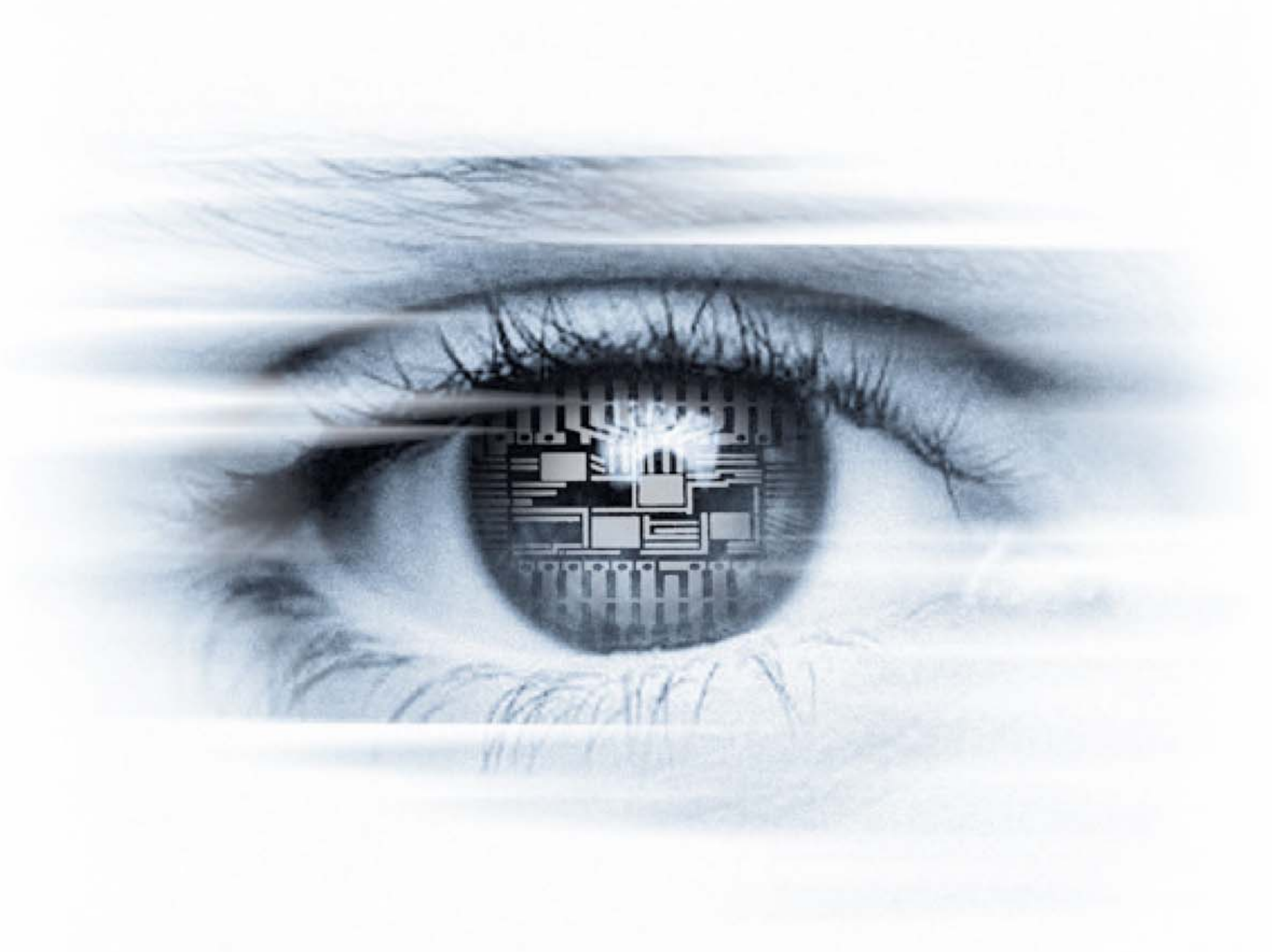
photon focus

User Manual
MV-D640 Series
CMOS Area Scan Cameras



THE PERFECT EYE

MAN006 11/2005 V2.0

Contents

1 Preface

1.1 About Photonfocus

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

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

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

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

1.2 Contact

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

Sales	Phone: +41 55 451 01 31	Email: sales@photonfocus.com
Support	Phone: +41 55 451 01 37	Email: support@photonfocus.com

1.3 Sales Offices

Photonfocus products are available through an extensive international distribution network; details of the distributor nearest to you can be found at www.photonfocus.com.

1.4 Further information

For further information on the products, documentation and software updates please see our website www.photonfocus.com or contact our distributors.

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

Photonfocus cannot be held responsible for any technical or typographical errors.

2 How to Get Started

2.1 First Steps with a MV-D640 CameraLink Model

1. Remove the camera from its package.

   Please make sure the following items are included with your camera:

   - 3-pole power supply plug
   - Camera body cap

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

2. Install the frame grabber software.

   Note: 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 protective cap from the camera and mount a suitable lens.

   Caution: **Protect the image sensor from particles and dust!** Remove the protective cap from the C-mount thread of the sensor module and screw in the lens. When removing the protective cap or changing the lens, the camera should always be held with the opening facing downwards to prevent dust falling onto the CMOS sensor.

   Note: For US and Canada: Ensure a UL listed power supply is used.

4. Download the PFInstaller from the Photonfocus website and install the software.

   Run PFInstaller.exe. Follow the instructions of the installer and choose "Any Camera-Link compliant grabber". Then follow the instructions described in the readme file.

5. Connect the delivered power supply to the camera.

   Caution: Check the correct power supply voltage and polarity! Do not exceed the maximum operating voltage of +5V DC (+10%, -5%) for the CameraLink model.

6. Connect the camera to your frame grabber with a CameraLink cable.

7. Start the camera software PFRemote.

   Double click on the communication port where you attached the camera.

8. Check the status LEDs on the rear side of the camera.

   See Section 5.1.6 for more information.

9. You may now display images using the software provided by your frame grabber manufacturer.

2.2 First Steps with a MV-D640 USB2.0 Model

10. Remove the camera from its package.

    Please make sure the following items are included with your camera:

    - 7-pole power supply plug
    - Camera body cap

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

11. Check if your computer fulfils the hardware requirements.

    See Section 4.8.2 for more information.

12. Remove the protective cap from the camera and mount a suitable lens.

    Caution: **Protect the image sensor from particles and dust!** Remove the protective cap from the C-mount thread of the sensor module and screw in the lens. When removing the protective cap or changing the lens, the camera should always be held with the opening facing downwards to prevent dust falling onto the CMOS sensor.

    Note: For US and Canada: Ensure a UL listed power supply is used.

13. Download the PFInstaller from the Photonfocus website and install the software.

    Run PFInstaller.exe. Follow the instructions of the installer and choose "Any Photonfocus USB camera".

    Important: During the installation, the camera **must not be connected** to the USB port.

14. Connect the delivered power supply to the camera.

    Caution: Check the correct power supply voltage and polarity! Do not exceed the maximum operating voltage of +12V DC (± 10%) for the USB2.0 model.

15. Connect the camera to your computer with a USB2.0 cable.

16. Let Windows install the driver.

    Windows should display the "New Hardware found" wizard automatically. If this wizard is not displayed, please continue as described under "Manual Driver Installation" below.

    Let the Hardware assistant install the drivers. It is not necessary to allow the search for current and updated software on the Internet. Proceed by choosing the option "Install the software automatically (Recommended)". Another Hardware Installation message will appear which can be ignored ("Continue Anyway").

    Note: The procedure described here applies to Windows XP SP2.

17. Start the software microDisplay USB.

    If you are not familiar with the microDisplay USB software please read the manual [MAN025] before acquiring images.

    Important: Always start the software microDisplay USB in the first step and proceed to start the camera software PFRemote in the second step. This is mandatory for proper operation of the camera, because microDisplay USB downloads the USB firmware into the camera.

Each time the power supply or the USB cable have been disconnected, you have to restart microDisplay USB in order to download the firmware again.

18. Start the camera software PFRemote.

    Double click on the communication port "USB0".

19. Check the status LEDs.

    See Section 5.1.6 for more information.

20. You may now display images using microDisplay USB.

Note: The maximum frame rate depends on the USB chipset of the PC and on the camera parameters.

Manual driver installation

If Windows did not automatically install the driver for your USB camera, please proceed as follows:

- Open the Device Manager in the Windows Control Panel.
- There will be an unknown device called "Silicon Software microUSB2".
- Right click on the unknown device and choose "Update Driver".
- The Hardware update wizard will appear. It is not necessary to allow the search for current and updated software on the Internet. Click on "No, not this time" and "Next".
- Then choose "Install the software automatically (Recommended)" and proceed with "Next".
- When you get asked for the driver location, specify \Photonfocus\microDisplayUSB\driver.

Note: This procedure applies to Windows XP SP2.

3 Product Specification

3.1 Introduction

The MV-D640 camera series from Photonfocus is aimed at demanding applications in industrial image processing. The cameras offer a high dynamic range of up to 60 dB with a resolution of 640x480 pixels and a full frame rate of up to 200 frames per second. The principal advantages are:

- Superior color rendition
- Exceptional linear response curve
- Superior SNR (signal to noise ratio)
- Low power consumption at high speeds
- Resistance to blooming
- Ideal for high speed applications: Global shutter, in combination with a selectable region of interest to increase speed
- USB2.0 or CameraLink interface
- Compact size

3.2 Technical Specification

Table 1: Sensor parameters

	MV-D640 Series
Technology	CMOS active pixel
Scanning system	progressive scan
Shutter type	global shutter
Resolution	640 x 480 pixels
Optical format / diagonal	1/2" / 7.92 mm
Pixel size	9.9 μm x 9.9 μm
Active optical area	6.34 mm x 4.75 mm
Random Noise	< 0.59 DN RMS @ 630 nm / 8 bit / gain = 1
Fixed Pattern Noise	< 1.5 DN RMS @ 630 nm / 8 bit / gain = 1
Full well capacity	90 ke^-
Spectral range	400 nm ... 1000 nm
Responsivity	480 x 10^3 DN / (J/m^2) @ 630 nm / 8 bit / gain = 1
Optical fill factor	50 %
Dynamic range	60 dB
Color format	monochrome / color (Bayer pattern)
Characteristic curve	linear
Shutter mode	global
Read-out mode	sequential or interleaved (automatically determined)

Table 2: Camera parameters

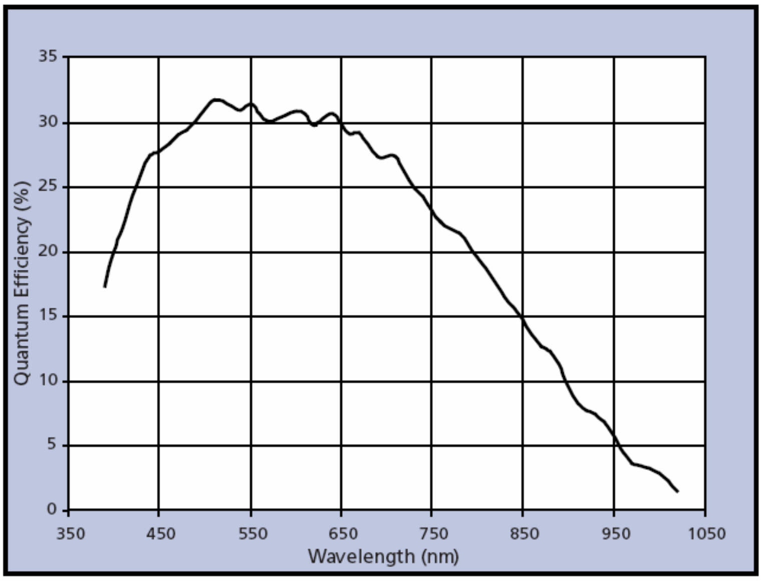
	MV-D640-66-CL-10 MV-D640C-66-CL-10	MV-D640-33-CL-10 MV-D640C-33-CL-10	MV-D640-48-U2-8	MV-D640C-48-U2-8
Exposure time	50 µs – 1.3 s			
Exposure time step size	20 µs	20 µs	16 µs	48 µs
Frame rate	up to 200 fps	up to 100 fps	up to 129 fps	up to 42 fps
Min. region of interest (ROI)	4x1 pixels		Width x height ≥ 1024 pixels	
Grayscale resolution	8 / 10 bit		8 bit	
Digital gain	x1, x2, x4			
Analog gain	x1 ... x8 (up to x18 possible, but not recommended)			
Pixel clock frequency	66 MHz	33 MHz	48 MHz (fast USB) 24 MHz (slow USB)	16 MHz (fast USB) 8 MHz (slow USB)
Pixel clock period	15.15 ns	30.30 ns	20.83 ns (fast (USB) 41.67 ns (slow USB)	62.5 ns (fast USB) 125 ns (slow USB)
Camera taps	1			

Note: The maximum frame rate depends on the configuration and the USB chipset on the PC. For more information regarding the fast and slow USB mode please refer to Section 4.8.2.

