



## SK2048GJR-4L

### Monochrome Line Scan Camera

2048 pixels, 14 µm x 14 µm, 10 MHz pixel frequency

Gigabit  
ETHERNET

FAST+FLEXIBLE

## Instruction Manual

09.2016



### Sample Configuration

- 1 CCD line scan camera  
**SK2048GJR-4L**  
mounted with
- 2 Mounting bracket SK5105-L
- 3 Clamping claws SK5101
- 4 Focus adapter FA22R-45 (two-piece),  
facilitates adjustment of any rotation angle
- 5 Enlarging lens Apo-Rodagon N 4.0/80



Read the manual carefully before the initial start-up. For the contents table, refer to page 3.  
The right to change the described specifications is retained as the products undergo continuous cycles of improvement.

## How to Use this Instruction Manual



Please read the following sections of this Instruction Manual before unpacking, assembly or use of the Line Camera System:

- The safety warnings on this page
- Introduction to the system, page 4
- Assembly and initial setup, page 7

Keep this Instruction Manual in a safe place for future reference.

## Safety Warnings



### ▶ Electricity Warning

Assembly and initial operation of the line scan camera must be carried out under dry conditions.

**Do not operate the camera if you notice any condensation or moisture in order to avoid danger of a short circuit or static discharge!**



Line scan cameras are mostly used in combination with a motion device such as a translation stage, a conveyer or a rotational drive, as well as with high intensity light sources.

For assembly close down these devices whenever possible. Beyond that, please consider the following warnings:



### ▶ Mechanics Warning

Ensure that the motion device and the scan way is free to move and that no obstacles are in the way.

**Do not place any part of the body in the way of moving parts!**



### ▶ Risk of High Power Lighting

According to the application, laser or high power LED light sources might be used. These can affect your eyesight temporarily or even cause permanent damage to the eyes or skin.

**Do not look directly into the light beam!**

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# 1 Introducing the SK2048GJR-4L Line Scan Camera

## 1.1 Intended Purpose and Overview

The SK line scan camera series is designed for a wide range of vision and inspection applications in both industrial and scientific environments. The GigE series camera SK2048GJR-4L uses the Gigabit Ethernet communication protocol, enabling fast image transfer using low cost standard cables up to 100 m in length. The Gigabit Ethernet interface makes the line scan camera highly scalable to faster Ethernet speeds, distinguishing it with high performance and total flexibility.

All of the GigE cameras from Schäfter+Kirchhoff are externally synchronizable and no grabber board is needed as signal preprocessing is performed inside the camera and does not impinge on CPU use.




Additional features include:

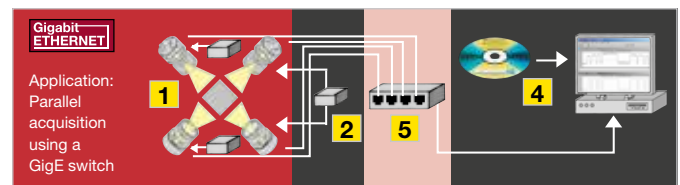
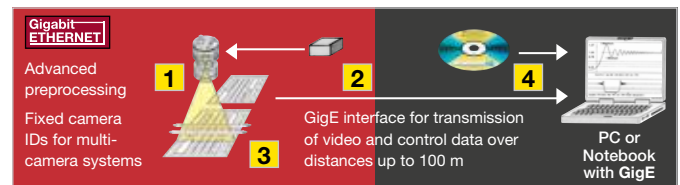
- customer-specific I/O signals in addition to the video signal
- special preprocessing algorithms can be implemented in the camera
- consistent attribution of camera IDs in multi-camera operations
- SDK from Schäfter+Kirchhoff with the SkLineScan operating program, libraries and examples.

The camera can be connected to a computer either via the GigE socket directly or through a Gigabit Ethernet switch.

Once the camera driver and the SkLineScan® program have been loaded from the SK91GigE-WIN CD then the camera can be parameterized. The parameters, such as integration time, synchronization mode or shading correction, are permanently stored in the camera even after a power-down or disconnection from the PC.

The oscilloscope display in the SkLineScan® program can be used to adjust the focus and aperture settings, for evaluating field-flattening of the lens and for orientation of the illumination and the sensor, see *Camera Control and Performing a Scan, p. 12*.

Features	Gigabit ETHERNET	
Shading Correction		X
Programmable Lookup Table		X
Thresholding		X
Window Function (ROI)		X
Line Trigger, Frame Trigger		X
Frame Trigger Delay		X
Threshold Trigger		X
Advanced Synchronization Ctrl.		X
Integration Control for R, G, B		X
Decoupling of line frequency		X
Extra signals for diagnosis		X
Data cable length		100 m
Windows		SK91GigE-WIN SDK
LabVIEW		SK91GigE-LV VI Library
Linux		-

