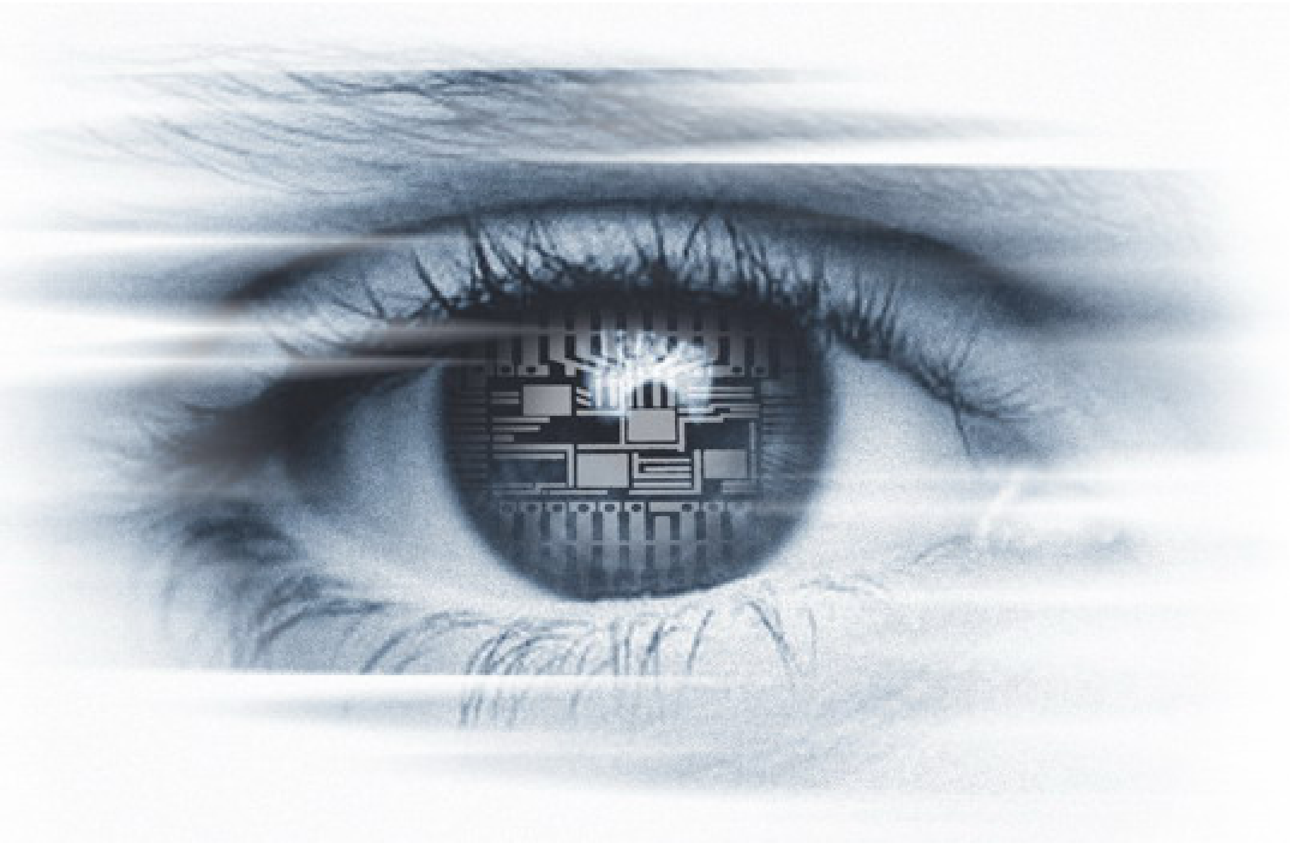
User Manual

MV1-D1024E CameraLink® Series

CMOS Area Scan Cameras



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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

☞ Photonfocus reserves the right to make changes to its products and documentation without notice. Photonfocus products are neither intended nor certified for use in life support systems or in other critical systems. The use of Photonfocus products in such applications is prohibited.

☞ Photonfocus is a trademark and LinLog® is a registered trademark of Photonfocus AG. CameraLink® and GigE Vision® are a registered mark of the Automated Imaging Association. Product and company names mentioned herein are trademarks or trade names of their respective companies.

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

How to get started (CameraLink®)

The following items are required to operate your Photonfocus CameraLink® camera:

- PC
- Suitable CameraLink® frame grabber card to be installed in the PC. All Photonfocus CameraLink® cameras are fully compatible with the CameraLink® standard 1.1 and later. Therefore, all framegrabbers complying with the standard will be compatible with Photonfocus cameras if they meet the interface and speed specifications of the cameras. Note that some framegrabbers use CameraLink® chipsets limited to 66 MHz pixel clocks. These framegrabbers are not compatible with Photonfocus MV1-D1024E-160 CameraLink® camera. If you have compatibility questions concerning your framegrabber, please contact our support team via support@photonfocus.com. Suitable CameraLink® frame grabbers can be purchased from Photonfocus directly (www.photonfocus.com) in some countries.
- CameraLink® cable. The cable length should not be too big for the camera. The camera includes test images 4.11 to measure the transmission quality of the system. CameraLink® cables can be purchased from directly Photonfocus (www.photonfocus.com) in some countries.
- A suitable power supply. A suitable power supply can be purchased at your Photonfocus dealership.
- C-Mount camera lens. Note that if you plan to use your NIR enhanced camera in the near infrared region (NIR), then you should use SWIR camera lenses.

1. Install a suitable frame grabber in your PC.
2. Install the frame grabber software.

   Without installed frame grabber software the camera configuration tool PFRemote will not be able to communicate with the camera. Please follow the instructions of the frame grabber supplier.

3. Remove the camera from its packaging. Please make sure the following items are included with your camera:
   - Power supply connector (7-pole power plug)
   - Camera body cap

   If any items are missing or damaged, please contact your dealership.
4. Remove the camera body cap from the camera and mount a suitable lens.

   When removing the camera body cap or when changing the lens, the camera should always be held with the opening facing downwards to prevent dust or debris falling onto the CMOS sensor.

   Do not touch the sensor surface. Protect the image sensor from particles and dirt!

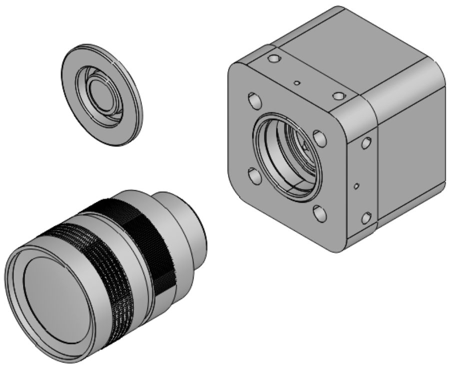


Figure 2.1: Camera with protective cap and lens.

To choose a lens, see the Lens Finder in the 'Support' area at www.photonfocus.com.

5. Connect the camera to the frame grabber with a suitable CameraLink® cable (see Fig. 2.2).

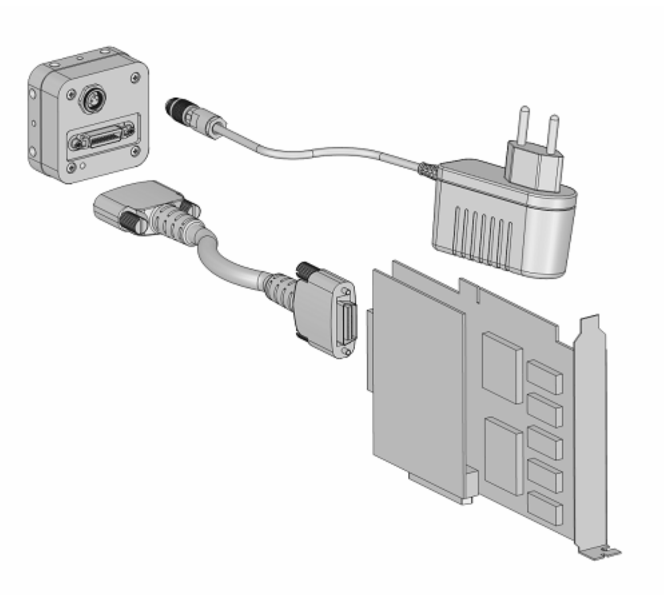


Figure 2.2: Camera with frame grabber, power supply and cable.

Do not connect or disconnect the CameraLink® cable while camera power is on! For more information about CameraLink® see Section 4.12.

6. Connect a suitable power supply to the provided 7-pole power plug. For the connector assembly see Fig. A.1. The pinout of the connector is shown in Appendix Appendix A.

Check the correct supply voltage and polarity! Do not exceed the maximum operating voltage of +12V DC ($\pm$ 10%).

7. Connect the power supply to the camera (see Fig. 2.2).

The status LED on the rear of the camera will light red for a short moment, and then flash green. For more information see Section 5.1.4.

8. Download the camera software PFRemote to your computer.

You can find the latest version of PFRemote on the support page at www.photonfocus.com.

9. Install the camera software PFRemote. Please follow the instructions of the PFRemote setup wizard.

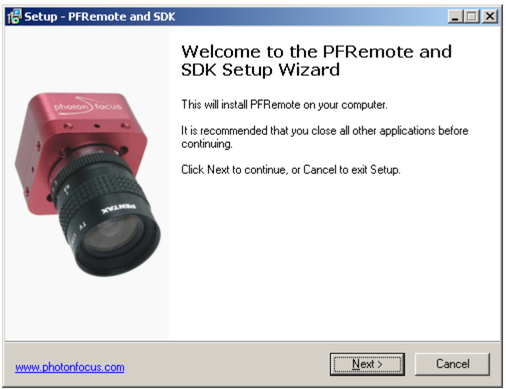


Figure 2.3: Screen shot PFremote setup wizard

10. Start the camera software PFRemote and choose the communication port.
11. Check the status LED on the rear of the camera.

The status LED lights green when an image is being produced, and it is red when serial communication is active. For more information see Section 5.1.4.

12. You may display images using the software that is provided by the frame grabber manufacturer.

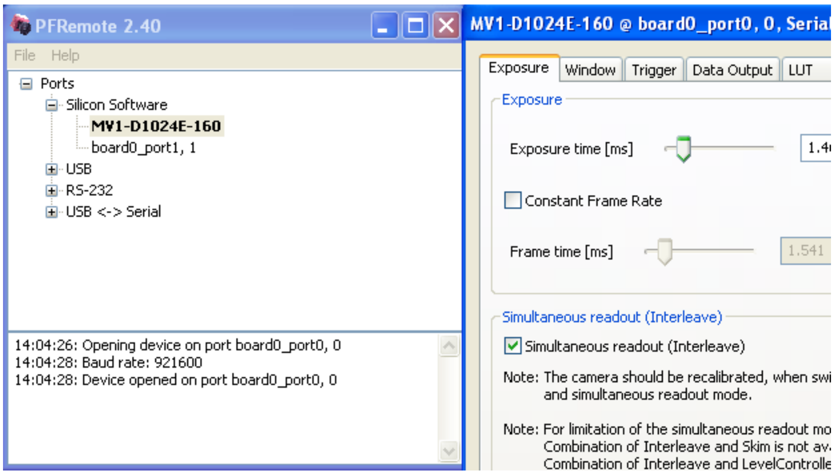


Figure 2.4: PFRemote start window

3 Product Specification

3.1 Introduction

The MV1-D1024E-CL CMOS camera series from Photonfocus is aimed at demanding applications in industrial image processing. It provides an exceptionally high dynamic range of up to 120 dB at a resolution of 1024 x 1024 pixels. The cameras are built around a monochrome CMOS image sensor, developed by Photonfocus. The principal advantages are:

- Resolution of 1024 x 1024 pixels
- Spectral sensitivity from 400 nm to 900 nm
- Superior signal-to-noise ratio (SNR).
- Low power consumption at high speeds
- Very high resistance to blooming
- Extremely high image contrast achieved by LinLog® technology.
- Ideal for high speed applications: global shutter
- Maximal frame rate at full resolution: 150 fps.
- Greyscale resolution of up to 12 bit
- On camera shading correction.
- Up to 512 regions of interest (MROI).
- 2 look-up tables (12-to-8 bit) on user-defined image region (Region-LUT).
- Crosshairs overlay on the image.
- Image information and camera settings inside the image (status line).
- Software provided for setting and storage of camera parameters.
- CameraLink® base interface.
- The rugged housing at a compact size of 55 x 55 x 40 mm^3 makes the MV1-D1024E camera series the perfect solution for applications in which space is at a premium.

3.2 Feature Overview

Characteristics	**MV1-D1024E-CL Series**
Interface	CameraLink® base configuration
Camera Control	PFRemote (Windows GUI) or programming library
Configuration Interface	CLSERIAL (9’600 baud up to 1.5Mbaud, user selectable)
Trigger Modes	Interface Trigger / External opto isolated trigger input
Image pre-processing	Shading Correction (Offset and Gain)
	2 look-up tables (12-to-8 bit) on user-defined image region (Region-LUT)
Features	Greyscale resolution 12 bit / 10 bit / 8 bit
	Region of Interest (ROI)
	Linear Mode / LinLog® Mode / Skimming
	Up to 512 regions of interest (MROI)
	Test pattern (LFSR and grey level ramp)
	Image information and camera settings inside the image (status line)
	Crosshairs overlay on the image
	High blooming resistance
	Opto isolated trigger input and opto isolated strobe output

Table 3.1: Feature overview (see Chapter 4 for more information)

Figure 3.1: MV1-D1024E-CL CMOS camera series with C-mount lens.

3.3 Available Camera Models

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

Name	Resolution	FPS	Color
MV1-D1024E-160-CL-12	1024 x 1024	150 fps [1)]	no

Table 3.2: Available Photonfocus MV1-D1024E-CL camera models (Footnotes: [1)]frame rate at at full resolution)

3.4 Difference to legacy MV-D1024E series

The MV1-D1024E-160-CL-12 is a direct replacement of the MV-D1024E-160-12 camera. The housing and the pinout of the power connector and the CameraLink® are identical.

The release of the MV1-D1024E-160 camera was required due to the non-availability of some electronic components.

The new MV1-D1024E-160 camera has some features not found in the legacy MV-1024E-160 camera:

- Number of MROI increased to 512.
- Enhanced trigger features: burst trigger (see Section 4.4.5).
- Gain correction is improved.
- Finer gain control through FineGain feature (see Section 4.7).
- 2 LUT instead of one and RegionLUT feature (see Section 4.8).
- Crosshairs overlay (see 4.9).
- More data fields in the status line (see Section 4.10.2).

3.5 Technical Specification

	MV1-D1024E-160-CL
Technology	CMOS active pixel
Scanning system	progressive scan
Optical format / diagonal	1” / 15.42 mm
Resolution	1024 x 1024 pixels
Pixel size	10.6 μm x 10.6 μm
Active optical area	10.9 mm x 10.9 mm
Random noise	< 0.5 DN RMS @ 8 bit / gain= 1
Fixed pattern noise (FPN)	< 1 DN RMS @ 8 bit / gain= 1 / offset correction on
Dark current	2 fA/pixel @ 30°C
Full well capacity	200 ke$^-$
Spectral range	400 nm ... 900 nm
Responsivity	120 x 10^3 DN / (J/m^2) @ 610 nm / 8 bit / gain = 1
Optical fill factor	35%
Dynamic range	up to 120 dB (with LinLog)
Colour format	monochrome
Characteristic curve	Linear, LinLog, Skimming
Shutter mode	global shutter
Greyscale Resolution	12 bit / 10 bit / 8 bit
Exposure Time	10 μs ... 0.41 s
Exposure Time Increment	25 ns
Frame Rate (T$_{int}$ = 10 μs)	150 fps
Pixel Clock Frequency	80 MHz
Camera Taps	2
Read out mode	sequential or simultaneous

Table 3.3: General specification of the MV1-D1024E-160-CL camera

	MV1-D1024E-160-CL
Operating temperature	0°C ... 50°C
Storage temperature / moisture	-25°C ... 60°C / 20 ... 95 %
Camera power supply	+12 V DC ($\pm$10%)
Trigger signal input range	+5 .. +15 V DC
Max. power consumption	4.0 W
Lens mount	C-Mount, CS-Mount (optional)
Dimensions	55 x 55 x 40 mm^3
Mass	210 g
Conformity	CE, RoHS, WEEE

Table 3.4: Physical characteristics and operating ranges

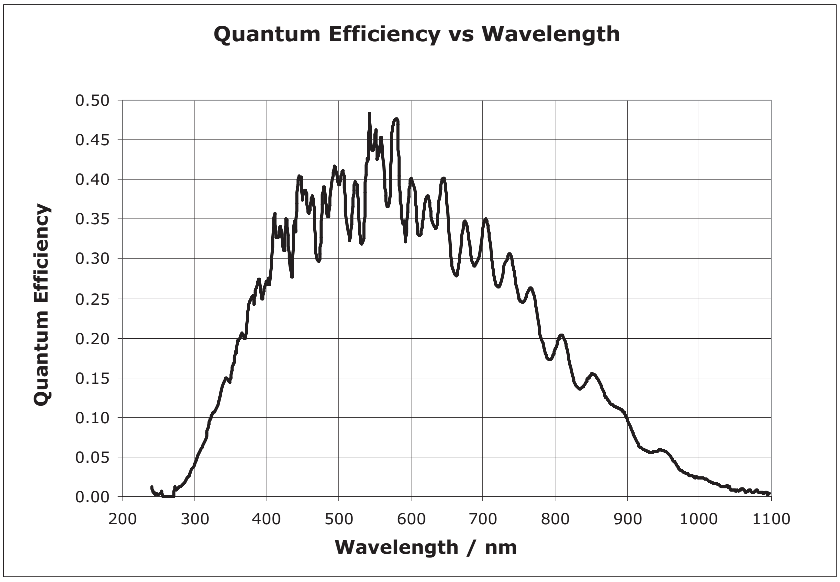


Figure 3.2: Spectral response of the A1024B CMOS sensor

3.6 Frame Grabber relevant Configuration

The parameters and settings, which are essential to configure the frame grabber are shown in the following table.

	MV1-D10124E-160-CL
Pixel Clock per Tap	80 MHz
Number of Taps	2
Greyscale resolution	12 bit / 10 bit / 8 bit
Line pause	8 clock cycles
CC1	EXSYNC
CC2	not used
CC3	not used
CC4	not used
Maximal average data rate @ 8 bit	160 MB/s
Maximal average data rate @ 10/12 bit [1)]	320 MB/s

Table 3.5: Summary of parameters needed for frame grabber configuration (Footnotes: [1)]assuming 16 bit/pixel data transmission)

CameraLink® port and bit assignments are compliant with the CameraLink® standard (see [CL]). Table 3.6 shows the tap configuration for the MV1-D1024E-160-CL camera.

Bit	Tap 0	Tap 1	Tap 0	Tap 1	Tap 0	Tap 1
	8 Bit	8 Bit	10 Bit	10 Bit	12 Bit	12 Bit
0 (LSB)	A0	B0	A0	C0	A0	C0
1	A1	B1	A1	C1	A1	C1
2	A2	B2	A2	C2	A2	C2
3	A3	B3	A3	C3	A3	C3
4	A4	B4	A4	C4	A4	C4
5	A5	B5	A5	C5	A5	C5
6	A6	B6	A6	C6	A6	C6
7 (MSB of 8 Bit)	A7	B7	A7	C7	A7	C7
8	-	-	B0	B4	B0	B4
9 (MSB of 10 Bit)	-	-	B1	B5	B1	B5
10	-	-	-	-	B2	B6
11 (MSB of 12 Bit)	-	-	-	-	B3	B7

Table 3.6: CameraLink® 2 Tap port and bit assignments for the MV1-D1024E-160 camera

4

Functionality

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 cameras is explained in later chapters.

4.1 Image Acquisition

4.1.1 Readout Modes

The MV1-D1024E CameraLink series provides two different readout modes:

Sequential readout Frame time is the sum of exposure time and readout time. Exposure time of the next image can only start if the readout time of the current image is finished.

Simultaneous readout (interleave) The frame time is determined by the maximum of the exposure time or of the readout time, which ever of both is the longer one. Exposure time of the next image can start during the readout time of the current image.

	MV1-D1024E-160-CL
Sequential readout	available
Simultaneous readout	available

Table 4.1: Available readout mode of MV1-D1024E-160-CL camera

The following figure illustrates the effect on the frame rate when using either the sequential readout mode or the simultaneous readout mode (interleave exposure).

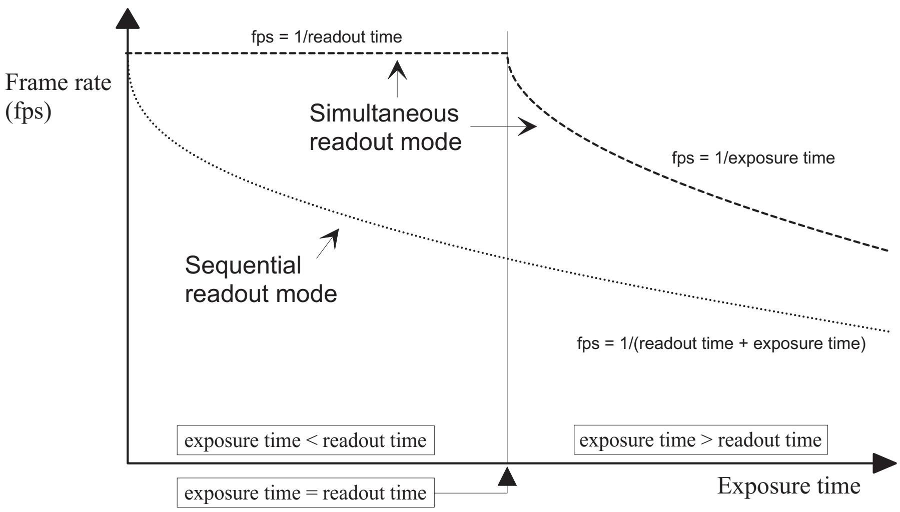


Figure 4.1: Frame rate in sequential readout mode and simultaneous readout mode

Sequential readout mode For the calculation of the frame rate only a single formula applies: frame rate equals approximately the inverse of the sum of exposure time and readout time.

Simultaneous readout mode (exposure time < readout time) The frame rate is given by the readout time. frame rate equals approximately the inverse of the readout time.

Simultaneous readout mode (exposure time > readout time) The frame rate is given by the exposure time. frame rate equals approximately the inverse of the exposure time.

The simultaneous readout mode allows higher frame rate. However, If the exposure time strongly exceeds the readout time, then the effect on the frame rate is neglectable.

In simultaneous readout mode image output faces minor limitations. The overall linear sensor reponse is partially restricted in the lower gray scale region.

A new calibration of the image correction is required when changing the read-out mode from sequential to simultaneous readout mode or vice versa.

Sequential readout

By default the camera continuously delivers images as fast as possible ("Free-running mode") in the sequential readout mode. Exposure time of the next image can only start if the readout time of the current image is finished.

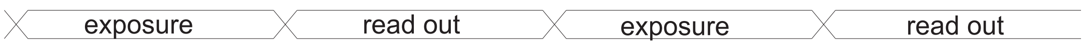


Figure 4.2: Timing in free-running sequential readout mode

When the acquisition of an image needs to be synchronised to an external event, an external trigger can be used (refer to Section 4.4). In this mode, the camera is idle until it gets a signal to capture an image.

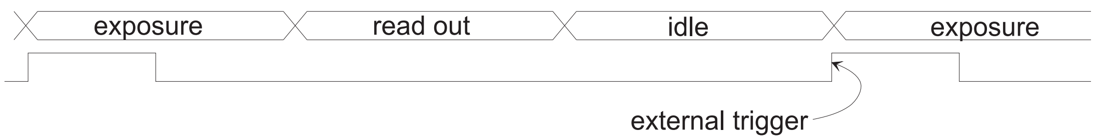


Figure 4.3: Timing in triggered sequential readout mode

Simultaneous readout (interleave exposure)

To achieve highest possible frame rates, the camera must be set to "Free-running mode" with simultaneous readout. The camera continuously delivers images as fast as possible. Exposure time of the next image can start during the readout time of the current image.
When the acquisition of an image needs to be synchronised to an external event, an external trigger can be used (refer to Section 4.4). In this mode, the camera is idle until it gets a signal to capture an image.

