_INC0 and ISO_INC1.

Fig. 6.4 shows the schematic of the inputs and outputs for the G2 models and Fig. 6.5 for the H2 models. All inputs and outputs are isolated. ISO_VCC is an isolated, internally generated voltage.

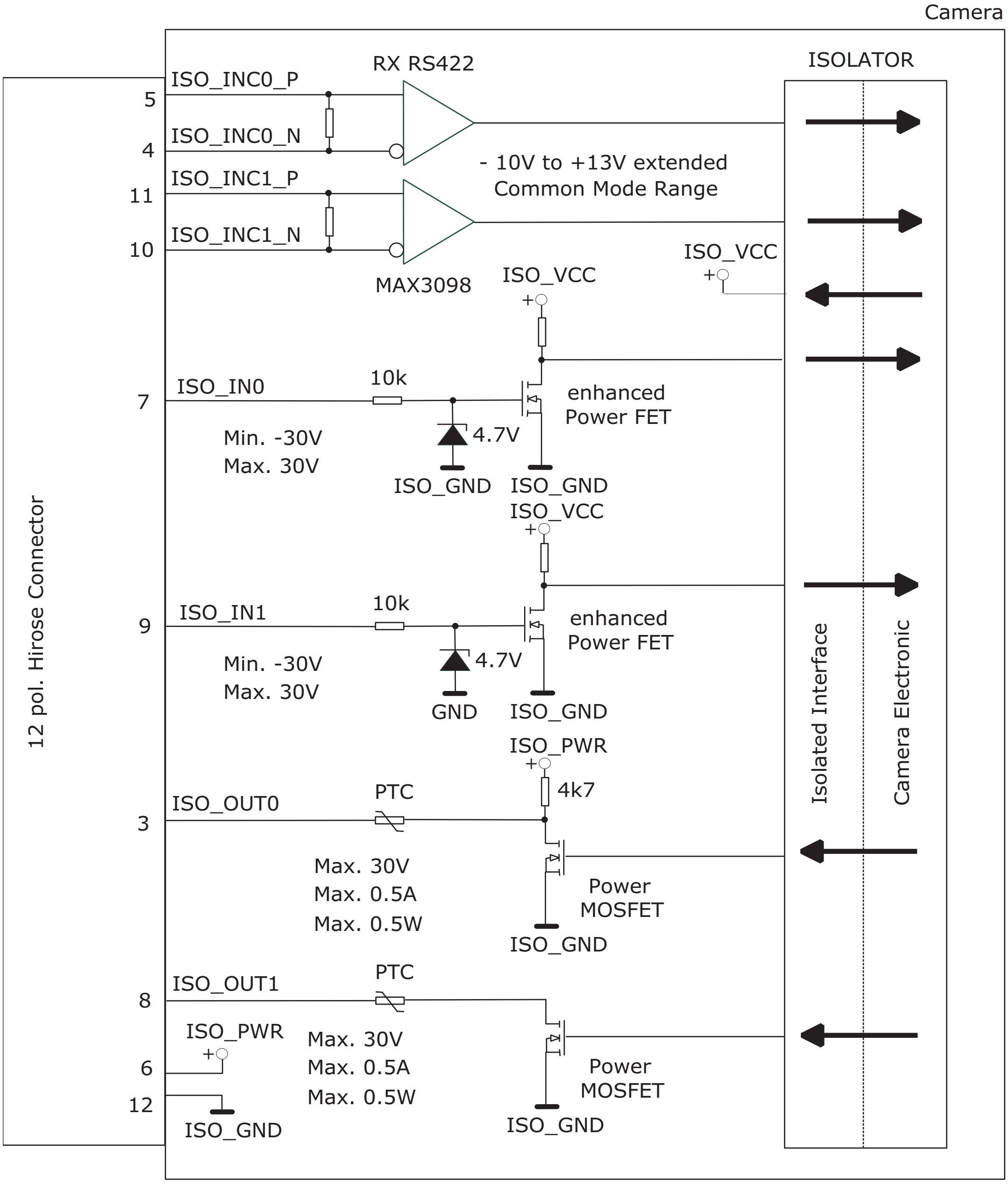

Figure 6.4: Schematic of inputs and output (G2 models)

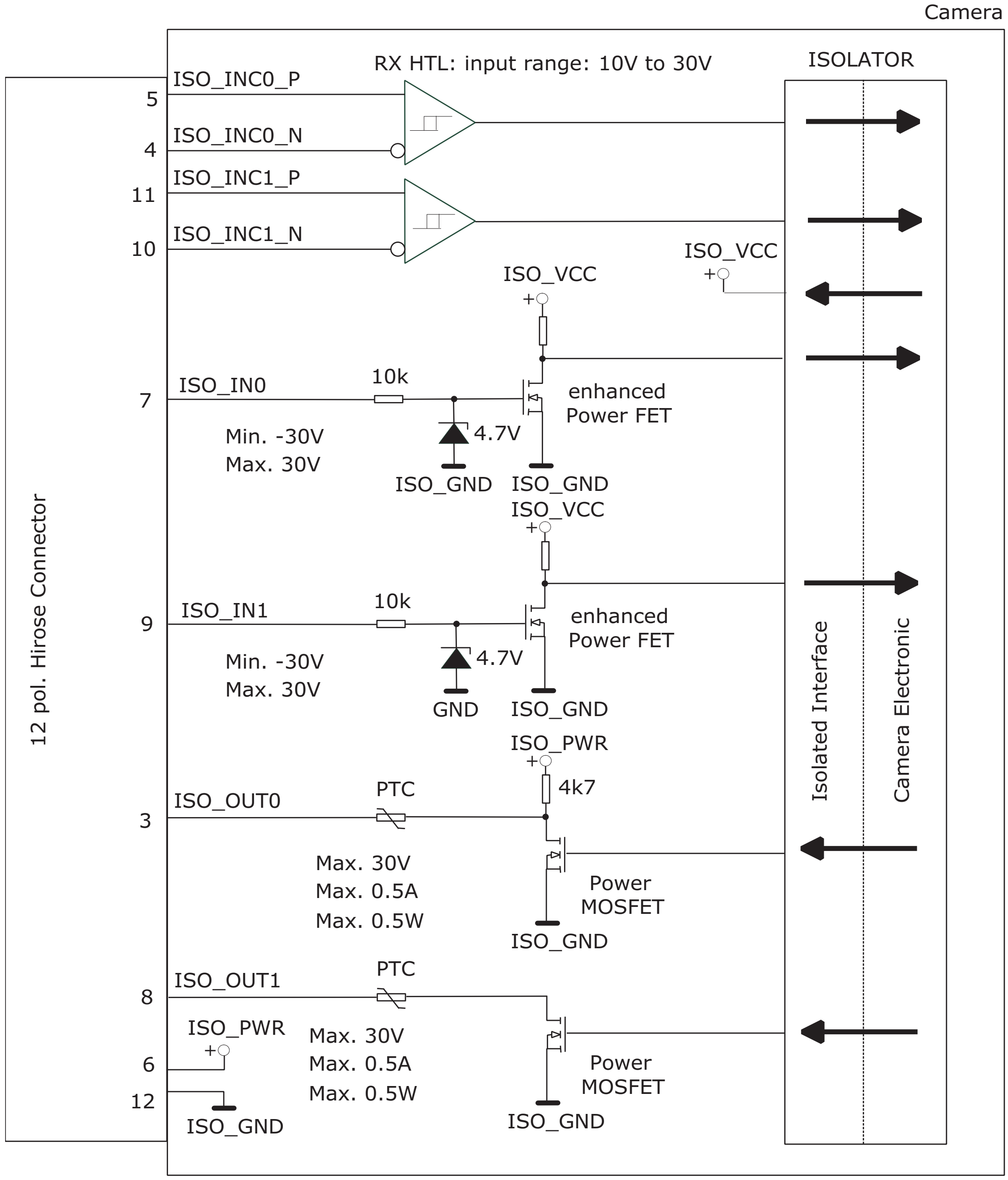

Figure 6.5: Schematic of inputs and output (H2 models)

6.6.2 Single-ended Inputs

ISO_IN0 and ISO_IN1 are single-ended isolated inputs. The input circuit of both inputs is identical (see Fig. 6.4).

Fig. 6.6 shows a direct connection to the ISO_IN inputs.

☞ In the camera default settings the PLC is configured to connect the ISO_IN0 to the PLC_Q4 camera trigger input. This setting is listed in Section 7.11.2.