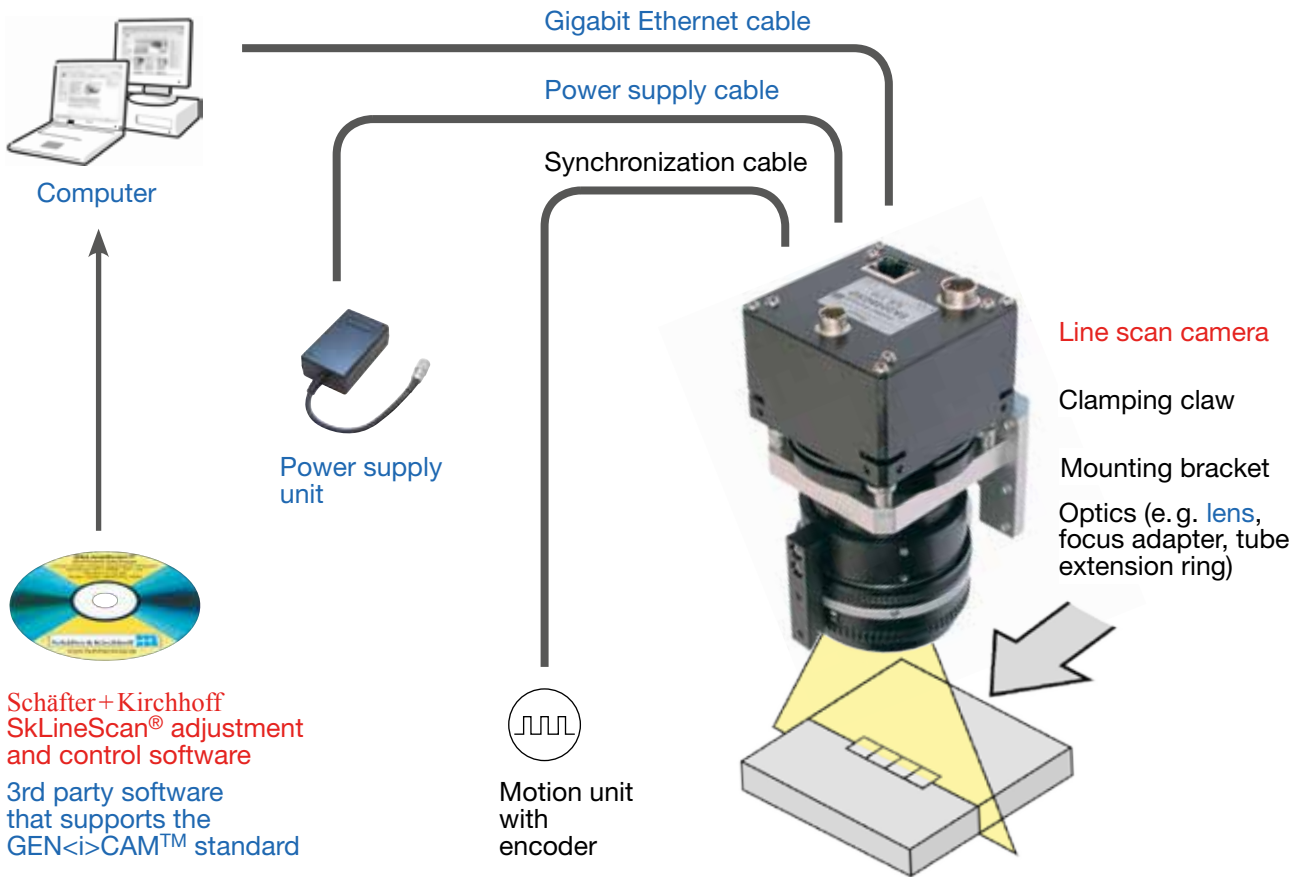


- |                               |   |
|-------------------------------|---|
| <b>1</b> CCD line scan camera | <b>4</b> Software, SDKs and eBus driver |
| <b>2</b> Power supply         | <b>5</b> GigE switch                    |
| <b>3</b> Illumination         |   |

## 1.2 System Setup at a Glance

- red: SK2048GJR-4L scope of delivery
- blue: accessories for minimum system configuration
- black: optional accessories

For accessory order details see *Accessories*, p. 32.



### 1.3 Computer System Requirements

- Intel Pentium Dual Core or AMD equivalent
- RAM min. 4GB, depending on size of acquired images
- High-performance video card, PCIe bus
- Operating Systems:  
Windows 7 / 8.1 / 10 (64 or 32-bit) or  
Linux kernel 3.13 or higher, Debian or openSUSE
- CD/DVD drive for software installation.

#### Network Adapter:

- Any Gigabit Ethernet network adapter as a card or on the motherboard is suitable. For the best performance, a network interface card (NIC) with Intel PRO/1000 chip is recommended.
- PCIe adapters outperform PCI adapters.
- Network adapters that support Jumbo Frames outperform adapters with fixed packet-size frames.

### 1.4 SK2048GJR-4L Line Scan Camera - Specifications

Sensor category	CCD Monochrome Sensor
Sensor type	ILX751
Pixel number	2048
Pixel size (width x height)	14 x 14 $\mu\text{m}^2$
Pixel spacing	14 $\mu\text{m}$
Active sensor length	28.7 mm
Anti-blooming	-
Integration control	x
Shading correction	x
Threshold detection	x
Line synchronization modes	Line Sync, Line Start, Exposure Start, Exposure Active
Frame synchronization	x
Pixel frequency	10 MHz
Maximum line frequency	4.73 kHz
Integration time	0.01 ... 20 ms
Dynamic range	1:625 (rms)
Spectral range	400 ... 900 nm
Video signal	monochrome 8/12 Bit digital
Interface	GigaBit Ethernet
Voltage	+24V
Power consumption	4.3 W
Casing	65 mm x 65 mm x 72.4 mm (Case type BG3)
Objective mount	M45x0.75
Flange focal length	19.5 mm
Weight	0.3 kg
Operating temperature	+5 ... +45°C

## 2 Installation and Setup

### 2.1 Mechanical Installation: Mounting Options and Dimensions

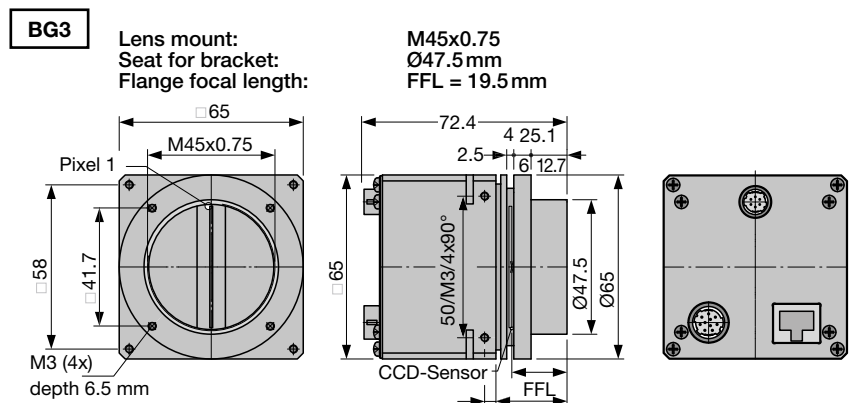
#### Mounting Options

- The best fixing point of the camera is the collar for the mounting bracket SK5105-L (available as an accessory).
- Four threaded holes M3x6.5mm provide further options for customized brackets.
- The length and weight of the optics might be beyond the capability of the standard mounting bracket SK5105-L. For this purpose, a second mounting bracket type SK5105-2L to hold the tube extension ring(s) is more appropriate.

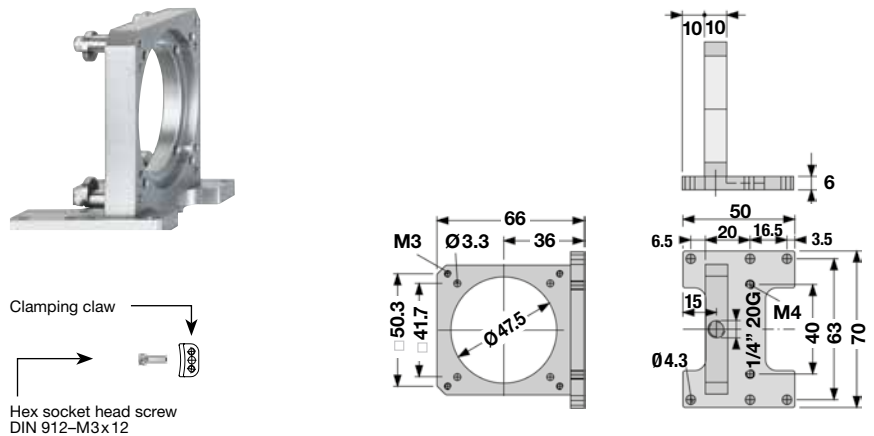
#### Optics Handling

- If the camera and the optics are ordered as a kit, the components are pre-assembled and shipped as one unit. Keep the protective cap on the lens until the mechanical installation is finished.
- If you must expose the sensor or lens surface, ensure the environment is as dust-free as possible.
- Gently blow off loose particles using clean compressed air.
- The sensor and lens surfaces can be cleaned with a soft tissue moistened with water or a water-based glass cleaner.