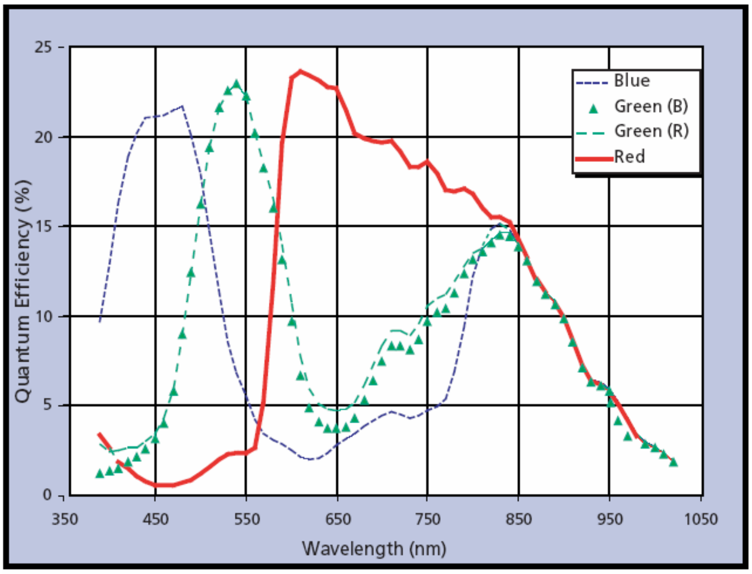
Table 3: Physical characteristics and operating ranges

	MV-D640-66-CL-10 MV-D640C-66-CL-10	MV-D640-33-CL-10 MV-D640C-33-CL-10	MV-D640-48-U2-8	MV-D640C-48-U2-8
Operating temperature	0 °C ... 60 °C			
Camera power supply	+5V DC (+10%, -5%)		+12V DC (± 10%)	
Trigger signal input range	–		+5 ... +15V DC	
Strobe signal power supply	–		+5 ... +15V DC	
Strobe signal sink current (average)	–		max. 8mA	
Power consumption	1.7 W	1.5 W	3.3 W	
Lens mount	C-mount			
Dimensions	55 x 55 x 37 mm^3		55 x 55 x 48 mm^3	
Mass	200 g		200 g	
Conformity	CE / UL			

Note: For US and Canada: Ensure an **UL listed** power supply marked "Class 2" is used and rated 5V DC/min. 400mA or 12V DC/min. 400mA, respectively. A suitable **UL listed** power supply is available from Photonfocus. Ensure the device downstream of the camera data path (eg: PC) is **UL listed** also.



Monochrome



Color

Figure 1: Quantum efficiency as function of wavelength

3.3 Frame grabber relevant Configuration (CameraLink models only)

Table 4: Summary of parameters needed for frame grabber configuration

	MV-D640(C)-66-CL-10	MV-D640(C)-33-CL-10
Pixel clock per tap	66 MHz	33 MHz
CC1	EXSYNC	
CC2	–	
CC3	–	
CC4	–	

Camera port and bit assignments are compliant to the CameraLink standard.

Table 5: CameraLink port and bit assignment for MV-D640 CameraLink series

Data Bit	Tap 0, 8 bit	Tap 0, 10 bit
0 (LSB)	A0	A0
1	A1	A1
2	A2	A2
3	A3	A3
4	A4	A4
5	A5	A5
6	A6	A6
7 (MSB for 8 bit mode)	A7	A7
8		B0
9 (MSB for 10 bit mode)		B1

4 Functionality

This chapter serves as an overview of the camera configuration modes and explains camera features.

4.1 Image Acquisition

4.1.1 Free-running and Trigger Mode

By default the camera continuously delivers images as fast as possible ("Free-running mode").

When the acquisition of an image needs to be synchronised to an external event, an external trigger can be used (refer to Sections 4.6 and 5.1.4). In this mode, the camera is idle until it receives a signal to capture an image.

4.1.2 Exposure Control

The exposure time defines the period during which the image sensor integrates the incoming light. Refer to Table 2 for the allowed exposure time range and see Section 5.2.

4.1.3 Maximum Frame Rate

The maximum frame rate depends on the exposure time and the size of the image (Region of Interest ROI, see Section 4.5). Depending on the exposure time and ROI size, the sensor is configured automatically in interleaved or non-interleaved mode (see Sections 4.1.4 and 4.5).

4.1.4 Sensor Read-out Mode

For an exposure time smaller than the read-out time, the sensor is operated in non-interleaved mode. To further increase the frame rate, the sensor is operated in interleaved mode when the exposure time is longer than the read-out time.

Note: The camera chooses the most advantageous mode (interleaved / non-interleaved) automatically without user-intervention.

Interleaved mode integrates an image while reading out the last image (see Figure 2) and does therefore increase the maximum frame rate.

Important: In external trigger mode, the camera will always be configured automatically in non-interleaved mode.

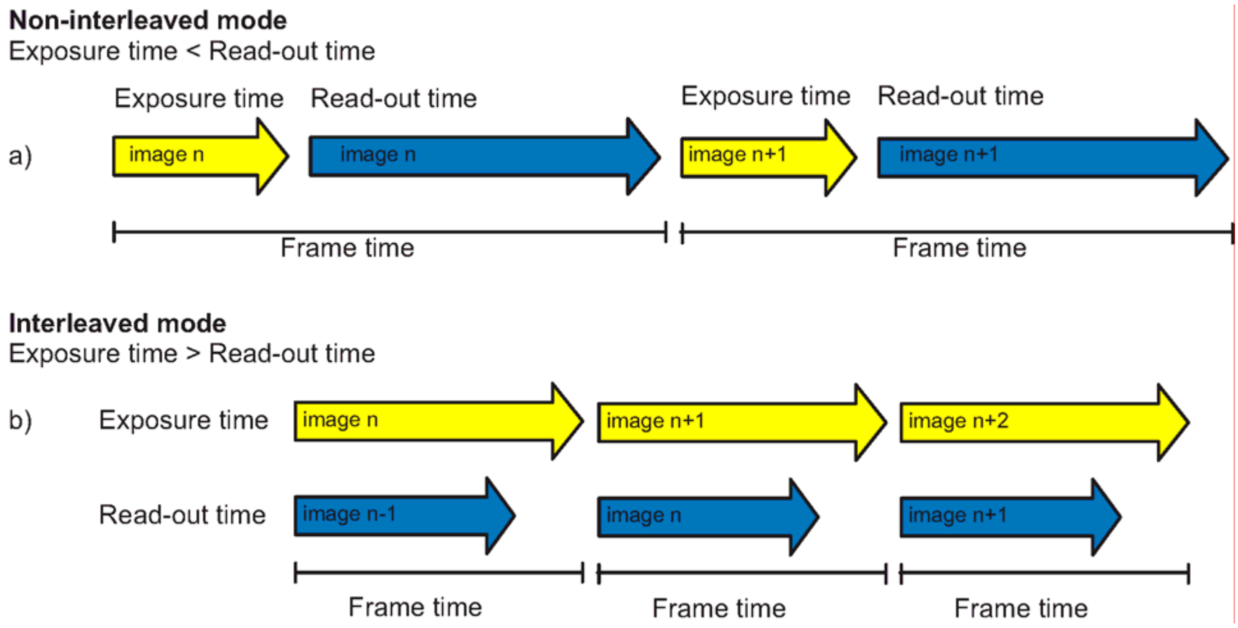


Figure 2: Difference between interleaved and non-interleaved mode

Following table gives the exposure time at which the read-out mode is switched for the full resolution of 640x480 pixels. See Section 4.5.3 for the calculation of the frame rate.

Table 6: Switching of the read-out mode for a full frame of 640x480

	Exposure time	
	Interleaved mode	Non-interleaved mode
MV-D640(C)-66-CL-10	< 4.9 ms	≥ 4.91 ms
MV-D640(C)-33-CL-10	< 9.8 ms	≥ 9.8 ms
MV-D640-48-U2-8	< 7.8 ms (fast USB mode) < 15.6 ms (slow USB mode)	≥ 7.8 ms (fast USB mode) ≥ 15.6 ms (slow USB mode)
MV-D640C-48-U2-8	< 23.1 ms (fast USB mode) < 46.2 ms (slow USB mode)	≥ 23.1 ms (fast USB mode) ≥ 46.2 ms (slow USB mode)

4.2 Pixel Response

4.2.1 Linear Response

Normally, the camera offers a linear response between input light signal and output gray level. In addition, a linear analog or digital gain may be applied.

4.2.2 Analog Gain

The MV-D640 camera series offer an analog on-chip gain between x1 and x18 in steps of 1. For the color model, the four color channels red, green1, blue, green2 can be adjusted independently.

Important! Using a high analog gain will degrade the image quality. Although it is possible to configure analog gain up to x18, we strongly recommend using a lower gain than gain x8.

4.2.3 Digital Gain

Gain x2 and x4 is a digital amplification, which means that the digital image data are multiplied by a factor 2 or 4 respectively, in the camera.

4.3 Bayer Color Pattern

The MV-D640 color model is equipped with a Bayer color pattern. A full RGB signal can be calculated using a Bayer algorithm. For the CameraLink models, this is performed by the frame grabber. For the USB2.0 model, the Bayer algorithm is performed in the camera.

(0,0) = Bottom left corner of sensor arrray

Figure 3: Bayer pattern example

Note: When using a region of interest, the start point for the Bayer decoder depends on the start point of the ROI.

Note: For the MV-D640C-66-CL model, the start point of the Bayer decoder must be reconfigured when switching between the fast (66 MHz) and slow (33 MHz) mode:
33 MHz mode: Pixel (0,0) = green
66 MHz mode: Pixel (0,0) = red

Important!

All Photonfocus color cameras are fitted with an IR/UV blocking filter as standard equipment. It is possible that, depending on the illumination source, this filter must be replaced by one corresponding to the illumination source, in order to achieve an optimal image in difficult illumination environments (e.g. halogen lamp with high red component).

4.4 Test Image

An LFSR (Linear Feedback Shift Register) test image outputs a constant pattern with a pseudo-random gray level sequence containing every possible gray level that is repeated for every row (Figure 23). Please refer to Chapter 11 for a detailed description of the LFSR pattern.

4.5 Reduction of Image Size

4.5.1 Region of Interest

Some applications do not need full image resolution. By reducing the image size to a certain region of interest (ROI), the frame rate can be drastically increased. A region of interest can be almost any rectangular window and is specified by its position within the full frame and its width and height. Figure 4 gives some possible configurations for a region of interest, and Table 7 shows some numerical examples of how the frame rate can be increased by reducing the ROI.