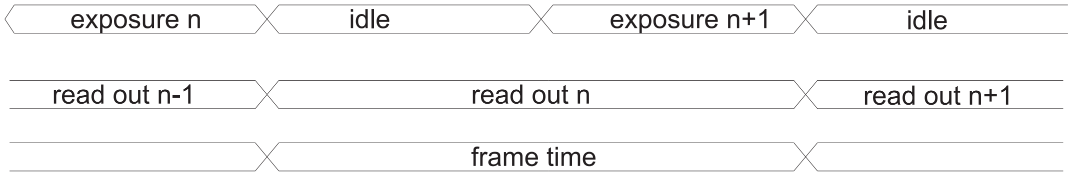


Figure 4.4: Timing in free-running simultaneous readout mode (readout time> exposure time)

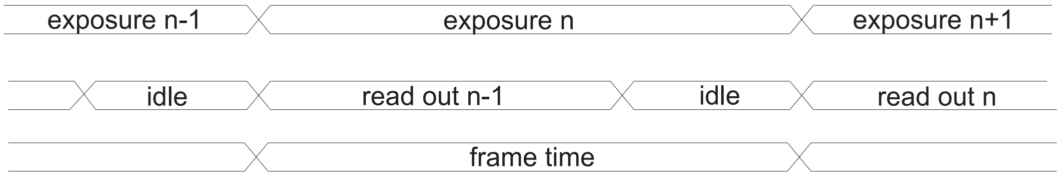


Figure 4.5: Timing in free-running simultaneous readout mode (readout time< exposure time)

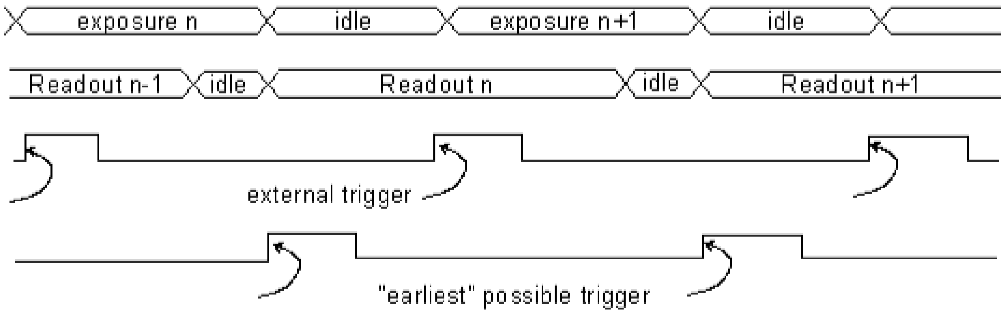


Figure 4.6: Timing in triggered simultaneous readout mode

4.1.2 Constant Frame Rate (CFR)

When the CFR mode is switched on, the target frame rate for the free-running mode can be setting the frame time property. Thus, fewer images can be acquired than would otherwise be possible.

When Constant Frame Rate is switched off, the camera delivers images as fast as possible, depending on the exposure time and the read-out time.

Constant Frame Rate mode (CFR) is not available together with external trigger mode.

4.2 Pixel Response

4.2.1 Linear Response

The camera offers a linear response between input light signal and output grey level. This can be modified by the use of LinLog or Skimming as described in the following sections. In addition, a linear digital gain may be applied (see Section 4.7).

Black Level Adjustment

The black level is the average image value at no light intensity. It can be adjusted by the software by changing the black level offset. Thus, the overall image gets brighter or darker. Use a histogram to control the settings of the black level.

4.2.2 LinLog®

Overview

The LinLog® technology from Photonfocus allows a logarithmic compression of high light intensities inside the pixel. In contrast to the classical non-integrating logarithmic pixel, the LinLog® pixel is an integrating pixel with global shutter and the possibility to control the transition between linear and logarithmic mode.

In situations involving high intrascene contrast, a compression of the upper grey level region can be achieved with the LinLog® technology. At low intensities each pixel shows a linear response. At high intensities the response changes to logarithmic compression (see Fig. 4.7). The transition region between linear and logarithmic response can be smoothly adjusted by software and is continuously differentiable and monotonic.

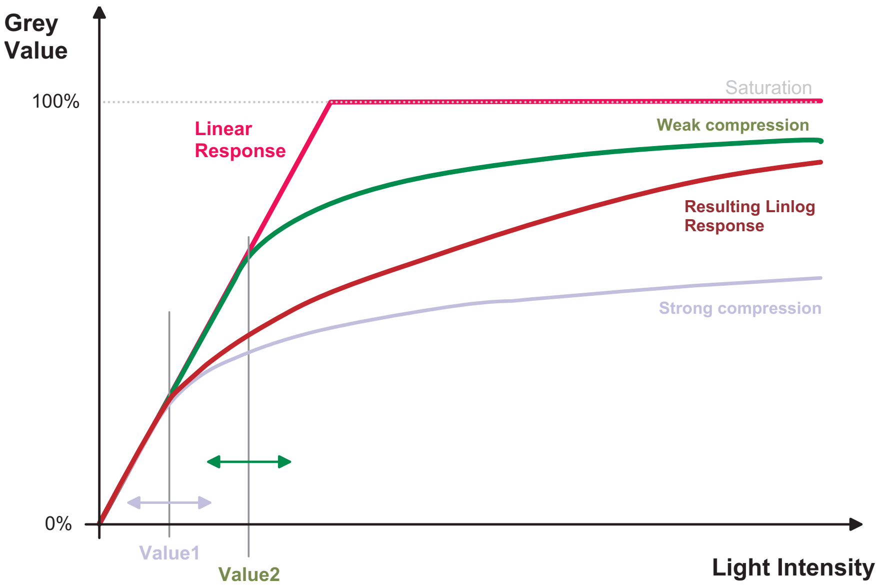


Figure 4.7: Resulting LinLog2 response curve

LinLog® is controlled by up to 4 parameters (`Time1`, `Time2`, `Value1` and `Value2`). `Value1` and `Value2` correspond to the LinLog® voltage that is applied to the sensor. The higher the parameters `Value1` and `Value2` respectively, the stronger the compression for the high light intensities. `Time1` and `Time2` are normalised to the exposure time. They can be set to a maximum value of 1000, which corresponds to the exposure time.

Examples in the following sections illustrate the LinLog® feature.

LinLog1

In the simplest way the pixels are operated with a constant LinLog® voltage which defines the knee point of the transition.This procedure has the drawback that the linear response curve changes directly to a logarithmic curve leading to a poor grey resolution in the logarithmic region (see Fig. 4.9).

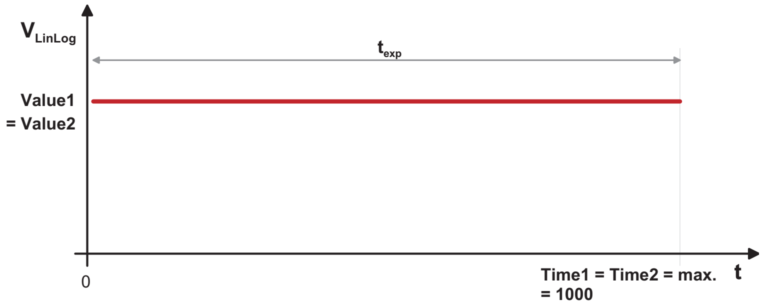


Figure 4.8: Constant LinLog voltage in the Linlog1 mode

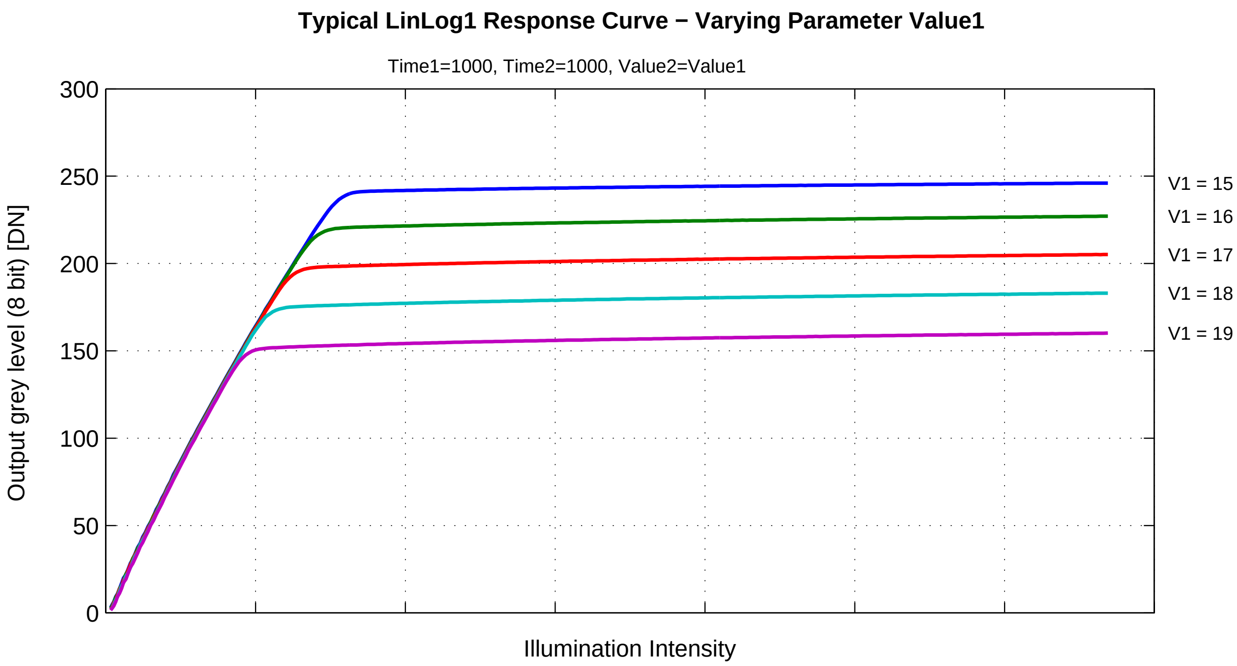


Figure 4.9: Response curve for different LinLog settings in LinLog1 mode

LinLog2

To get more grey resolution in the LinLog® mode, the LinLog2 procedure was developed. In LinLog2 mode a switching between two different logarithmic compressions occurs during the exposure time (see Fig. 4.10). The exposure starts with strong compression with a high LinLog®voltage (`Value1`). At `Time1` the LinLog®voltage is switched to a lower voltage resulting in a weaker compression. This procedure gives a LinLog®response curve with more grey resolution. Fig. 4.11 and Fig. 4.12 show how the response curve is controlled by the three parameters `Value1`, `Value2` and the LinLog®time `Time1`.

☞ Settings in LinLog2 mode, enable a fine tuning of the slope in the logarithmic region.

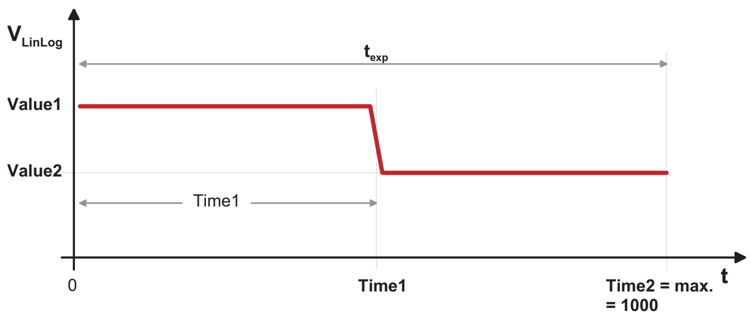


Figure 4.10: Voltage switching in the Linlog2 mode

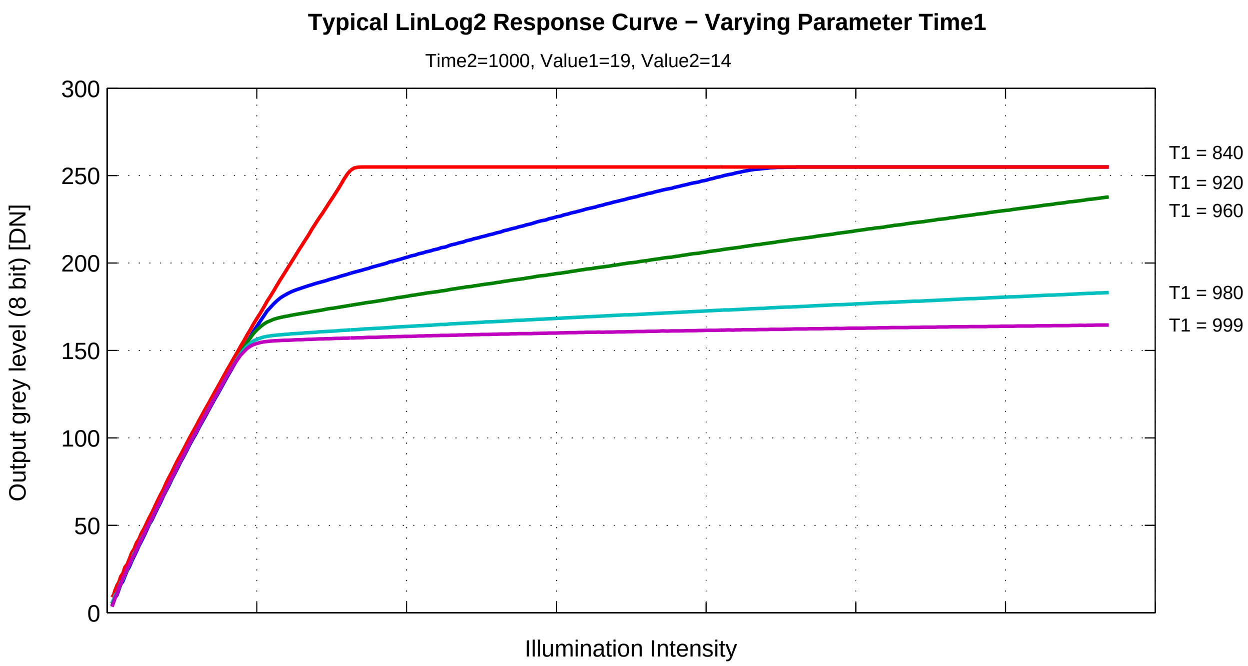


Figure 4.11: Response curve for different LinLog settings in LinLog2 mode

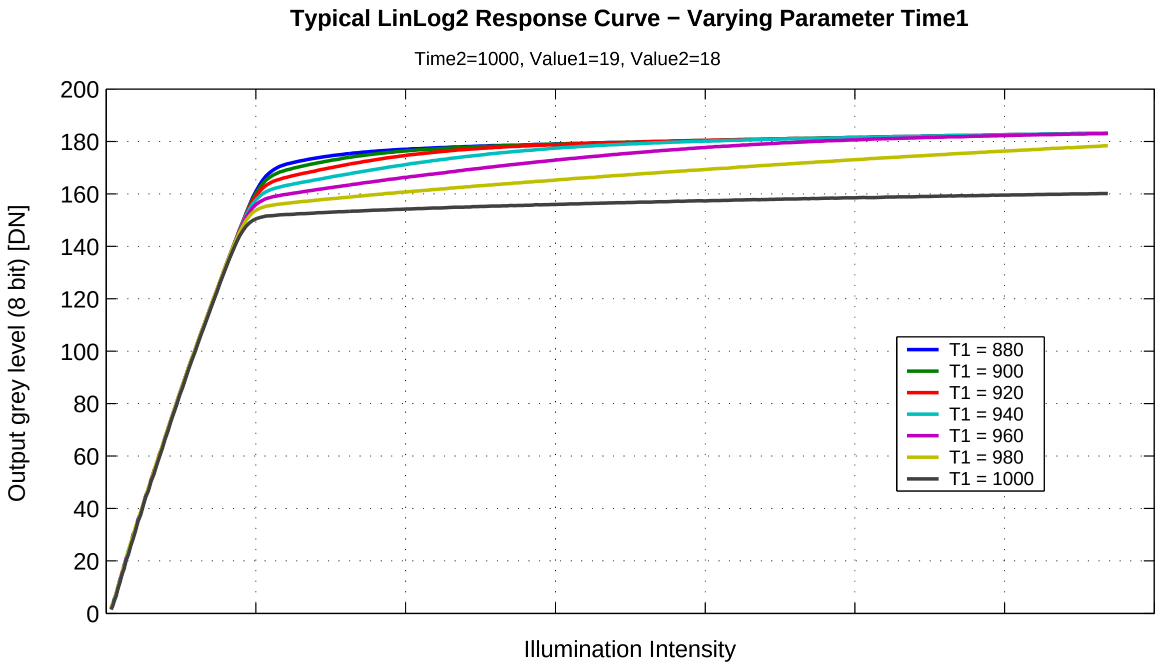


Figure 4.12: Response curve for different LinLog settings in LinLog2 mode

LinLog3

To enable more flexibility the LinLog3 mode with 4 parameters was introduced. Fig. 4.13 shows the timing diagram for the LinLog3 mode and the control parameters.

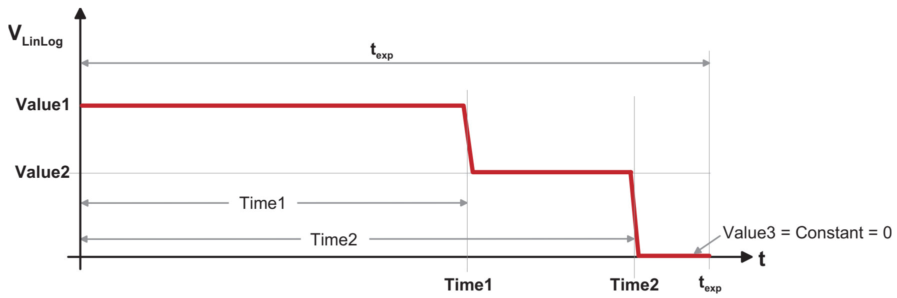


Figure 4.13: Voltage switching in the LinLog3 mode

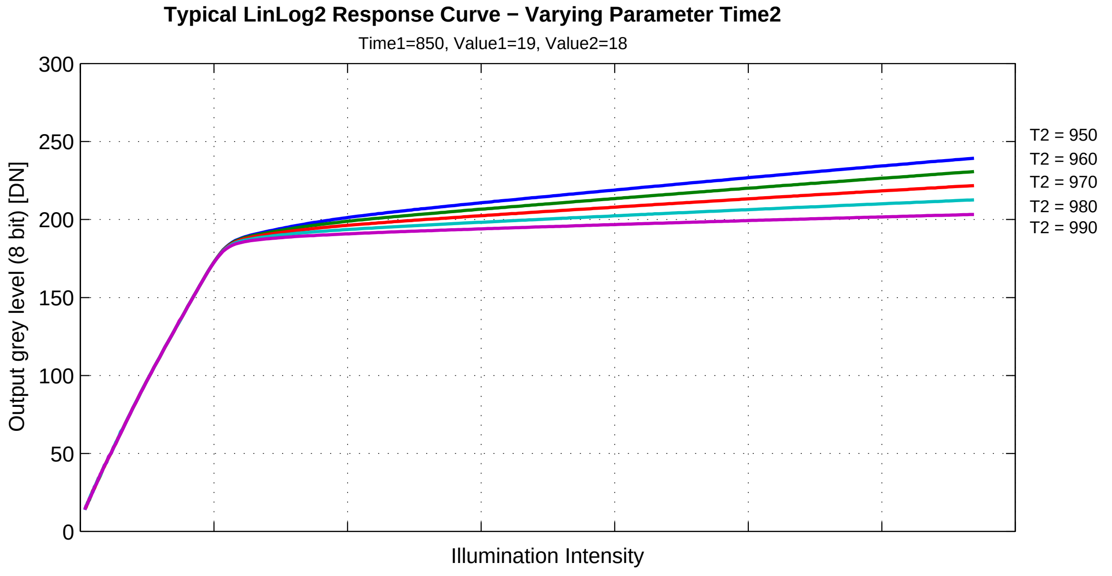


Figure 4.14: Response curve for different LinLog settings in LinLog3 mode

4.2.3 Skimming

Skimming is a Photonfocus proprietary technology to enhance detail in dark areas of an image. Skimming provides an adjustable level of in-pixel gain for low signal levels. It can be used together with LinLog®to give a smooth monotonic transfer function from high gain at low levels, through normal linear operation, to logarithmic compression for high signal levels (see Fig. 4.15). The resulting response is similar to a gamma correction.

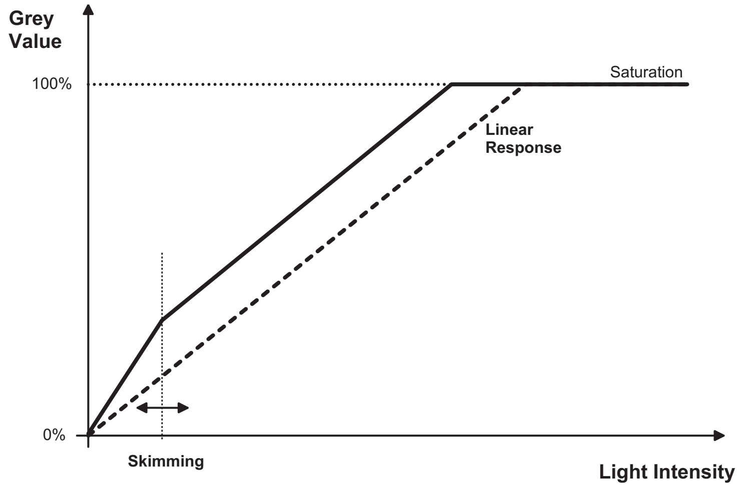


Figure 4.15: Response curve for different skimming settings

4.3 Reduction of Image Size

With Photonfocus cameras there are several possibilities to focus on the interesting parts of an image, thus reducing the data rate and increasing the frame rate. The most commonly used feature is Region of Interest (ROI).

4.3.1 Region of Interest (ROI)

Some applications do not need full image resolution (e.g. 1024x1024 pixels). 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. Fig. 4.16 gives some possible configurations for a region of interest, and Table 4.2 shows some numerical examples of how the frame rate can be increased by reducing the ROI. Table 4.3 shows the frame rate as a function of the read out mode and the exposure time.

☞ Both reductions in x- and y-direction result in a higher frame rate.

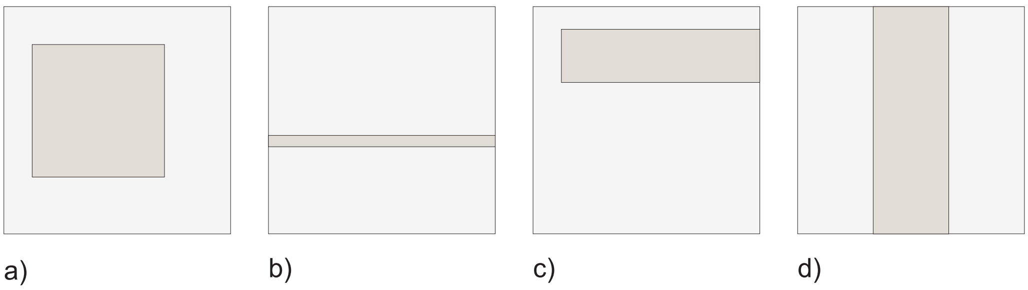


Figure 4.16: ROI configuration examples

ROI Dimension	MV1-D1024E-160-CL
1024 x 1024	149 fps
512 x 512	586 fps
256 x 256	2225 fps
128 x 128	7780 fps
128 x 16	36065 fps

Table 4.2: Frame rates of different ROI settings (minimal exposure time; CFR off, skimming off and sequential readout mode).

Exposure time	MV1-D1024E-160-CL
10 μs	149 / 148 fps
100 μs	147 / 146 fps
500 μs	139 / 139 fps
1 ms	130 / 140 fps
2 ms	115 / 140 fps
5 ms	85 / 140 fps
10 ms	60 / 99 fps
12 ms	53 / 82 fps

Table 4.3: Frame rate of different exposure times, [sequential readout mode / simultaneous readout mode], resolution 1024x1024 pixel (correction off, CFR off and skimming off).