#### Casing type BG3

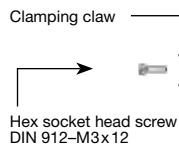


#### Mounting bracket SK5105-L



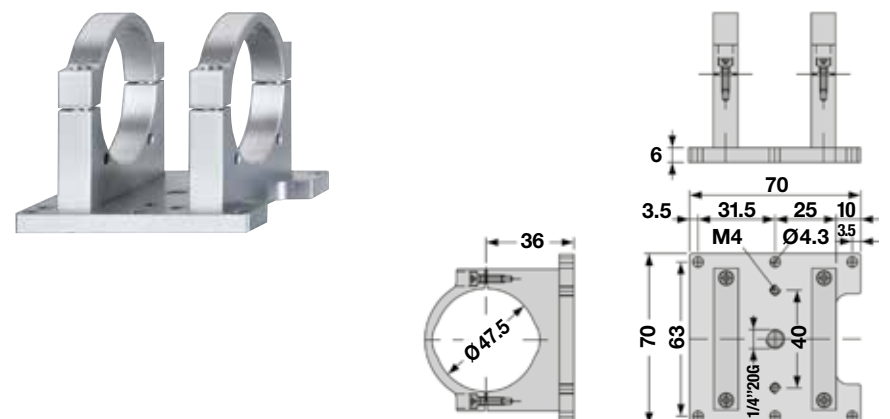
#### Clamping set SK5101

Set of 4 pcs. clamping claws  
incl. screws



#### Mounting system SK5105-2L

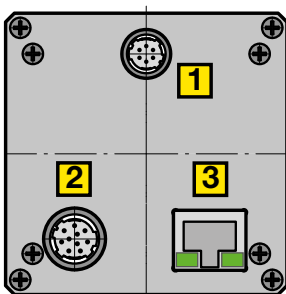
for cameras with a tube  
extension > 52 mm



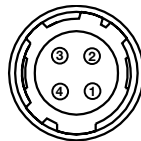


## 2.2 Electrical Installation: Connections and I/O Signals

- For the SK2048GJR-4L line scan camera-data transfer and camera control is provided by the Gigabit Ethernet interface **3**. Use a CAT6 twisted-pair cable to connect the camera to a PC; the maximum cable length is 100m.
- The operating power must be supplied by an external source using socket **1**
- If you want to operate the camera in FREE RUN trigger mode, the connections are complete with the CAT6 Ethernet cable and the connection to an external power supply.
- For any kind of synchronized operation, the external trigger signal(s) must be wired to socket **2** as well. A frame-synchronization signal and two separate line-synchronization signals can be handled. The various trigger modes are described fully in section *Synchronization of the Imaging Procedure and the Object Scan Velocity*, p. 18



### 1 Power +24V

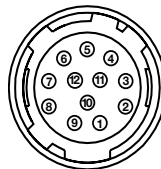


Hirose series 10A, male 4-pin

Pin	Signal	Pin	Signal
1	n.c.	3	min. +18 V max. +36 V
2	GND	4	n.c.

Total power: 4.3 W

### 2 I/O Connector



Hirose series 10A, male 12-pin

Pin	Signal *)
1	GND
8	FrameSync IN
10	LineSync A IN
6	LineSync B IN

\*) Signal Specification (TTL)

Max. input frequency	16.5 MHz
Input voltage, absolute max. range	min -0.5 V max 7.0 V
Input voltage max. low	0.99 V
Input voltage min. high	2.31 V
Input current	10 µA

### 3 Data

RJ45 connector for Gigabit Ethernet cable

#### Status indicators

Network connection speed



Network activity

- off no connection, 10 Mbyte/s connection, or 100 Mbyte/s connection
- on 1 Gbyte/s connection

- off no connection
- on connected
- flash light data is being transmitted or received

Accessories (see also *Accessories*, p. 5):

#### Power Cable SK9014.xF

Use this cable to feed external supply voltage into socket **1**.

Connector:

Hirose plug HR10A, female 4 pin (camera side), open cable end (other side)

Length 1.5 m (standard), 3 m, or 5 m

#### Network Cable CAT6.x

For connecting socket **3** with the PC Ethernet interface. Both ends with RJ45 connectors.

#### External Synchronization Cable SK9024.x

Use this cable to feed external synchronization signals into socket **2**.

Connectors:

Hirose plug HR10A, female 12 pin (camera side)  
Phoenix 6 pin connector incl. terminal block (for synchronization signals)

Length 3 m or 5 m. Other lengths on request.





### 2.3 GigE Connections and SkLineScan Software Installation

This section is a quick reference for installing the **SkLineScan** adjustment and configuration software and to set up the Gigabit Ethernet network adapter. SkLineScan and the SkLineScan manual is provided for download on the Schäfter+Kirchhoff website under <http://www.sukhamburg.com/support.html>. It is also part of the fee-based software development kit **SK91GigE-WIN**.

- |  |   |
|--|---|
| <p><b>Step 1:</b> Install <b>SkLineScan</b></p> <p><b>Step 2:</b> If the Gigabit network interface controller (NIC) has an INTEL PRO/1000 chip then install the <b>High Performance Driver</b></p> | <p><b>Step 3:</b> Plug in the CAT6 network cable to the camera and switch on the power supply.</p> <p><b>Step 4:</b> Check the network connection.</p> <p><b>Step 5:</b> Start the <b>SkLineScan</b> program.</p> |
|--|---|

#### ■ SkLineScan Installation

Prior to the installation, power on the PC (not the camera) and unpack the downloaded zip-file to a temporary folder. Alternatively, if your installation medium is a CD, insert the disk to the drive.

The autostart function may launch the setup program automatically from CD. Otherwise, look for one of these installation files:

- |                             |                      |
|-----------------------------|----------------------|
| SkLineScan-GigE-Win_x64.msi | SK91GigE-Win_x64.msi |
| SkLineScan-GigE-Win_x86.msi | SK91GigE-Win_x86.msi |

Then start the applicable installation file manually. This will set up the Schäfter + Kirchhoff **SkLineScan** camera control and adjustment tool as well as the Pleora **Network Driver Installation Tool**.

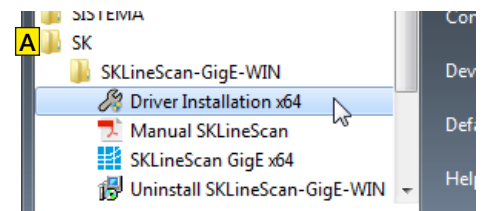
#### ■ Network Driver Installation

##### High Performance Driver for Intel PRO/1000 Chip

- If the line scan camera is connected to a network interface card (NIC) with Intel PRO/1000 chip, then install the "High Performance IP Device Driver". This is the recommended system configuration for optimum performance.