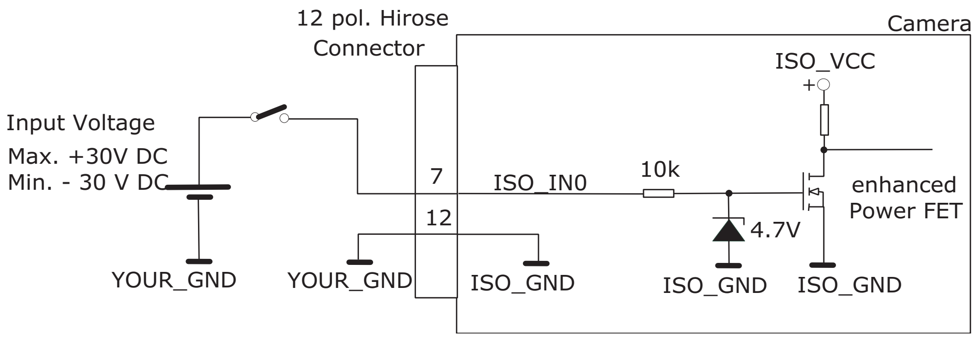

Figure 6.6: Direct connection to ISO_IN

Fig. 6.7 shows how to connect ISO_IN to TTL logic output device.

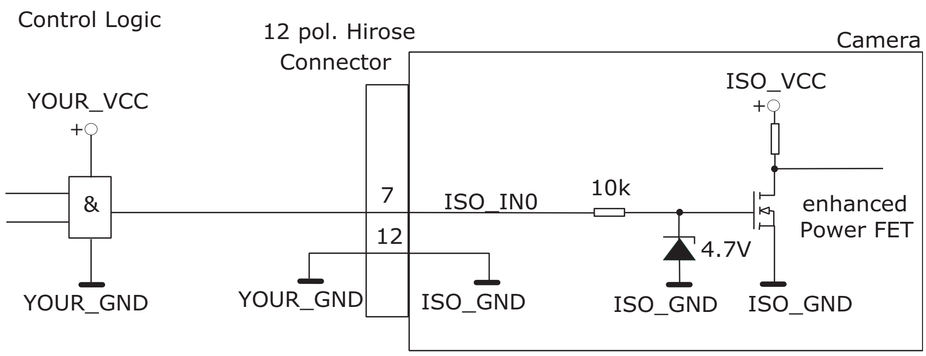

Figure 6.7: Connection to ISO_IN from a TTL logic device

6.6.3 Single-ended Outputs

ISO_OUT0 and ISO_OUT1 are single-ended isolated outputs.

ISO_OUT0 and ISO_OUT1 have different output circuits: ISO_OUT1 doesn't have a pullup resistor and can be used as additional Strobe out (by adding Pull up) or as controllable switch. Maximal ratings that must not be exceeded: voltage: 30 V, current: 0.5 A, power: 0.5 W.

Fig. 6.8 shows the connection from the ISO_OUT0 output to a TTL logic device. PTC is a current limiting device.

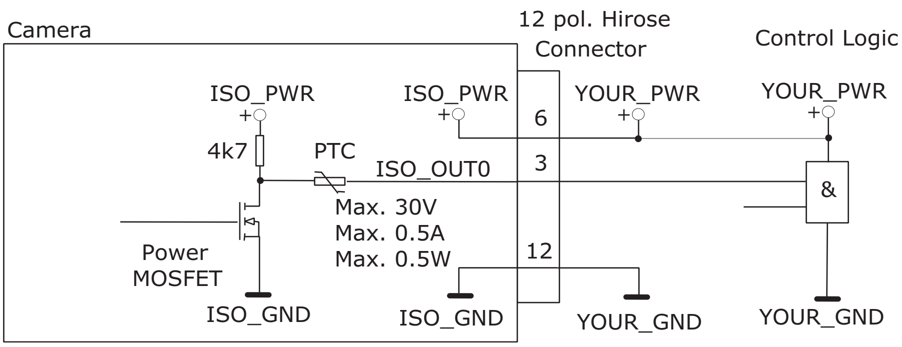

Figure 6.8: Connection example to ISO_OUT0

Fig. 6.9 shows the connection from ISO_OUT1 to a TTL logic device. PTC is a current limiting device.

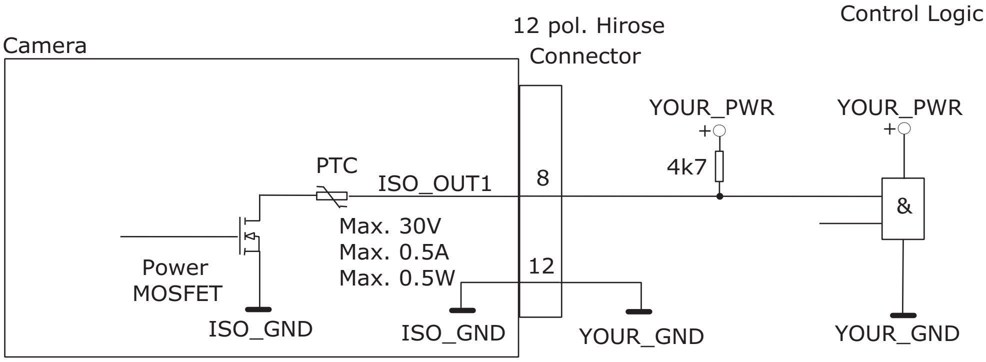

Figure 6.9: Connection from the ISO_OUT1 output to a TTL logic device

Fig. 6.10 shows the connection from ISO_OUT1 to a LED.

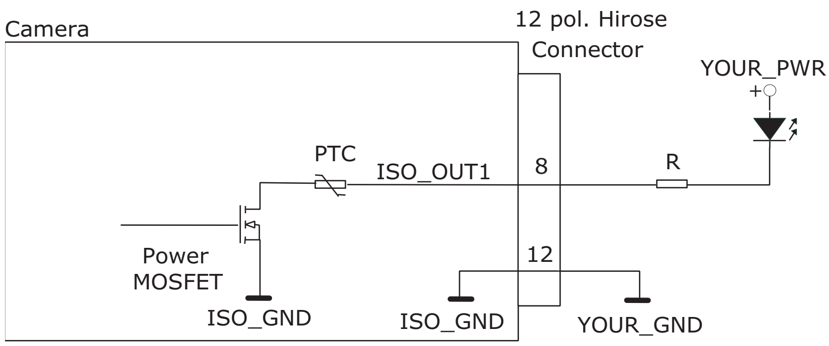

Figure 6.10: Connection from ISO_OUT1 to a LED

Respect the limits of the POWER MOSFET in the connection to ISEO_OUT1. Maximal ratings that must not be exceeded: voltage: 30 V, current: 0.5 A, power: 0.5 W. (see also Fig. 6.11). The type of the Power MOSFET is: International Rectifier IRLML0100TRPbF.

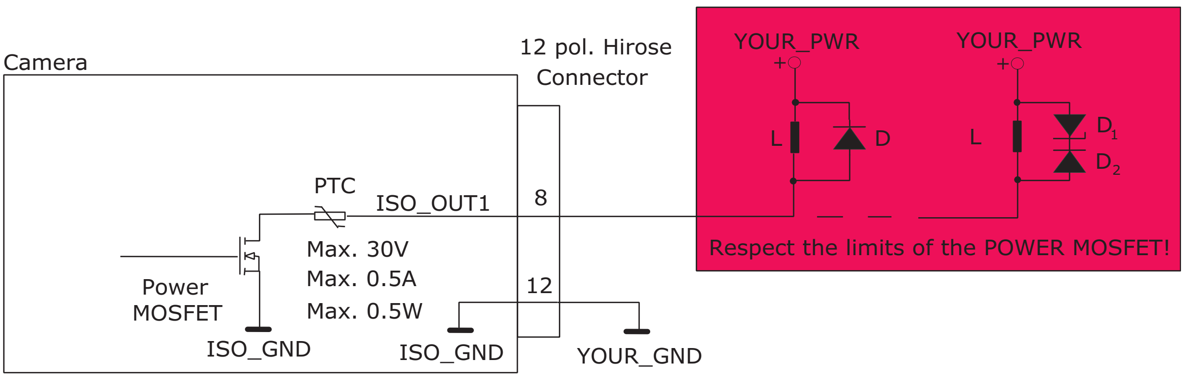

Figure 6.11: Limits of ISO_OUT1 output

6.6.4 Differential RS-422 Inputs (G2 models)

ISO_INC0 and ISO_INC1 are isolated differential RS-422 inputs (see also Fig. 6.4). They are connected to a Maxim MAX3098 RS-422 receiver device. Please consult the data sheet of the MAX3098 for connection details.

Don't connect single-ended signals to the differential inputs ISO_INC0 and ISO_INC1 (see also Fig. 6.12).