4.3.2 Multiple Regions of Interest

The Photonfocus MV1-D1024E-160-CL camera can handle up to 512 different regions of interest. This feature can be used to reduce the amount image data and increase the frame rate. An application example for using multiple regions of interest (MROI) is a laser triangulation system with several laser lines. The multiple ROIs are joined together and form a single image, which is transferred to the frame grabber.

An individual MROI region is defined by its starting value in y-direction and its height. The starting value in horizontal direction and the width is the same for all MROI regions and is defined by the ROI settings. The maximum frame rate in MROI mode depends on the number of rows and columns being read out. Overlapping ROIs are not allowed and no row must be read out more than once.

The individual ROI in a MROI must not overlap and no row should be included in more than one ROI.

Fig. 4.17 compares ROI and MROI: the setups (visualized on the image sensor area) are displayed in the upper half of the drawing. The lower half shows the dimensions of the resulting image. On the left-hand side an example of ROI is shown and on the right-hand side an example of MROI. It can be readily seen that the resulting image with MROI is smaller than the resulting image with ROI only and the former will result in an increase in image frame rate.

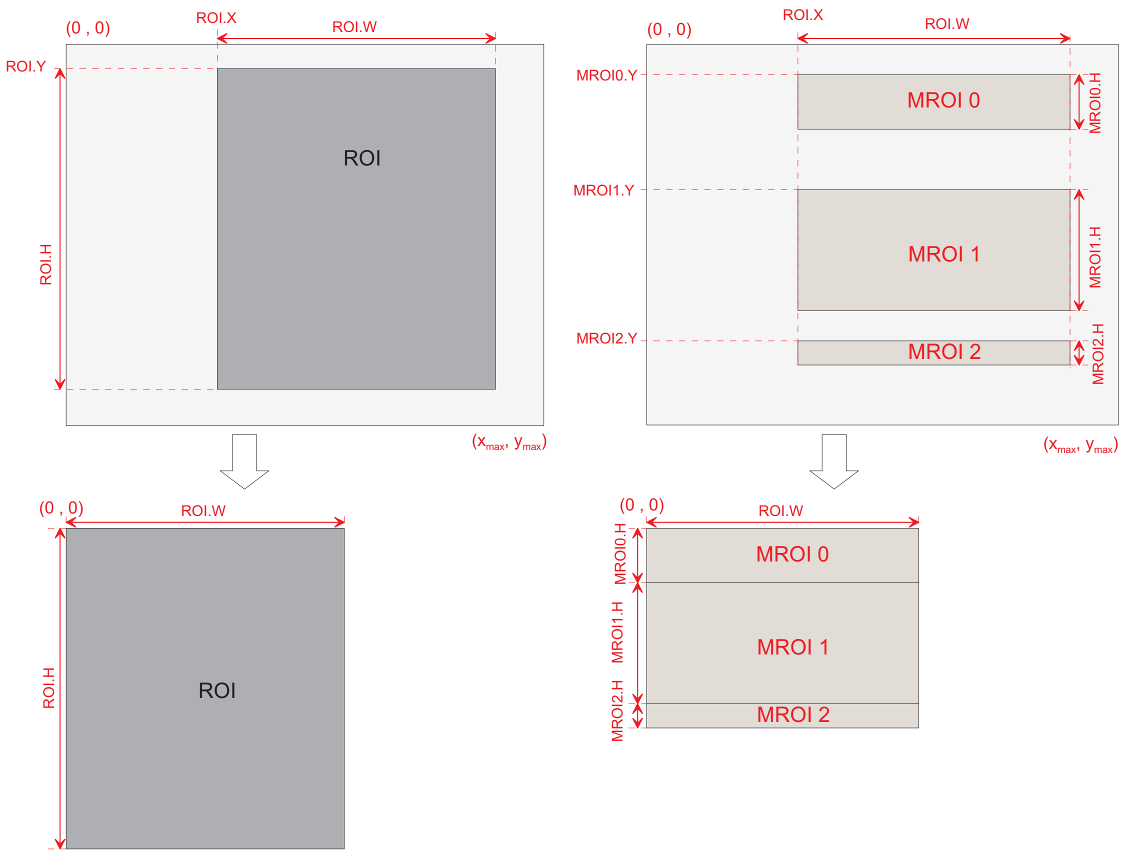


Figure 4.17: Multiple Regions of Interest

Fig. 4.18 shows another MROI drawing illustrating the effect of MROI on the image content.

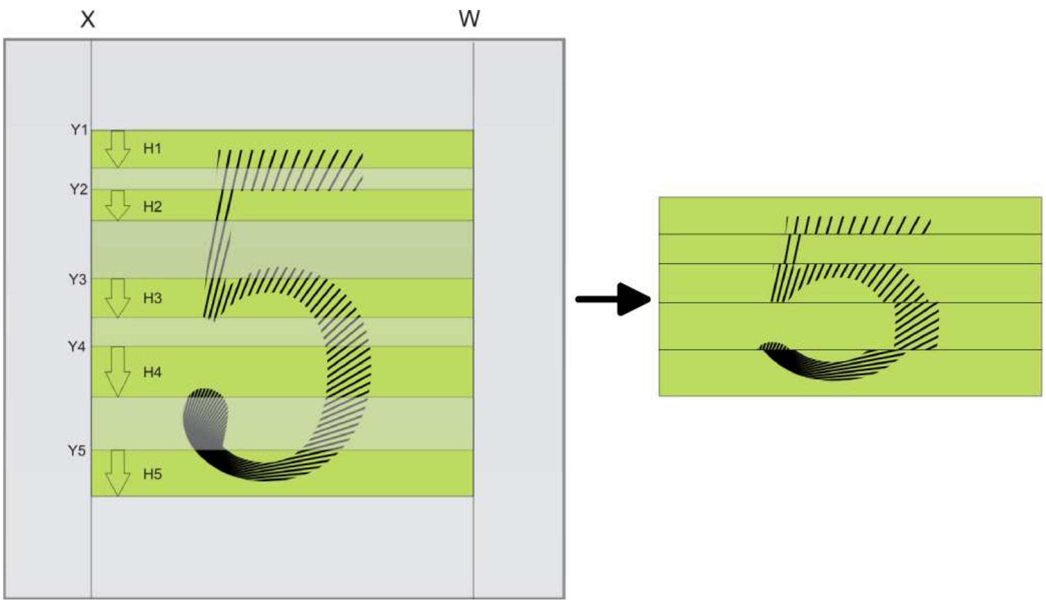


Figure 4.18: Multiple Regions of Interest with 5 ROIs

4.3.3 Decimation

Decimation reduces the number of pixels in y-direction. Decimation in y-direction transfers every n^{th}row only and directly results in reduced read-out time and higher frame rate respectively.

☞ Decimation can also be used together with ROI or MROI. In this case every ROI should have a height that is a multiple of the decimation setting. E.g. if decimation=3, then the height of every ROI should be a multiple of 3.

Fig. 4.19 shows decimation on the full image. The rows that will be read out are marked by red lines. Row 0 is read out and then every n^{th} row.

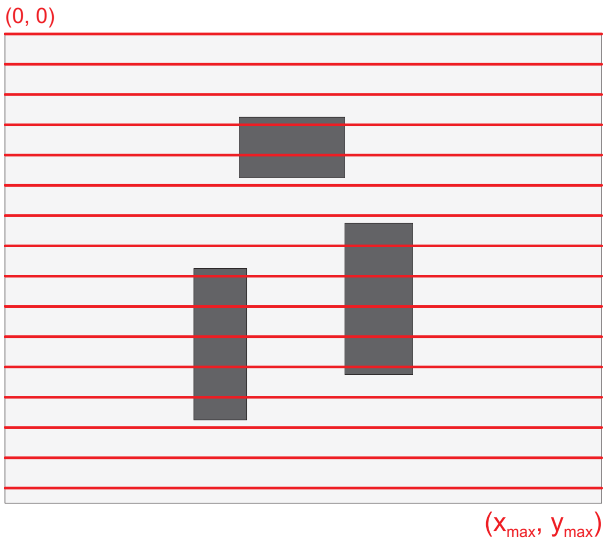


Figure 4.19: Decimation in full image

Fig. 4.20 shows decimation on a ROI. The row specified by the Window.Y setting is first read out and then every n^{th} row until the end of the ROI.
Fig. 4.21 shows decimation and MROI. For every MROI region m, the first row read out is the row specified by the MROI<m>.Y setting and then every n^{th} row until the end of MROI region m.

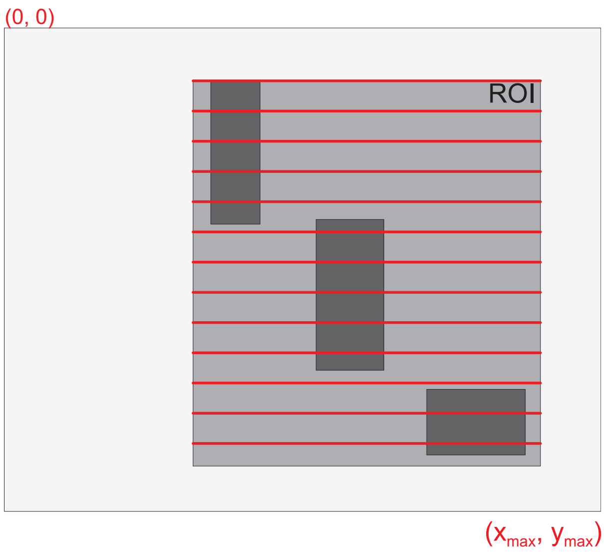


Figure 4.20: Decimation and ROI

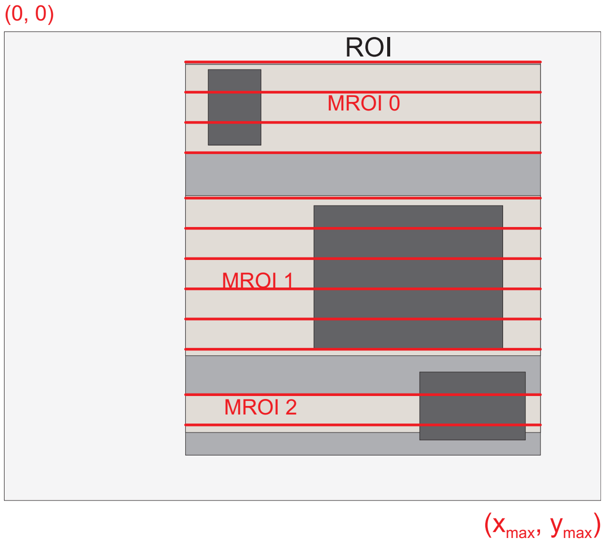


Figure 4.21: Decimation and MROI

The image in Fig. 4.22 on the right-hand side shows the result of decimation 3 of the image on the left-hand side.

Figure 4.22: Image example of decimation 3

An example of a high-speed measurement of the elongation of an injection needle is given in Fig. 4.23. In this application the height information is less important than the width information. Applying decimation 2 on the original image on the left-hand side doubles the resulting frame rate.

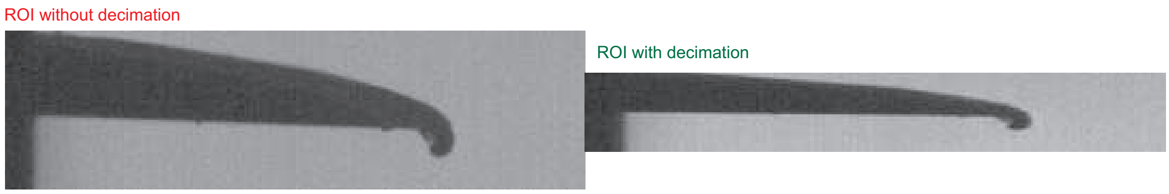


Figure 4.23: Example of decimation 2 on image of injection needle

4.4 Trigger and Strobe

4.4.1 Introduction

The start of the exposure of the camera's image sensor is controlled by the trigger. The trigger can either be generated internally by the camera (free running trigger mode) or by an external device (external trigger mode).

This section refers to the external trigger mode if not otherwise specified.

In external trigger mode, the trigger can be applied through the CameraLink ® interface (interface trigger) or directly by the power supply connector of the camera (I/O Trigger) (see Section 4.4.2). The trigger signal can be configured to be active high or active low. When the frequency of the incoming triggers is higher than the maximal frame rate of the current camera settings, then some trigger pulses will be missed. A missed trigger counter counts these events. This counter can be read out by the user.

The exposure time in external trigger mode can be defined by the setting of the exposure time register (camera controlled exposure mode) or by the width of the incoming trigger pulse (trigger controlled exposure mode) (see Section 4.4.3).

An external trigger pulse starts the exposure of one image. In Burst Trigger Mode however, a trigger pulse starts the exposure of a user defined number of images (see Section 4.4.5).

The start of the exposure is shortly after the active edge of the incoming trigger. An additional trigger delay can be applied that delays the start of the exposure by a user defined time (see Section 4.4.4). This often used to start the exposure after the trigger to a flash lighting source.

4.4.2 Trigger Source

The trigger signal can be configured to be active high or active low. 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 Constant Frame Rate mode is disabled. In Constant Frame Rate mode, exposure starts after a user-specified time (Frame Time) has elapsed from the previous exposure start and therefore the frame rate is set to a user defined value.

Interface Trigger In the interface trigger mode, the trigger signal is applied to the camera by the CameraLink® interface. Fig. 4.24 shows a diagram of the interface trigger setup. The trigger is generated by the frame grabber board and sent on the CC1 signal through the CameraLink® interface. Some frame grabbers allow the connection external trigger devices through an I/O card. A schematic diagram of this setup is shown in Fig. 4.25.

I/O Trigger In the I/O trigger mode, the trigger signal is applied directly to the camera by the power supply connector (via an optocoupler). A setup of this mode is shown in Fig. 4.26. The electrical interface of the I/O trigger input and the strobe output is described in Section 5.1.3.

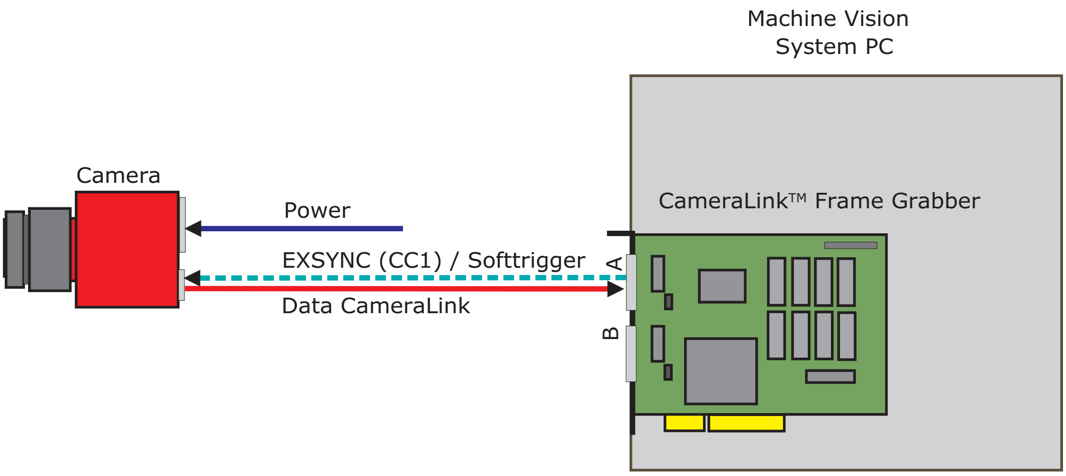


Figure 4.24: Interface trigger source

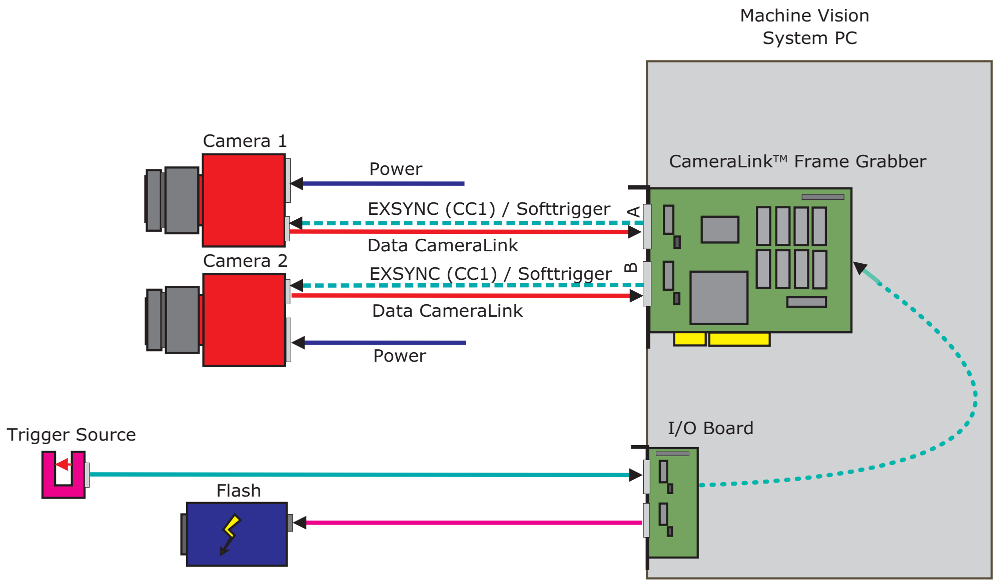


Figure 4.25: Interface trigger with 2 cameras and frame grabber I/O card

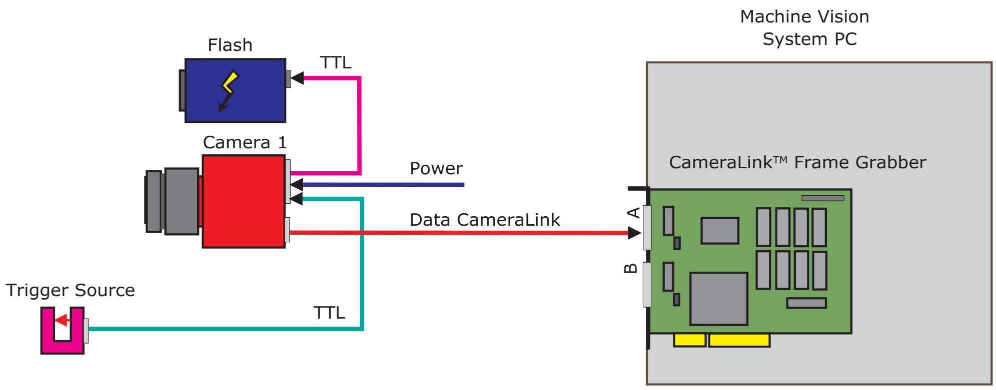


Figure 4.26: I/O trigger source

4.4.3 Exposure Time Control

Depending on the trigger mode, the exposure time can be determined either by the camera or by the trigger signal itself:

Camera-controlled Exposure time In this trigger mode 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 preprogrammed exposure time has elapsed. The exposure time is defined by the software.

Trigger-controlled Exposure time In this trigger mode the exposure time is defined by the pulse width of the trigger pulse. For an active high trigger signal, the camera starts the exposure with the positive edge of the trigger signal and stops it with the negative edge.

External Trigger with Camera controlled Exposure Time

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. 4.27 shows the detailed timing diagram for the external trigger mode with camera controlled exposure time.

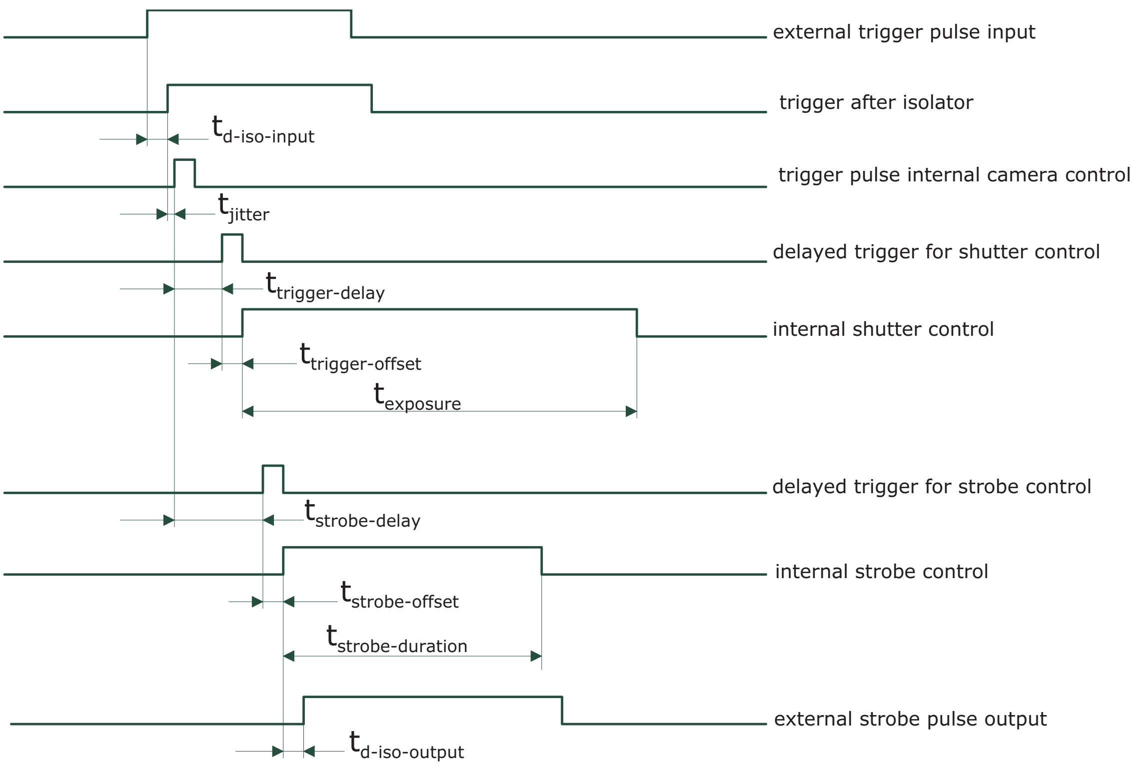


Figure 4.27: Timing diagram for the camera controlled exposure time

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 and from to requirement to start an exposure at a fixed point from the start of the read out of a row. 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 4.4 gives an overview over the minimum and maximum values of the parameters.

External Trigger with Pulsewidth controlled Exposure Time

In the external trigger mode with Pulsewidth controlled exposure time the rising edge of the trigger pulse starts the camera states machine, which controls the sensor. The falling edge of the trigger pulse stops the image acquisition. Additionally the optional external strobe output is controlled by the rising edge of the trigger pulse. Timing diagram Fig. 4.28 shows the detailed timing for the external trigger mode with pulse width controlled exposure time.