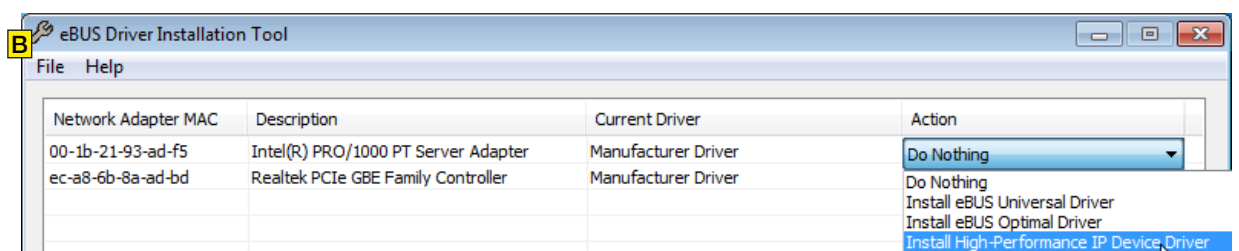
Open the program menu **A** and start the network driver installation manually:

- For 64-bit operating systems choose "Driver Installation x64".
- For 32-bit systems (Windows 7 32-bit, XP) use "Driver Installation x86".

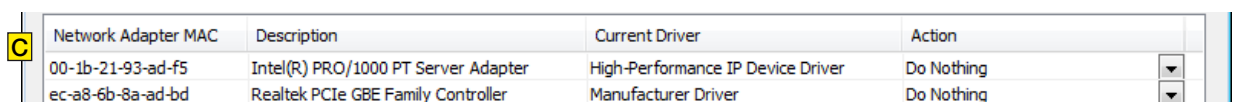


Start Driver Installation Tool from Start Menu

The eBUS driver installation tool window **B** will show up to list the available network adapters and the currently installed network drivers in the system.



Plug in the CAT6 network cable to the camera and switch on the power supply. Then restart the system and check the driver installation with the driver installation tool **C**.



The High-Performance driver is installed, further network adjustments are not required.

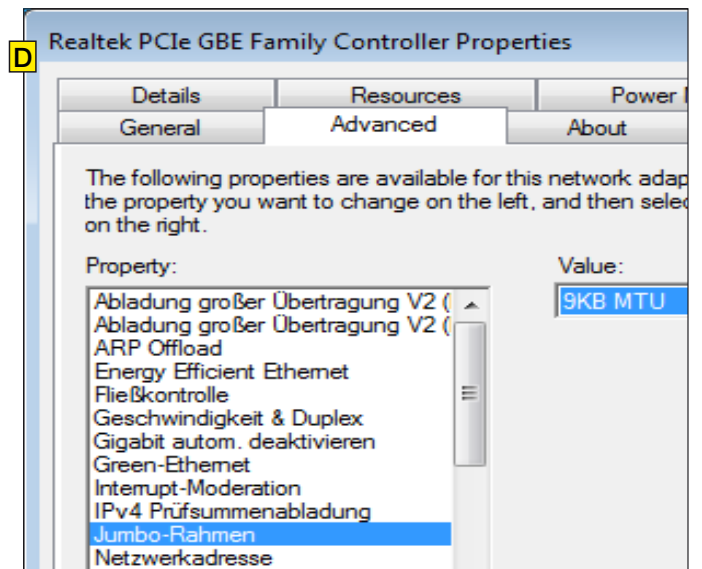
### Standard GigE Network Adapters

- For non-Intel PRO/1000 network adapters install the driver recommended by the manufacturer.

**!** This kind of GigE network adapters do require additional setup. These settings should be optimized during installation in the Advanced Properties tab **D** of the Network Adapter:

Jumbo Frames	9014 Bytes
Receive Descriptors	2048
Interrupt Moderation Rate	extreme
Energy Efficient Ethernet	OFF

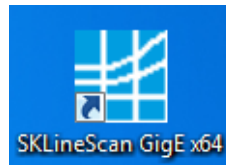
LAN adapters for GigE cameras that do not work with the High Performance Driver must use a fixed IP address, e.g. 192.168.0.99.



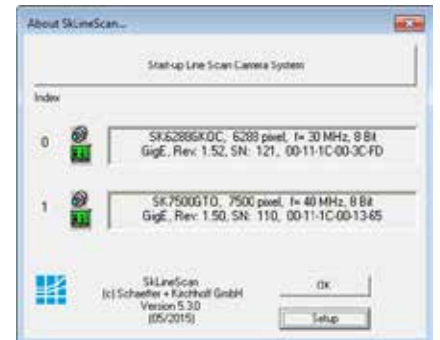
Network Controller Properties: Note, the terms can differ depending on the installed Ethernet card and driver.

### SkLineScan Start-up

- Start SkLineScan. A start-up dialog box pops up and displays the connected cameras that have been automatically detected.



Desktop Icon



### Camera Setup

Use the Setup dialog for

- activating/deactivating a connected GigE camera (activated device is ticked)
- changing the IP address
- changing the pixel frequency
- setting the bit depth of the video signal to 8 or 12-bit.



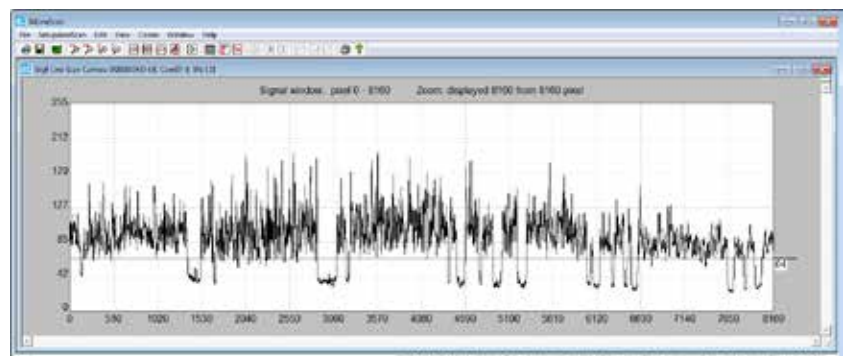
SkLineScan Setup dialog

The MAC addresses are displayed for identification of each camera with the defined CamID (0, 1, ...). This is useful when several cameras with the same name are connected.

### Initial Function Test

- Quit the SkLineScan startup dialog box.
- Select "OK" in the SkLineScan start-up dialog.

The Signal Window showing the current brightness versus the pixel number indicates the correct installation.



### 3 Camera Control and Performing a Scan

#### 3.1 Software: SkLineScan

This section is a brief introduction to the SkLineScan adjustment and configuration software. A more detailed description is provided in the separate SkLineScan manual. The pdf is included in the SkLineScan installation package or is available for download from the Schäfter + Kirchhoff website under <http://www.sukhamburg.com/support.html>.

For an in-depth guide on how to perform imaging and to use the obtained data using the Schäfter + Kirchhoff software package, see the *SkLineScan Software Manual*.