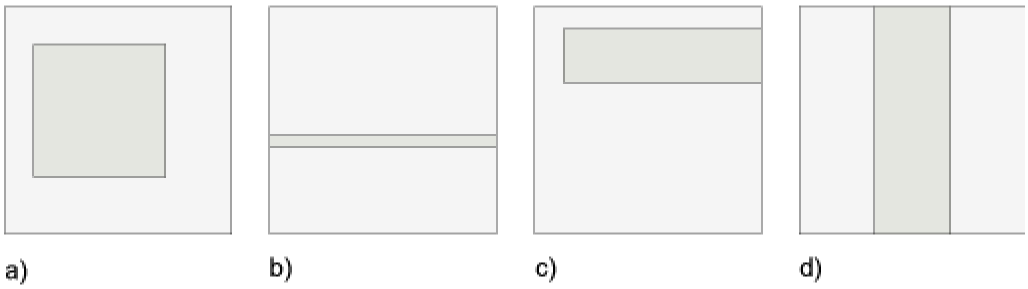


Figure 4: ROI configuration examples

Note: Only the reduction in y-direction (image height) results in a higher frame rate.

4.5.2 ROI Example Configurations

The following tables show how the frame rate is increased by reducing the number of rows. The tables give round numbers, the actual maximum values could be slightly higher.

Table 7: Maximum image rates for the CameraLink models

ROI t_{exp} = 50 µs	MV-D640-66-CL-10 MV-D640C-66-CL-10	MV-D640-33-CL-10 MV-D640C-33-CL-10
640 x 480	200 fps	100 fps
640 x 240	390 fps	200 fps
640 x 120	770 fps	390 fps
640 x 60	1490 fps	760 fps
640 x 30	2660 fps	1420 fps

Table 8: Maximum image rates for the USB2.0 camera models

ROI	MV-D640-48-U2-8		MV-D640C-48-U2-8	
t_{exp} = 50 µs	Intel supported chipset (fast mode)	No Intel supported chipset (slow mode)	Intel supported chipset (fast mode)	No Intel supported chipset (slow mode)
640 x 480	129 fps	64 fps	43 fps	20 fps
640 x 240	255 fps	128 fps	85 fps	40 fps
640 x 120	500 fps	250 fps	165 fps	85 fps
640 x 60	960 fps	490 fps	330 fps	165 fps
640 x 30	1780 fps	930 fps	630 fps	320 fps

4.5.3 Frame Rate Calculation Formula

The frame rate depends on the exposure time and the ROI. For the USB models, the maximum frame rate also depends on the USB chipset of the PC. Please refer to Section 4.8.2 for more information.

The frame rate can be calculated using the following formula:

$t_{readout} = t_u * [CPRE + (P_y + 2) * (R_x + HB) + RESET] * MODE$
if $t_{exp} < t_{readout}$,
  $t_{frame} = t_{exp} + t_{readout}$
else
  $t_{frame} = t_{exp} + t_u * (CPRE + RESET) * MODE$
end
Frame rate = $1/ t_{frame}$

Table 9: Symbols used in the frame rate calculation formula

	CameraLink		USB2.0	
	MV-D640-66-CL MV-D640C-66-CL	MV-D640-33-CL MV-D640C-33-CL	MV-D640-48-U2 (monochrome)	MV-D640C-48-U2 (color)
Horizontal Blanking HB	3		96	
CPRE	127 + HB			
RESET	550			
Pixel clock f_u	66 MHz	33 MHz	48 MHz	16 MHz
Pixel clock period t_u	15.15 ns	30.30 ns	20.83 ns	62.5 ns
MODE	Constant MODE = 1		Intel supported chipset: MODE = 1 No Intel supported chipset: MODE = 2	
R_x	Constant R_x = 671, independent of ROI			
P_y	Height of the ROI			
t_{exp}	Exposure time in [s]			
$t_{readout}$	Read-out time [s]			

Example 1: MV-D640-66-CL, ROI 100x100 pixel, exposure time t_{exp} = 6 ms

- $t_{readout} = t_u * [CPRE + (P_y + 2) * (R_x + HB) + RESET] * MODE = 1.05$ ms
- $t_{readout} < t_{exp} \Rightarrow t_{frame} = t_{exp} + t_u * (CPRE + RESET) * MODE = 6.01$ ms
- Frame rate = 1 / t_{frame} = 166 fps

Example 2: MV-D640C-33-CL, ROI 640x300 pixel, exposure time t_{exp} = 1 ms

- $t_{readout} = t_u * [CPRE + (P_y + 2) * (R_x + HB) + RESET] * MODE = 6.19$ ms
- $t_{readout} > t_{exp} \Rightarrow t_{frame} = t_{exp} + t_{readout} = 7.19$ ms
- Frame rate = 1 / t_{frame} = 139 fps

Example 3: MV-D640C-48-U2, ROI 200x100 pixel, exposure time t_{exp} = 5 ms, Intel supported chipset (fast mode)

- $t_{readout} = t_u * [CPRE + (P_y + 2) * (R_x + HB) + RESET] * MODE = 4.94$ ms
- $t_{readout} < t_{exp} \Rightarrow t_{frame} = t_{exp} + t_u * (CPRE + RESET) * MODE = 5.05$ ms
- Frame rate = 1 / t_{frame} = 198 fps

Example 4: MV-D640C-48-U2, ROI 200x100 pixel, exposure time t_{exp} = 5 ms, no Intel supported chipset (slow mode)

- $t_{readout} = t_u * [CPRE + (P_y + 2) * (R_x + HB) + RESET] * MODE = 9.88$ ms
- $t_{readout} > t_{exp} \Rightarrow t_{frame} = t_{exp} + t_{readout} = 14.88$ ms
- Frame rate = 1 / t_{frame} = 67 fps

Note: For a small ROI and small exposure time, the actual frame rate may differ from this calculated value due to the minimum exposure step size as defined in Table 2.

4.6 External Trigger and Strobe

An external trigger is an event that starts an exposure. If a trigger signal is applied to the camera during the exposure or read-out time, the trigger will be ignored.

4.6.1 Trigger Source

The MV-D640 camera models with CameraLink interface are triggered over the CC1 signal via frame grabber.

The MV-D640 camera models with USB2.0 interface are triggered over a signal available on the power supply connector (see Section 5.1.4).

Note: For the USB models, both trigger and strobe must be configured in microDisplay. See [MAN025] for more information.

4.6.2 Trigger Mode

In external trigger mode, the sensor is always operated in non-interleaved mode (compare to Section 4.5). Figure 5 and Figure 6 compare the maximum frame rate in free running and external trigger mode with increasing exposure time. In the free running mode, the step in the curve indicates the switching between non-interleaved and interleaved mode.

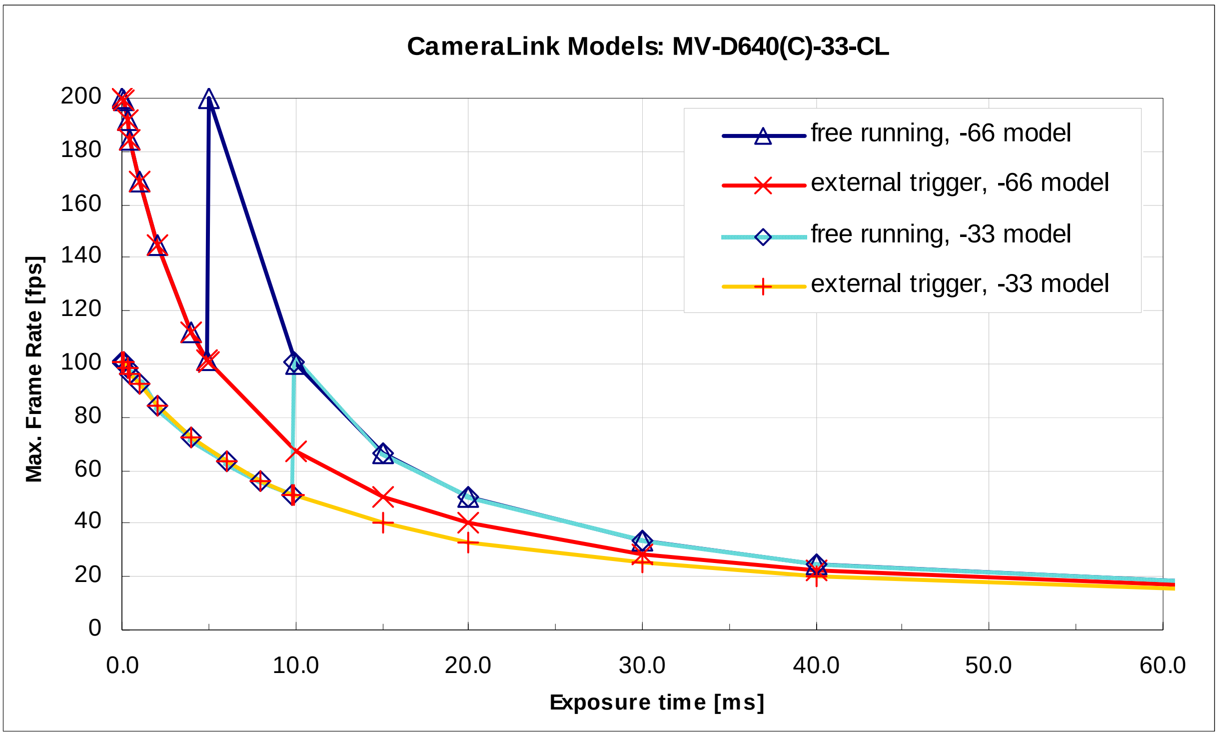


Figure 5: Frame rate of MV-D640-66 camera in free running and external trigger mode

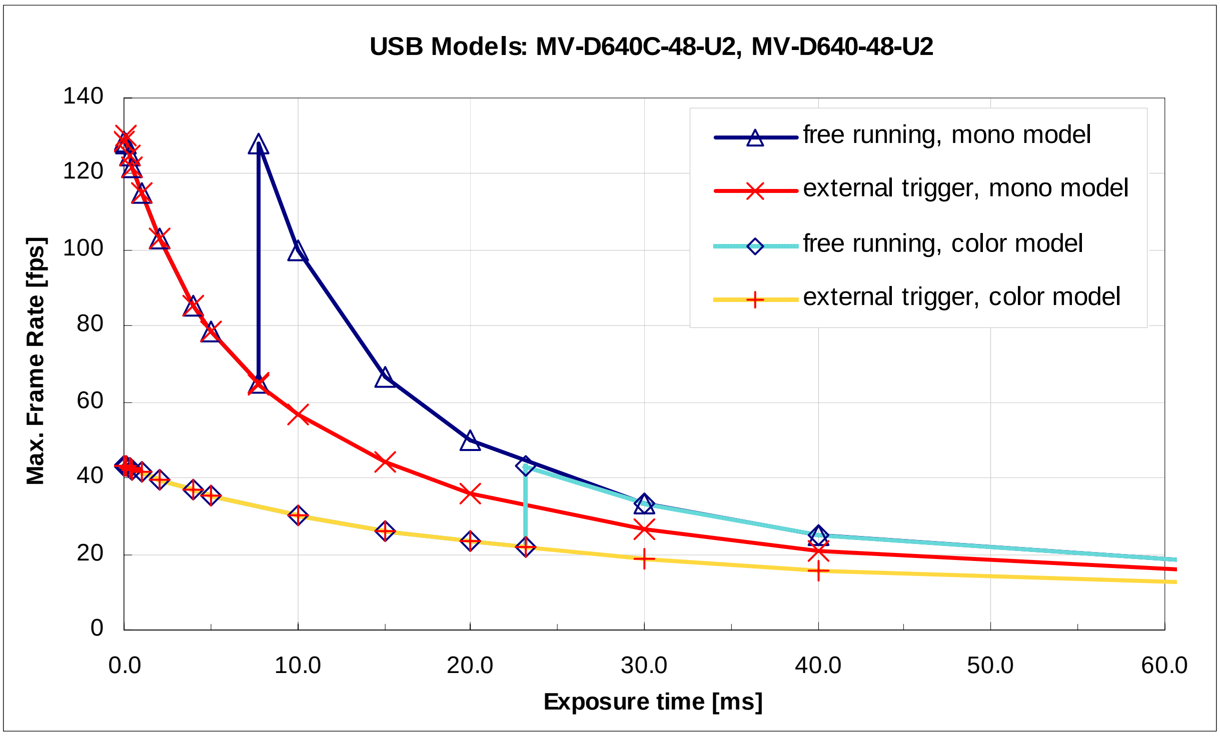


Figure 6: Frame rate of the USB2.0 models in free running and external trigger mode

4.6.3 Strobe Output

When using a CameraLink model, the strobe output must be provided by the frame grabber.