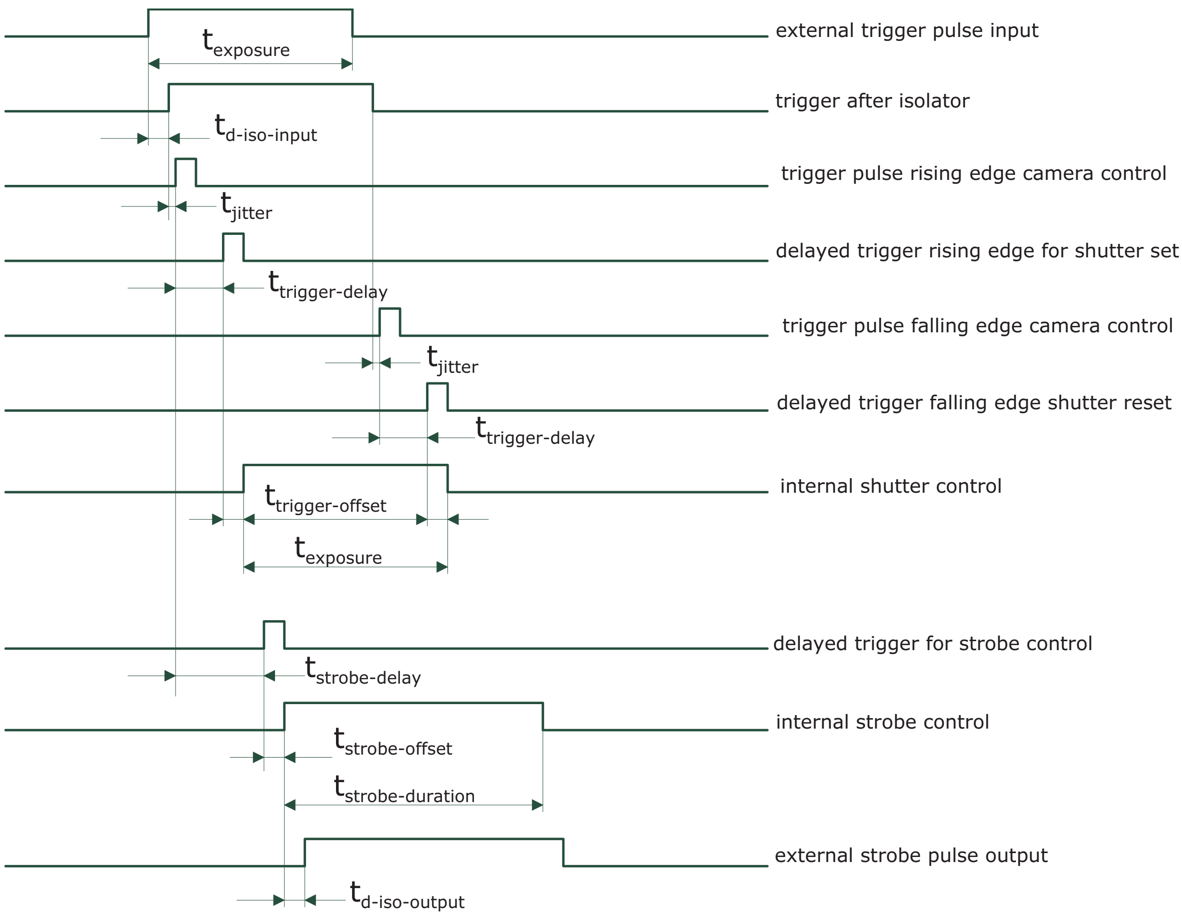


Figure 4.28: Timing diagram for the Pulsewidth controlled exposure time

The timing of the rising edge of the trigger pulse until to the start of exposure and strobe is equal to the timing of the camera controlled exposure time (see Section 4.4.3). In this mode however the end of the exposure is controlled by the falling edge of the trigger Pulsewidth:

The falling edge of the trigger pulse is delayed by the time $t_{d-iso-input}$ which results from the signal isolator. This signal is clocked into the FPGA which leads to a jitter of t_{jitter}. The pulse is then delayed by $t_{trigger-delay}$ by the user defined value which can be configured via camera software. After the trigger offset time $t_{trigger-offset}$ the exposure is stopped.

In the trigger pulse width controlled exposure mode the image sensor operates in sequential read out mode (see Section 4.1.1). The maximal frame rate is therefore lower than normal as the exposure start is only allowed after the read out of the previous frame.

4.4.4 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 to external strobe with the exposure of the camera.

4.4.5 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 timing diagram of the burst trigger mode is shown in Fig. 4.29. The timing of the "external trigger pulse input" until to the "trigger pulse internal camera control" is equal to the timing in the section Fig. 4.28. This trigger pulse then starts after a user configurable burst trigger delay time $t_{burst-trigger-delay}$ the internal burst engine, which generates n internal triggers for the shutter- and the strobe-control. A user configurable value defines the time $t_{burst-period-time}$ between two acquisitions.

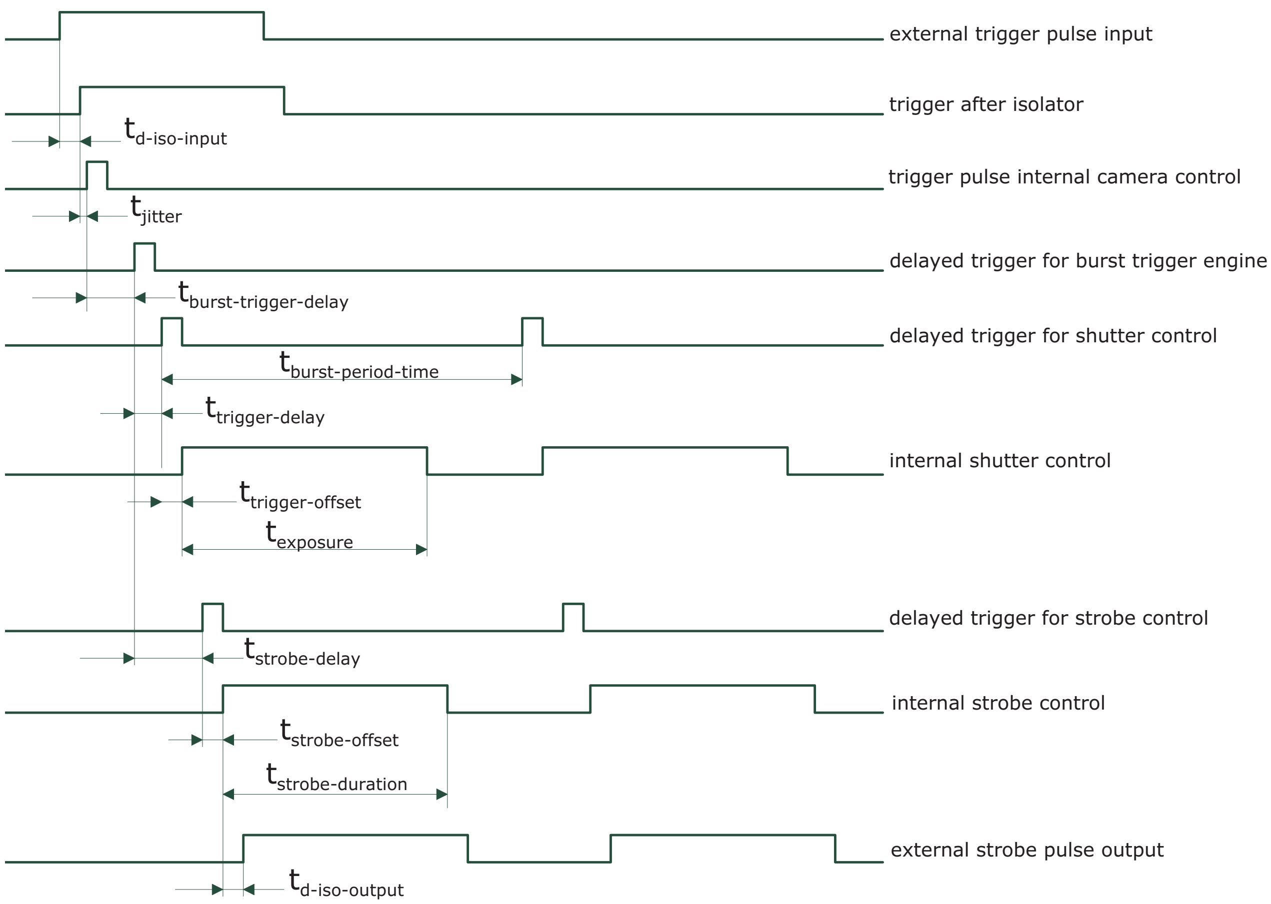


Figure 4.29: Timing diagram for the burst trigger mode

4.4.6 Trigger timing values

Table 4.4 shows the values of the trigger timing parameters.

	MV1-D1024E-160-CL	**MV1-D1024E-160-CL**
Timing Parameter	**Minimum**	**Maximum**
$t_{d-iso-input}$	45 ns	60 ns
t_{jitter}	0	25 ns
$t_{trigger-delay}$	0	0.41 s
$t_{burst-trigger-delay}$	0	0.41 s
$t_{burst-period-time}$	depends on camera settings	0.41 s
$t_{trigger-offset}$ (non burst mode)	100 ns	duration of 1 row
$t_{trigger-offset}$ (burst mode)	125 ns	125 ns
$t_{exposure}$	10 μs	0.41 s
$t_{strobe-delay}$	0	0.41 s
$t_{strobe-offset}$ (non burst mode)	100 ns	100 ns
$t_{strobe-offset}$ (burst mode)	125 ns	125 ns
$t_{strobe-duration}$	200 ns	0.41 s
$t_{d-iso-output}$	45 ns	60 ns
$t_{trigger-pulsewidth}$	200 ns	n/a
Number of bursts n	1	30000

Table 4.4: Summary of timing parameters relevant in the external trigger mode using the MV1-D1024E-160-CL camera

4.4.7 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 `Interface Trigger` or `I/O Trigger`.

4.4.8 Missed Trigger Counters

Missed Trigger Counter If an external trigger (interface trigger or I/O trigger) is applied while the camera is not ready to accept a new trigger, a counter (Missed Trigger Counter) is incremented and the trigger is rejected. The value of the Missed Trigger Counter can be read out from a camera register (`Counter.MissedTrigger`) or from the status line (see Section 4.10). When the Missed Trigger Counter reaches its maximal value it will not wrap around. The user can reset the Missed Trigger Counter.

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 was not ready to accept a new trigger. To avoid this, the Burst Period Time must be incremented so that the minimal frame time for the current settings is not violated. The value of the Missed Burst Trigger Counter can be read out from a camera register (Counter.MissedBurstTrigger) or from the status line (see Section 4.10). When the Missed Trigger Counter reaches its maximal value it will not wrap around. The user can reset the Missed Burst Trigger Counter.

4.4.9 Strobe Output

The strobe output is an opto-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 5.1.3 and Fig. 4.25 and Fig. 4.26 for more information.

4.5 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. 4.30.

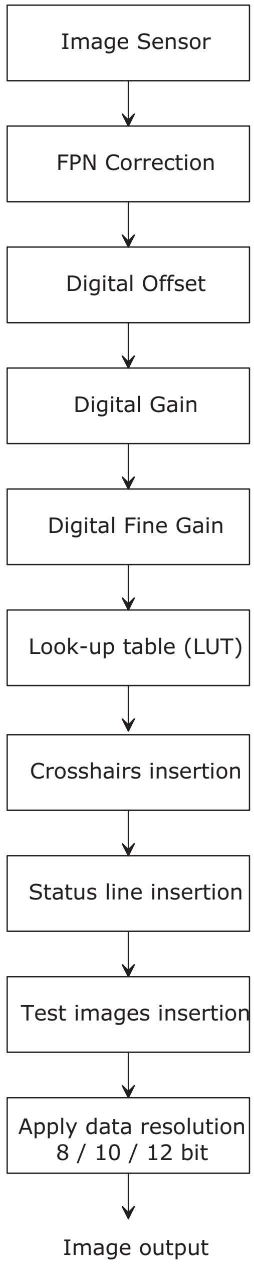


Figure 4.30: camera data path

4.6 Image Correction

4.6.1 Overview

The camera possesses image pre-processing features, that compensate for non-uniformities caused by the sensor, the lens or the illumination. This method of improving the image quality is generally known as 'Shading Correction' or 'Flat Field Correction' and consists of a combination of offset correction, gain correction and pixel interpolation.

Since the correction is performed in hardware, there is no performance limitation of the cameras for high frame rates.

The offset correction subtracts a configurable positive or negative value from the live image and thus reduces the fixed pattern noise of the CMOS sensor. In addition, hot pixels can be removed by interpolation. The gain correction can be used to flatten uneven illumination or to compensate shading effects of a lens. Both offset and gain correction work on a pixel-per-pixel basis, i.e. every pixel is corrected separately. For the correction, a black reference and a grey reference image are required. Then, the correction values are determined automatically in the camera.

Do not set any reference images when gain or LUT is enabled! Read the following sections very carefully.

Correction values of both reference images can be saved into the internal flash memory, but this overwrites the factory presets. Then the reference images that are delivered by factory cannot be restored anymore.

4.6.2 Offset Correction (FPN, Hot Pixels)

The offset correction is based on a black reference image, which is taken at no illumination (e.g. lens aperture completely closed). The black reference image contains the fixed-pattern noise of the sensor, which can be subtracted from the live images in order to minimise the static noise.

Offset correction algorithm

After configuring the camera with a black reference image, the camera is ready to apply the offset correction:

1. Determine the average value of the black reference image.
2. Subtract the black reference image from the average value.
3. Mark pixels that have a grey level higher than 1008 DN (@ 12 bit) as hot pixels.
4. Store the result in the camera as the offset correction matrix.
5. During image acquisition, subtract the correction matrix from the acquired image and interpolate the hot pixels (see Section 4.6.2).

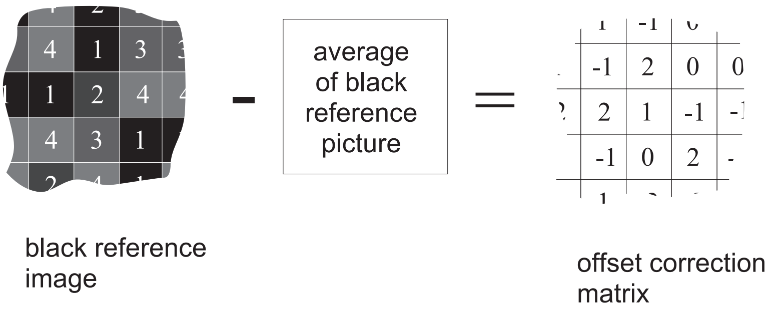


Figure 4.31: Schematic presentation of the offset correction algorithm

How to Obtain a Black Reference Image

In order to improve the image quality, the black reference image must meet certain demands.

The detailed procedure to set the black reference image is described in Section 7.1.7.

- The black reference image must be obtained at no illumination, e.g. with lens aperture closed or closed lens opening.
- It may be necessary to adjust the black level offset of the camera. In the histogram of the black reference image, ideally there are no grey levels at value 0 DN after adjustment of the black level offset. All pixels that are saturated black (0 DN) will not be properly corrected (see Fig. 4.32). The peak in the histogram should be well below the hot pixel threshold of 1008 DN @ 12 bit.
- Camera settings may influence the grey level. Therefore, for best results the camera settings of the black reference image must be identical with the camera settings of the image to be corrected.

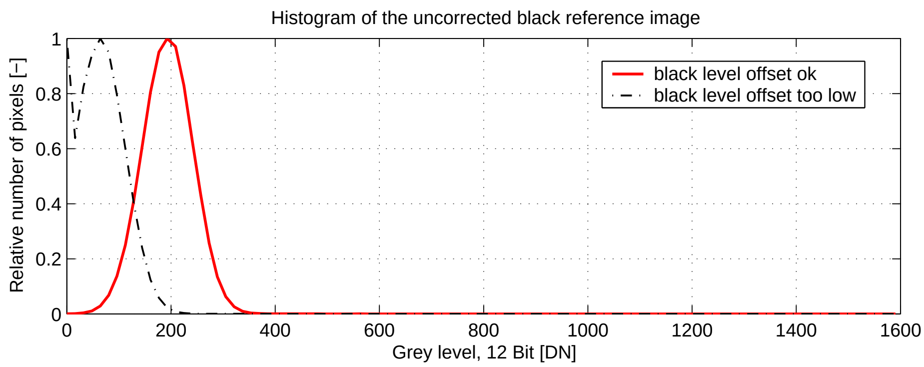
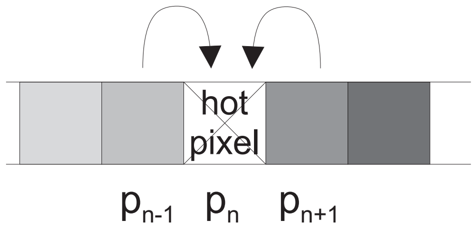


Figure 4.32: Histogram of a proper black reference image for offset correction

Hot pixel correction

Every pixel that exceeds a certain threshold in the black reference image is marked as a hot pixel. If the hot pixel correction is switched on, the camera replaces the value of a hot pixel by an average of its neighbour pixels (see Fig. 4.33).



$$p_n = \frac{p_{n-1} + p_{n+1}}{2}$$

Figure 4.33: Hot pixel interpolation

4.6.3 Gain Correction

The gain correction is based on a grey reference image, which is taken at uniform illumination to give an image with a mid grey level.

Gain correction is not a trivial feature. The quality of the grey reference image is crucial for proper gain correction.

Gain correction algorithm

After configuring the camera with a black and grey reference image, the camera is ready to apply the gain correction:

1. Determine the average value of the grey reference image.
2. Subtract the offset correction matrix from the grey reference image.
3. Divide the average value by the offset corrected grey reference image.
4. Pixels that have a grey level higher than a certain threshold are marked as hot pixels.
5. Store the result in the camera as the gain correction matrix.
6. During image acquisition, multiply the gain correction matrix from the offset-corrected acquired image and interpolate the hot pixels (see Section 4.6.2).

Gain correction is not a trivial feature. The quality of the grey reference image is crucial for proper gain correction.

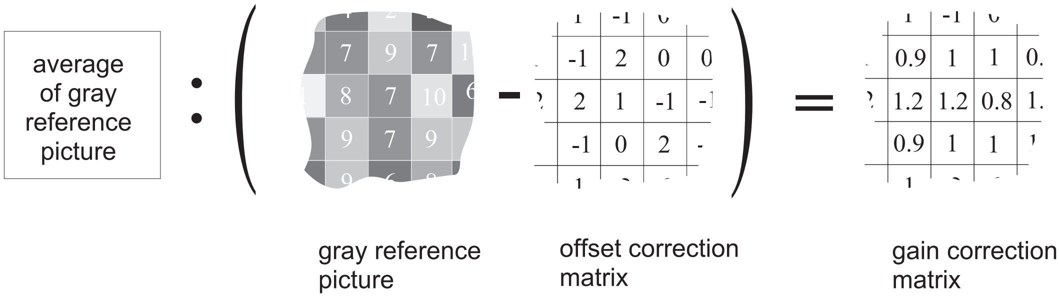


Figure 4.34: Schematic presentation of the gain correction algorithm

Gain correction always needs an offset correction matrix. Thus, the offset correction always has to be performed before the gain correction.

How to Obtain a Grey Reference Image

In order to improve the image quality, the grey reference image must meet certain demands.

The detailed procedure to set the grey reference image is described in Section 7.1.7.

- The grey reference image must be obtained at uniform illumination.

  Use a high quality light source that delivers uniform illumination. Standard illumination will not be appropriate.

- When looking at the histogram of the grey reference image, ideally there are no grey levels at full scale (4095 DN @ 12 bit). All pixels that are saturated white will not be properly corrected (see Fig. 4.35).
- Camera settings may influence the grey level. Therefore, the camera settings of the grey reference image must be identical with the camera settings of the image to be corrected.

4.6.4 Corrected Image

Offset, gain and hot pixel correction can be switched on separately. The following configurations are possible:

- No correction
- Offset correction only
- Offset and hot pixel correction
- Hot pixel correction only
- Offset and gain correction
- Offset, gain and hot pixel correction

In addition, the black reference image and grey reference image that are currently stored in the camera RAM can be output.

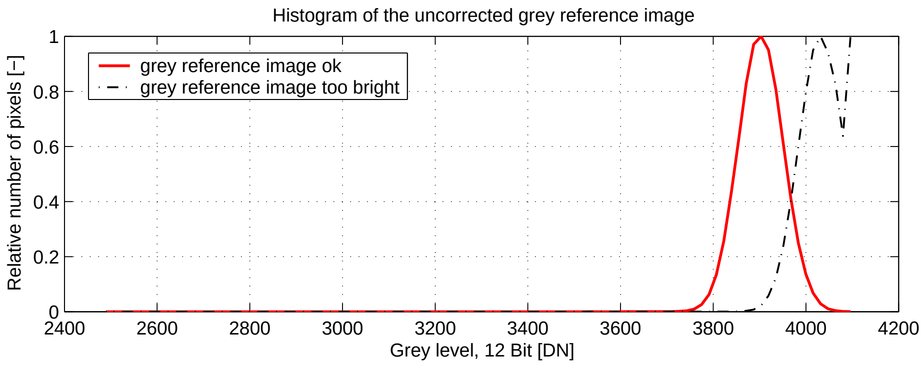


Figure 4.35: Proper grey reference image for gain correction

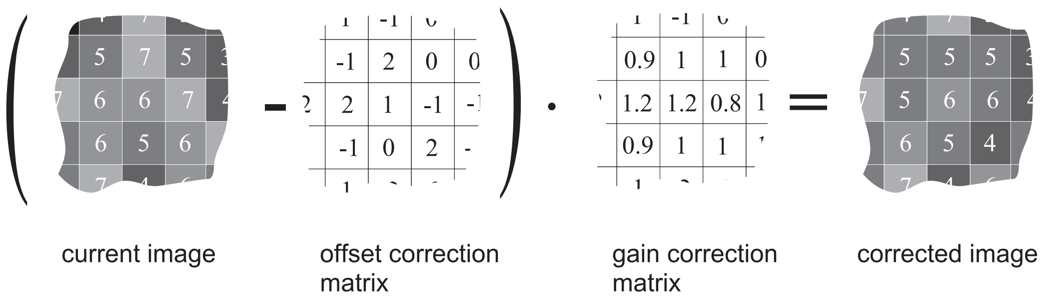


Figure 4.36: Schematic presentation of the corrected image using gain correction algorithm

4.6.5 Correction Ranges

Table 4.5 shows the minimum and maximum values of the correction matrices, i.e. the range that the offset and gain algorithm can correct.

	Minimum	Maximum
Offset correction	-1023 DN @ 12 bit	+1023 DN @ 12 bit
Gain correction	0.7	1.69

Table 4.5: Offset and gain correction ranges

4.7 Gain and Offset

There are two different gain settings on the camera:

Gain (Digital Fine Gain) Digital fine gain accepts fractional values from 0.01 up to 15.99. It is implemented as a multiplication operation.

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 two 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.

4.8 Grey Level Transformation (LUT)

Grey level transformation is remapping of the grey level values of an input image to new values. The look-up table (LUT) is used to convert the greyscale value of each pixel in an image into another grey value. It is typically used to implement a transfer curve for contrast expansion. The camera performs a 12-to-8-bit mapping, so that 4096 input grey levels can be mapped to 256 output grey levels. The use of the three available modes is explained in the next sections.

☞ The output grey level resolution of the look-up table (independent of gain, gamma or user-definded mode) is always 8 bit.

☞ There are 2 predefined functions, which generate a look-up table and transfer it to the camera. For other transfer functions the user can define his own LUT file.

Some commonly used transfer curves are shown in Fig. 4.37. Line `a` denotes a negative or inverse transformation, line `b` enhances the image contrast between grey values x0 and x1. Line `c` shows brightness thresholding and the result is an image with only black and white grey levels. and line `d` applies a gamma correction (see also Section 4.8.2).

4.8.1 Gain

The ’Gain’ mode performs a digital, linear amplification with clamping (see Fig. 4.38). It is configurable in the range from 1.0 to 4.0 (e.g. 1.234).