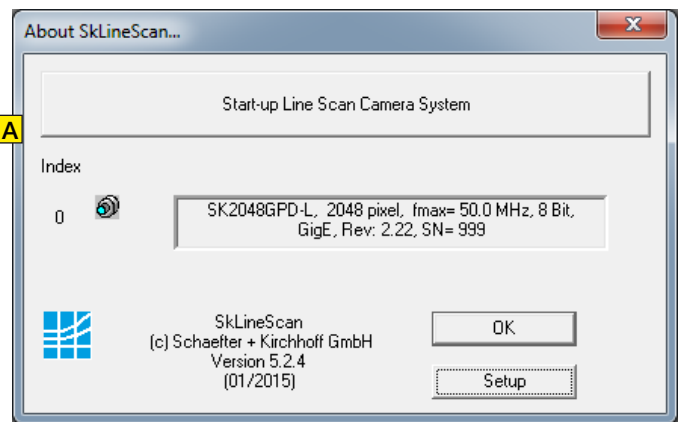
The most common functions of the line scan camera can be controlled by menu items and dialog boxes.

Commands controlling comprehensive camera functionality can be entered in the "Camera Gain / Offset Control" dialog.

Click on the desktop icon to start the **SkLineScan** program.

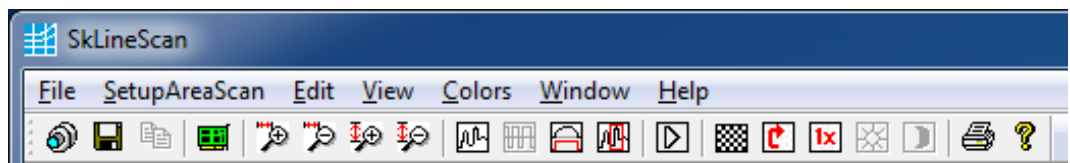
The SkLineScan program recognizes the connected line scan cameras automatically. The identified cameras are shown in the start-up dialog **A**, and the index corresponds with the individual MAC addresses of the cameras.

If the SK2048GJR-4L camera is identified correctly, confirm with "OK". The "Signal window" graphically showing the intensity signals of the sensor pixels (oscilloscope display) will open. It is responsive in real-time and the zoom function can be used to highlight an area of interest. The oscilloscope display is ideally suited for parameterizing the camera, for evaluating object illumination, for focussing the image or for aligning the line scan camera correctly.











SkLineScan: Start-up dialog

#### Function Overview: SkLineScan Toolbar



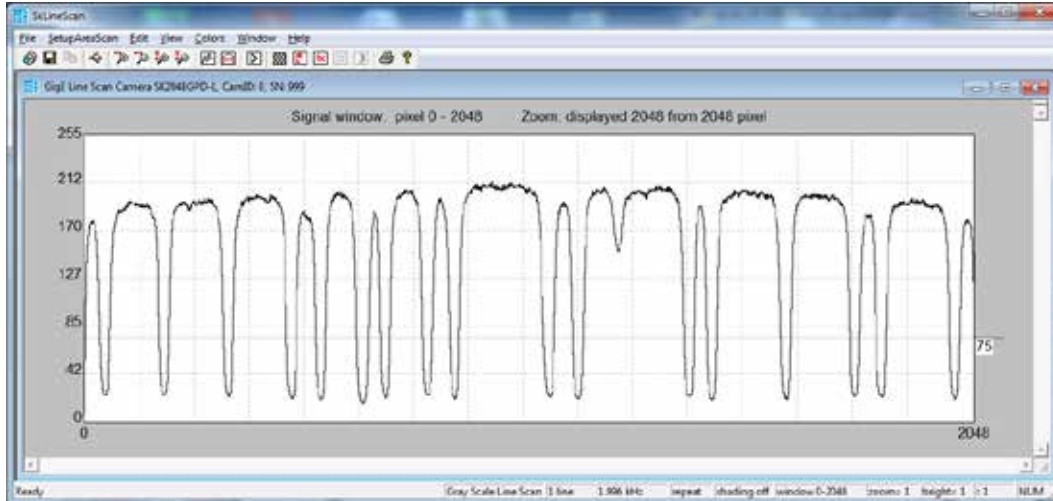
SkLineScan: Toolbar

-  New line scan. All open "Signal window" windows will be closed. [F2]
-  "Camera Control" dialog for parameter settings: integration time, line frequency, synchronization mode, thresholding
-  Zooming in and out
-  New line scan. "Area Scan" windows will be closed, "Signal window" windows will remain open. [F2]
-  Threshold mode in new binary signal window.
-  "Shading Correction" dialog to adjust the white balance [Alt+s]
-  "Gain/Offset Control" dialog, also for commands input [Shif+F4]
-  New area scan

## Basic Visualization of the Sensor Output

### Signal Window / Oscilloscope Display

The signal window plots the digitalized brightness profile as signal intensity (y-axis) versus the sensor length (x-axis) at a high refresh rate. The scaling of the y-axis depends on the resolution of the A/D converter: The scale range is from 0 to 255 for 8-bits and from 0 to 4095 for 12-bits. The scaling of the x-axis corresponds with the number of pixels in the line sensor.



**B**

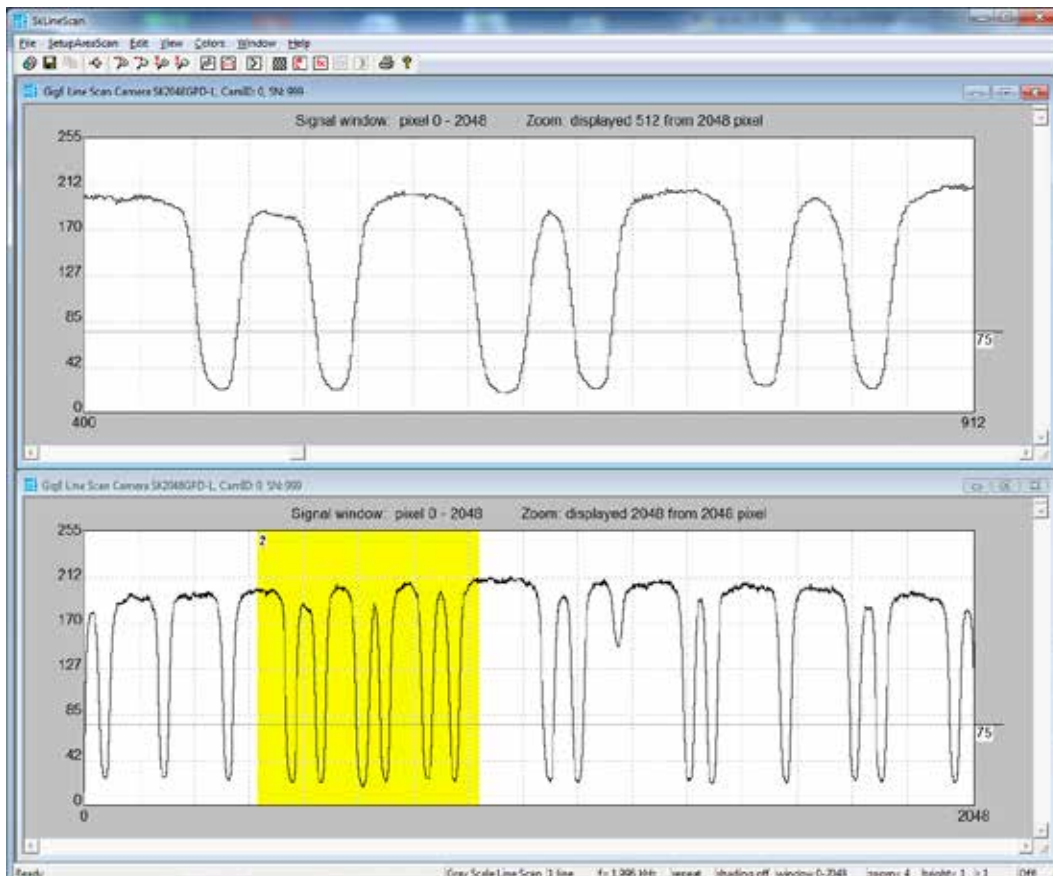
Line scan in Signal Window: brightness vs. pixel number