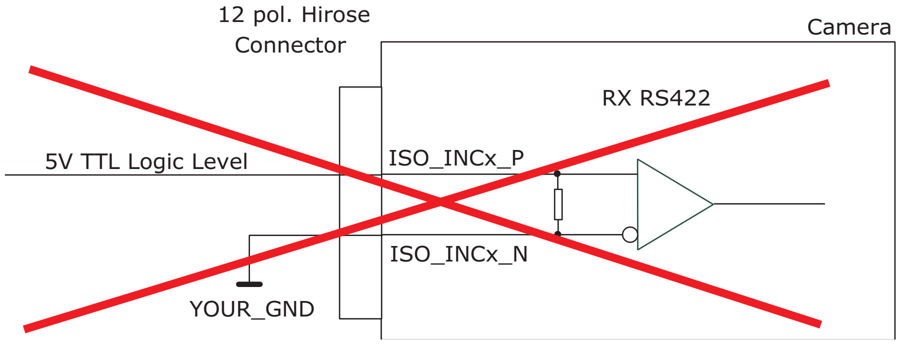

Figure 6.12: Incorrect connection to ISO_INC inputs

6.6.5 Master / Slave Camera Connection

The trigger input of one Photonfocus G2 camera can easily connected to the strobe output of another Photonfocus G2 camera as shown in Fig. 6.13. This results in a master/slave mode where the slave camera operates synchronously to the master camera.

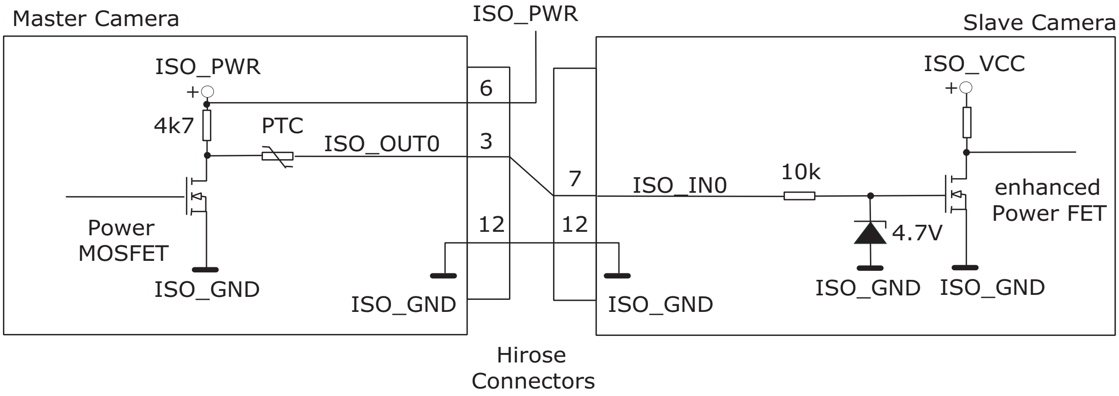

Figure 6.13: Master / slave connection of two Photonfocus G2 cameras

6.7 PLC connections

The PLC (Programmable Logic Controller) is a powerful device where some camera inputs and outputs can be manipulated and software interrupts can be generated. Sample settings and an introduction to PLC are shown in Section 7.11. PLC is described in detail in the document [PLC].

Name	Direction	Description
A0 (Line0)	Power connector -> PLC	ISO_IN0 input signal
A1(Line1)	Power connector -> PLC	ISO_IN1 input signal
A2 (Line2)	Power connector -> PLC	ISO_INC0 input signal
A3 (Line3)	Power connector -> PLC	ISO_INC1 input signal
A4	camera head -> PLC	FVAL (Frame Valid) signal
A5	camera head -> PLC	LVAL (Line Valid) signal
A6	camera head -> PLC	DVAL (Data Valid) signal
A7	camera head -> PLC	Reserved (CL_SPARE)
Q0	PLC ->	not connected
Q1	PLC -> power connector	ISO_OUT1 output signal (signal is inverted)
Q2	PLC ->	not connected
Q3	PLC ->	not connected
Q4	PLC -> camera head	PLC_Q4 camera trigger
Q5	PLC -> camera head	Reserved for future use
Q6	PLC -> camera head	Incremental encoder A signal
Q7	PLC -> camera head	Incremental encoder B signal

Table 6.2: Connections to/from PLC

7 Software

7.1 Software for MV1-D2048-3D03/3D04

Various software packages for Photonfocus the MV1-D2048-3D03/3D04 camera series are available on the Photonfocus website:

eBUS SDK Contains the Pleora SDK and the Pleora GigE filter drivers. Many examples of the SDK are included.

PFInstaller Contains the PF_GEVPlayer, the PF 3D Suite and SDK, a property list for every GigE camera and additional documentation and examples.

PF 3D Suite and SDK Visualization tool for Photonfocus 3D cameras. This tool is described in a separate manual [MAN053] and is included in the PFInstaller.

7.2 PF_GEVPlayer

The camera parameters can be configured by a Graphical User Interface (GUI) tool for Gigabit Ethernet Vision cameras or they can be programmed with custom software using the SDK.

A GUI tool that can be downloaded from Photonfocus is the PF_GEVPlayer. How to obtain and install the software and how to connect the camera is described in Chapter 3.

After connecting to the camera, the camera properties can be accessed by clicking on the `GEV Device control` button (see also Section 7.2.2).

☞ The PF_GEVPlayer is described in more detail in the GEVPlayer Quick Start Guide [GEVQS] which is included in the PFInstaller.

☞ There is also a GEVPlayer in the Pleora eBUS package. It is recommended to use the PF_GEVPlayer as it contains some enhancements for Photonfocus GigE cameras such as decoding the image stream in DR1 cameras.

7.2.1 PF_GEVPlayer main window

After connecting the camera (see Chapter 3), the main window displays the following controls (see Fig. 7.1):

Disconnect Disconnect the camera

Mode Acquisition mode

Play Start acquisition

Stop Stop acquisition

Acquisition Control Mode Continuous, Single Frame or Multi Frame modes. The number of frames that are acquired in Multi Frame mode can be set in the GEV Device Control with `AcquisitionFrameCount` in the `AcquisitionControl` category.

Communication control Set communication properties.

GEV Device control Set properties of the camera head, IP properties and properties of the PLC (Programmable Logic Controller, see also Section 6.7 and document [PLC]).

Image stream control Set image stream properties and display image stream statistics.

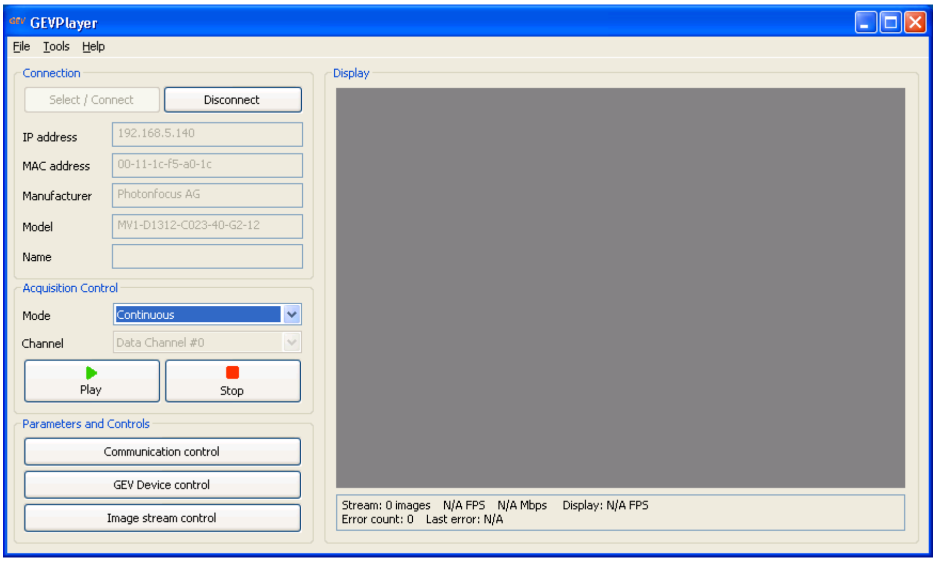

Figure 7.1: PF_GEVPlayer main window

Below the image display there are two lines with status information

7.2.2 GEV Control Windows

This section describes the basic use of the GEV Control windows, e.g. the `GEV Device Control` window.

The view of the properties in the control window can be changed as described below. At start the properties are grouped in categories which are expanded and whose title is displayed in bold letters. An overview of the available view controls of the GEV Control windows is shown in Fig. 7.2.

To have a quick overview of the available categories, all categories should be collapsed. The categories of interest can then be expanded again. If the name of the property is known, then the alphabetical view is convenient. If this is the first time that you use a Photonfocus GigE camera, then the visibility should be left to `Beginner`.