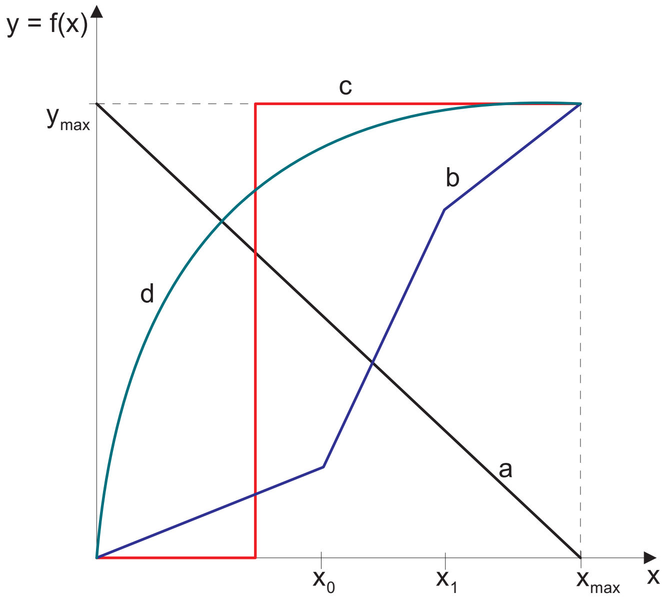


Figure 4.37: Commonly used LUT transfer curves

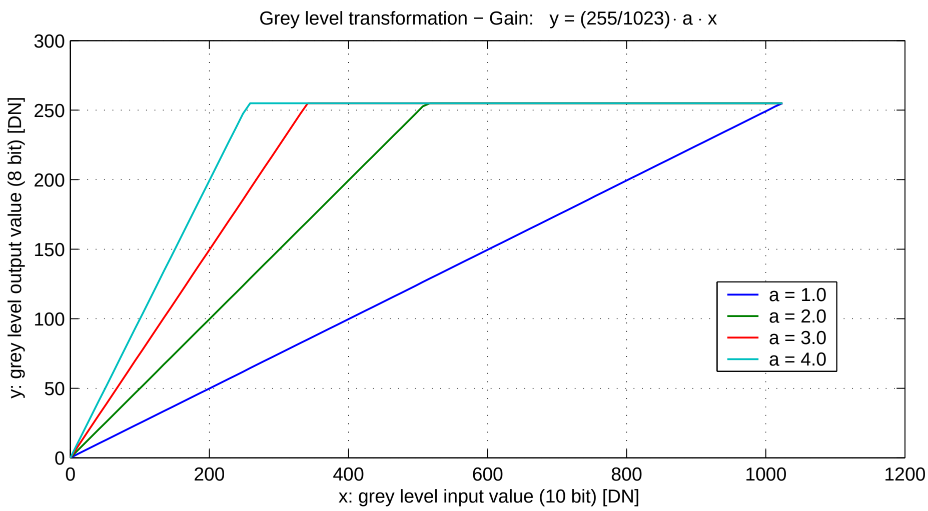


Figure 4.38: Applying a linear gain with clamping to an image

4.8.2 Gamma

The 'Gamma' mode performs an exponential amplification, configurable in the range from 0.4 to 4.0. Gamma > 1.0 results in an attenuation of the image (see Fig. 4.39), gamma < 1.0 results in an amplification (see Fig. 4.40). Gamma correction is often used for tone mapping and better display of results on monitor screens.

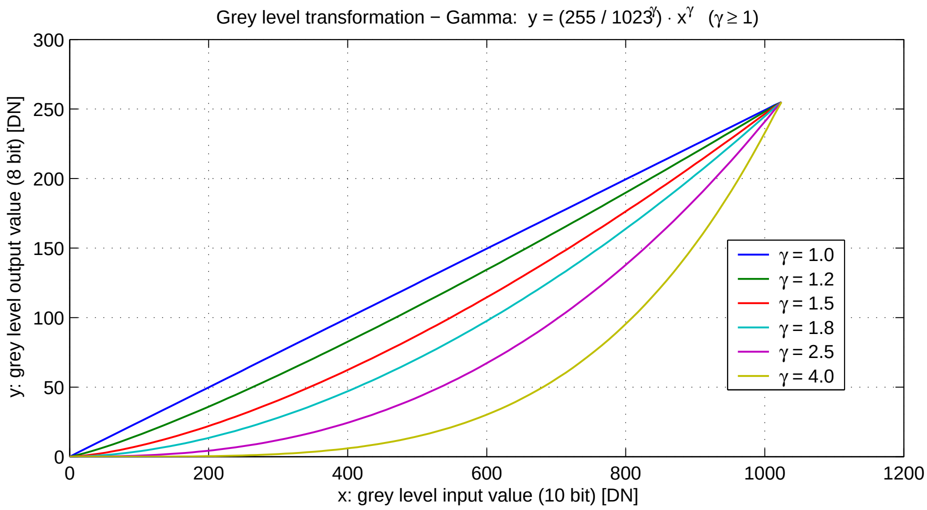


Figure 4.39: Applying gamma correction to an image (gamma > 1)

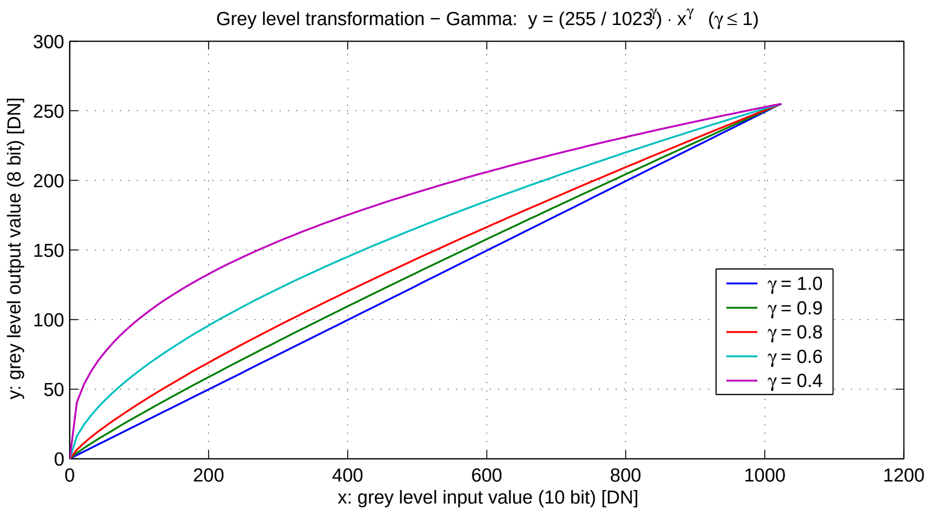


Figure 4.40: Applying gamma correction to an image (gamma < 1)

4.8.3 User-defined Look-up Table

In the 'User' mode, the mapping of input to output grey levels can be configured arbitrarily by the user. There is an example file in the PFRemote folder. LUT files can easily be generated with a standard spreadsheet tool. The file has to be stored as tab delimited text file.

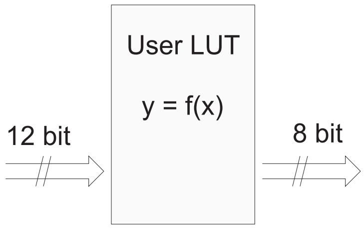


Figure 4.41: Data path through LUT

4.8.4 Region LUT and LUT Enable

Two LUTs and a Region-LUT feature are available in the Photonfocus MV1-D1024E camera series. Both LUTs can be enabled independently (see Table 4.6). LUT 0 superseeds LUT1.

Enable LUT 0	Enable LUT 1	Enable Region LUT	Description
-	-	-	LUT are disabled.
X	don't care	-	LUT 0 is active on whole image.
-	X	-	LUT 1 is active on whole image.
X	-	X	LUT 0 active in Region 0.
X	X	X	LUT 0 active in Region 0 and LUT 1 active
			in Region 1. LUT 0 supersedes LUT1.

Table 4.6: LUT Enable and Region LUT

When Region-LUT feature is enabled, then the LUTs are only active in a user defined region. Examples are shown in Fig. 4.42 and Fig. 4.43.

Fig. 4.42 shows an example of overlapping Region-LUTs. LUT 0, LUT 1 and Region LUT are enabled. LUT 0 is active in region 0 ((x00, x01), (y00, y01)) and it supersedes LUT 1 in the overlapping region. LUT 1 is active in region 1 ((x10, x11), (y10, y11)).
Fig. 4.43 shows an example of keyhole inspection in a laser welding application. LUT 0 and LUT 1 are used to enhance the contrast by applying optimized transfer curves to the individual regions. LUT 0 is used for keyhole inspection. LUT 1 is optimized for seam finding.

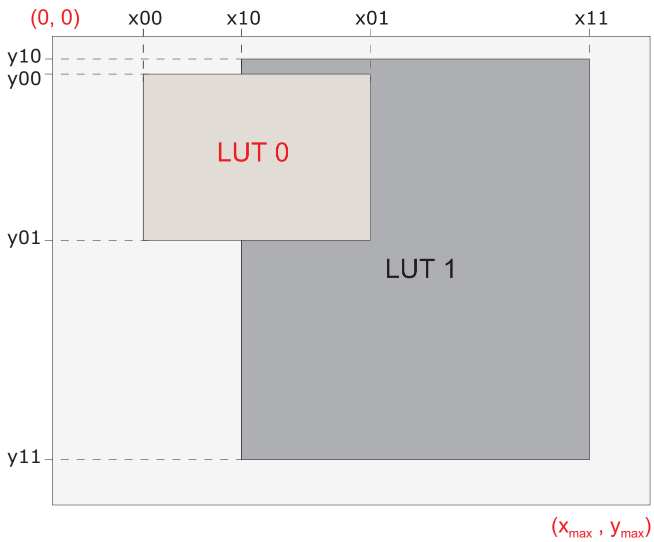
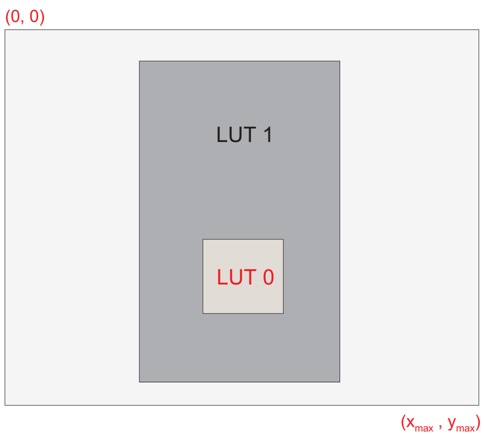


Figure 4.42: Overlapping Region-LUT example



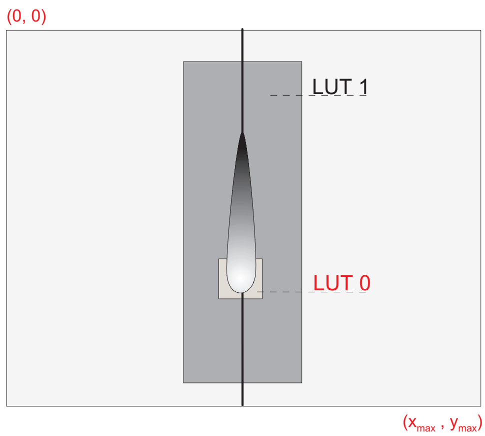


Figure 4.43: Region-LUT in keyhole inspection

Fig. 4.44 shows the application of the Region-LUT to a camera image. The original image without image processing is shown on the left-hand side. The result of the application of the Region-LUT is shown on the right-hand side. One Region-LUT was applied on a small region on the lower part of the image where the brightness has been increased.

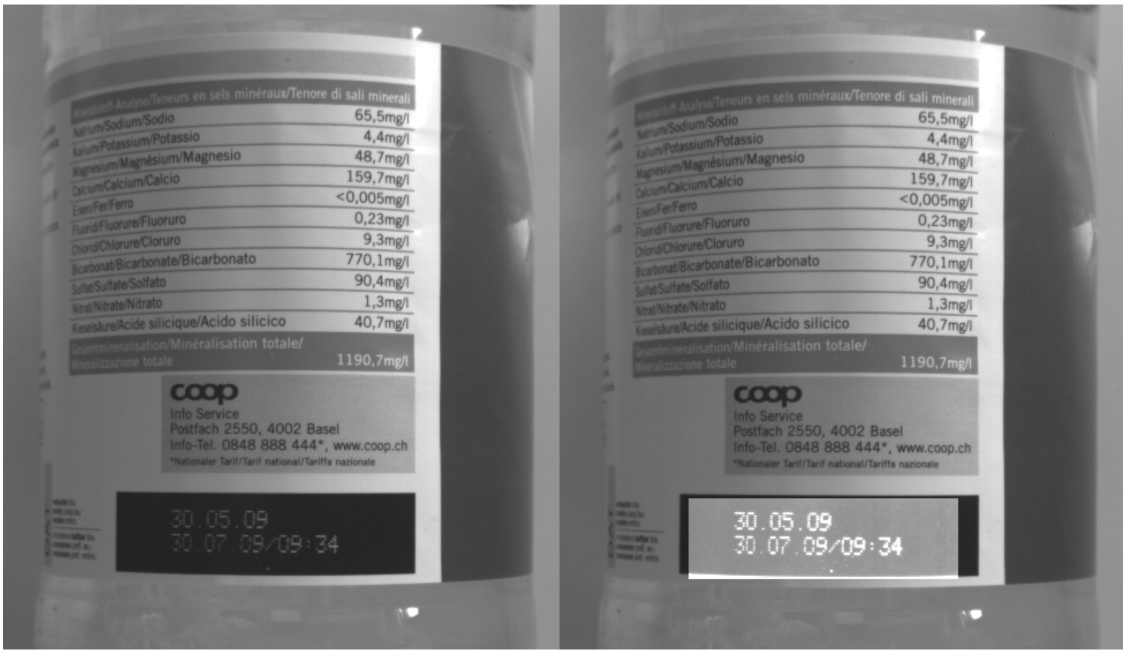


Figure 4.44: Region-LUT example with camera image; left: original image; right: gain 4 region in the are of the date print of the bottle

4.9 Crosshairs

4.9.1 Functionality

The crosshairs inserts a vertical and horizontal line into the image. The width of these lines is one pixel. The grey level is defined by a 12 bit value (0 means black, 4095 means white). This allows to set any grey level to get the maximum contrast depending on the acquired image. The x/y position and the grey level can be set via the camera software. Figure Fig. 4.45 shows two examples of the activated crosshairs with different grey values. One with white lines and the other with black lines.

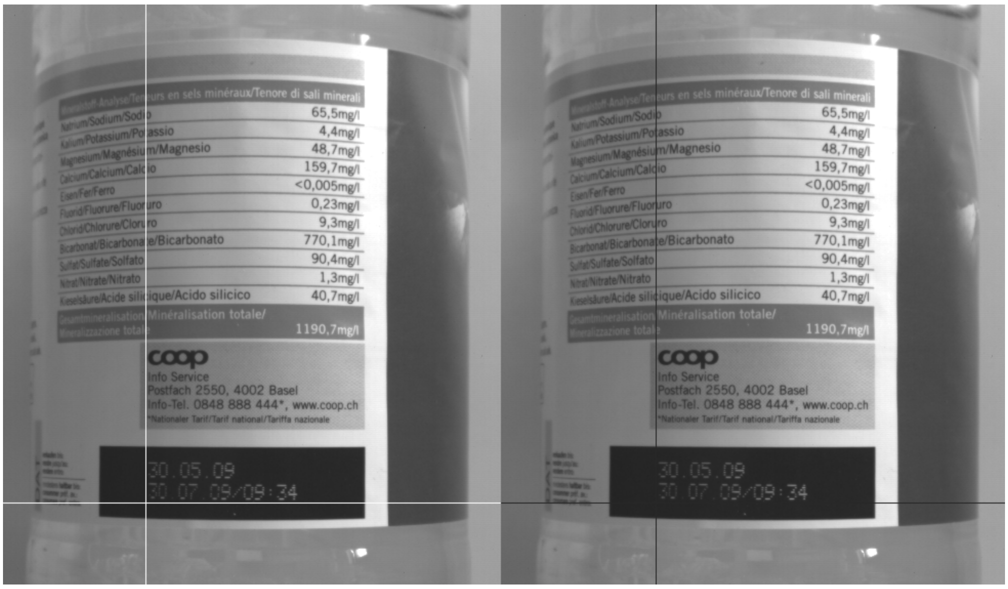


Figure 4.45: Crosshairs Example with different grey values

The x- and y-positon is absolute to the sensor pixel matrix. It is independent on the ROI, MROI or decimation configurations. Figure Fig. 4.46 shows two situations of the crosshairs configuration. The same MROI settings is used in both situations. The crosshairs however is set differently. The crosshairs is not seen in the image on the right, because the x- and y-position is set outside the MROI region.

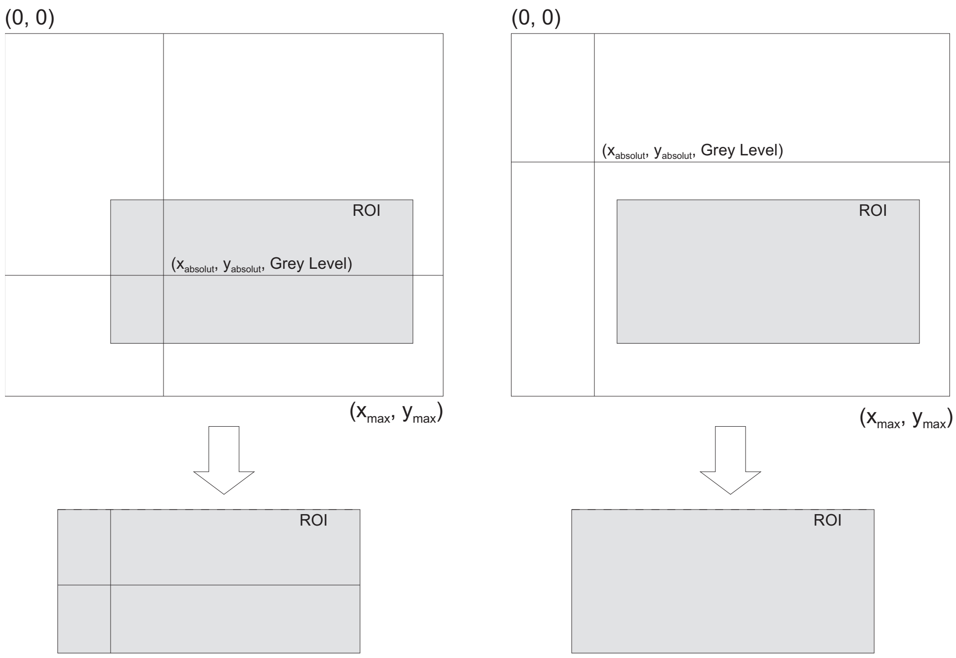


Figure 4.46: Crosshairs absolute position

4.10 Image Information and Status Line

There are camera properties available that give information about the acquired images, such as an image counter, average image value and the number of missed trigger signals. These properties can be queried by software. Alternatively, a status line within the image data can be switched on that contains all the available image information.

4.10.1 Counters and Average Value

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 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) (see also Section 4.4.8).

Missed burst trigger counter When the camera is in burst trigger mode (see Section 4.4.5), a missed burst trigger counter will be incremented, when a subsequent external trigger (`TriggerMode=On`) is applied while a burst sequence is running (see also Section 4.4.8).

Average image value The average image value gives the average of an image in 12 bit format (0 .. 4095 DN), regardless of the currently used grey level resolution.

4.10.2 Status Line

If enabled, the status line replaces the last row of the image with camera status information. Every parameter is coded into fields of 4 pixels (LSB first) and uses the lower 8 bits of the pixel value, so that the total size of a parameter field is 32 bit (see Fig. 4.47). The assignment of the parameters to the fields is listed in Table 4.7.

☞ The status line is available in all camera modes.

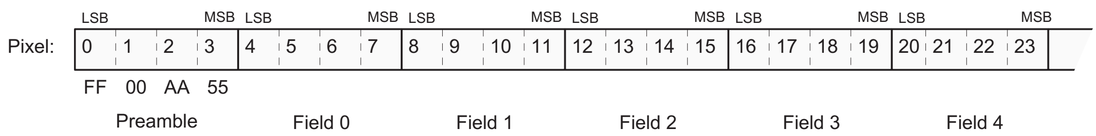


Figure 4.47: Status line parameters replace the last row of the image

Start pixel index	Parameter width [bit]	Parameter Description
0	32	Preamble: 0x55AA00FF
4	24	Image Counter (see Section 4.10.1)
8	32	Real Time Counter (see Section 4.10.1)
12	8	Missed Trigger Counter (see Section 4.10.1)
16	12	Image Average Value("raw" data without taking in account gain settings) (see Section 4.10.1)
20	24	Integration Time in units of clock cycles (see Table 3.3)
24	16	Burst Trigger Number
28	8	Missed Burst Trigger Counter
32	11	Horizontal start position of ROI (Window.X)
36	11	Horizontal end position of ROI (= Window.X + Window.W - 1)
40	11	Vertical start position of ROI (Window.Y). In MROI-mode this parameter is the start position of the first ROI.
44	11	Number of rows -1
48	2	Trigger Source
52	2	Digital Gain
56	2	Digital Offset
60	16	Camera Type Code (see Table 4.8)
64	32	Camera Serial Number
68	32	Reserved
72	32	Reserved
76	16	FineGain. This is fixed a point value in the format: 4 digits integer value, 12 digits fractional value.
80	24	Reserved
84	32	Reserved
88	32	Reserved
92	4	Trigger Level: signal level of the trigger input signal. Bit 0: ExSync (CC1): Bit 1: I/O Trigger; Bit 2: CC3; Bit 3: CC4.

Table 4.7: Assignment of status line fields

4.10.3 Camera Type Codes

Camera Model	Camera Type Code
MV1-D1024E-160-CL-12	110

Table 4.8: Type codes of Photonfocus MV1-D1024E camera series

4.11 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 frame grabber. 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 that are caused most often by a defective cable between camera and frame grabber.

The analysis of the test images with a histogram tool gives gives a flat histogram only if the image width is a multiple of 1024 (in 10 bit or 12 bit mode) or 256 (in 8 bit mode). The height should be a multiple of 1024 In 12 bit mode.

4.11.1 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. 4.48).

Figure 4.48: Ramp test images: 8 bit (left), 10 bit (middle), 12 bit (right)

4.11.2 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.
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.

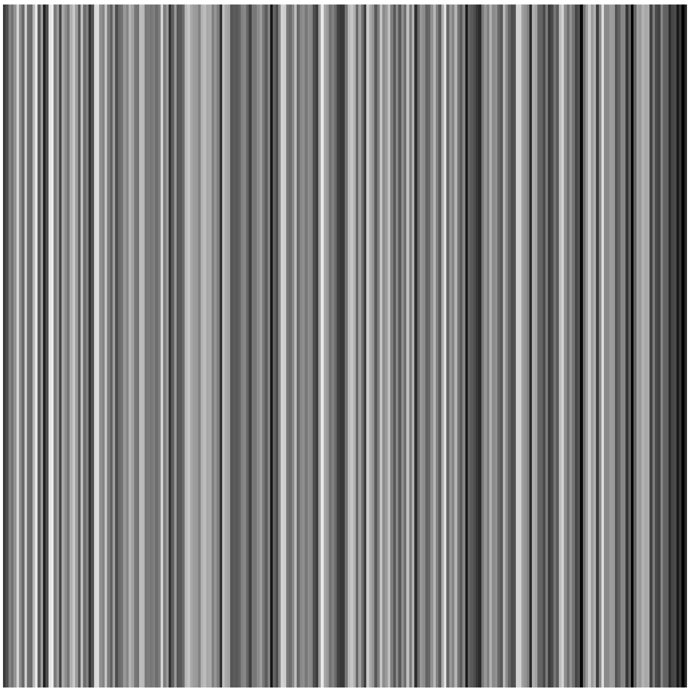


Figure 4.49: LFSR (linear feedback shift register) test image

4.11.3 Troubleshooting using the LFSR

To control the quality of your complete imaging system enable the LFSR mode, set the camera window to a width that is a multiple of 1024 and check the histogram. If your frame grabber application does not provide a real-time histogram, store the image and use a graphic software tool 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 error free, the histogram of the received LFSR test pattern will be flat (Fig. 4.50). On the other hand, a non-flat histogram (Fig. 4.51) indicates problems, that may be caused either by the cable, by the connectors or by the frame grabber.

A possible origin of failure message can be caused by the CameraLink® cable which exceeds the maximum length. The maximal cable length depends on the frequency of the pixel clock. At a pixel clock of 80 MHz, a length of 8 m can be achieved with a good cable. Also, CameraLink® cables may suffer either from stress due to wrong installation or from severe electromagnetic interference.

Some thinner CameraLink® cables have a predefined direction. In these cables not all twisted pairs are separately shielded to meet the RS644 standard. These pairs are used for the transmission of the RX/TX and for the CC1 to CC4 low frequency control signals.