### Zoom Function

For high numbers of sensor pixels, the limited number of display pixels might be out of range, in which case the zoom function can be used to visualize the brightness profile in detail. Magnification of one or several sections of the signal allows individual pixels to be resolved for a detailed evaluation of the line scan signal.

### Window Split Function

The signal window can be split horizontally into two sections. Use the split handle **B** at the top of the vertical scrollbar and afterwards arrange the frames using the zoom buttons in the toolbar.



Line scan in Signal Split signal window. The upper frame shows a magnified section of the lower frame.



### 3.2 Adjustments for Optimum Scan Results

Prior to a scan, the following adjustments and parameter settings should be considered for optimum scan signals:

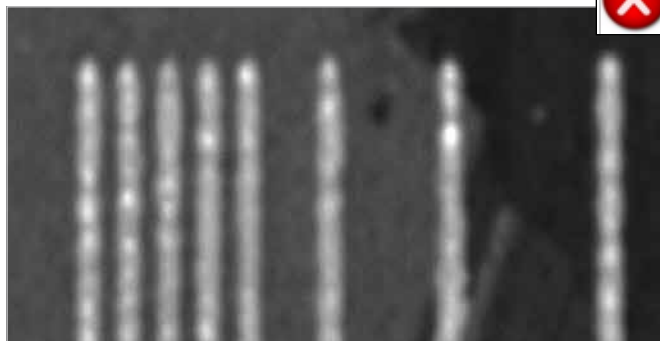
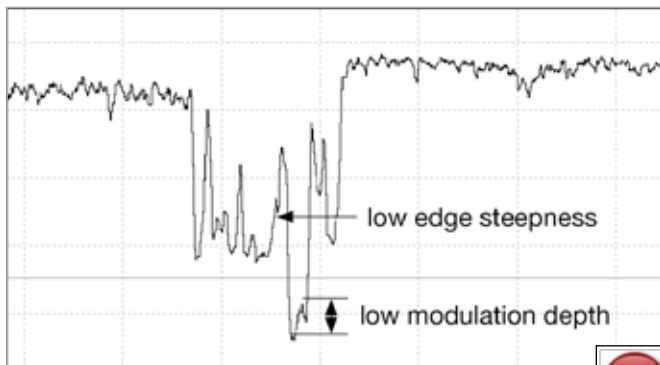
- Lens focussing
- Sensor alignment
- Gain/Offset
- Shading correction
- Integration time
- Synchronization of the sensor exposure and the object surface velocity, trigger mode options.

Start with the signal window / oscilloscope display. Any changes in the optical system or camera parameters are displayed in real-time when using an open dialog box.

#### ■ Lens Focussing

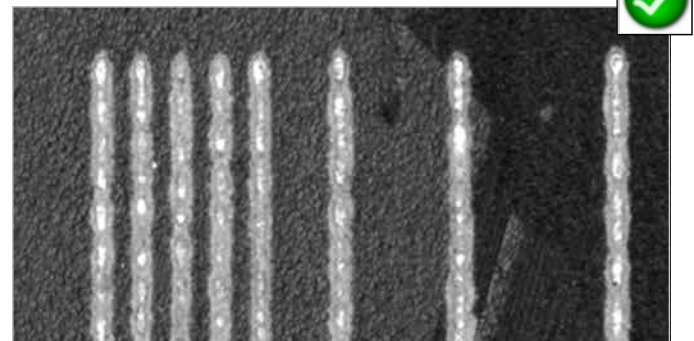
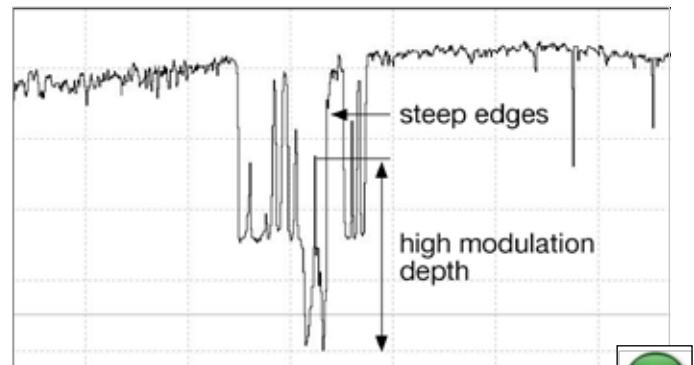
The oscilloscope display facilitates the effective focussing of the line scan camera system, even for two-dimensional measurement tasks. For determining the correct focus, the edge steepness at dark-bright transitions and the modulation of the line scan signal are the most important factors.

- Adjust the focus using a fully opened aperture to restrict the depth of field and to amplify the effects of focus adjustments.
- The signal amplitude may require trimming when using a fully opened aperture and this can be achieved most readily by shortening the integration time, as described in section *Integration Time, p. 17*.



Out-of-focus:

- Low edge steepness
- Signal peaks are blurred
- High-frequency gray values with low modulation

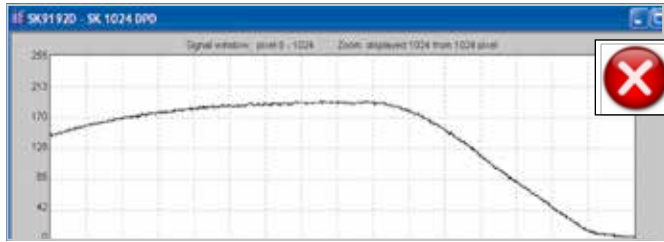


Optimum focus:

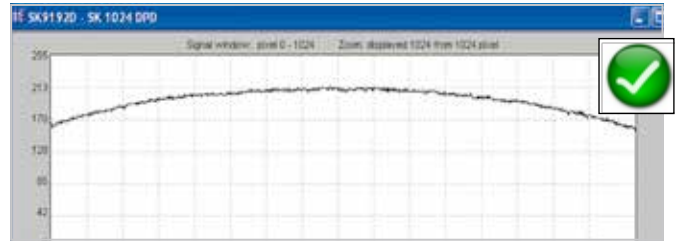
- Dark-bright transitions with steep edges
- Large modulation in the signal peaks
- High-frequency gray value variations

### Sensor Alignment

If you are operating with a linear illumination source, check the alignment of the illumination source and the sensor prior to performing a shading correction, as rotating the line sensor results in asymmetric vignetting.