The description of the currently selected property is shown at the bottom ot the window.

☞ After selecting a property from a drop-down box it is necessary to press <Enter> or to click with the mouse on the control window to apply the property value to the camera.

A red cross at the upper right corner of the GEV Control Window indicates a parameter error, i.e. a parameter is not correctly set. In this case you should check all properties. A red exclamation mark (!) at the right side of a parameter value indicates that this parameters has to be set correctly.

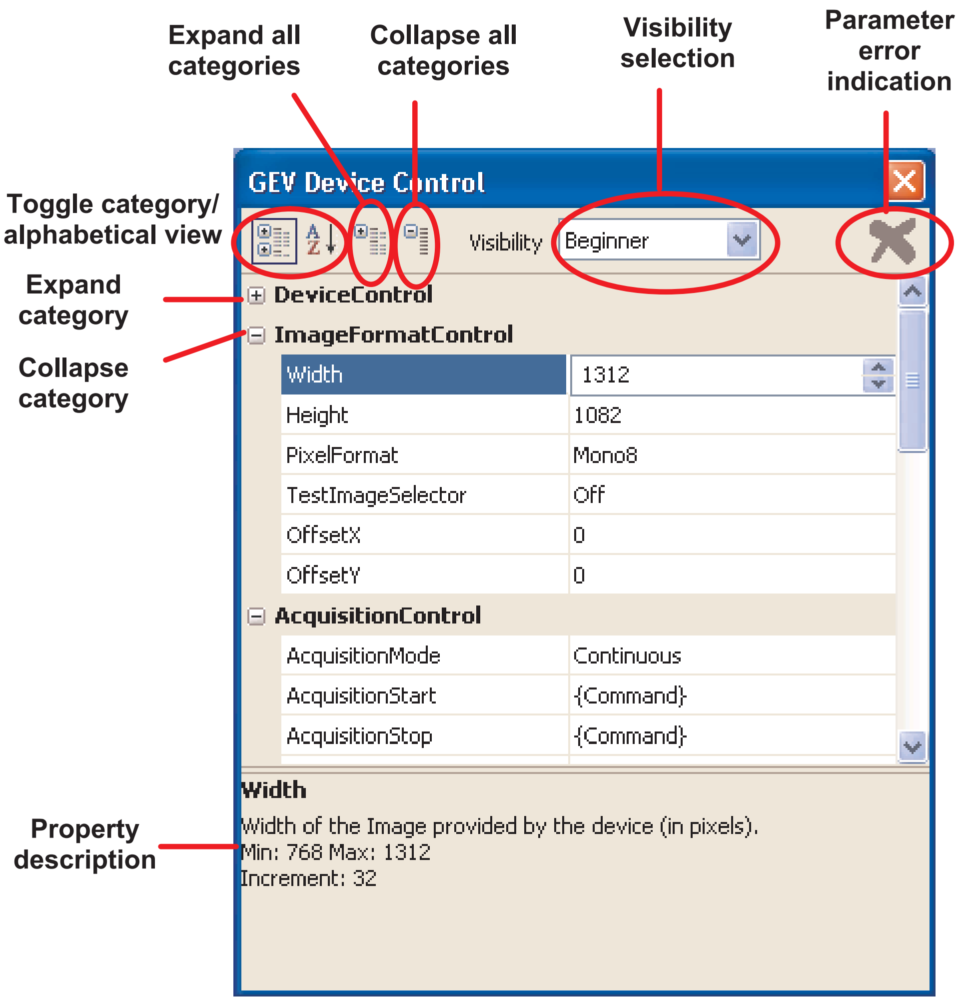

Figure 7.2: PF_GEVPlayer Control Window

7.2.3 Display Area

The images are displayed in the main window in the display area. A zoom menu is available when right clicking in the display area. Another way to zoom is to press the Ctrl button while using the mouse wheel.

7.2.4 White Balance (Colour cameras only)

A white balance utility is available in the PF_GEVPlayer in `Tools -> Image Filtering` (see Fig. 7.3). The gain of the colour channels can be adjusted manually by sliders or an auto white balance of the current image can be set by clicking on the `White Balance` button. To have a correct white balance setting, the camera should be pointed to a neutral reference (object that reflects all colours equally), e.g. a special grey reference card while clicking on the White Balance button.

The white balance settings that were made as described in this section, are applied by the PF_GEVPlayer software and are not stored in the camera. To store the colour gain values in the camera, the Gain settings in the GEV Device Control (in AnalogControl) must be used. If the gain properties in the camera are used, then the PF_GEVPlayer RGB Filtering should be disabled.

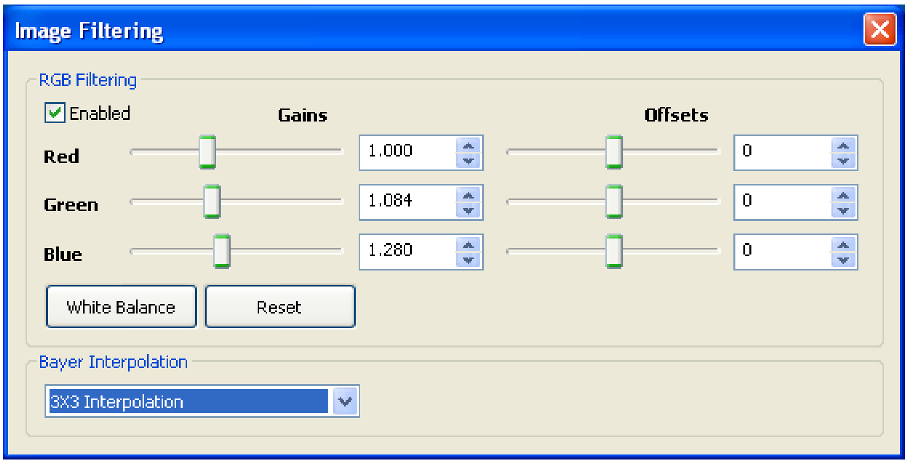

Figure 7.3: PF_GEVPlayer image filtering dialog

7.2.5 Save camera setting to a file

The current camera settings can be saved to a file with the PF_GEVPlayer (`File` -> `Save` or `Save As...`). This file can later be applied to camera to restore the saved settings (`File` -> `Open`), Note, that the Device Control window must not be open to do this.

The MROI and LUT settings are not saved in the file.

7.2.6 Get feature list of camera

A list of all features of the Photonfocus G2 cameras in HTML format can be found in the `GenICam_Feature_Lists` sub-directory (in `Start -> All Programs -> Photonfocus -> GigE_Tools`).

Alternatively, the feature list of the connected camera can be retrieved with the PF_GEVPlayer (`Tools -> Save Camera Features as HTML...`).

7.3 Pleora SDK

The eBUS package provides the PureGEV C++ SDK for image acquisition and the setting of properties. A help file is installed in the Pleora installation directory, e.g. `C:\Program Files\Pleora Technologies Inc\eBUS SDK\Documentation`.

Various code samples are installed in the installation directory, e.g. `C:\Program Files\Pleora Technologies Inc\eBUS SDK\Samples`. The sample `PvPipelineSample` is recommended to start with.

Samples that show how to set device properties are included in the PFInstaller that can be downloaded from the Photonfocus webpage.

7.4 Frequently used properties

The following list shows some frequently used properties that are available in the Beginner mode. The category name is given in parenthesis.

Width (ImageFormatControl) Width of the camera image ROI (region of interest)

Height (ImageFormatControl) Width of the camera image ROI

OffsetX, OffsetY (ImageFormatControl) Start of the camera image ROI

ExposureTime (AcquisitionControl) Exposure time in microseconds

TriggerMode (AcquisitionControl) External triggered mode

TriggerSource (AcquisitionControl) Trigger source if external triggered mode is selected

Header_Serial (Info / CameraInfo) Serial number of the camera

UserSetSave (UserSetControl) Saves the current camera settings to non-volatile flash memory.

7.5 Height setting

The `Height` property must be set manually to the value of `HeightInterface` whenever a property relevant to the height setting is modified (an example for this can be found in Section 7.6). The height relevant properties are:

- PeakDetector_NrOfPeaks
- PeakDetector_Mode
- Peak0_3DH
- Peak1_3DH
- FrameCombine

The height can be directly written to the Height property in 2Donly mode.

7.6 3D (Peak Detector) settings

This section describes how to the set the 3D properties. These properties are described in Section 5.2.