For the USB models, there is an opto isolated strobe output on the power supply connector available.

Note: The strobe output needs a separate power supply due to the opto-coupled output. Please see Section 5.1.4 for more information. For the configuration, see [MAN025].

4.7 Black Level Adjustment

The black level offset (the mean value of the image when the lens aperture is completely closed) is calibrated by factory for Gain=2 (default setting). Changing the gain may need to adjust the black level offset with the following procedure:

1. Close the aperture of the lens, or close the lens opening of the camera with the camera body cap.
2. In your frame grabber software, display a histogram of the captured black image. If there is no histogram available, store the image and use a standard image manipulation tool.
3. Open the camera in PFRemote 1.0.
4. In the 'Special' tab of PFRemote, change the value of 'Black Level Offset', until the histogram of the black image looks as in Figure 7.
5. To save the current settings including the new black level offset in the camera, use the "Store as defaults" button.

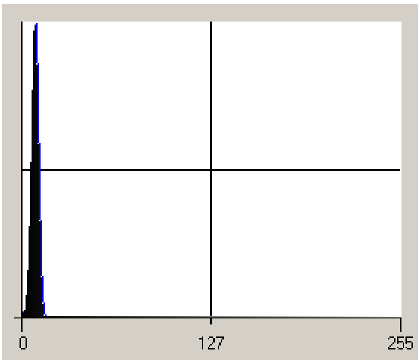


Figure 7: Histogram for a correct black level

Note: For PFRemote version 0.65, refer to Chapter 12.

4.8 Configuration Interface

4.8.1 CameraLink Interface

A CameraLink camera can be controlled by the user via an RS232 compatible asynchronous serial interface. This interface is contained within the CameraLink interface as shown in Figure 8 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.

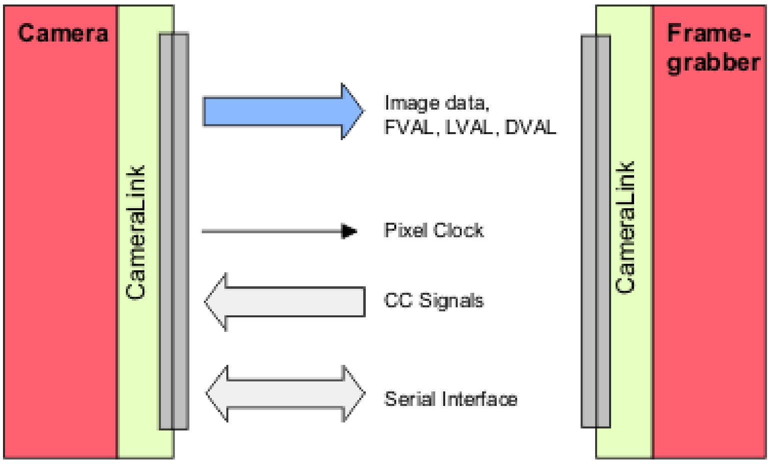


Figure 8: CameraLink serial interface for camera communication

To interface different cameras to different frame grabbers, the CameraLink standard defines a software API. It defines how the functions to initialise, read from, write to and close the serial interface should look. The code behind these functions is frame grabber specific and is written by the frame grabber manufacturer. The functions are then compiled into a DLL called clserXXX.dll, where XXX is a unique identifier for the frame grabber manufacturer.

The PFRemote camera configuration tool as well as the PFLib API use the serial interface to communicate with the camera and to control its functions. The serial interface is accessed via the clserXXX.dll. Therefore, the appropriate clserXXX.dll for the frame grabber manufacturer needs to be in the same directory as the PFRemote executable (e.g. C:\Program Files\Photonfocus\PFRemote). This DLL is usually located in the windows\system32 directory after installing the frame grabber driver.

The serial configuration parameters are defined in the CameraLink standard and are as follows: 9600 baud, 1 start bit, 1 stop bit, no parity, no handshaking.

4.8.2 USB 2.0 Interface

The abbreviation USB stands for "Universal Serial Bus" and is a bus system developed in 1995 by a consortium of leading companies in the computer industry, in cooperation with Intel. The USB 1.1 specification defined a port speed to be 12 MBit/s, the USB 2.0 specification a remarkable 480 MBit/s. However, not every PC with an USB 2.0 interface can be used in the fast mode to reach a maximum speed of data transfer (24 MByte/s or 48 MByte/s). Depending on the available USB chipset on the PC, it is possible that only a data rate of 24 MByte/s can be achieved.

Note: The maximum speed of the USB interface (24 MByte/s or 48 MByte/s) is determined by the USB driver automatically and cannot be configured.

Software requirements

To reach the full performance of 48 MByte/s, Windows XP with Service Pack 2 is required. For Windows 2000 and Windows XP with Service Pack 1, the camera will run with 24 Mbyte/s only.

Note: The camera can only be operated with the software MicroDisplay USB to grab images, together with PFRemote to control the camera. Alternatively, the frame grabber module USB SDK and the PFLib SDK can be used. Other software is not supported.

Attention: The camera firmware, which is essential for the operation of the camera, is automatically transmitted to the camera via USB during the start-up of the MicroDisplay USB software. Therefore, the camera must always be connected to the USB port during start up, otherwise the camera will not be functional.

Hardware requirements

To reach the full performance of 48 Mbyte/s (isochronous mode), a PC Mainboard with Intel chipsets is required and the Southbridge must support ICH4, ICH5 or higher. The camera must be connected to a USB port that is provided by the Southbridge of the PC and not by an additional USB2.0 host adapter. More information about the Southbridge is available in the motherboard manual of your PC. A list of Intel chip sets is available at www.intel.com/products/chipsets/index.htm.

Note: Intel provides the tool chiputil.exe to determine the chip set being used on a PC. It can be downloaded from:
ftp://aiedownload.intel.com/df-support/7355/eng/chiputil.exe
Alternative link: http://downloadfinder.intel.com/scripts-df/support_intel.asp (search for 'chiputil')

Note: The camera is optimised for high data transfer, and other USB devices may stop functioning or perform poorly.

Note: Additional USB 2.0 host adapters may only transfer up to 24 Mbyte/s because they are not directly connected to the Southbridge and therefore do not support the isochronous mode.

The data transfer mode of the camera (48 MByte/s or 24 MByte/s) is indicated by the upper LED on the back of the camera (see Section 5.1.5) or in the Info tab of PFRemote.

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 D-Ribbon (MDR) connector to transmit configuration, image data and trigger.

The CameraLink interface and connector are specified in [CL]. For further details including the pinout please refer to Chapter 8. This connector is used to transmit configuration, image data and trigger signals.

5.1.2 USB2.0 Connector

The USB 2.0 camera model is interfaced to external components via USB 2.0 (B-Type) connector (see Figure 9).

Figure 9: USB 2.0 Type B connector

5.1.3 Power Supply

The camera requires a single voltage input (see Table 3). The camera meets all performance specifications using standard switching power supplies, although well-regulated linear power supplies provide optimum performance.

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

Important: For US and Canada: Ensure a UL listed power supply is used. A suitable UL listed power supply is available from Photonfocus.

For further details including the pinout please refer to Section 8.

5.1.4 Trigger and Strobe Signals for USB2.0 models

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

Warning: The input voltage to the TRIGGER pin must not exceed +15V DC, to avoid damage of the optocoupler!

In order to use the strobe, the 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 10) to STROBE_VDD (5 .. 15 V DC) as shown in Figure 10. This resistor should be located directly at the signal receiver.

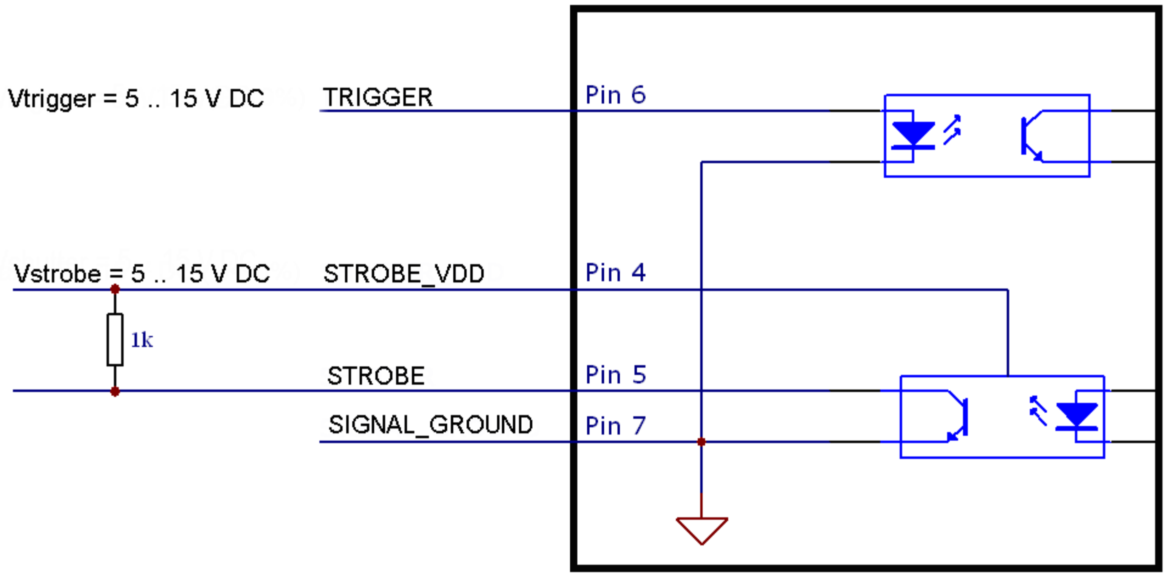


Figure 10: Circuit for the Trigger/Shutter signals (USB)

Caution: 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!

Table 10: Pull-up resistor for the strobe output

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

5.1.5 Status Indicator for CameraLink Models

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

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.
LED Red	Red indicates an active serial communication with the camera.

5.1.6 Status Indicator for USB2.0 Models

Two dual-color LEDs on the back of the camera give information about the current camera and USB status.

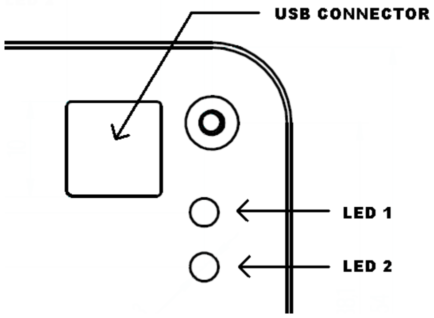


Figure 11: Position of the status indicator LEDs

Table 11: Description of the status indicator LEDs

LED 1 Green	Green when a physical USB connection is established.
LED 1 Red	After the USB-firmware was uploaded to the camera by microDisplay USB, the camera is ready for data transfer. The blinking frequency of the red LED indicates the current transfer mode. In the slow mode (24 MByte/s), the blinking interval is 1 Hz, in the fast mode (48 Mbyte/s) it is 4 Hz.
LED 2 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.
LED 2 Red	Red indicates active serial communication with the camera.

5.2 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 4 for the CC assignment).

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 an RS232 compatible asynchronous serial interface. This interface is contained within the CameraLink interface and is physically not directly accessible. Refer to Section 4.8.1 for more information.