Figure 4.50: LFSR test pattern received at the frame grabber and typical histogram for error-free data transmission

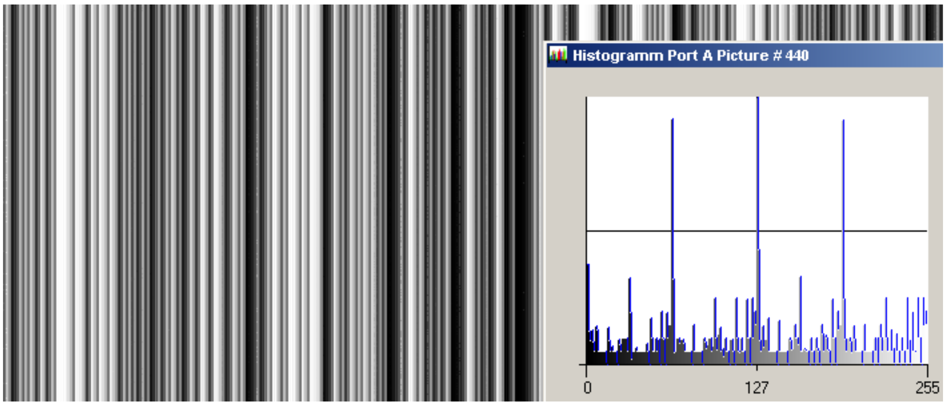


Figure 4.51: LFSR test pattern received at the frame grabber and histogram containing transmission errors

CameraLink® cables contain wire pairs, which are twisted in such a way that the cable impedance matches with the LVDS driver and receiver impedance. Excess stress on the cable results in transmission errors which causes distorted images. Therefore, please do not stretch and bend a CameraLink cable.

In robots applications, the stress that is applied to the CameraLink® 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. Appropriate CameraLink® cable solutions are available from Photonfocus.

4.12 Configuration Interface (CameraLink®)

A CameraLink® camera can be controlled by the user via a RS232 compatible asynchronous serial interface. This interface is contained within the CameraLink® interface as shown in Fig. 4.52 and is physically not directly accessible. Instead, the serial communication is usually routed through the frame grabber. For some frame grabbers it might be necessary to connect a serial cable from the frame grabber to the serial interface of the PC.

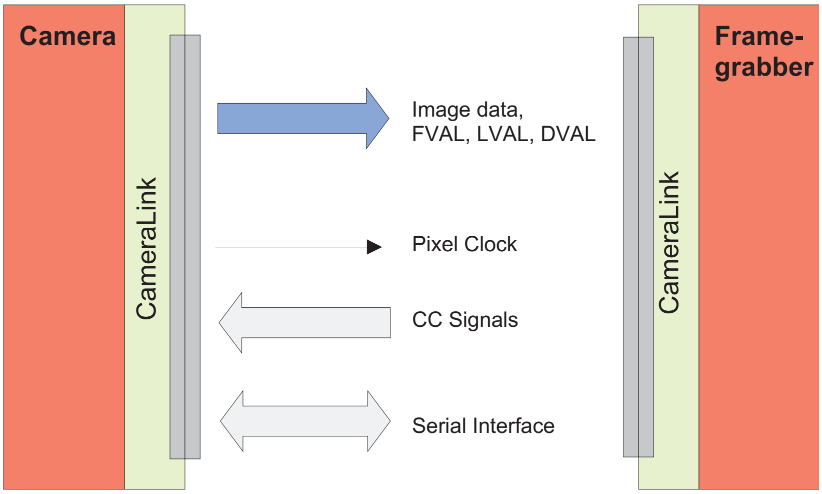


Figure 4.52: CameraLink serial interface for camera communication

5

Hardware Interface

5.1 Connectors

5.1.1 CameraLink® Connector

The CameraLink® cameras are interfaced to external components via

- a CameraLink® connector, which is defined by the CameraLink® standard as a 26 pin, 0.5" Mini Delta-Ribbon (MDR) connector to transmit configuration, image data and trigger.
- a subminiature connector for the power supply, 7-pin Binder series 712.

The connectors are located on the back of the camera. Fig. 5.1 shows the plugs and the status LED which indicates camera operation.

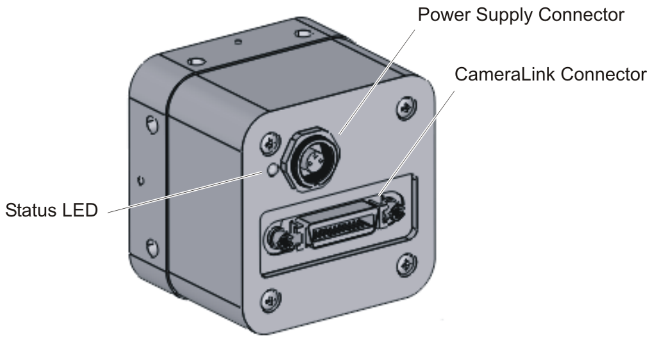


Figure 5.1: Rear view of the CameraLink camera

The CameraLink® interface and connector are specified in [CL]. For further details including the pinout please refer to Appendix Appendix A. This connector is used to transmit configuration, image data and trigger signals.

5.1.2 Power Supply

The camera requires a single voltage input (see Table 3.4). 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.

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

5.1.3 Trigger and Strobe Signals

The power connector contains an external trigger input and a strobe output.

The trigger input is equipped with a constant current diode which limits the current of the optocoupler over a wide range of voltages. Trigger signals can thus directly get connected with the input pin and there is no need for a current limiting resistor, that depends with its value on the input voltage. The input voltage to the TRIGGER pin must not exceed +15V DC, to avoid damage to the internal ESD protection and the optocoupler!

In order to use the strobe output, the internal optocoupler must be powered with 5 .. 15 V DC. The STROBE signal is an open-collector output, therefore, the user must connect a pull-up resistor (see Table 5.1) to STROBE_VDD (5 .. 15 V DC) as shown in Fig. 5.2. This resistor should be located directly at the signal receiver.

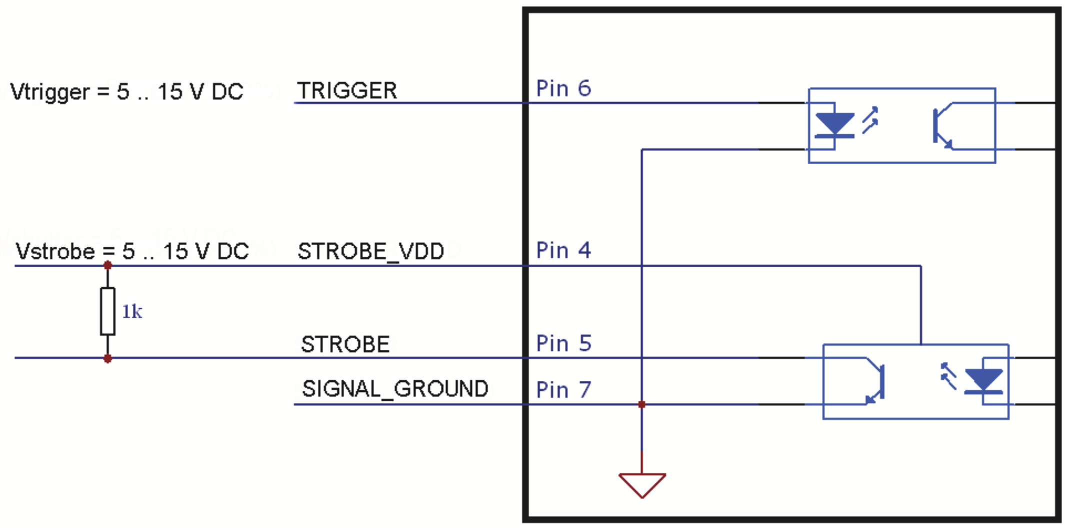


Figure 5.2: Circuit for the trigger input signals

The maximum sink current of the STROBE pin is 8 mA. *Do not connect inductive or capacitive loads*, such loads may result in damage of the optocoupler! If the application requires this, please use voltage suppressor diodes in parallel with this components to protect the optocoupler.

STROBE_VDD	Pull-up Resistor
15 V	> 3.9 kOhm
10 V	> 2.7 kOhm
8 V	> 2.2 kOhm
7 V	> 1.8 kOhm
5 V	> 1.0 kOhm

Table 5.1: Pull-up resistor for strobe output and different voltage levels

5.1.4 Status Indicator (CameraLink® cameras)

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

LED Green	Green when an image is output. At slow frame rates, the LED blinks with the `FVAL` signal. 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. A pulsating heartbeat indicates, that the camera is powered up and is in idle mode without sending images.
LED Red	Red indicates an active serial communication with the camera.

Table 5.2: Meaning of the LED of the CameraLink® cameras

5.1.5 CameraLink® Data Interface

The CameraLink® standard contains signals for transferring the image data, control information and the serial communication.

Data signals: CameraLink® data signals contain the image data. In addition, handshaking signals such as `FVAL`, `LVAL` and `DVAL` are transmitted over the same physical channel.

Camera control information: Camera control signals (CC-signals) can be defined by the camera manufacturer to provide certain signals to the camera. There are 4 CC-signals available and all are unidirectional with data flowing from the frame grabber to the camera. For example, the external trigger is provided by a CC-signal (see Table 5.3 for the CC assignment).

`CC1`	`EXSYNC`	External Trigger. May be generated either by the frame grabber itself (software trigger) or by an external event (hardware trigger).
`CC2`	`CTRL0`	Control0. This signal is reserved for future purposes and is not used.
`CC3`	`CTRL1`	Control1. This signal is reserved for future purposes and is not used.
`CC4`	`CTRL2`	Control2. This signal is reserved for future purposes and is not used.

Table 5.3: Summary of the Camera Control (CC) signals as used by Photonfocus

Pixel clock: The pixel clock is generated on the camera and is provided to the frame grabber for synchronisation.

Serial communication: A CameraLink® camera can be controlled by the user via a RS232 compatible asynchronous serial interface. This interface is contained within the CameraLink® interface and is physically not directly accessible. Refer to Section 4.12 for more information.

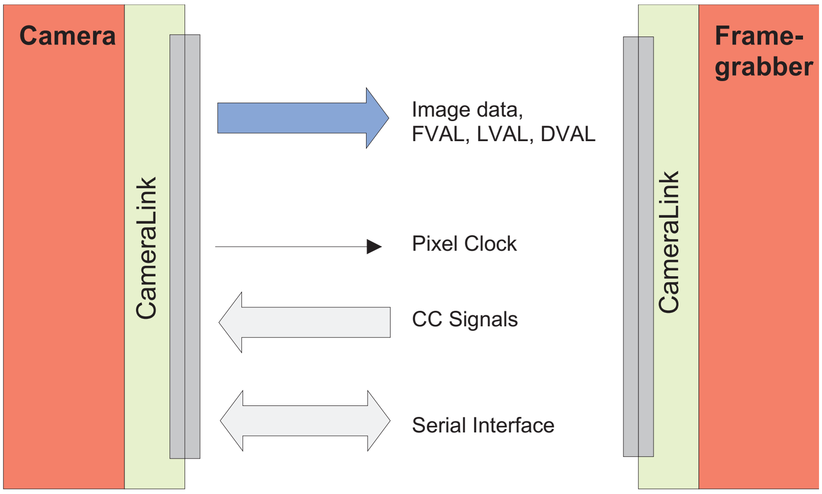


Figure 5.3: CameraLink interface system

The frame grabber needs to be configured with the proper tap and resolution settings, otherwise the image will be distorted or not displayed with the correct aspect ratio. Refer to Table 3.3 and to Section 3.6 for a summary of frame grabber relevant specifications. Fig. 5.3 shows symbolically a CameraLink® system. For more information about taps refer to the relevant application note [AN021] on the Photonfocus website.

6

The PFRemote Control Tool

6.1 Overview

PFRemote is a graphical configuration tool for Photonfocus cameras. The latest release can be downloaded from the support area of www.photonfocus.com.

All Photonfocus cameras can be either configured by PFRemote, or they can be programmed with custom software using the PFLib SDK ([PFLIB]).

6.2 PFRemote and PFLib

As shown in Fig. 6.1, the camera parameters can be controlled by PFRemote and PFLib respectively. To grab an image use the software or the SDK that was delivered with your frame grabber.

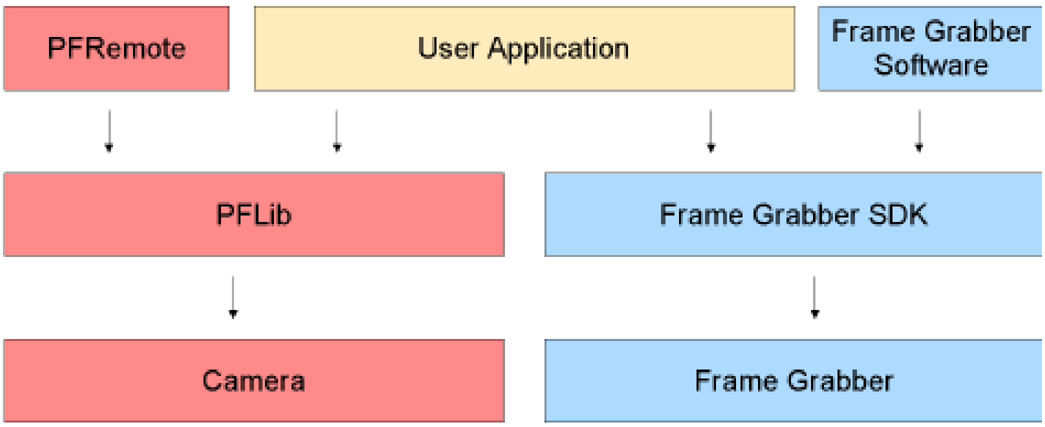


Figure 6.1: PFRemote and PFLib in context with the CameraLink frame grabber software

6.3 Operating System

The PFRemote GUI is available for Windows OS only. For Linux or QNX operating systems, we provide the necessary libraries to control the camera on request, but there is no graphical user interface available.

If you require support for Linux or QNX operating systems, you may contact us for details of support conditions.

6.4 Installation Notes

Before installing the required software with the PFInstaller, make sure that your frame grabber software is installed correctly.

Several DLLs are necessary in order to be able to communicate with the cameras:

- `PFCAM.DLL`: The main DLL file that handles camera detection, switching to specific camera DLL and provides the interface for the SDK.
- `'CAMERANAME'.DLL`: Specific camera DLL
- `COMDLL.DLL`: Communication DLL. This COMDLL is not necessarily CameraLink® specific, but may depend on a CameraLink® API compatible DLL, which should also be provided by your frame grabber manufacturer.
- `CLALLSERIAL.DLL`: Interface to CameraLink® frame grabber which supports the clallserial.dll.
- `CLSER_USB.DLL`: Interface to USB port.

More information about these DLLs is available in the SDK documentation [SW002].

6.5 Graphical User Interface (GUI)

PFRemote consists of a main window (Fig. 6.2) and a configuration dialog. In the main window, the camera port can be opened or closed, and log messages are displayed at the bottom. The configuration dialog appears as a sub window as soon as a camera port was opened successfully. In the sub window of PFRemote the user can configure the camera properties.

The following sections describe the general structure of PFRemote.

6.5.1 Port Browser

On start, PFRemote displays a list of available communication ports in the main window.

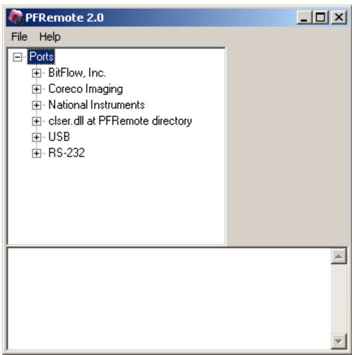


Figure 6.2: PFRemote main window with PortBrowser and log messages

To open a camera on a specific port double click on the port name (e.g. USB). Alternatively right click on the port name and choose **Open & Configure...**. The port is then queried for a compatible Photonfocus camera.

In the PFRemote main window, there are two menus with the following entries available:

File Menu

Clear Log: Clears the log file buffer

Quit: Exit the program

Help Menu

About: Copyright notice and version information

Help F1: Invoke the online help (PFRemote documentation)

6.5.2 Ports, Device Initialization

After starting **PFRemote**, the main window as shown in Fig. 6.2 will appear. In the PortBrowser in the upper left corner you will see a list of supported ports.

☞ Depending on the configuration, your port names may differ, and not every port may be functional.

If your frame grabber supports clallserial.dll version 1.1 (CameraLink® compliant standard Oct 2001), the name of the manufacturer is shown in the PortBrowser.

If your frame grabber supports clallserial.dll version 1.0 (CameraLink® compliant standard Oct 2000), the PortBrowser shows either the name of the dll or the manufacturer name or displays "Unknown".

If your frame grabber does not support clallserial.dll, copy the clserXXXX.dll of your frame grabber in the PFRemote directory and rename it to clser.dll. The PortBrowser will then indicate this DLL as "clser.dll at PFRemote directory".

After connecting the camera, the device can be opened with a double click on the port name or by right-clicking on the port name and choosing **Open & Configure**. If the initialisation of the camera was successful, the configuration dialog will open. The device is closed when PFRemote is closed. Alternatively, e.g. when connecting another camera or evaluation kit, the device can also be closed explicitely by right clicking on the port name and choosing **Close**. Make sure that the configuration dialog is closed prior to closing the port.

✎ Errors, warnings or other important activities are logged in a log window at the bottom of the main window.

If the device does not open, check the following:

- Is the power LED of the camera active? Do you get an image in the display software of your frame grabber?
- Verify all cable connections and the power supply.
- Check the communication LED of the camera: do you see some activity when you try to access the camera?

6.5.3 Main Buttons

The buttons on the right side of the configuration dialog store and reset the camera configuration.

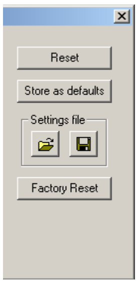


Figure 6.3: Main buttons

Reset: Reset the camera and load the default configuration.

Store as defaults: Store the current configuration in the camera flash memory as the default configuration. After a reset, the camera will load this configuration by default.

Settings file - File Load: Load a stored configuration from a file.

Settings file - File Save: Save current configuration to a file.

Factory Reset: Reset camera and reset the configuration to the factory defaults.

6.6 Device Properties

Cameras or sensor devices are generally addressed as 'device' in this software. These devices have properties that are accessed by a property name. These property names are translated into register accesses on the driver DLL. The property names are reflected in the GUI as far as practicable. A property name normally has a special mark up throughout this document, for example: `ExposureTime`. Some properties are grouped into a structure whose member is accessed via dot notation, e.g. `Window.X` (for the start X value of a region of interest). When changing a property, the property name can always be seen in the log window of the main program window.

7 Graphical User Interface (GUI)

7.1 MV1-D1024E-160

This section describes the parameters of the following MV1-D1024E-160-CL-12 camera.

The following sections are grouped according to the tabs in the configuration dialog.

Figure 7.1: Frame rate and average value indication

Frame Rate [fps]: Shows the actual frame rate of the camera in frames per second.

Update: To update the value of the frame rate, click on this button.

Average Value: Greyscale average of the actual image. This value is in 12bit (0...4095).

Update: To update the value of the average, click on this button.

7.1.1 Exposure

This tab contains exposure settings.

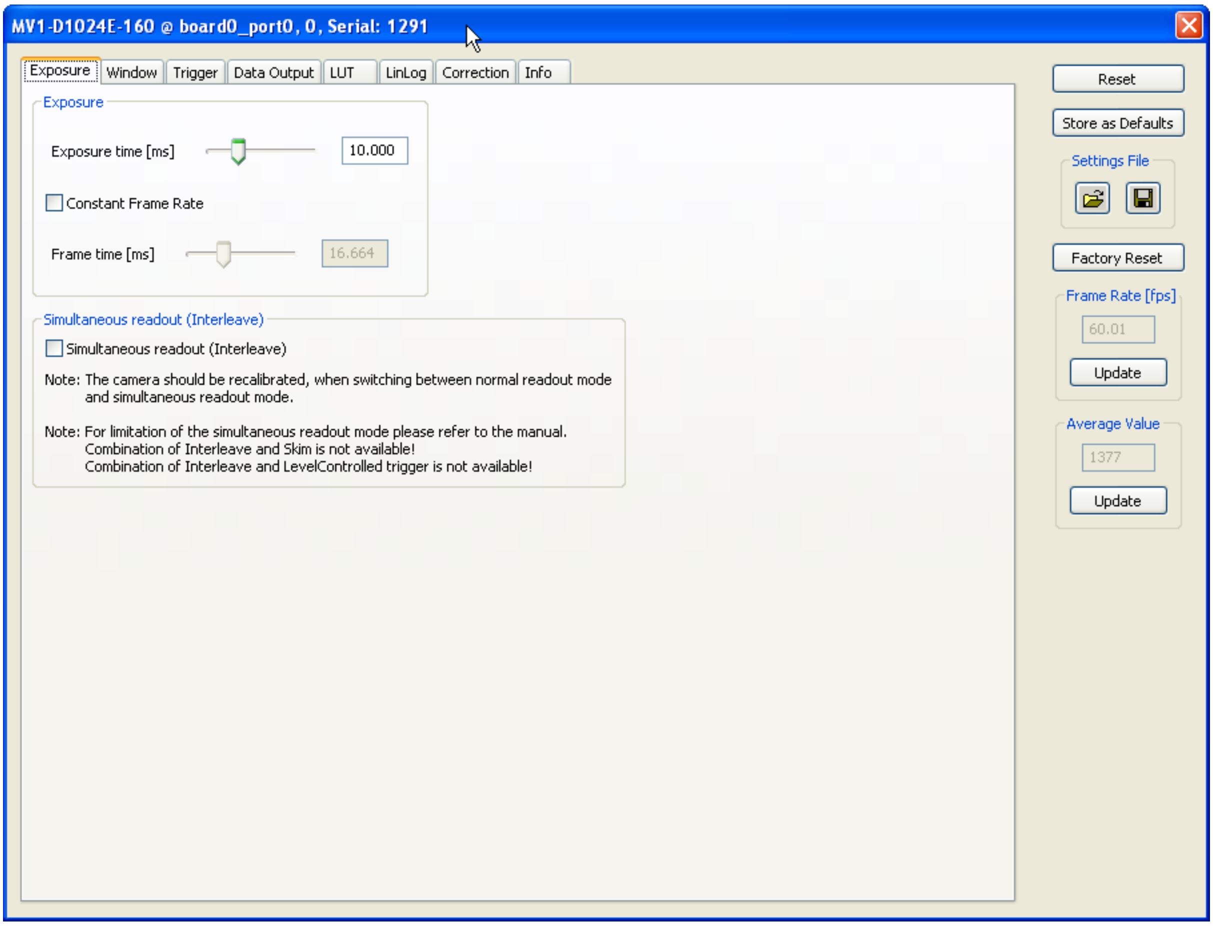


Figure 7.2: Exposure panel

Exposure

Exposure time [ms]: Configure the exposure time in milliseconds.

Constant Frame Rate: When the Constant Frame Rate (CFR) is switched on, the frame rate (number of frames per second) can be varied from almost 0 up to the maximum frame rate. Thus, fewer images can be acquired than would otherwise be possible. When Constant Frame Rate is switched off, the camera delivers images as fast as possible, depending on the exposure time and the read-out time.

Frame time [ms]: Configure the frame time in milliseconds. Only available if Constant Frame Rate is enabled. The minimum frame time depends on the exposure time and readout time.

Simultaneous readout (Interleave)

The simultaneous readout mode allows higher frame rate.

Simultaneous readout (Interleave): Enable the simultaneous readout mode.

☞ Combination of property `Trigger.Interleave` and property `LinLog.Mode` is not available! Combination of property `Trigger.Interleave` and property `Trigger.LevelControlled` is not available! Combination of property `Trigger.Interleave` and property `Trigger.EnBurstTrigger` is not available!

7.1.2 Window

This tab contains the settings for the region of interest.