1. Set threshold value for peak 0 with property `Peak0_Threshold` (in category `PeakDetector/Peak0`) (see also note in Section 5.2.3).
2. Set scan area for peak 0 by setting the start row (`Peak0_3DY` in category `PeakDetector/Peak0`) the height (`Peak0_3DH` in category `PeakDetector/Peak0`) (see also Section 5.3.2).
3. Set image (2D) row for peak 0 by setting `Peak0_2DY` (in category `PeakDetector/Peak0`). Note that this value must be outside the scan areas.
4. If two peaks are required then repeat steps 1 to 3 with peak 1, replacing Peak0 with Peak1 in the property names.
5. Set `PeakDetector_Mode` (in category `PeakDetector`) to `Mode_3Donly` or to `Mode_2Dand3D`. Note that `Mode_3Donly` should be selected for maximal frame rate.
6. Set `PeakDetector_NrOfPeaks` to the required number of peaks (1 or 2).
7. If `PeakDetector_Mode` is set to `Mode_2Dand3D` then skip steps 8 to 10 and continue at step 11.
8. The number of frames of the FrameCombine feature (`FrameCombine_NrOfFrames`) should be set to a value that the resulting frame rate is below 200 for most applications (see also Section 5.2.12). The resulting frame rate is the trigger rate divided by `FrameCombine_NrOfFrames`. In free running mode (`TriggerMode = Off`) the frame rate can be read from the property `AcquisitionFrameRateMax` (in category `AcquisitionControl`). The lower the resulting frame rate, the fewer interrupts are generated by the GigE driver and the less load is produced on the computer's CPU. E.g. if the trigger rate is 4000 fps then `FrameCombine_NrOfFrames` should be set to 20 or more.
9. If FrameCombine is used, then the parameter `FrameCombine_Timeout` (in microseconds) should be set (see also Section 5.2.12. The value should be higher than the longest time between triggers, e.g. if the trigger rate is constant, then it could be set to twice the time between triggers.
10. If FrameCombine is used then `FrameCombine_Enable` should be set to `True`.
11. Read the value of the parameter `HeightInterface` and set `Height` to this value.

7.7 Column FPN Correction

7.7.1 Enable / Disable the Column FPN Correction

The Column FPN Correction can be enabled or disabled with the property `ColCorrection_Enable` (in category `Correction/ColCorrection`). By default the correction is enabled.

7.7.2 Calibration of the Column FPN Correction

The Column FPN Correction of the camera is correctly calibrated at Photonfocus production facility. Although a new calibration is normally not required, you can recalibrate the Column FPN Correction with the following instructions:

1. Setup the camera to the mode where it will be usually used. (Exposure time, ...). The width should be set to its maximal value. Due to the internal structure of the camera, best performance of calibration will be achieved when calibrating under "real conditions". When the camera will be run in 3Donly mode, which is required for maximal frame rate, then the following settings should be applied: `PeakDetector_Mode = Mode_3Donly` (category

PeakDetector), PeakDetector_NrOfPeaks = 1 (category PeakDetector), Peak0_3DY = 0 (category PeakDetector / Peak0 / Peak0_3D,) Peak0_3DH = 1024 (category PeakDetector / Peak0 / Peak0_3D, Peak0_2DY = 1024 (category PeakDetector / Peak0 / Peak0_2D), Width = 2048 (category ImageFormatControl), Height = 5 (category ImageFormatControl)

✎ If different exposure times will be used, calibrate the camera under the longest exposure time.

2. Put the camera in free-running mode by setting the property TriggerMode to Off.
3. Start grabbing of the camera by clicking on the Play button.
4. Wait until the camera has achieved working temperature.
5. Close the lens of the camera or put a cap on the lense.
6. Set the visibility of the Device Control window of the PF_GEVPlayer to Expert.
7. Run the command ColCorrection_CalibrateBlack (category Correction / ColCorrection) by clicking on the corresponding button. The camera transmits a test image during calibration.
8. Run the command ColCorrection_Update by clicking on the corresponding button. Read the ColCorrection_Busy value which should be 0 after the calibration has finished. Repeat this step if its value is not 0. If the ColCorrection_Busy value doesn't show 0 after various tries, check if the camera receive triggers or set the TriggerMode of the camera to Off.
9. Check the values of the properties ColCorrection_Overflow and ColCorrection_Underflow. Both should have the value 0 after calibration. If ColCorrection_Overflow is not 0, then decrease BlackLevel (in category AnalogControl) and re-run the procedure from step 6 on. If ColCorrection_Underflow is not 0, then increase BlackLevel (in category AnalogControl) and re-run the procedure from step 6 on.
10. The Column FPN correction is now calibrated. The calibration values are stored in the camera's RAM and these values are lost when the camera power is turned off. To store the calibration values to permanent memory see Section 7.7.3.

7.7.3 Storing the calibration in permanent memory

After running the calibration procedure (see Section 7.7.2) the calibration values are stored in RAM. When the camera is turned off, their values are lost.

To prevent this, the calibration values must be stored in flash memory. This can be done by clicking on the property ColCorrection_SaveToFlash (in category Calibration). Wait until the command has been finished, i.e.the property ColCorrection_Busy (category Correction / ColCorrection) is 0. ColCorrection_Busy can be updated by clicking on the property ColCorrection_Update (in category Calibration).

7.8 Outliers Correction

The Outliers Correction feature is explained in Section 5.8. This section shows its properties.

7.8.1 Black Pixel Correction

The Black Pixel Outliers Correction can be enabled by the property OutliersCorrection_EnBlackPixel (in category Correction / OutliersCorrection / BlackPixel). A black pixel must have a grey value smaller than OutliersCorrection_BlackLimit and the minimal difference to its two neighbours on the same row is OutliersCorrection_BlackDiff. All values are specified at 12 bit resolution, i.e. 4095 is the value for a saturated pixel.

7.8.2 White Pixel Correction

The White Pixel Outliers Correction can be enabled by the property OutliersCorrection_EnWhitePixel (in category Correction / OutliersCorrection / WhitePixel). A White pixel must have a grey value bigger than OutliersCorrection_WhiteLimit and the minimal difference to its two neighbours on the same row is OutliersCorrection_WhiteDiff. All values are specified at 12 bit resolution, i.e. 4095 is the value for a saturated pixel.

7.9 Permanent Parameter Storage / Factory Reset

The property UserSetSave (in category UserSetControl) stores the current camera settings in the non-volatile flash memory. At power-up these values are loaded.

The property UserSetSave (in category UserSetControl) overwrites the current camera settings with the settings that are stored in the flash memory.

The command CameraHeadFactoryReset (in category PhotonfocusMain) restores the settings of the camera head

☞ The property CameraHeadStoreDefaults (in category PhotonfocusMain) stores only the settings of the camera head in the flash memory. It is recommended to use UserSetSave instead, as all properties are stored.

☞ The calibration values of the FPN calibration are not stored with UserSetSave (or CameraHeadStoreDefaults). Use the command Correction_SaveToFlash for this (see Correction_SaveToFlash).

7.10 Persistent IP address

It is possible to set a persistent IP address:

1. Set GevPersistentIPAddress (in category TransportLayerControl) to the desired IP address.
2. Set GevPersistentSubnetMask (in category TransportLayerControl) to the sub net mask.
3. Set GevCurrentIPConfigurationPersistent (in category TransportLayerControl) to True.
4. Set GevCurrentIPConfigurationDHCP (in category TransportLayerControl) to False.
5. The selected persistent IP address will be applied after a reboot of the camera.

7.11 PLC Settings

7.11.1 Introduction

The Programmable Logic Controller (PLC) is a powerful tool to generate triggers and software interrupts. A functional diagram of the PLC tool is shown in Fig. 7.4. The PLC tool is described in detail with many examples in the [PLC] manual which is included in the PFInstaller.

The AB Trigger feature is not available on all camera revisions, see Appendix B for a list of available features.