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 Section 3.3 for a summarised table of frame grabber relevant specifications. Figure 8 shows symbolically a 1-tap system. For more information about taps refer to [AN021] on our website on www.photonfocus.com.

5.3 Read-out Timing

5.3.1 Free Running Mode

By default, the camera is in free running mode and delivers images without any external control signals. Depending on the exposure and read-out time, the sensor is operated either in interleaved or non-interleaved mode.

Non-Interleaved Mode

If the read-out time exceeds the exposure time, the sensor is automatically operated in non-interleaved mode, which means that the sensor is read out after the preset exposure time. Then the sensor is reset, a new exposure starts and the readout of the image information begins again. The data is output on the rising edge of the pixel clock. The signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER indicates the active integration phase of the sensor and is shown for clarity only.

Figure 12 visualises the timing behaviour of the control and data signals in the non-interleaved mode.

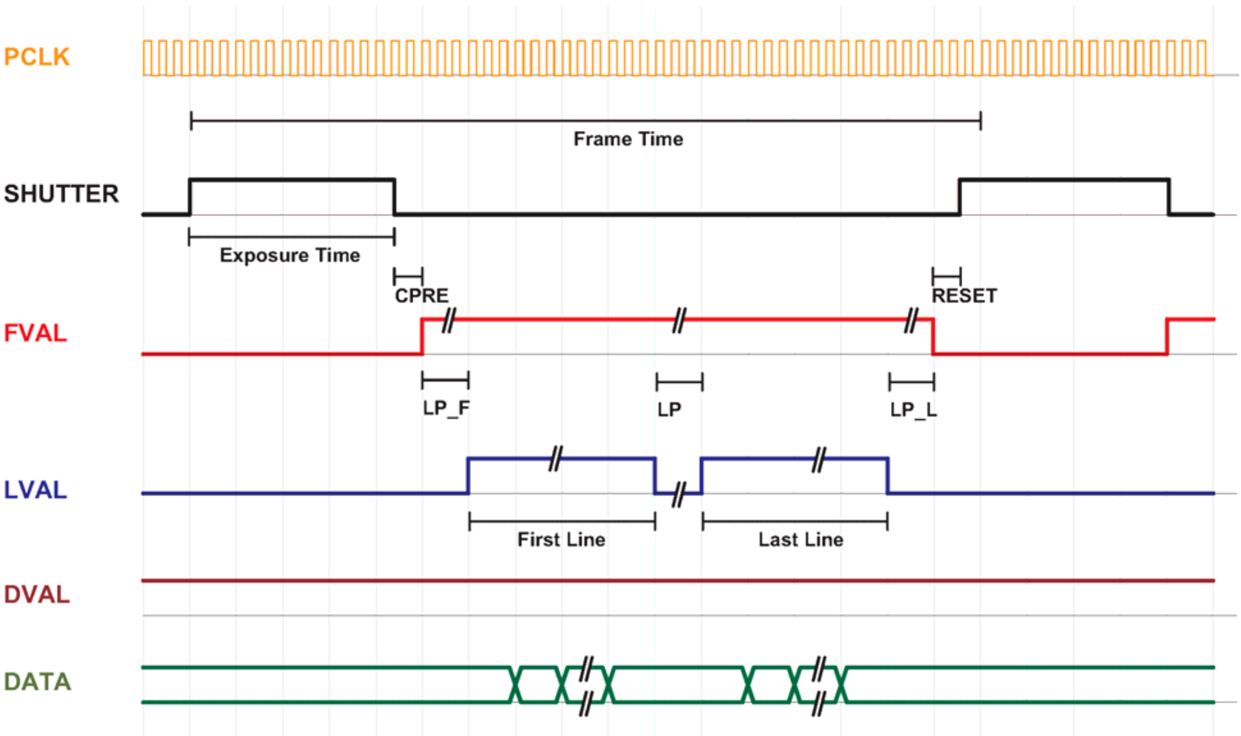


Figure 12: Timing Diagram frame read-out in free-running, non-interleaved mode

Table 12: Explanation of control and data signals used in the timing diagram

Frame time	Maximum frame time is defined as exposure time plus data read out time.
Exposure time	Period during which the pixels are integrating the incoming light.
PCLK	Pixel clock on CameraLink interface.
SHUTTER	Internal signal, shown only for clarity. Is 'high' during the exposure time, during which the pixels integrate the incoming light and the image is acquired.
FVAL (Frame Valid)	Is 'high' while the data of one whole frame are transferred.
LVAL (Line Valid)	Is 'high' while the data of one line are transferred. Example: To transfer an image with 640x480 pixels, there are 480 LVAL within one FVAL active high period. One LVAL lasts 640 pixel clock cycles.
DVAL (Data Valid)	Is 'high' while data are valid.
DATA	Transferred pixel values. Example: For a 100x100 pixel image, there are 100 values transferred within one LVAL active high period, or 100*100 values within one FVAL period.
Line pause LP	Delay after the first line and after every following line except the last when reading out the image data. LP = Rx – Px + HB (Px = image width)*
LP_F	First line pause in an FVAL period. LP_F = 2 * (Rx + HB) + 16*
LP_L	Last line pause in an FVAL period. LP_L = 13 + HB*
CPRE	Constant delay between end of exposure time and beginning of read-out.
RESET	Constant delay between end of read-out and earliest begin of a new exposure.

* Compare with Section 4.5.3.

Interleaved Mode

If the read-out time is smaller than the exposure time, the sensor is automatically operated in interleaved mode, which means that during the exposure of the next image, the last image is read out. Then the sensor is reset and a new exposure starts and the readout of the image information begins again. The data is output on the rising edge of the pixel clock. The signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER indicates the active integration phase of the sensor and is shown for clarity only.

Figure 13 visualises the timing behaviour of the control and data signals in the interleaved mode.

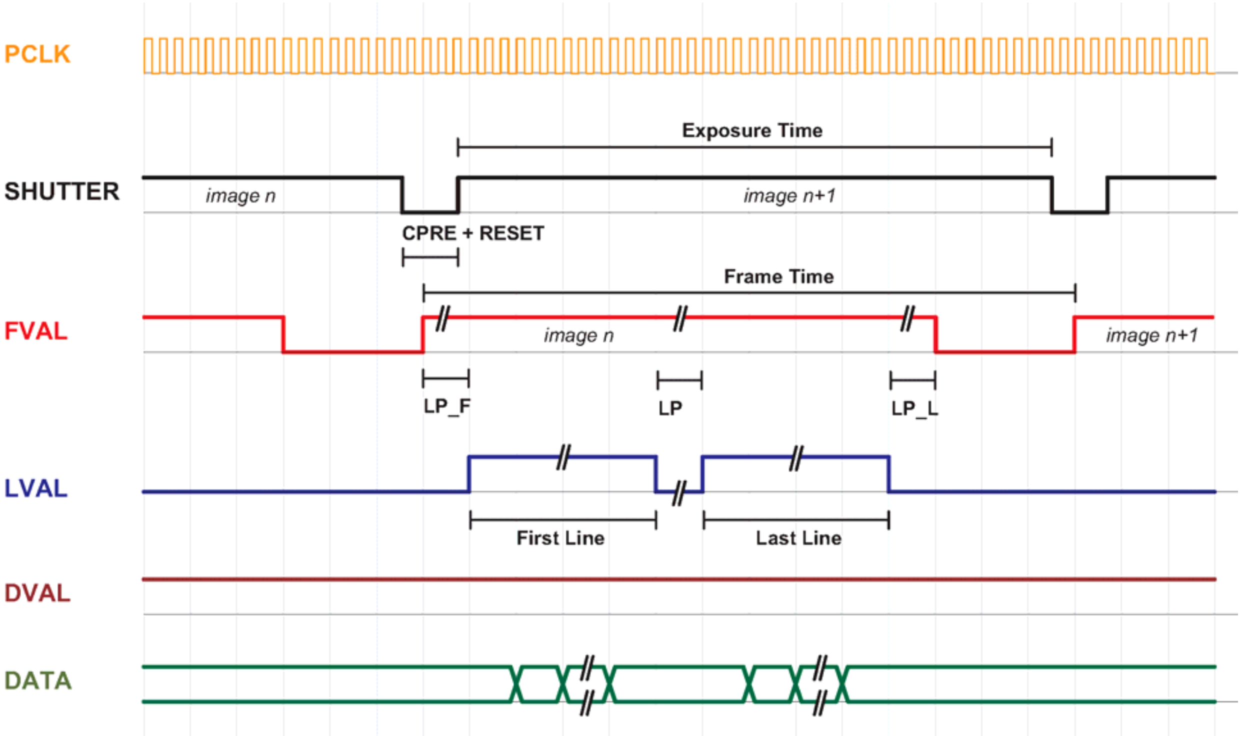


Figure 13: Timing Diagram frame read-out in free-running, interleaved mode

5.3.2 External Trigger Mode

In the external trigger mode, the exposure is defined by the camera and is configurable by software. For an active high trigger signal, the image acquisition begins with the rising edge of the trigger signal. The image is read out after the pre-configured exposure time. After the readout, the sensor returns to the reset state and the camera waits for a new trigger pulse (see Figure 14).

Note: In external trigger mode, the camera is always operated in non-interleaved mode.

The data is output on the rising edge of the pixel clock, the handshaking signals FRAME_VALID (FVAL) and LINE_VALID (LVAL) mask valid image information. The signal SHUTTER in Figure 14 indicates the active integration phase of the sensor and is shown for clarity only.

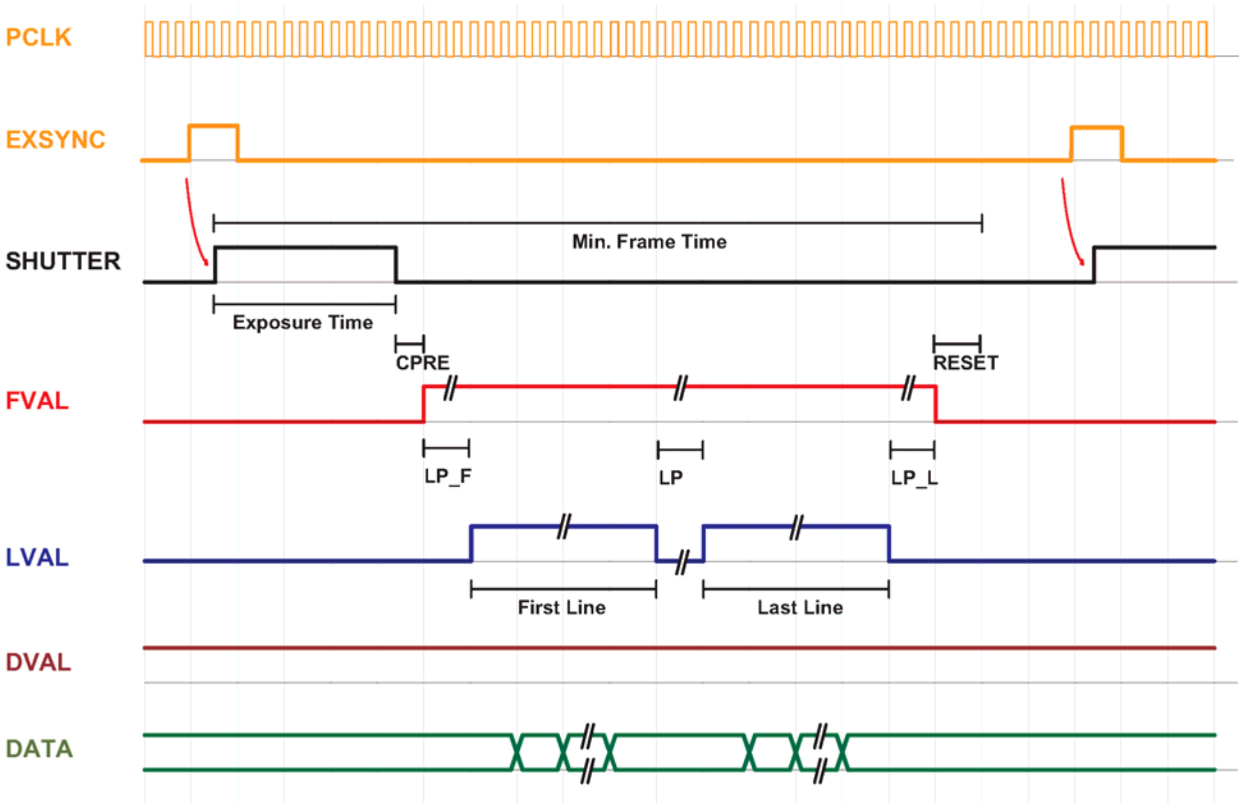


Figure 14: Timing diagram for external trigger

5.3.3 Trigger Delay

MV-D640 CameraLink Models

The total delay between the trigger edge and the camera exposure consists of the delay in the frame grabber and the camera.