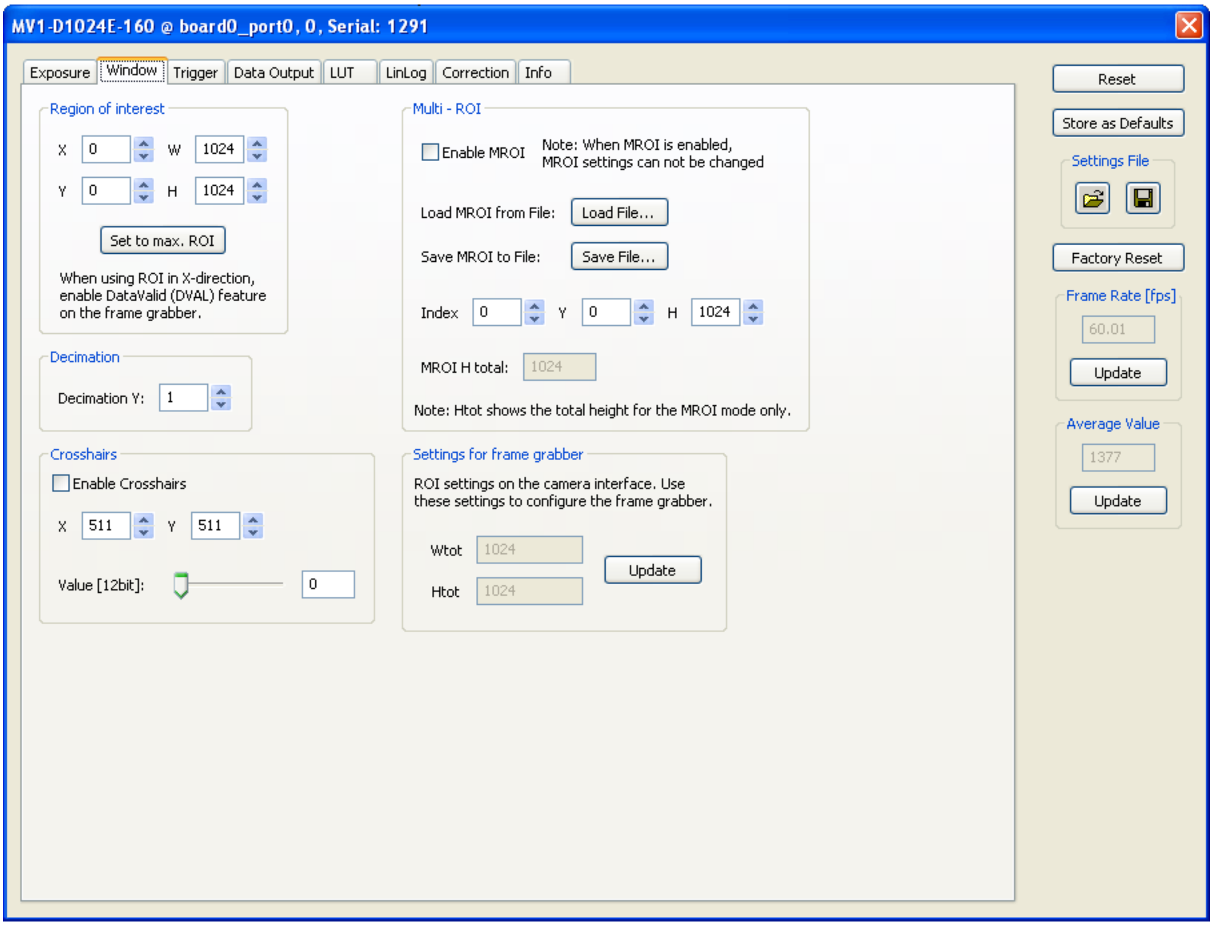


Figure 7.3: Window panel

Region of Interest

The region of interest (ROI) is defined as a rectangle (X, Y), (W, H) where

X: X - coordinate, starting from 0 in the upper left corner.

Y: Y - coordinate, starting from 0 in the upper left corner.

W: Window width (in steps of 8 pixels).

H: Window height.

Set to max ROI: Set Window to maximal ROI (X=0; Y=0; W=1024; H=1024).

Window width is only available in steps of 8 pixels.

Decimation

`Decimation` reduces the number of pixels in y-direction. Decimation can also be used together with a ROI or MROI. Decimation in y-direction transfers every n-th row only and directly results in reduced read-out time and higher frame rate respectively.

Decimation Y: Decimation value for y-direction. Example: Value = 3 reads every third row only.

Crosshairs

Crosshairs is a cross inside the image. The crosshairs value is overlapped the original image data. The position of the crosshairs can be configured. The unit of the grey value is always 12 bit.

Enable Crosshairs: Enable crosshairs.

X: Vertical line position of crosshairs.

Y: Horizontal line position of crosshairs

Value [12bit]: Crosshairs grey value in 12bit.

Multi - ROI

This camera can handle up to 512 different regions of interest. The multiple ROIs are joined together and form a single image, which is transferred to the frame grabber. A ROI is defined by its starting value in y-direction and its height. The width and the horizontal offset are specified by X and W settings. The maximum frame rate in MROI mode depends on the number of rows and columns being read out. Overlapping ROIs are NOT allowed. No row should be included in more than one ROI.

Enable MROI: Enable MROI. If MROI is enabled, the ROI and MROI settings cannot be changed.

Load File...: Load a user defined MROI-file into the camera. A sample MROI configuration file (`mv1_d1024e_160_mroi.txt`) with description of the data format is available in the directory `MROI-files` located in the PFRemote installation directory.

Save File...: Save the current MROI settings to a *.txt file.

Index: Select one of the 512 MROI.

Y: Y - coordinate of the current MROI (selected by Index).

H: Height of the current MROI (selected by Index).

H tot: Shows the sum of all MROIs as the total image height.

Settings for frame grabber

Shows the ROI settings on the camera interface. Use these settings to configure the frame grabber.

Wtot: Number of pixels in a line (Width of the image).

Htot: Number of lines out of the camera (Height of the image).

Update: Update values of Wtot and Htot.

7.1.3 Trigger

This tab contains trigger and strobe settings.

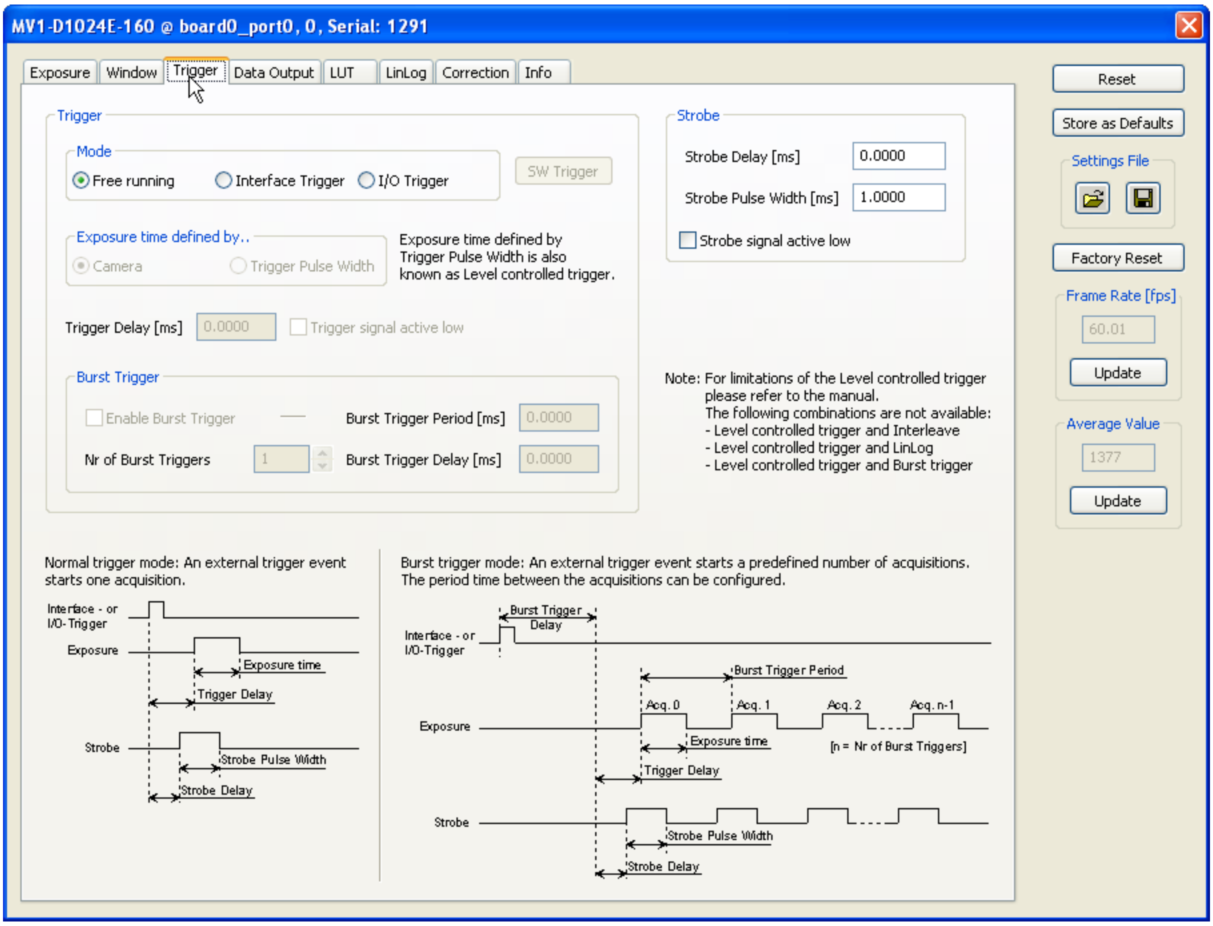


Figure 7.4: Trigger panel

Trigger

Trigger Source:

Free running: The camera continuously delivers images with a certain configurable frame rate.

Interface Trigger: The Trigger signal is applied to the camera by the CameraLink frame grabber.

I/O Trigger: The trigger signal is applied directly to the camera on the power supply connector.

Exposure time defined by:

Camera: The exposure time is defined by the property `ExposureTime`.

Trigger Pulse Width: The exposure time is defined by the pulse width of the trigger signal (level-controlled exposure).

☞ This property disables LinLog and Burst trigger.

☞ Exposure time defined by "Trigger Pulse Width" is also known as Level controlled trigger.

Further trigger settings:

Trigger Delay [ms]: Programmable delay in milliseconds between the incoming trigger edge and the start of the exposure.

Trigger signal active low: Define the trigger signal to be active high (default) or active low.

Burst Trigger

An external trigger event start a predefined number of acquisition. The period time between the acquisitions can be configured.

Enable Burst Trigger: Delay in milliseconds from the input trigger edge to the rising edge of the strobe output signal.

Number of Burst Triggers: Set the number of burst

Burst Trigger Period [ms]: Set the time between the burst in milliseconds.

Burst Trigger Delay [ms]: Set the delay of the burst trigger in milliseconds.

Strobe

The camera generates a strobe output signal that can be used to trigger a strobe. The delay, pulse width and polarity can be defined by software. To turn off strobe output, set StrobePulseWidth to 0.

Strobe Delay [ms]: Delay in milliseconds from the input trigger edge to the rising edge of the strobe output signal.

Strobe Pulse Width [ms]: The pulse width of the strobe trigger in milliseconds.

Strobe signal active low: Define the strobe output to be active high (default) or active low.

7.1.4 Data Output

This tab contains image data settings.

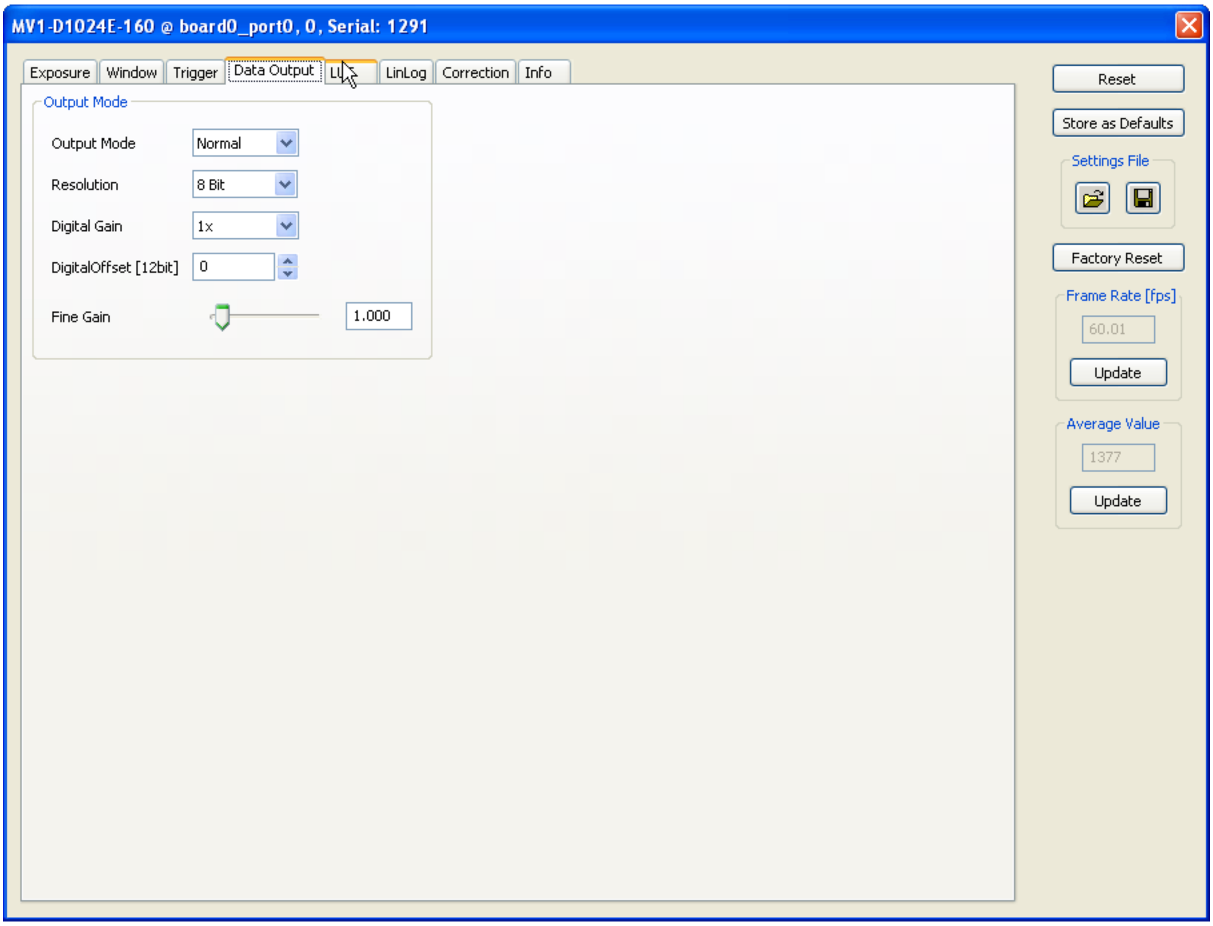


Figure 7.5: Data output panel

Output Mode

Output Mode:

Normal: Normal mode.

LFSR: Test image. Linear feedback shift register (pseudo-random image). The pattern depends on the grey level resolution.

Ramp: Test image. Values of pixel are incremented by 1, starting at each row. The pattern depends on the grey level resolution.

Resolution:

8 Bit: Grey level resolution of 8 bit.

10 Bit: Grey level resolution of 10 bit.

12 Bit: Grey level resolution of 12 bit.

Digital Gain:

1x: No digital gain, normal mode.

2x: Digital gain 2.

4x: Digital gain 4.

8x: Digital gain 8.

Digital Offset: Substracts an offset from the data. Only available in gain mode. Fine Gain: The fine gain can be used to adjust the brightness of the whole image in small steps.

7.1.5 LUT (Look-Up-Table)

This tab contains LUT settings.

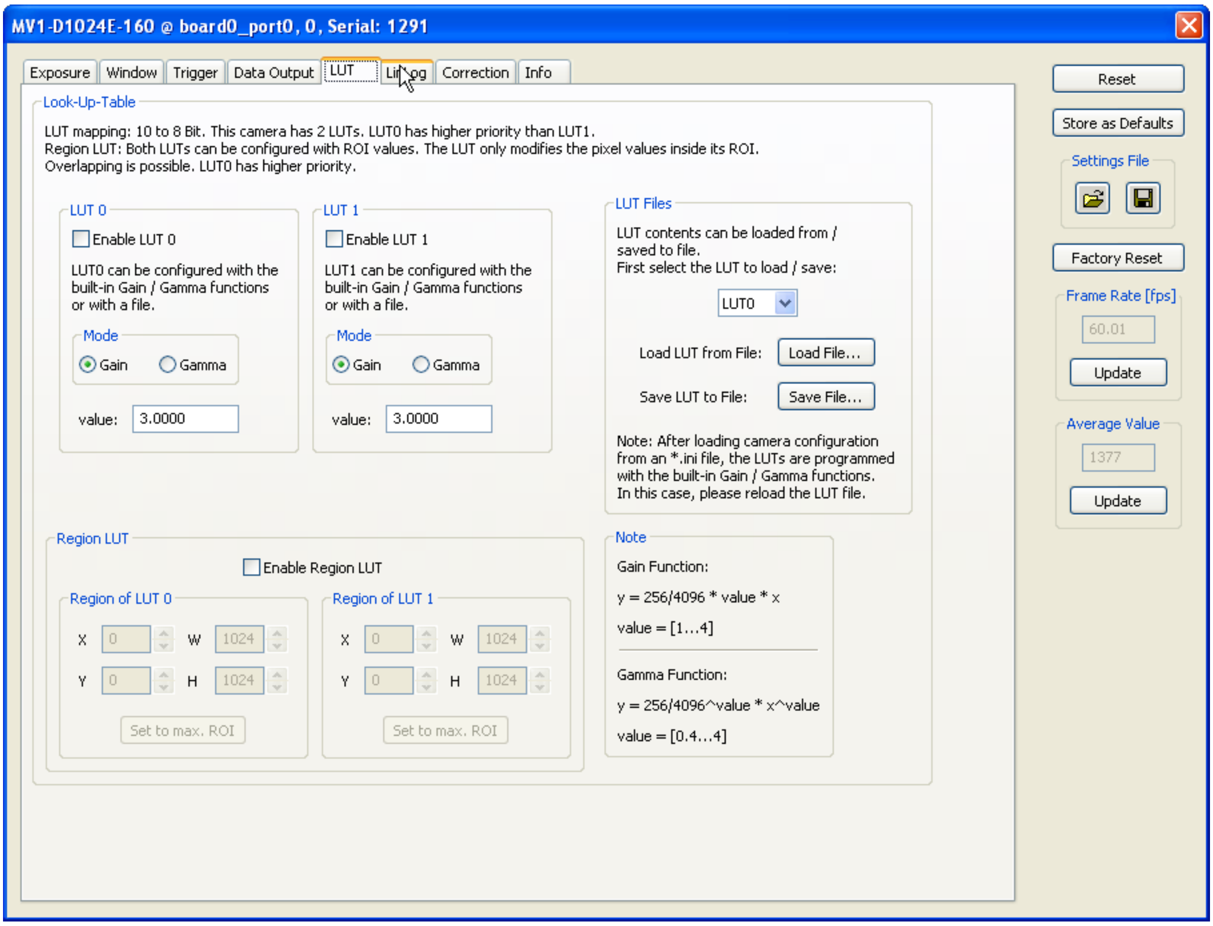


Figure 7.6: LUT panel

Grey level transformation is remapping of the grey level values of an input image to new values which transform the image in some way. The look-up-table (LUT) is used to convert the greyscale value of each pixel in an image into another grey value. It is typically used to implement a transfer curve for contrast expansion.

This camera performs a 12-to-8-bit mapping, so that 4096 input grey levels can be mapped to 256 output grey levels (0 to 4096 and 0 to 255).

This camera support 2 LUT, both are identical. The default LUTs is a gain function with value = 1. LUT0 has higher priority as LUT1.

Both LUT can be configured with the built-in Gain / Gamma functions or with a LUT-file

LUTX

Enable LUT X Enable the LUTX

Gain: Linear function. Y = 256 / 4096 * value * X; Valid range for `value` [1...4].

Gamma: Gamma function. Y = 256 / 4096^value * X ^ value; Valid range for `value` [0.4...4].

value: Enter a value. The LUT will be calculated and downloaded to the camera.

Region LUT

Both LUT can be configured with ROI vlaues. The LUT is only working inside the the ROI values. Overlapping is possible. LUT0 has higher priority.

Enable Region LUT: Enable the region LUT functionality.

Region of LUT:

X: X - coordinate of region LUT, starting from 0 in the upper left corner.

Y: Y - coordinate of region LUT, starting from 0 in the upper left corner.

W: Region LUT window width (in steps of 2 pixel).

H: Region LUT window height.

Set to max ROI: Set Region LUT window to maximal ROI (X=0; Y=0; W=1024; H=1024).

LUT Files

To load or save a LUT file

LUT Index: Select the LUT, you want to load or save a file.

File functions:

Load File...: Load a user defined LUT - file into the camera (*.txt tab delimited). There is an example file (mv1_d1024e_160_lut.txt) in the directory LUT-files located in the PFRemote installation directory.

Save File...: Save LUT from camera into a file.

7.1.6 LinLog

This tab contains LinLog and Skimming settings.

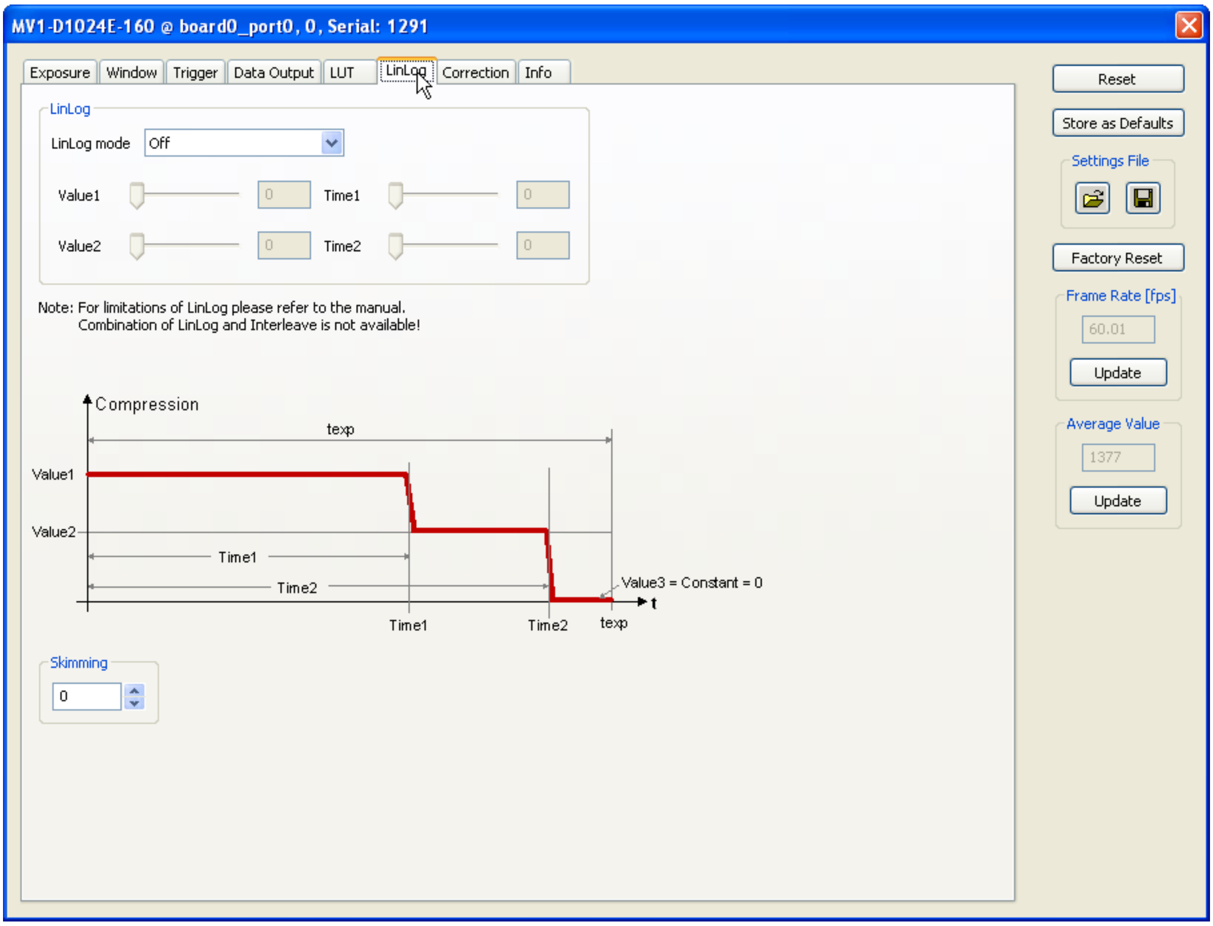


Figure 7.7: Linlog panel

LinLog

The LinLog technology from Photonfocus allows a logarithmic compression of high light intensities. In contrast to the classical non-integrating logarithmic pixel, the LinLog pixel is an integrating pixel with global shutter and the possibility to control the transition between linear and logarithmic mode (See also the corresponding section in the camera manual.). There are 3 predefined LinLog settings available. Alternatively, custom settings can be defined in the `User defined` Mode.