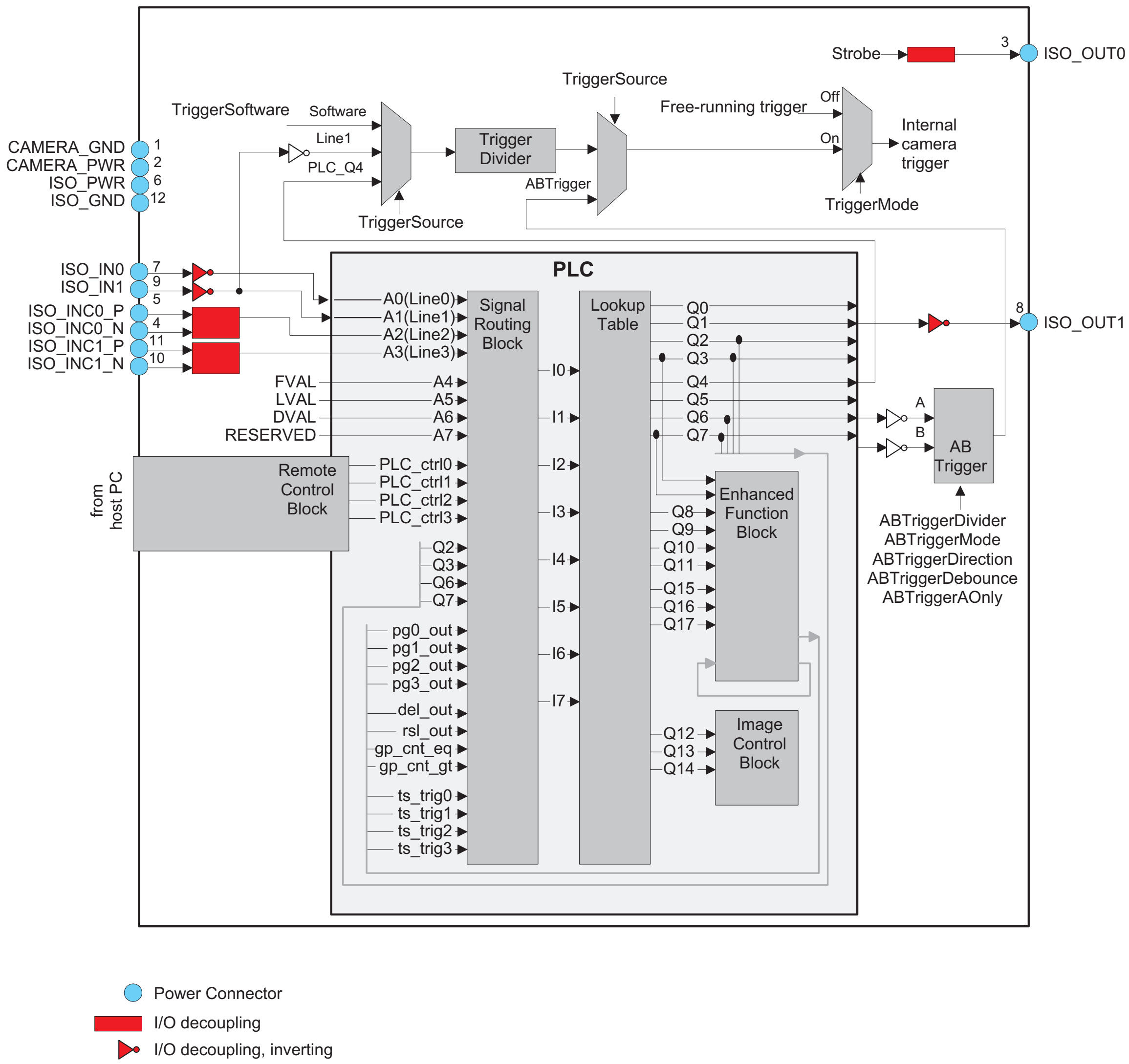

Figure 7.4: PLC functional overview and trigger connections

The simpliest application of the PLC is to connect a PLC input to a PLC output. The connection of the ISO_IN0 input to the PLC_Q4 camera trigger is given as an example. The resulting configuration is shown in Section 7.11.2.

1. Identify the PLC notation of the desired input. A table of the PLC mapping is given in Section 6.7. In our example, ISO_IN0 maps to A0 or Line0.
2. Select a Signal Routing Block (SRB) that has a connection to the desired PLC input and connect it to the PLC input. In our example, SRB PLC_I0 will be used as it has a connection to Line0. To connect the SRB to input, set PLC_I<x> to the input. In the example, set PLC_I0 to Line0.
3. Identify the PLC notation of the desired output. A table of the PLC mapping is given in Section 6.7. In the example Q4 is the desired output.
4. Connect the LUT that corresponds to the desired output to the SRB from step 2. In the example, PLC_Q4 is connected to PLC_I0. Note that every LUT has the capability to connect up to 4 inputs. In the example only the first input (PLC_Q4_Variable0) is used. The other inputs are ignored by setting the PLC_Q4_Variable to Zero and the PLC_Q4_Operator to Or for inputs 1 to 3.
5. If a PLC output is used to connect to a camera trigger, then the corresponding Trigger Source must be activated. In the example, TriggerSource is set to PLC_Q4 and TriggerMode is set to On.

7.11.2 PLC Settings for ISO_IN0 to PLC_Q4 Camera Trigger

This setting connects the ISO_IN0 to the internal camera trigger, see Table 7.1 (the visibility in the PF_GEVPlayer must be set to `Guru` for this purpose).

Feature	Value	Category
TriggerMode	On	AcquisitionControl
TriggerSource	PLC_Q4	AcquisitionControl
PLC_I0	Line0	<PLC>/SignalRoutingBlock
PLC_Q4_Variable0	PLC_I0_Not	<PLC>/LookupTable/Q4
PLC_Q4_Operator0	Or	<PLC>/LookupTable/Q4
PLC_Q4_Variable1	Zero	<PLC>/LookupTable/Q4
PLC_Q4_Operator1	Or	<PLC>/LookupTable/Q4
PLC_Q4_Variable2	Zero	<PLC>/LookupTable/Q4
PLC_Q4_Operator2	Or	<PLC>/LookupTable/Q4
PLC_Q4_Variable3	Zero	<PLC>/LookupTable/Q4

Table 7.1: PLC Settings for ISO_IN0 to PLC_Q4 Camera Trigger (<PLC> = in category IPEngine/ProgrammableLogicController)

7.11.3 PLC Settings for A/B Trigger from differential inputs

This settings connects the ISO_INC differential inputs to the A/B camera inputs. ISO_INC0 is mapped to the A signal and ISO_INC1 to the B signal, see Table 7.2 (the visibility in the PF_GEVPlayer must be set to `Guru` for this purpose).

The AB Trigger feature is not available on all camera revisions, see Appendix B for a list of available features.

Feature	Value	Category
TriggerMode	On	AcquisitionControl
TriggerSource	ABTrigger	AcquisitionControl
PLC_I2	Line2	<PLC>/SignalRoutingBlock
PLC_I3	Line3	<PLC>/SignalRoutingBlock
PLC_Q6_Variable0	PLC_I2	<PLC>/LookupTable/Q6
PLC_Q6_Operator0	Or	<PLC>/LookupTable/Q6
PLC_Q6_Variable1	Zero	<PLC>/LookupTable/Q6
PLC_Q6_Operator1	Or	<PLC>/LookupTable/Q6
PLC_Q6_Variable2	Zero	<PLC>/LookupTable/Q6
PLC_Q6_Operator2	Or	<PLC>/LookupTable/Q6
PLC_Q6_Variable3	Zero	<PLC>/LookupTable/Q6
PLC_Q7_Variable0	PLC_I3	<PLC>/LookupTable/Q7
PLC_Q7_Operator0	Or	<PLC>/LookupTable/Q7
PLC_Q7_Variable1	Zero	<PLC>/LookupTable/Q7
PLC_Q7_Operator1	Or	<PLC>/LookupTable/Q7
PLC_Q7_Variable2	Zero	<PLC>/LookupTable/Q7
PLC_Q7_Operator2	Or	<PLC>/LookupTable/Q7
PLC_Q7_Variable3	Zero	<PLC>/LookupTable/Q7

Table 7.2: PLC Settings for A/B Trigger from differential inputs (<PLC> = in category IPEngine/ProgrammableLogicController)

7.11.4 PLC Settings for A/B Trigger from single-ended inputs

This configuration maps the single-ended inputs to the A/B camera inputs: ISO_IN0 is mapped to the A signal and ISO_IN1 to the B signal see Table 7.3 (the visibility in the PF_GEVPlayer must be set to `Guru` for this purpose).

The AB Trigger feature is not available on all camera revisions, see Appendix B for a list of available features.