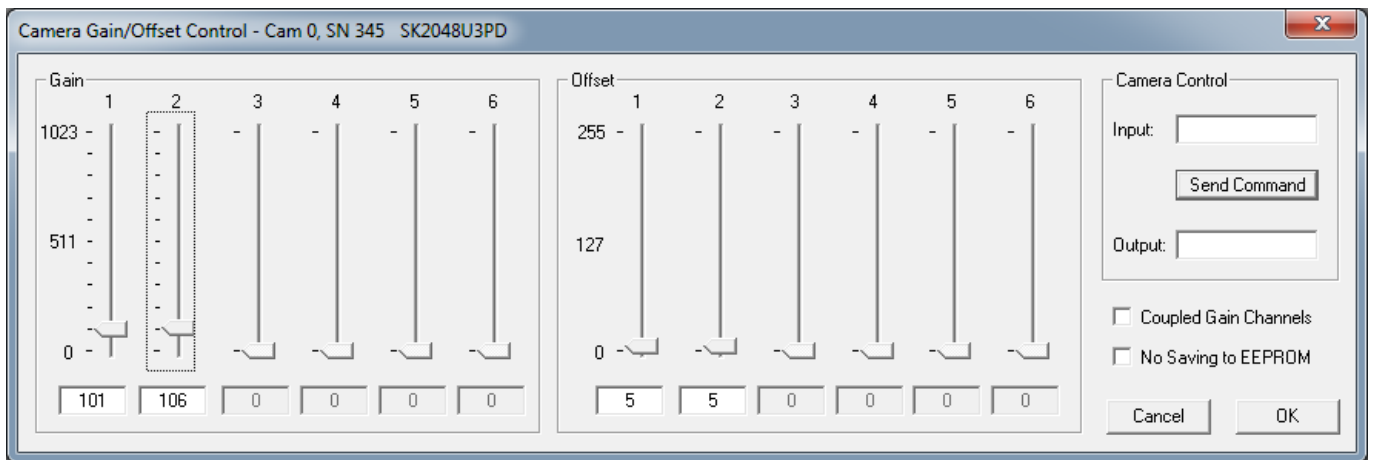
Sensor and optics rotated in apposition



Sensor and optics aligned

### Gain/Offset Adjustment

Cameras are shipped prealigned with gain/offset factory settings. Open the "Gain/Offset Control" dialog to re-adjust or customize these settings.



Gain/Offset Control dialog

The gain/offset dialog contains up to 6 sliders for altering gain and offset. The number of active sliders depends on the individual number of adjustable gain/offset channels of the camera. When "Coupled Gain Channels" is ticked, all channels are adjusted synchronously with one slider.

Enter commands for advanced software functions in the 'Camera Control' field (see page 13).

### Adjustment principle

#### 1. Offset

To adjust the zero baseline of the video signal, totally block the incident light and enter "00" (volts) for channel 1.

For a two- or multi-channel sensor, minimize any differences between the channels by adjusting the other Offset sliders.

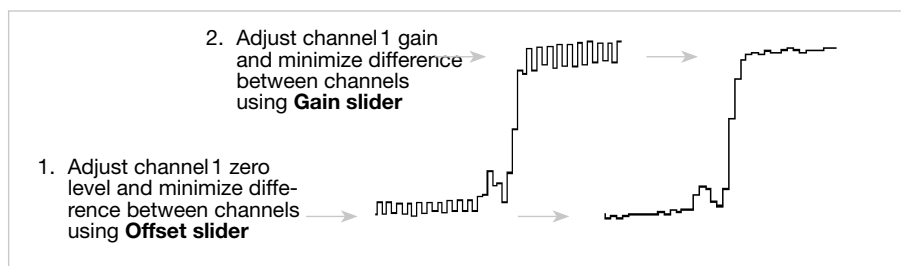
A slight signal noise should be visible in the zero baseline.

#### 2. Gain

Illuminate the sensor with a slight overexposure in order to identify the maximum clipping. Use the Gain slider "1" to adjust the maximum output voltage.

For a two- or multi-channel sensor, minimize any differences between the channels by adjusting the other Gain sliders.

For the full 8-bit resolution of the camera, the maximum output voltage is set to 255 and for 12-bit is set to 4095.



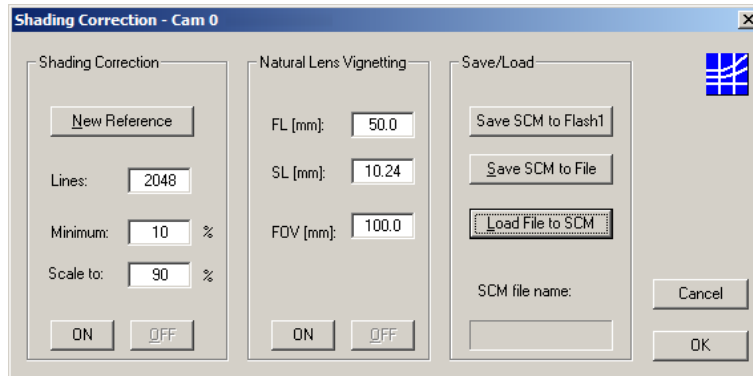
Offset and gain adjustment for more than one gain/offset channel



## ■ Shading Correction

Shading Correction compensates for non-uniform illumination, lens vignetting as well as any differences in pixel sensitivity. The signal from a white homogeneous background is obtained and used as a reference to correct each pixel of the sensor with an individual factor, scaled up to the intensity maximum (255 at 8-bit resolution and 4095 at 12-bit) to provide a flat signal. The reference signal is stored in the Shading Correction Memory (SCM) of the camera and subsequent scans are normalized using the scale factors from this white reference.

- Open the "Shading Correction" dialog (Alt+s).



Shading Correction dialog

- Use a homogeneous white object to acquire the reference data, e.g. a white sheet of paper.
- Click on button **New Reference**
- Either take a 2-dimensional scan ("Area Scan Function" [F3]) or
- Click on **Save SCM to Flash** to save the SCM reference signal in the flash memory of the camera

use a single line signal that was averaged over a number of single line scans.

- To suppress any influence of the surface structure, move the imaged object during the image acquisition.
- Input the scale range:

**Minimum in %:** intensity values lower than "Minimum" will not be changed.

A typical appropriate value is 10% of the full intensity range, i.e. 26 (= 10% · 255) for an 8-bit intensity scale.

**Maximum in %:** target value for scaling

A typical appropriate value is 90% of the full intensity range. The result will be a homogeneous line at 230 (= 90% · 255) for an 8-bit intensity scale.