LinLog Mode: Off: LinLog is disabled. Low/Normal/High compression: Three LinLog presettings. User defined: `Value1`, `Time1`, `Value2` and `Time2`. The Linlog times are per thousand of the exposure time. Time 800 means 80% of the exposure time.

Skimming

Skimming is a Photonfocus proprietary technology to enhance detail in dark areas of an image.

Skimming: Skimming value. If 0, Skimming is disabled. See also the corresponding section in the camera manual.

7.1.7 Correction

This tab contains correction settings.

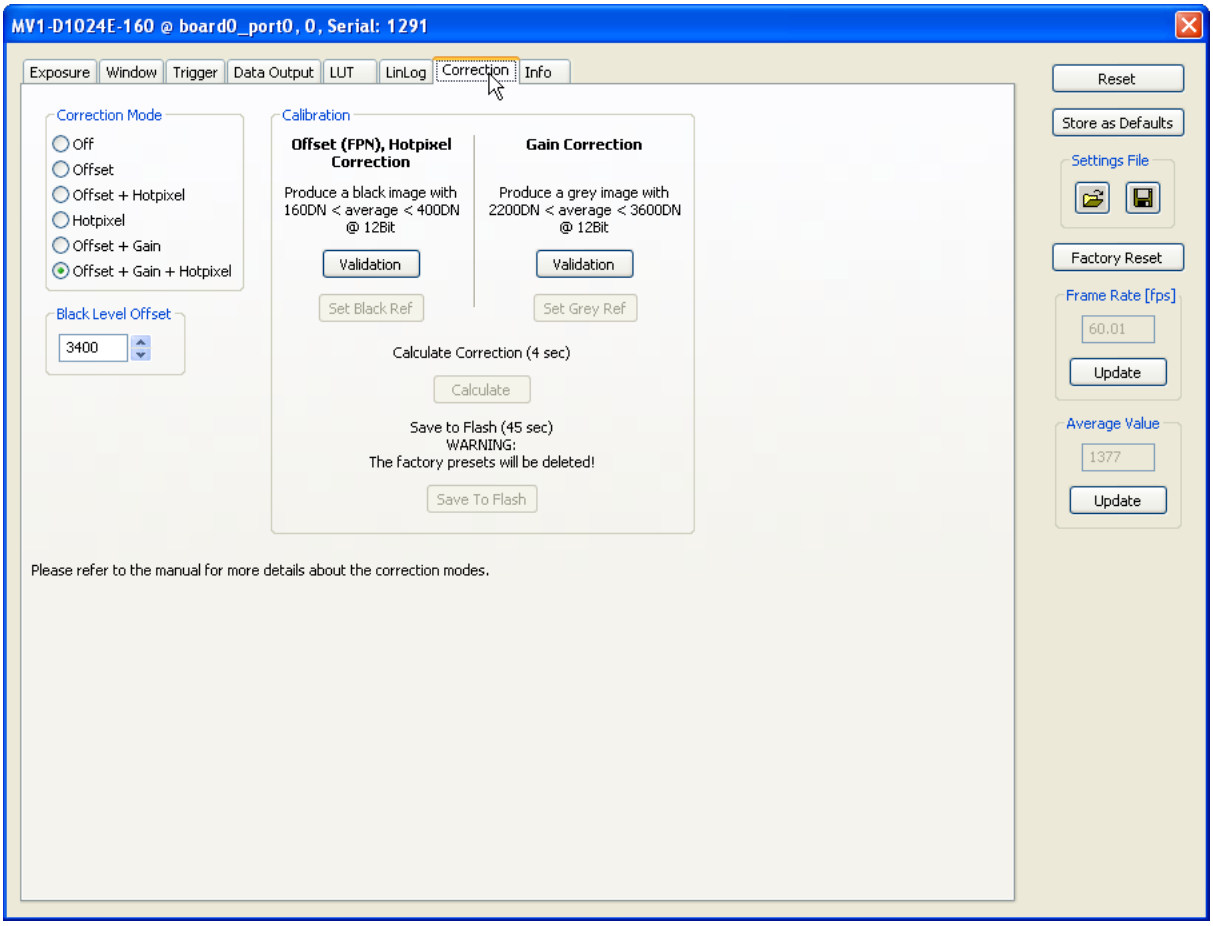


Figure 7.8: Correction panel

Correction Mode

This camera has image pre-processing features, that compensate for non-uniformities caused by the sensor, the lens or the illumination.

Off: No correction.

Offset: Activate offset correction

Offset + Hotpixel: Activate offset and hot pixel correction.

Hotpixel: Activate hot pixel correction.

Offset + Gain: Activate offset and gain correction.

Offset + Gain + Hotpixel: Activate offset, gain and hot pixel correction.

Calibration

Offset (FPN), Hotpixel Correction: The offset correction is based on a black reference image, which is taken at no illumination (e.g. lens aperture completely closed). The black reference image contains the fixed-pattern noise of the sensor, which can be subtracted from the live images in order to minimize the static noise. Close the lens of the camera. Click on the Validation button. If the Set Black Ref - button is still inactive, the average of the image is out of range. Change to panel Charateristics and change the Property `BlackLevelOffset` until the average of the image is between 160 and 400DN. Click again on the Validation button and then on the Set Black Ref Button.

If only offset and hot pixel correction is needed it is not necessary to calibrate a grey image. (see Calculate)

Gain Correction: The gain correction is based on a grey reference image, which is taken at uniform illumination to give an image with a mid grey level.

Gain correction is not a trivial feature. The quality of the grey reference image is crucial for proper gain correction.

Produce a grey image with an average between 2200 and 3600DN. Click on the Validation button to check the average. If the average is in range, the Set Grey Ref button is active.

Calculate: Calculate the correction values into the camera RAM. To make the correction values permanent, use the 'Save to Flash' button.

Save to Flash: Save the current correction values to the internal flash memory.

This will overwrite the factory presets.

7.1.8 Info

This panel shows camera specific information such as type code, serial number and firmware revision of the FPGA and microcontroller and the description of the camera interface.

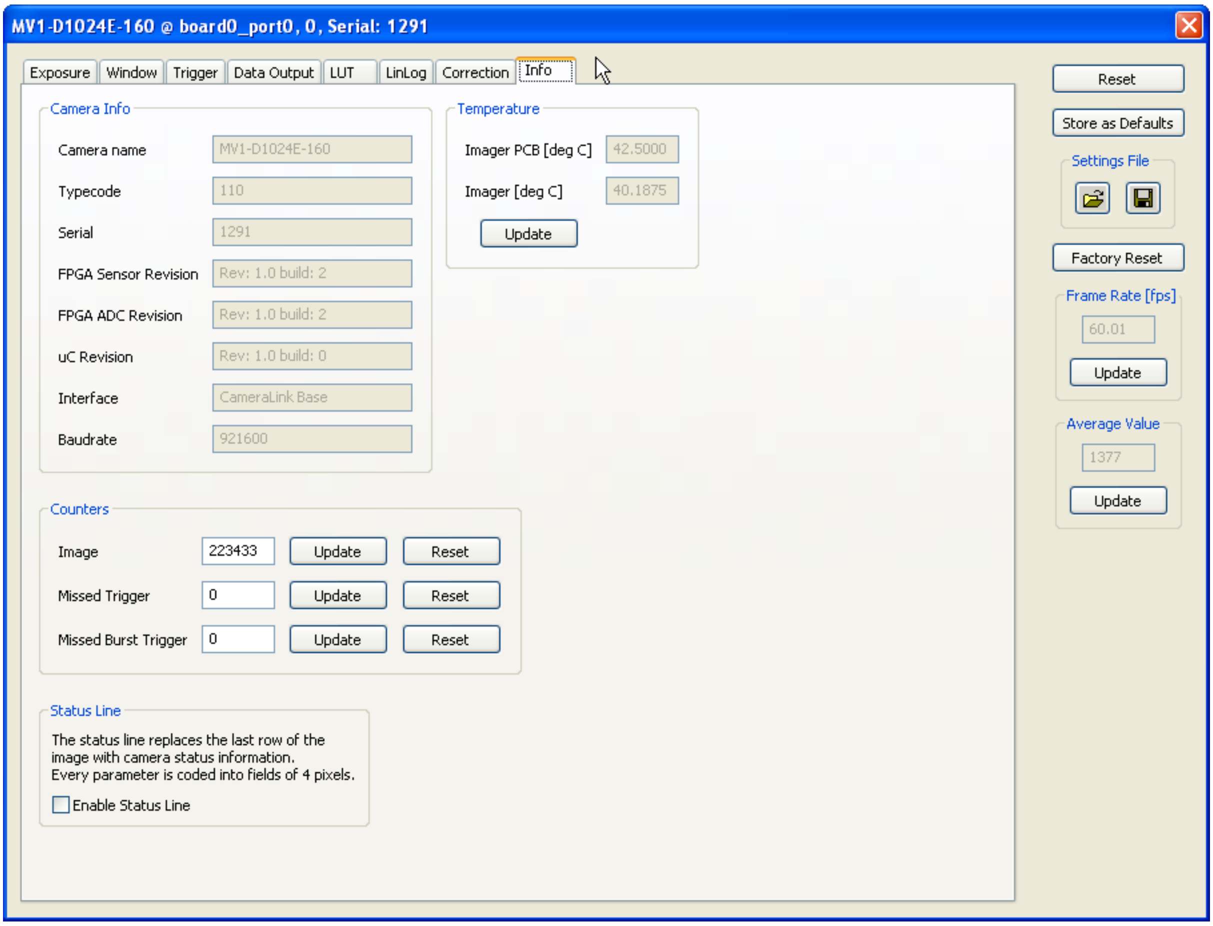


Figure 7.9: Info panel

Camera Info

Camera name: Name of the connected camera.

Typecode: Type code of the connected camera.

Serial: Serial number of the connected camera.

FPGA Sensor Revision: Firmware revision of built-in FPGA on the sensor PCB of the connected camera.

FPGA ADC Revision: Firmware revision of built-in FPGA on the ADC PCB of the connected camera.

uC Revision: Firmware revision of built-in microcontroller of the connected camera.

Interface: Description of the camera interface.

Baudrate: The actual baud rate between camera and frame grabber.

☞ For any support requests, please enclose the information provided on this panel.

Counters

The camera has the following counters.

Image: The image counter is a 24 bit real-time counter and is incremented by 1 for every new image.

Missed Trigger: This is a counter for trigger pulses that were blocked because the trigger pulse was received during image exposure or readout. In free-running mode it counts all pulses received from interface trigger or from I/O trigger interface.

Missed Burst Trigger: This is a counter for burst trigger pulses that were blocked because the burst trigger pulse was received during the last burst is not yet finished.

To update the value of the information properties, click on the Update-Button; to reset the properties, click on the Reset-Button.

Status Line

Enable Status Line: The status line replaces the last line of an image with image information, please refer the manual for additional information.

Temperature

Image PCB [deg C]: The temperature of the board (PCB) where the image sensor is located.

Image [deg C]: The temperature of the image sensor.

Update: Press this button to update all temperature values.

8

Mechanical and Optical Considerations

8.1 Mechanical Interface for CameraLink Camera Models

Fig. 8.1 shows the mechanical drawings of the CameraLink camera models. Table 8.1 summarizes model-specific parameters.

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.

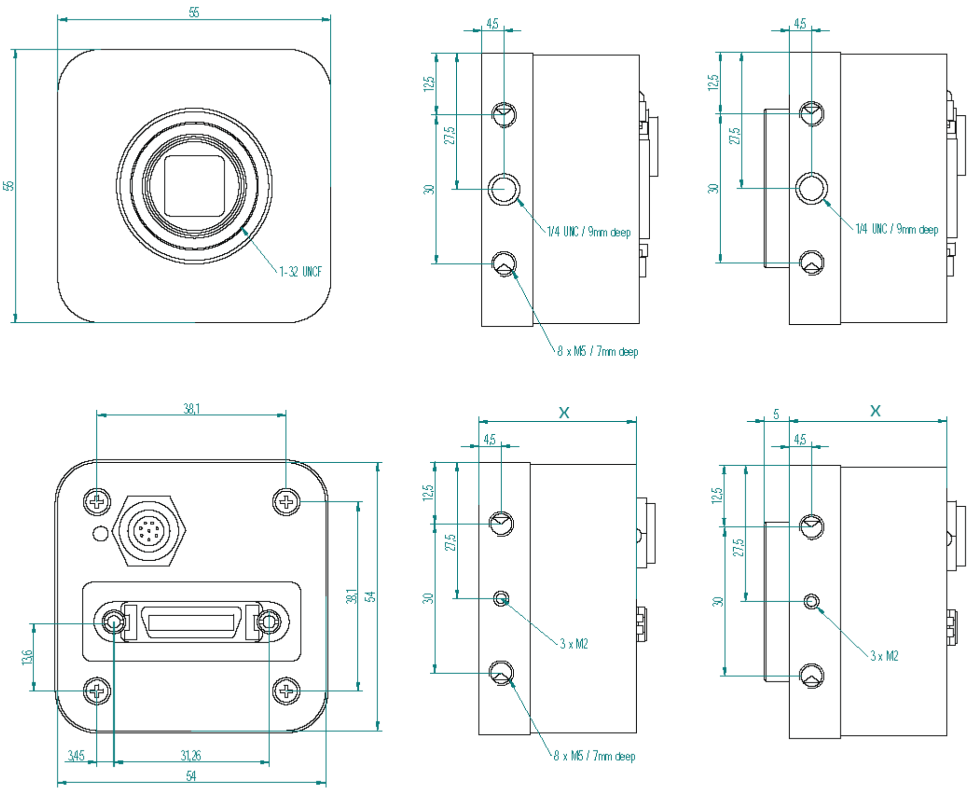


Figure 8.1: Mechanical dimensions of the CameraLink model with or without C-Mount adapter

All values are in [mm].

	MV1-D1024E-160-CL
X (housing depth)	40 mm

Table 8.1: Model-specific parameters

8.2 Adjusting the Back Focus

The back focus of your Photonfocus camera is correctly adjusted in the production of the camera.

This section describes the procedure to adjust the back focus if you require that because e.g. you are using a special lens.

1. Screw a lens strongly into the camera's C-mount ring.
2. Unscrew the 3 small screws that lock the C-mount ring with a hex-wrench of size 0.89 mm. The position of the screws is shown in Fig. 8.2. The ring can now be screwn upwards or downwards by turning the lens.
3. To adjust the back focus fully open the aperture of the lens and set the focus to infinite.
4. Start the image acquisition and point the camera to a straight edge/line in a distance x (x = infinite distance of your lens) from the camera, e.g. a door frame.
5. Screw the ring upwards or downwards until the straight edge/line (distance: infinite) is also straight on the camera image.
6. Tighten the small screws. As the ring is locked, the lens can now be easily removed.

Figure 8.2: Position of the 3 small screws that lock C-mount.ring

8.3 Optical Interface

8.3.1 Cleaning the Sensor

The sensor is part of the optical path and should be handled like other optical components: **with extreme care**.

Dust can obscure pixels, producing dark patches in the images captured. Dust is most visible when the illumination is collimated. Dark patches caused by dust or dirt shift position as the angle of illumination changes. Dust is normally not visible when the sensor is positioned at the exit port of an integrating sphere, where the illumination is diffuse.

1. The camera should only be cleaned in ESD-safe areas by ESD-trained personnel using wrist straps. Ideally, the sensor should be cleaned in a clean environment. Otherwise, in dusty environments, the sensor will immediately become dirty again after cleaning.
2. Use a high quality, low pressure air duster (e.g. Electrolube EAD400D, pure compressed inert gas, www.electrolube.com) to blow off loose particles. This step alone is usually sufficient to clean the sensor of the most common contaminants.

   Workshop air supply is not appropriate and may cause permanent damage to the sensor.

3. If further cleaning is required, use a suitable lens wiper or Q-Tip moistened with an appropriate cleaning fluid to wipe the sensor surface as described below. Examples of suitable lens cleaning materials are given in Table 8.2. Cleaning materials must be ESD-safe, lint-free and free from particles that may scratch the sensor surface.

   Do not use ordinary cotton buds. These do not fulfil the above requirements and permanent damage to the sensor may result.

4. Wipe the sensor carefully and slowly. First remove coarse particles and dirt from the sensor using Q-Tips soaked in 2-propanol, applying as little pressure as possible. Using a method similar to that used for cleaning optical surfaces, clean the sensor by starting at any corner of the sensor and working towards the opposite corner. Finally, repeat the procedure with methanol to remove streaks. It is imperative that no pressure be applied to the surface of the sensor or to the black globe-top material (if present) surrounding the optically active surface during the cleaning process.

Product		Supplier	Remark
EAD400D	Airduster	Electrolube, UK	www.electrolube.com
Anticon Gold 9"x 9"	Wiper	Milliken, USA	ESD safe and suitable for class 100 environments. www.milliken.com
TX4025	Wiper	Texwipe	www.texwipe.com
Transplex	Swab	Texwipe	
Small Q-Tips SWABS BB-003	Q-tips	Hans J. Michael GmbH, Germany	www.hjm-reinraum.de
Large Q-Tips SWABS CA-003	Q-tips	Hans J. Michael GmbH, Germany	
Point Slim HUBY-340	Q-tips	Hans J. Michael GmbH, Germany	
Methanol	Fluid	Johnson Matthey GmbH, Germany	Semiconductor Grade 99.9% min (Assay), Merck 12,6024, UN1230, slightly flammable and poisonous. www.alfa-chemcat.com
2-Propanol (Iso-Propanol)	Fluid	Johnson Matthey GmbH, Germany	Semiconductor Grade 99.5% min (Assay) Merck 12,5227, UN1219, slightly flammable. www.alfa-chemcat.com

Table 8.2: Recommended materials for sensor cleaning

For cleaning the sensor, Photonfocus recommends the products available from the suppliers as listed in Table 8.2.

✎ Cleaning tools (except chemicals) can be purchased from Photonfocus (www.photonfocus.com).

8.4 CE compliance

The Photonfocus camera serie MV1-D1024E-CL 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.

CL CameraLink® Specification, January 2004

SW002 PFLib Documentation, Photonfocus, August 2005

AN001 Application Note "LinLog", Photonfocus, December 2002

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

AN008 Application Note "Photometry versus Radiometry", Photonfocus, December 2004

AN010 Application Note "Camera Clock Concepts", Photonfocus, July 2004

AN021 Application Note "CameraLink®", Photonfocus, July 2004

AN026 Application Note "LFSR Test Images", Photonfocus, September 2005

A

Pinouts

A.1 Power Supply Connector

The power supply plugs are available from Binder connectors at www.binder-connector.de. Fig. A.2 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.

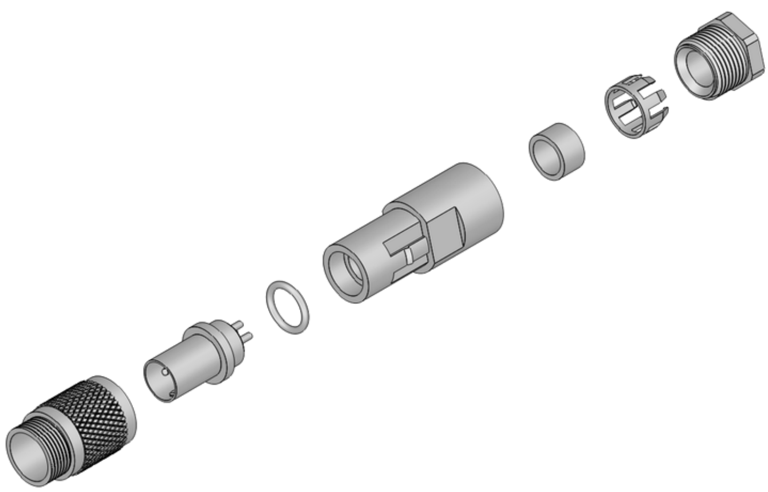


Figure A.1: Power connector assembly

Connector Type	Order Nr.
7-pole, plastic	99-0421-00-07
7-pole, metal	99-0421-10-07

Table A.1: Power supply connectors (Binder subminiature series 712)

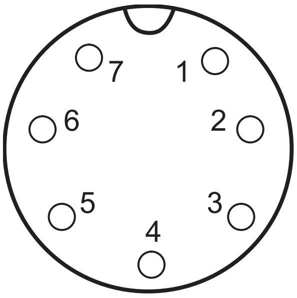


Figure A.2: Power supply plug, 7-pole (rear view of plug, solder side)

Pin	*I/O Type*	*Name*	*Description*
1	PWR	VDD	+12 V DC ($\pm$ 10%)
2	PWR	GND	Ground
3	O	RESERVED	Do not connect
4	PWR	STROBE-VDD	+5 .. +15 V DC
5	O	STROBE	Strobe control (opto-isolated)
6	I	TRIGGER	External trigger (opto-isolated), +5 .. +15V DC
7	PWR	GROUND	Signal ground (for opto-isolated strobe signal)

Table A.2: Power supply plug pin assignment

A.2 CameraLink® Connector

The pinout for the CameraLink® 26 pin, 0.5" Mini D-Ribbon (MDR) connector is according to the CameraLink® standard ([CL]) and is listed here for reference only (see Table A.3). The drawing of the CameraLink® cable plug is shown in Fig. A.3.

☞ CameraLink® cables can be purchased from Photonfocus directly (www.photonfocus.com).

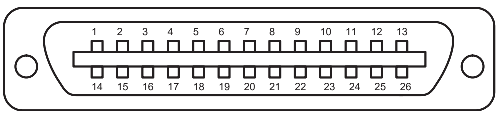


Figure A.3: CameraLink cable 3M MDR-26 plug (both ends)

PIN	IO	Name	Description
1	PW	SHIELD	Shield
2	O	N_XD0	Negative LVDS Output, CameraLink® Data D0
3	O	N_XD1	Negative LVDS Output, CameraLink® Data D1
4	O	N_XD2	Negative LVDS Output, CameraLink® Data D2
5	O	N_XCLK	Negative LVDS Output, CameraLink® Clock
6	O	N_XD3	Negative LVDS Output, CameraLink® Data D3
7	I	P_SERTOCAM	Positive LVDS Input, Serial Communication to the camera
8	O	N_SERTOFG	Negative LVDS Output, Serial Communication from the camera
9	I	N_CC1	Negative LVDS Input, Camera Control 1 (CC1)
10	I	N_CC2	Positive LVDS Input, Camera Control 2 (CC2)
11	I	N_CC3	Negative LVDS Input, Camera Control 3 (CC3)
12	I	P_CC4	Positive LVDS Input, Camera Control 4 (CC4)
13	PW	SHIELD	Shield
14	PW	SHIELD	Shield
15	O	P_XD0	Positive LVDS Output, CameraLink® Data D0
16	O	P_XD1	Positive LVDS Output, CameraLink® Data D1
17	O	P_XD2	Positive LVDS Output, CameraLink® Data D2
18	O	P_XCLK	Positive LVDS Output, CameraLink® Clock
19	O	P_XD3	Positive LVDS Output, CameraLink® Data D3
20	I	N_SERTOCAM	Negative LVDS Input, Serial Communication to the camera
21	O	P_SERTOFG	Positive LVDS Output, Serial Communication from the camera
22	I	P_CC1	Positive LVDS Input, Camera Control 1 (CC1)
23	I	N_CC2	Negative LVDS Input, Camera Control 2 (CC2)
24	I	P_CC3	Positive LVDS Input, Camera Control 3 (CC3)
25	I	N_CC4	Negative LVDS Input, Camera Control 4 (CC4)
26	PW	SHIELD	Shield
S	PW	SHIELD	Shield

Table A.3: Pinout of the CameraLink® connector

B

Revision History

Revision	Date	Changes
1.0	September 2014	First version