For the delay in the frame grabber, please ask your frame grabber manufacturer. The camera delay consists of a constant trigger delay and a variable delay (jitter).

Table 13: Maximum camera trigger delay (CameraLink models)

Camera Model	Trigger Delay t_d (constant)	Max. Trigger Jitter t_i
MV-D640(C)-66-CL	15 ns	15 ns
MV-D640(C)-33-CL	30 ns	30 ns

MV-D640 USB2.0 Models

The delay between a trigger edge applied via the trigger pin on the power supply connector consists of a constant and a variable delay as shown in Table 15.

Table 14: Maximum camera trigger delay (USB2.0 models)

Camera Model	Trigger Delay t_d (constant)	Max. Trigger Jitter t_j
MV-D640-48-U2	500 ns	250 ns
MV-D640C-48-U2	500 ns	250 ns

6 Mechanical and Optical Considerations

6.1 Transport

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 to local regulations.

6.2 Mechanical Interface

The general mechanical data of the cameras are listed in Table 1 and Table 2.

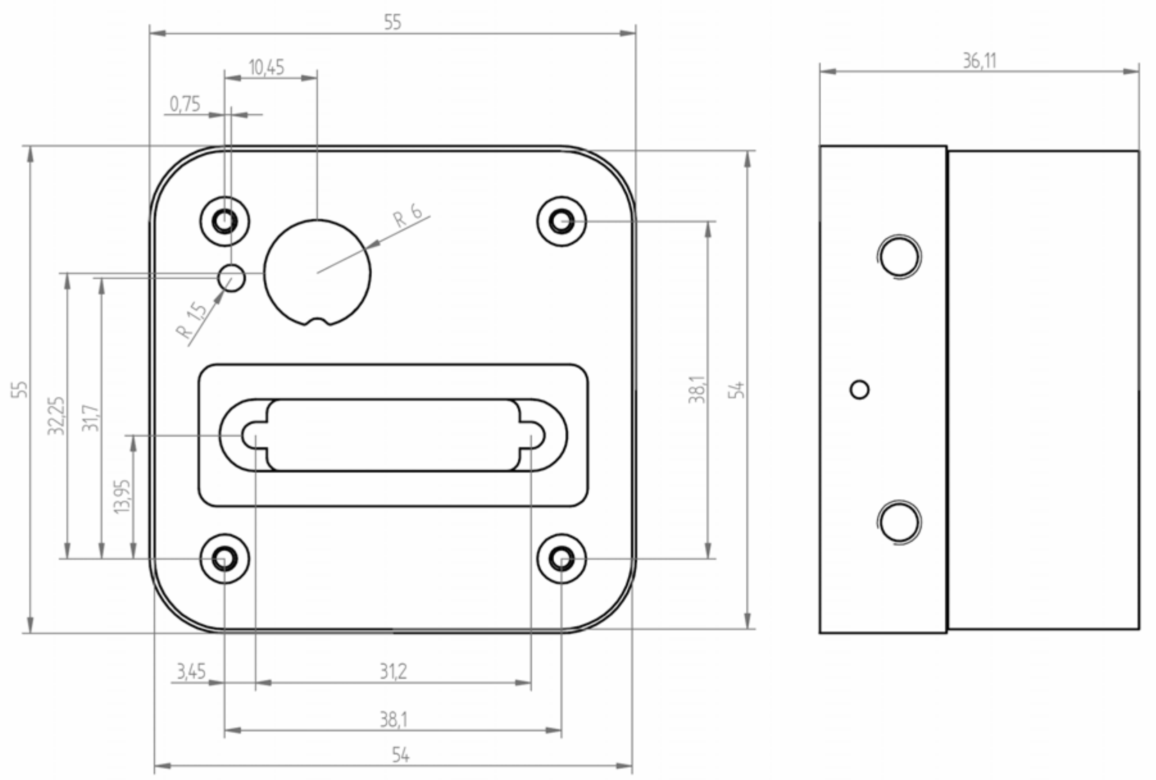


Figure 15: CameraLink^{TM} back plate

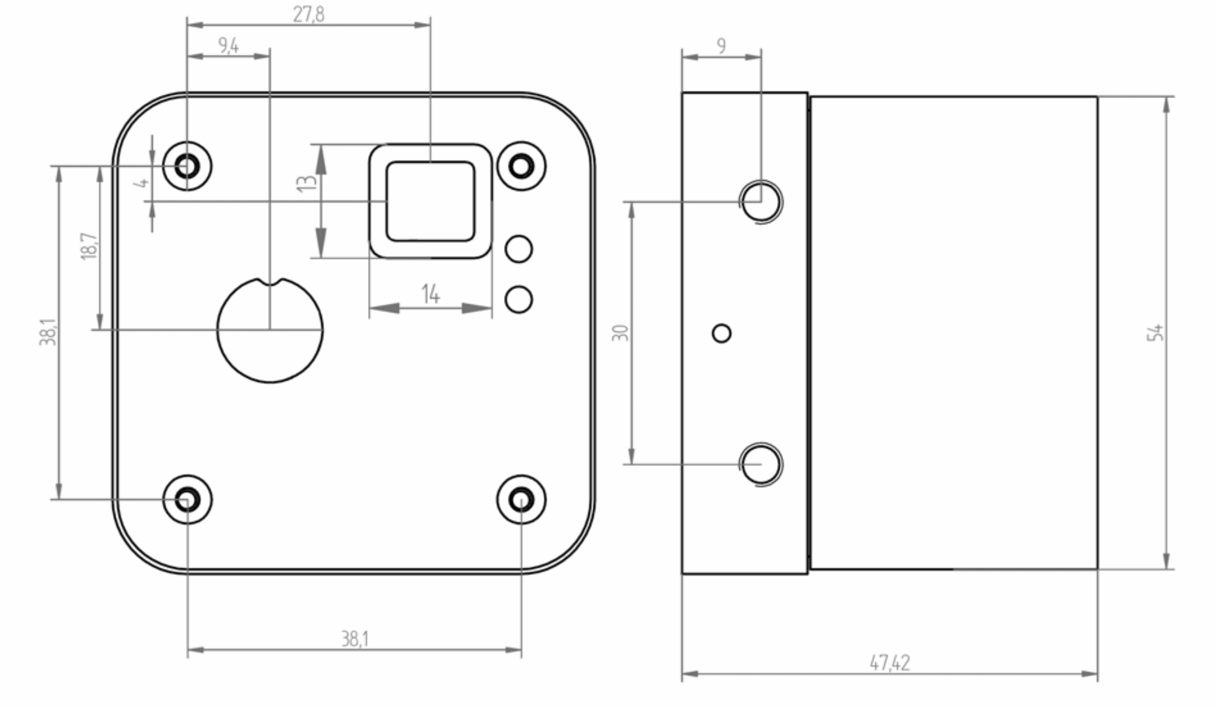


Figure 16: USB 2.0 back plate

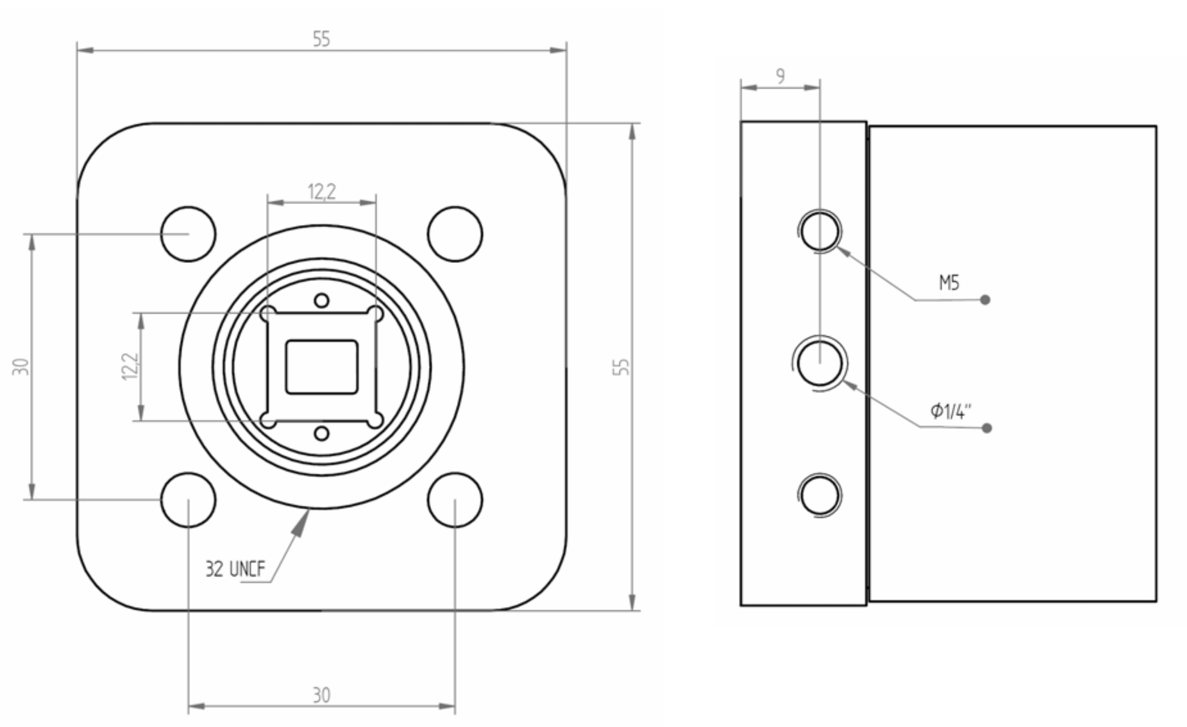


Figure 17: CameraLink^{TM} and USB front plate

6.3 Optical Interface

6.3.1 Mounting the Lens

Remove the protective cap from the C-/CS-mount thread of the camera and install the lens. When removing the protective cap or changing the lens, the camera should always be held with the opening facing downwards to prevent durst from falling into the CMOS sensor. If the lens is removed, the protective cap should be refitted. If the camera is opened in a dusty environment, we recommend the use of a constant stream of clean air in front of the objective.

6.3.2 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 in the images 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 compressed air spray) to blow off loose particles. This step alone is usually sufficient to clean the sensor of the most common contaminants.

Warning!

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

3. If further cleaning is requried, use a suitable lens wiper or Q-Tip moistened with an appropriate cleaning fluid to wipe the sensor surface as described below. Cleaning materials must be ESD-safe, lint-free and free from particles that may scratch the sensor surface. For cleaning the sensor, Photonfocus recommends the products available from the suppliers as listed in Table 15.

Warning!

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.