Feature	Value	Category
TriggerMode	On	AcquisitionControl
TriggerSource	ABTrigger	AcquisitionControl
PLC_I0	Line0	<PLC>/SignalRoutingBlock
PLC_I1	Line1	<PLC>/SignalRoutingBlock
PLC_Q6_Variable0	PLC_I0	<PLC>/LookupTable/Q6
PLC_Q6_Operator0	Or	<PLC>/LookupTable/Q6
PLC_Q6_Variable1	Zero	<PLC>/LookupTable/Q6
PLC_Q6_Operator1	Or	<PLC>/LookupTable/Q6
PLC_Q6_Variable2	Zero	<PLC>/LookupTable/Q6
PLC_Q6_Operator2	Or	<PLC>/LookupTable/Q6
PLC_Q6_Variable3	Zero	<PLC>/LookupTable/Q6
PLC_Q7_Variable0	PLC_I1	<PLC>/LookupTable/Q7
PLC_Q7_Operator0	Or	<PLC>/LookupTable/Q7
PLC_Q7_Variable1	Zero	<PLC>/LookupTable/Q7
PLC_Q7_Operator1	Or	<PLC>/LookupTable/Q7
PLC_Q7_Variable2	Zero	<PLC>/LookupTable/Q7
PLC_Q7_Operator2	Or	<PLC>/LookupTable/Q7
PLC_Q7_Variable3	Zero	<PLC>/LookupTable/Q7

Table 7.3: PLC Settings for A/B Trigger from single-ended inputs (<PLC> = in category IPEngine/ProgrammableLogicController)

8 Mechanical and Optical Considerations

8.1 Mechanical Interface

During storage and transport, the camera should be protected against vibration, shock, moisture and dust. The original packaging protects the camera adequately from vibration and shock during storage and transport. Please either retain this packaging for possible later use or dispose of it according to local regulations.

8.1.1 Cameras with GigE Interface

Fig. 8.1 shows the mechanical drawing of the camera housing for the Photonfocus D/L2048 GigE camera series.

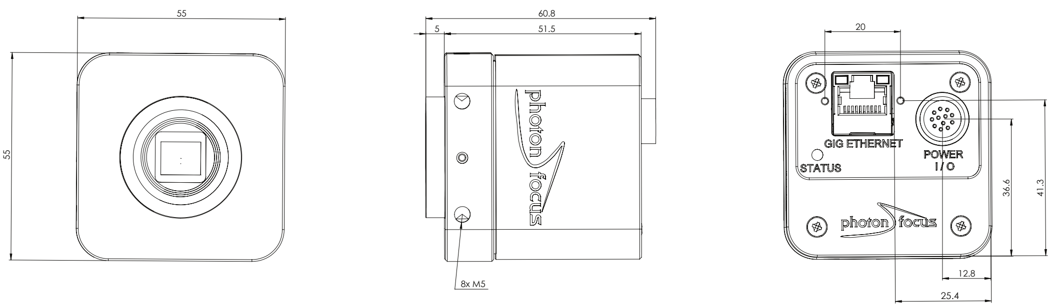

Figure 8.1: Mechanical dimensions of the Photonfocus 2048 GigE cameras

For long life and high accuracy operation, we highly recommend to mount the camera thermally coupled, so that the mounting acts as a heat sink. To verify proper mounting, camera temperature can be monitored using the GeniCam command `DeviceTemperature` under GEVDeviceControl.

8.2 CE compliance

The Photonfocus MV1-D2048-3D03/3D04 camera series is in compliance with the below mentioned standards according to the provisions of European Standards Directives:

- EN 61 000 - 6 - 3 : 2001
- EN 61 000 - 6 - 2 : 2001
- EN 61 000 - 4 - 6 : 1996
- EN 61 000 - 4 - 4 : 1996
- EN 61 000 - 4 - 3 : 1996
- EN 61 000 - 4 - 2 : 1995
- EN 55 022 : 1994

9 Warranty

The manufacturer alone reserves the right to recognize warranty claims.

9.1 Warranty Terms

The manufacturer warrants to distributor and end customer that for a period of two years from the date of the shipment from manufacturer or distributor to end customer (the "Warranty Period") that:

- the product will substantially conform to the specifications set forth in the applicable documentation published by the manufacturer and accompanying said product, and
- the product shall be free from defects in materials and workmanship under normal use.

The distributor shall not make or pass on to any party any warranty or representation on behalf of the manufacturer other than or inconsistent with the above limited warranty set.

9.2 Warranty Claim

The above warranty does not apply to any product that has been modified or altered by any party other than manufacturer, or for any defects caused by any use of the product in a manner for which it was not designed, or by the negligence of any party other than manufacturer.

10 References

All referenced documents can be downloaded from our website at www.photonfocus.com.

AN007 Application Note "Camera Acquisition Modes", Photonfocus, March 2004

GEVQS GEVPlayer Quick Start Guide, Pleora Technologies. Included in eBUS installer.

MAN051 Manual "Photonfocus GigE Quick Start Guide", Photonfocus

MAN053 Manual "PF 3D Suite", Photonfocus

PLC iPORT Programmable Logic Controller Reference Guide, Pleora Technologies. Included in GigE software package.

A

Pinouts

A.1 Power Supply Connector

The power supply connectors are available from Hirose connectors at www.hirose-connectors.com. Fig. A.1 shows the power supply plug from the solder side. The pin assignment of the power supply plug is given in Table A.2.

It is extremely important that you apply the appropriate voltages to your camera. Incorrect voltages will damage or destroy the camera.

The connection of the input and output signals is described in Section 6.6.

A suitable power supply can be ordered from your Photonfocus dealership.

Connector Type	Order Nr.
12-pole Hirose HR10A-10P-12S soldering	110-0402-0
12-pole Hirose HR10A-10P-12SC crimping	110-0604-4

Table A.1: Power supply connectors (Hirose HR10 series, female connector)

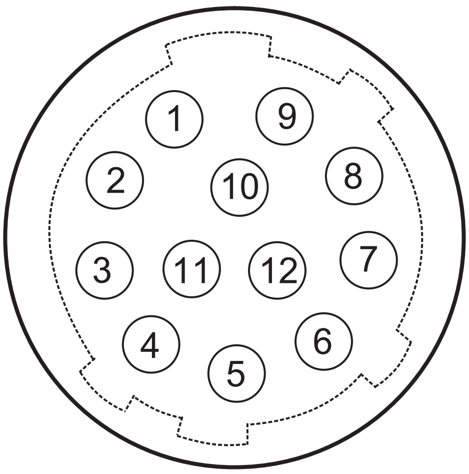

Figure A.1: Power supply connector, 12-pole female (rear view of connector, solder side)

Pin	I/O Type	Name	Description
1	PWR	CAMERA_GND	Camera GND, 0V
2	PWR	CAMERA_PWR	Camera Power 12V..24V
3	O	ISO_OUT0	Default Strobe out, internally Pulled up to ISO_PWR with 4k7 Resistor
4	I	ISO_INC0_N	INC0 differential input (G2: RS-422, H2: HTL), negative polarity
5	I	ISO_INC0_P	INC0 differential input (G2: RS-422, H2: HTL), positive polarity
6	PWR	ISO_PWR	Power supply 5V..24V for output signals; Do NOT connect to camera Power
7	I	ISO_IN0	IN0 input signal
8	O	ISO_OUT1 (MISC)	Q1 output from PLC, no Pull up to ISO_PWR ; can be used as additional output (by adding Pull up) or as controllable switch (max. 100mA, no capacitive or inductive load)
9	I	ISO_IN1(Trigger IN)	Default Trigger IN
10	I	ISO_INC1_N	INC1 differential input (G2: RS-422, H2: HTL), negative polarity
11	I	ISO_INC1_P	INC1 differential input (G2: RS-422, H2: HTL), positive polarity
12	PWR	ISO_GND	I/O GND, 0V

Table A.2: Power supply connector pin assignment

B Camera Revisions

B.1 General Remarks

This chapter lists differences between the revisions of the camera models.

Always the newest camera revision is shipped if not otherwise mentioned by the customer. If a previous version is required then this must be clearly mentionend on the purchase order.

The version of your camera is stored in the property `uCRevision` (in category `Info` / `CameraInfo`, set visibility to Expert). It is a number with at least 5 digits. The two rightmost digits are the build number, the next two digits (counting from the right side) are the minor revision number and the remaining digits are the major revision number. `uCRevision`=10203 would therefore indicate the version 1.2 (build 3).

B.2 Glossary of terms used in revision table

List of terms used in the revision tables in this chapter:

Standard Trigger Standard trigger features. Trigger Source: Free running, Software Trigger, Line1 Trigger, PLC_Q4 Trigger. Exposure Time Control: Camera-controlled, Trigger-controlled. Additional features: Trigger Delay, Burst Trigger and Strobe.

A/B Trigger Bug In the affected revisions, the bug is present in single A/B trigger mode: when the encoder position moves back and forth by a small amount, the `EncoderCounter` is incremented and the decrement is sometime omitted, leading to a wrong `EncoderPosition` indication in the camera. Therefore the single A/B trigger mode should not be used in the affected versions. A workaround to have the same behaviour as the single trigger mode, but without the bug: use the double A/B mode and double the value of `ABTriggerDivider`.