Table 15: Recommended materials for sensor cleaning

Product		**Supplier**	**Remark**
Anticon Gold 9“ x 9“	Wiper	Milliken	ESD safe and suitable for class 100 environments.
TX4025	Wiper	Texwipe	
Transplex	Swab	Texwipe	
Small Q-Tips SWABS BB-003	Q-Tips	Hans J. Michael GmbH, Germany	
Large Q-Tips SWABS CA-003	Q-Tips	Hans J. Michael GmbH, Germany	
Point Slim HUBY-340	Q-Tips	Sharp	
Methanol	Fluid	Johnson Matthey GmbH, Germany	Semiconductor Grade 99.9 % min (Assay), Merck 12,6024, UN1230, slightly flammable and poisonous
2-Propanol (Iso-Propanol)	Fluid	Johnson Matthey GmbH, Germany	Semiconductor Grade 99.5 % min (Assay), Merck 12,5227, UN1219, slightly flammable

7 Warranty

The manufacturer alone reserves the right to recognize warranty claims.

7.1 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.

7.2 Warranty Claim

The above warranty does not apply to any product that has been opened, 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.

8 Pinouts

8.1 Power Supply

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

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

Important: For US and Canada: Ensure a UL listed power supply is used. A suitable UL listed power supply is available from Photonfocus.

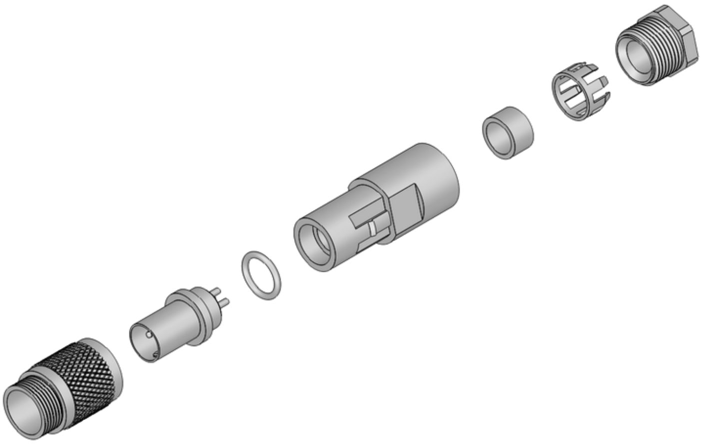


Figure 18: Power connector assembly

8.1.1 Power Supply Connector for CameraLink Model

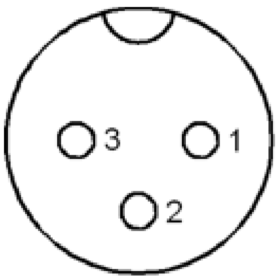


Figure 19: Power supply plug for CameraLink model (rear view of plug, solder side)

Table 16: Pinout of the power supply connector (CameraLink model)

PIN	I/O	Name	Description
1	PW	VDD	+ 5 V voltage supply
2	PW	GND	Ground
3	PW	VDD2	Reserved

Table 17: Power supply connectors (Binder subminiatur series 712)

Connector Type	Order Nr.
3-pole, plastic	99-0405-00-03
3-pole, metal	99-0405-10-03

8.1.2 Power Supply Connector for USB2.0 Model

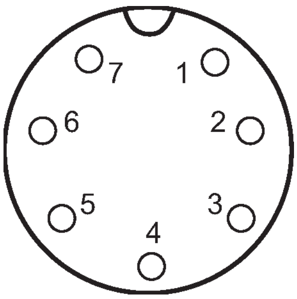


Figure 20: Power supply plug for USB2.0 model (rear view of plug, solder side)

Table 18: Pinout of the power supply connector (USB2.0 model)

PIN	I/O	Name	Description
1	PW	VDD	+ 12 V DC (+/-10%) power supply
2	PW	GND	Ground
3	PW	NC	NC
4	PW	Shutter-VDD	+ 5 V DC (-/+ 10%)
5	O	Shutter	Exposure Control (optically insulated)
6	I	Trigger	External Trigger (optically insulated)
7	PW	Ground	Signal Ground

Table 19: Power supply connectors (Binder subminiatur series 712)

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

8.2 CameraLink Connector

The pinout for the CameraLink 26 pin, 0.5" Mini D-Ribbon (MDR) connector is compliant to the CameraLink standard ([CL]) and is listed here for reference only.

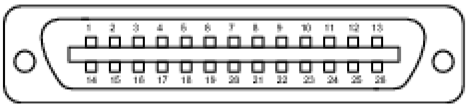


Figure 21: CameraLink connector 3M MDR-26 plug

Table 20: Pin assignments for the CameraLink MDR26 socket

PIN	I/O	Name	Description
1	PW	SHIELD	Shield
2	O	N_XD0	Negative LVDS Output, CameraLink DataD0
3	O	N_XD1	Negative LVDS Output, CameraLink DataD1
4	O	N_XD2	Negative LVDS Output, CameraLink DataD2
5	O	N_XCLK	Negative LVDS Output, CameraLink Clock
6	O	N_XD3	Negative LVDS Output, CameraLink DataD3
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
10	I	P_CC2	Positive LVDS Input
11	I	N_CC3	Negative LVDS Input
12	I	P_CC4	Positive LVDS Input
13	PW	SHIELD	Shield
14	PW	SHIELD	Shield
15	O	P_XD0	Positive LVDS Output, CameraLink DataD0
16	O	P_XD1	Positive LVDS Output, CameraLink DataD1
17	O	P_XD2	Positive LVDS Output, CameraLink DataD2
18	O	P_XCLK	Positive LVDS Output, CameraLink clock
19	O	P_XD3	Positive LVDS Output, CameraLink DataD3
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
23	I	N_CC2	Negative LVDS Input
24	I	P_CC3	Positive LVDS Input
25	I	N_CC4	Negative LVDS Input
26	PW	SHIELD	Shield
S	PW	SHIELD	Shield

8.3 USB2.0 Connector

The USB 2.0 interface and connector were developed by a group of companies (Intel, Agere Systems, NEC, Hewlett-Packard, Philips, etc.) which are now organized in the USB Implementers Forum (www.usb.org).

The USB connector is used to transmit configuration signals and image data. The pinout complies with the standard USB pinout and is listed here for the sake of completeness.

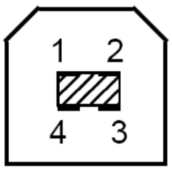


Figure 22: USB Type B connector (front view)

Table 21: Pinout USB connector

Pin	IO	Name	Description
1	PWR	VBUS	+5V power supply
2	I/O	DATA-	Negative Data
3	I/O	DATA+	Positivie Data
4	PWR	GND	Ground

9 Troubleshooting

9.1 Common pitfalls with microDisplay USB and PFRemote

Message "mEnable not found" appears after microDisplay USB was started

- The USB driver is not installed correctly. Try reinstalling PFInstaller.
- When the camera is connected to the USB bus and powered on, check if there is a "Multifunction adapter" with the entry "Silicon Software GmbH microUSB2" in the Windows device manager.
- Reinstall the driver manually. It is located in \Photonfocus\microDisplayUSB\driver.

PFRemote cannot communicate

- microDisplay USB must always be started before PFRemote, because it downloads the USB firmware to the camera.

No image is output

- Check if the camera is outputting images (check if the lower LED is green, see Section 5.1.5 and 5.1.6). Maybe the camera is in external trigger mode and does not receive a trigger signal.
- The camera USB interface or power supply has been disconnected since the last start of microDisplay USB. Restart microDisplay USB.
- Due to the minimum data frame size that can be transferred by USB, the minimum ROI must be at least 1024 bytes. Choose an ROI of Width x Height > 1024 pixels.
- If there is already an earlier USB driver installed on your PC and you have problems installing the new PFInstaller, please contact the Photonfocus support at support@photonfocus.com.

Camera clock on port A is inactive

- A wrong hardware applet was downloaded to the camera when starting microDisplay USB. Always choose the correct camera model at the start of microDisplay USB.
- The camera USB interface or power supply has been disconnected since the last start of microDisplay USB. Restart microDisplay USB.

10 References

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

CL CameraLink Specification, January 2004

SW002 PFLib SDK Documentation, Photonfocus, August 2005

MAN025 microDisplay USB2.0 User Manual, Photonfocus, November 2005

AN007 Application Note “Camera Acquisition Modes”, Photonfocus, March 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

11 Appendix A – Pseudo random number generator

In order to test the interface between camera and frame grabber, a 10-bit LFSR with many-to-one feedback structure was implemented. An XOR feedback of taps 2 and 9 was implemented for the maximum sequence length of 1023 states. The state 0 does not exist in this implementation. The sequence starts with the value 1 at the beginning of each line. The first 256 values are presented in Table 22. A resulting pattern of vertical stripes can be seen in the acquired image (see Figure 23).

Table 22: States 0 – 127 of the pseudo random number generator

Nr.	HEX	BIN	Nr.	HEX	BIN	Nr.	HEX	BIN	Nr.	HEX	BIN
0	001	1000000000	32	331	1000110011	64	0E0	0000011100	96	0EC	0011011100
1	002	0100000000	33	263	1100011001	65	1C0	0000001110	97	1D9	1001101110
2	004	0010000000	34	0C7	1110001100	66	380	0000000111	98	3B2	0100110111
3	009	1001000000	35	18F	1111000110	67	301	1000000011	99	365	1010011011
4	012	0100100000	36	31F	1111100011	68	203	1100000001	100	2CA	0101001101
5	024	0010010000	37	23E	0111110001	69	007	1110000000	101	195	1010100110
6	049	1001001000	38	07C	0011111000	70	00F	1111000000	102	32B	1101010011
7	092	0100100100	39	0F9	1001111100	71	01F	1111100000	103	257	1110101001
8	124	0010010010	40	1F2	0100111110	72	03F	1111110000	104	0AE	0111010100
9	249	1001001001	41	3E4	0010011111	73	07F	1111111000	105	15D	1011101010
10	093	1100100100	42	3C8	0001001111	74	0FF	1111111100	106	2BB	1101110101
11	126	0110010010	43	391	1000100111	75	1FF	1111111110	107	177	1110111010
12	24D	1011001001	44	323	1100010011	76	3FF	1111111111	108	2EF	1111011101
13	09A	0101100100	45	247	1110001001	77	3FE	0111111111	109	1DE	0111101110
14	134	0010110010	46	08E	0111000100	78	3FC	0011111111	110	3BD	1011110111
15	269	1001011001	47	11D	1011100010	79	3F8	0001111111	111	37A	0101111011
16	0D3	1100101100	48	23B	1101110001	80	3F1	1000111111	112	2F5	1010111101
17	1A6	0110010110	49	077	1110111000	81	3E3	1100011111	113	1EA	0101011110
18	34D	1011001011	50	0EF	1111011100	82	3C7	1110001111	114	3D4	0010101111
19	29A	0101100101	51	1DF	1111101110	83	38E	0111000111	115	3A8	0001010111
20	135	1010110010	52	3BF	1111110111	84	31C	0011100011	116	351	1000101011
21	26B	1101011001	53	37E	0111111011	85	238	0001110001	117	2A3	1100010101
22	0D7	1110101100	54	2FC	0011111101	86	071	1000111000	118	147	1110001010
23	1AF	1111010110	55	1F8	0001111110	87	0E2	0100011100	119	28F	1111000101
24	35F	1111101011	56	3F0	0000111111	88	1C4	0010001110	120	11E	0111100010
25	2BE	0111110101	57	3E1	1000011111	89	389	1001000111	121	23D	1011110001
26	17C	0011111010	58	3C3	1100001111	90	313	1100100011	122	07A	0101111000
27	2F9	1001111101	59	387	1110000111	91	227	1110010001	123	0F4	0010111100
28	1F3	1100111110	60	30E	0111000011	92	04E	0111001000	124	1E9	1001011110
29	3E6	0110011111	61	21C	0011100001	93	09D	1011100100	125	3D2	0100101111
30	3CC	0011001111	62	038	0001110000	94	13B	1101110010	126	3A5	1010010111
31	398	0001100111	63	070	0000111000	95	276	0110111001	127	34A	0101001011