DataFormat3D `DataFormat3D` introduced enables the output of 8 bit intensity values (`LL_HEIGHT`) instead of 4 bit values (`DataFormat3D`=1). In this mode the laser line width (`LL_WIDTH`) is reduced to 4 bits instead of 6 bits. The position of these parameters in the 3D data is also modified if `DataFormat3D`=1. `DataFormat3D`=0 is the default mode which is also the mode used in revisions that don't have the `DataFormat3D` feature.

Status information Status information fields (Section 5.10): IMG_CNT[23:0], ENC_POS[23:0], M_TRIG[7:0], M_FC_TRIG[7:0]

B.3 MV1-D2048x1088-3D03 Revision 1.1 / 04.04.2012

First version. uCRevision = 10100.

Not recommended for new designs.

Order information: Order number 605030.101, MV1-D2048x1088-3D03-760-G2-8 R1

B.4 MV1-D2048x1088-3D03 Revision 2.x

Revision 2.0 brought a lot of improvements and new functionality compared to version 1.1. The following list shows the modifications of revision 2.0 compared with revision 1.1:

- 3D frame rate increased.
- Maximal 3D scan area increased to 2048x1024 pixels.
- Added gain and digital offset function to the 2D line.
- PeakFilter can be set individually for each peak.
- Added `MirrorPeak` function.
- A/B Trigger: added `ABTriggerAOnly`.
- Encoder position indication: optionally the encoder position is calculated also when trigger source is not ABTrigger (property `ABTriggerCountAlways`).
- Column Fixed Pattern Noise (FPN) Correction added.
- Outliers Correction (black and white pixel) added.
- Test images added.
- Green status LED now blinks also when camera is not grabbing images to always see if camera is powered.
- Improvement: in FrameCombine mode, image counter is now incremented with every image from sensor. Previously the image counter was incremented for every combined image, resulting in the same image number for all frames in one combined frame.
- Bug fixed: the applied `FrameCombineTimeout` value is now as set by the property. Previously it was ten times smaller than set.
- Bug fixed: in the previous version, the status info bits disappeared when UserSetSave command was issued. This is now solved.
- Improvement: the values of the status info bits are captured at exposure start. Previously it was sampled at the time when the status info bits are inserted into the image.

Revision changes for revision 2.0 and beyond are listed in tabular form in the next subsections.

B.4.1 MV1-D2048x1088-3D03 Revision table 2.x

Table B.1 shows the revision table of the revision 2.x of the Photonfocus MV1-D2048x1088-3D03 camera series. Some terms used in this table are listed in Section B.2.

Item	V2.0	V2.1	V2.2	V2.3	V2.4
2D&3D mode (Section 5.2.5)	yes	yes	yes	yes	yes
3Donly mode (Section 5.2.5)	yes	yes	yes	yes	yes
Dual peak (Section 5.2.7)	yes	yes	yes	yes	yes
2D Line (Section 5.2.8)	yes	yes	yes	yes	yes
Peak mirror (Section 5.2.6)	yes	yes	yes	yes	yes
DataFormat3D (Section 5.2.9)	no	yes	yes	yes	yes
Frame combine (Section 5.2.12)	yes	yes	yes	yes	yes
Peak filter (Section 5.2.13)	yes	yes	yes	yes	yes
Absolute coordinates (Section 5.2.14)	no	no	yes	yes	yes
High speed mode (Section 5.2.15)	no	no	no	no	yes
Standard trigger	yes	yes	yes	yes	yes
A/B trigger (Section 5.4.8)	yes	yes	yes	yes	yes
A/B Trigger Bug	yes	yes	yes	yes	no
External counter reset (Section 5.4.9)	no	no	no	yes	yes
Trigger Acquisition (Section 5.4.10)	no	no	no	yes	yes
Multiple slope (Section 5.5)	yes	yes	yes	yes	yes
Column FPN correction (Section 5.7)	yes	yes	yes	yes	yes
Outliers correction (Section 5.8)	yes	yes	yes	yes	yes
Gain and offset (Section 5.9)	yes	yes	yes	yes	yes
Status information	yes	yes	yes	yes	yes
Status information field M_TRIG_LEVEL[3:0]	no	no	no	no	yes
Test image (Section 5.11)	yes	yes	yes	yes	yes

Table B.1: Revision table MV1-D2048x1088-3D03

B.4.2 MV1-D2048-3D04 Revision table

Table B.2 shows the revision table of the Photonfocus MV1-D2048-3D04 camera series. Some terms used in this table are listed in Section B.2.

Item	V1.0
2D&3D mode (Section 5.2.5)	yes
3Donly mode (Section 5.2.5)	yes
Dual peak (Section 5.2.7)	yes
2D Line (Section 5.2.8)	yes
Peak mirror (Section 5.2.6)	yes
DataFormat3D (Section 5.2.9)	yes
Frame combine (Section 5.2.12)	yes
Peak filter (Section 5.2.13)	yes
Absolute coordinates (Section 5.2.14)	yes
High speed mode (Section 5.2.15)	yes
Standard trigger	yes
A/B trigger (Section 5.4.8)	yes
A/B Trigger Bug	no
External counter reset (Section 5.4.9)	yes
Trigger Acquisition (Section 5.4.10)	yes
Multiple slope (Section 5.5)	yes
Column FPN correction (Section 5.7)	yes
Outliers correction (Section 5.8)	yes
Gain and offset (Section 5.9)	yes
Status information	yes
Status information field M_TRIG_LEVEL[3:0]	yes
Test image (Section 5.11)	yes

Table B.2: Revision table MV1-D2048-3D04

C

Revision History

Revision	Date	Changes
1.0	February 2012	First version
1.1	February 2012	Chapter "Product Specification": camera dimensions and lens mount corrected. Chapter "Mechanical Interface": mechanical drawing corrected. Note about thermal coupling of the camera added.
1.2	February 2012	Chapter "Functionality", section "3D Features" / "Peak Filter": Diagrams added; Property `PeakFilter_EnPeakNr` removed. Chapter "Functionality", section "Reduction of Image Size": frame rates corrected Chapter "Functionality", section "Exposure Time Control": trigger-controlled exposure time removed Chapter "Functionality", section "A/B Trigger for Incremental Encoder": ABTriggerResolution renamed to ABTriggerDivider (ABTriggerDivder = ABTriggerResolution+1) Chapter "Functionality". section "High Dynamic Range (multiple slope) Mode" added.
1.3	April 2012	Chapter "Product Specification": full well capacity corrected to 11 ke^- (from 13.5 ke^-).
1.4	May 2012	Adapted to PFInstaller_2_30 and later

Revision	Date	Changes
2.0	January 2013	Chapter Product Specification, section Technical Specification: minimal exposure time corrected. Value of 1μs was not correct. Maximal 3D scan area increased to 2048x1024 pixels. Chapter Functionality, section 3D Features: 2D line is now described in its own section. Added section Mirror Peak. Chapter Functionality, section 3D Features (3D data format): added STAT description and reference to status information section. Chapter Functionality, section 3D Features (Peak Filter): parameters can now be set for every peak. Chapter Functionality, section 3D Features (Frame Combine / Aborting Frame Combine): More text about value of the filler rows added. Chapter Functionality, section Reduction of Image Size (Region of Interest (ROI) in 3D modes): frame rates are higher in camera version 2. Chapter Functionality, section Trigger and Strobe: sections Trigger Divider, A Only Trigger and Encoder Position (both in A/B Trigger for Incremental Encoder) added. Chapter Functionality: sections Column FPN Correction, Outliers Correction and Test Images added. Chapter Hardware Interface, section Status Indicator (GigE cameras): green LED now blinks also when camera is idle. Chapter Software, sections Column FPN Correction and Outliers Correction. Chapter Software, section PLC Settings: PLC drawing improved.
2.1	February 2013	Chapter Functionality, section 3D data format (3D Features): new property DataFormat3D introduced. Chapter Functionality, section Region of Interest (ROI) in 3D modes (Reduction of Image Size): description improved.
2.2	November 2013	FrameCombine documentation improved.New feature "absolute coordinates" added.
2.3	February 2014	Section Peak Filter: property names corrected. Section Reduction of Image Size: frame rates corrected Section Counter Reset by an External Signal added. Section Trigger Acquisition added. Camera Revision 2.3 added.
2.4	May 2014	Section FrameCombine: replaced FrameCombineAbort (erroneous name) by FrameCombine_ForceTimeout.

Revision	Date	Changes
2.5	June 2014	MV1-D2048-3D04 camera models added. New model variants H2 (HTL encoder interface) and S10 (Scheimpflug 10°) added. Chapter `Introduction` added. Section `High Speed Mode` added. Status field `M_TRIG_LEVEL[3:0]` added. Section `Power and Ground Connection for GigE H2 Cameras` added. Revision information now shown in tabular form