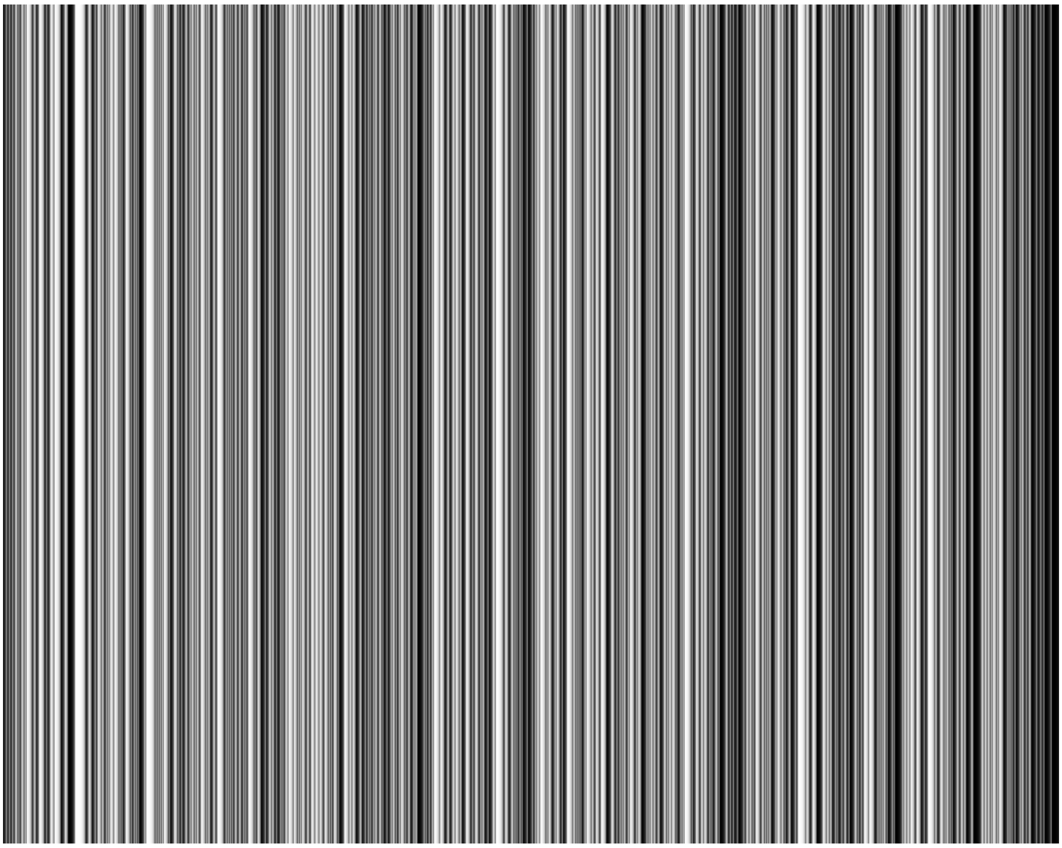
HEX: Hexadecimal value
BIN: Binary value, Bit sequence bits 0 - 7

Table 22 (cont.): States 128 – 255 of the pseudo random number generator

Nr.	HEX	BIN	Nr.	HEX	BIN	Nr.	HEX	BIN	Nr.	HEX	BIN
128	295	1010100101	160	2F4	0010111101	192	2CF	1111001101	224	2A6	0110010101
129	12A	0101010010	161	1E8	0001011110	193	19E	0111100110	225	14C	0011001010
130	254	0010101001	162	3D0	0000101111	194	33D	1011110011	226	299	1001100101
131	0A8	0001010100	163	3A1	1000010111	195	27A	0101111001	227	133	1100110010
132	150	0000101010	164	343	1100001011	196	0F5	1010111100	228	266	0110011001
133	2A0	0000010101	165	287	1110000101	197	1EB	1101011110	229	0CC	0011001100
134	141	1000001010	166	10E	0111000010	198	3D6	0110101111	230	199	1001100110
135	282	0100000101	167	21D	1011100001	199	3AC	0011010111	231	332	0100110011
136	105	1010000010	168	03A	0101110000	200	358	0001101011	232	265	1010011001
137	20B	1101000001	169	074	0010111000	201	2B1	1000110101	233	0CA	0101001100
138	017	1110100000	170	0E9	1001011100	202	163	1100011010	234	194	0010100110
139	02F	1111010000	171	1D2	0100101110	203	2C6	0110001101	235	329	1001010011
140	05F	1111101000	172	3A4	0010010111	204	18C	0011000110	236	253	1100101001
141	0BF	1111110100	173	348	0001001011	205	319	1001100011	237	0A7	1110010100
142	17F	1111111010	174	291	1000100101	206	233	1100110001	238	14F	1111001010
143	2FF	1111111101	175	123	1100010010	207	067	1110011000	239	29F	1111100101
144	1FE	0111111110	176	246	0110001001	208	0CF	1111001100	240	13E	0111110010
145	3FD	1011111111	177	08C	0011000100	209	19F	1111100110	241	27D	1011111001
146	3FA	0101111111	178	119	1001100010	210	33F	1111110011	242	0FA	0101111100
147	3F5	1010111111	179	232	0100110001	211	27E	0111111001	243	1F4	0010111110
148	3EA	0101011111	180	065	1010011000	212	0FC	0011111100	244	3E9	1001011111
149	3D5	1010101111	181	0CB	1101001100	213	1F9	1001111110	245	3D3	1100101111
150	3AA	0101010111	182	196	0110100110	214	3F2	0100111111	246	3A7	1110010111
151	355	1010101011	183	32D	1011010011	215	3E5	1010011111	247	34E	0111001011
152	2AA	0101010101	184	25A	0101101001	216	3CA	0101001111	248	29C	0011100101
153	155	1010101010	185	0B5	1010110100	217	395	1010100111	249	138	0001110010
154	2AB	1101010101	186	16B	1101011010	218	32A	0101010011	250	270	0000111001
155	157	1110101010	187	2D6	0110101101	219	255	1010101001	251	0E1	1000011100
156	2AF	1111010101	188	1AC	0011010110	220	0AA	0101010100	252	1C2	0100001110
157	15E	0111101010	189	359	1001101011	221	154	0010101010	253	384	0010000111
158	2BD	1011110101	190	2B3	1100110101	222	2A9	1001010101	254	308	0001000011
159	17A	0101111010	191	167	1110011010	223	153	1100101010	255	211	1000100001

HEX: Hexadecimal value
BIN: Binary value, Bit sequence bits 0 - 7

Figure 23: Acquired image with activated 10-bit LFSR



VHDL Code Example (10 bit LFSR):

```
signal REG: STD_LOGIC_VECTOR (9 downto 0);
signal DATAIN: STD_LOGIC;

SR10R: process (ICLK)                --  10 bit LFSR
begin
     if (ICLK'event and ICLK='1') then
       if (RESET = '1') then         --  at reset, init.shift register to 1
         REG <= "0000000001";
       else
         REG <= REG(8 downto 0) & DATAIN;
       end if;
     end if;
end process SR10R;

DATAIN   <= REG(2) xor REG(9);
LFSR_OUT <= REG;
```

12 Appendix B – Adjusting the Black Level Offset with PFRemote 0.65

The black level offset (the mean value of the image when the lens aperture is completely closed) is calibrated by factory for Gain=2 (default setting). Changing the gain may need to adjust the black level offset with the following procedure:

1. Close the aperture of the lens, or close the lens opening of the camera with the camera body cap.
2. In your frame grabber software, display a histogram of the captured black image. If there is no histogram available, store the image and use a standard image manipulation tool.
3. Open the camera in PFRemote.
4. In the PFRemote main window, go to the menu 'Camera' and choose 'Registers'. In the appearing dialog box the camera registers can be written and read directly and without checking for errors. All values that are entered here are hex values.
5. Required registers for the black level offset:
   Register 0x0d: "Dark current compensation"
   Register 0x17: "Voff working point"
6. Read registers 0x0d and 0x17 by pressing the "Reread all" button and write down the value for later reference.
7. Set register 0x0d to the value 0x02.
8. Change register 0x17 in such a way, that the low grey levels are not saturated black (see Figure 24).
   The value range of register 0x17 is 0x00 to 0x0f. The larger the value in the register, the brighter the image.
9. To save the current settings including the new black level offset in the camera, use the "Store in EEPROM" button.
   Warning: The factory calibration settings will be overwritten!

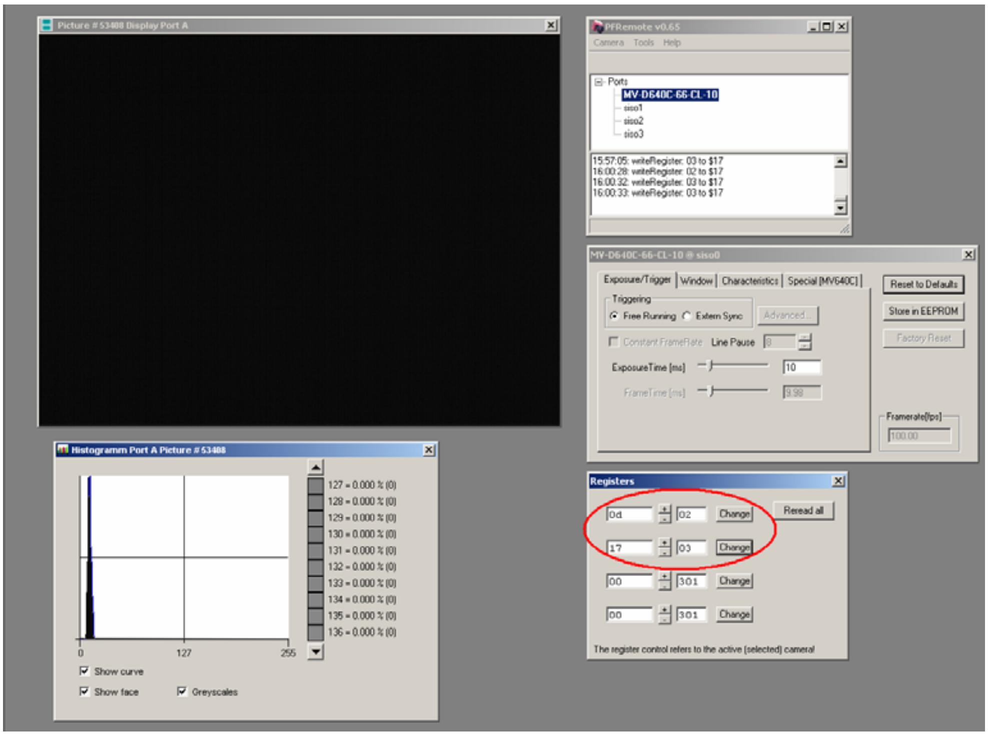


Figure 24: Screenshot to adjusting the black level offset

13 Appendix C – CE Compliance Statement

CE Compliance Statement

We,

Photonfocus AG,
CH-8853 Lachen, Switzerland

declare under our sole responsibility that the following products:

MV-D1024-28-CL-10, MV-D1024-80-CL-8, MV-D1024-160-CL-8

MV-D1024x128-28-CL-10, MV-D1024x128-80-CL-8,
MV-D1024x128-160-CL-8

MV-D752-28-CL-10, MV-D752-80-CL-8, MV-D752-160-CL-8

MV-D640-33-CL-10, MV-D640-66-CL-10, MV-D640-48-U2-10
MV-D640C-33-CL-10, MV-D640C-66-CL-10, MV-D640C-48-U2-10

HURRICANE-40, THUNDER-90, BLIZZARD-60 (CameraLink Models)
HURRICANE-40, THUNDER-90 (USB2.0 Models)

Digipeater CLB26

are 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

Photonfocus AG, October 2005

14 Appendix D - Revision History

REV	Description of changes	Date
1.0	First edition	06/03/2003
2.0	Completely revised version	16/12/2005