Once the reference signal is copied from the shading correction memory (SCM) to the camera flash memory it will persist even after a power down. On a re-start, this data will be restored from the flash memory back to the SCM. The current shading correction status - active or not active - is also retained on power down.

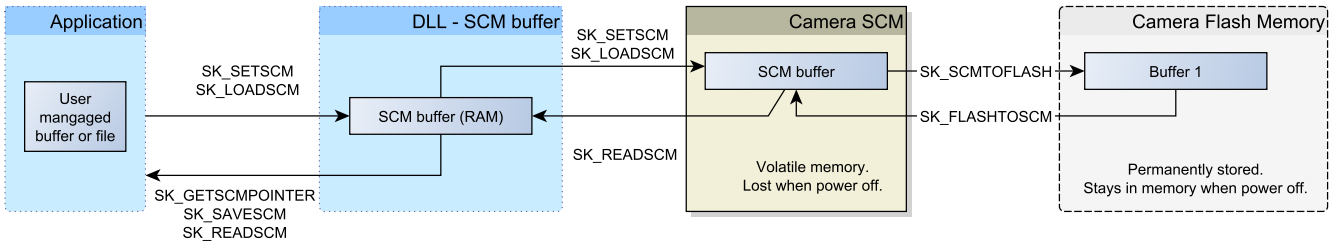
- ON** Activate Shading Correction with the reference signal which is stored in the SCM.
- OFF** Switch off Shading Correction. The Shading Correction is not retained in camera flash memory at the next start – even if the SCM data has already been saved into the flash memory previously.
- Load File to SCM** A stored reference signal will be loaded in the SCM of the camera. If the load process completes then the Shading Correction is active.



After shading correction, the line scan signal has a homogeneous intensity at 255 (8 bit, Maximum 100%)

## Shading Correction Memories and API Functions

As an alternative to the user dialog, a new shading correction reference signal can also be created by using application programming interface (API) functions. The relationship between the storage locations and the related API functions are shown in the diagram below. The API functions are included in the SK91USB3-WIN software package. See the *SK91USB3-WIN manual* for details.



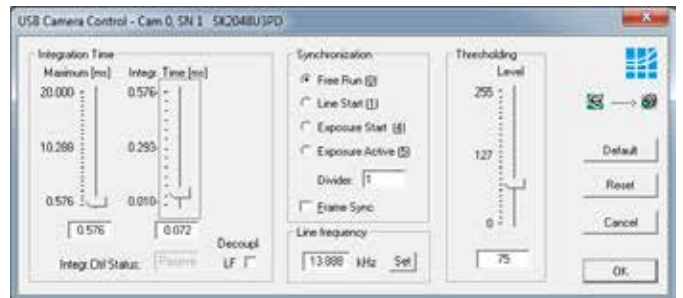
Structure of the shading correction memories and the related API functions for memory handling

## Integration Time

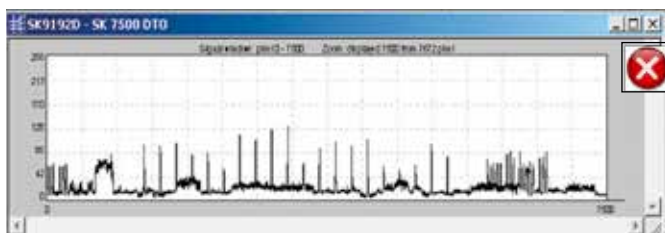
The range of intensity distribution of the line scan signal is affected by the illumination intensity, the aperture setting and the camera integration time. Conversely, the aperture setting influences the depth of field as well as the overall quality of the image and the perceived illumination intensity.

The line scan signal is optimum when the signal from the brightest region of the object corresponds to 95% of the maximum gain. Full use of the digitalization depth (256 at 8-bit, 4096 at 12-bit) provides an optimum signal sensitivity and avoids over-exposure (and blooming).

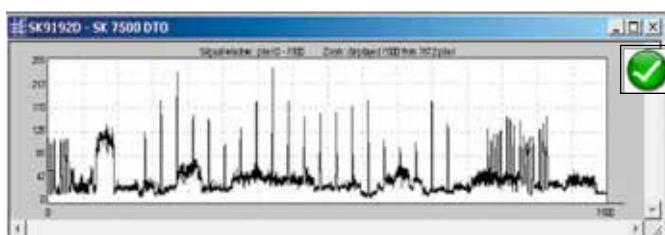
- Open the "Camera Control" dialog. Menu *Edit -> Operation Parameters* or *[F4]*



SkLineScan Camera Control dialog



A camera signal exhibiting insufficient gain: the integration time is too short as only about 50% of the B/W gray scale is used.

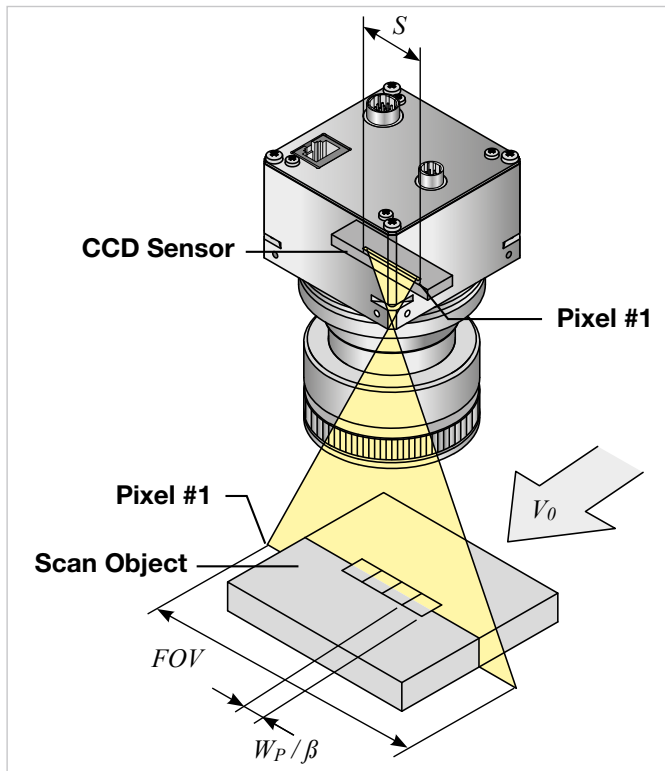


Optimized gain of the camera signal after increasing the integration time, by a factor of 4, to 95% of the available scale.

- The integration time can be set by two vertical sliders or two input fields in the section "Integration Time" of this dialog. The left slider is for coarser the right for finer adjustments.
- The current line frequency is displayed in the Line Frequency status field.
- The adjustment of the integration time in the range of Integration Control (shutter) that is shorter than the minimum exposure period does not change the line frequency. This will be held at the maximum.
- The 'Default' button sets the integration time to the minimum exposure period that is determined from the maximum line frequency.
- 'Reset' restores the start values.
- 'Cancel' closes the dialog without changes.
- 'OK' stores the integration time values and closes the dialog.
- For synchronization settings, see section *Synchronization of the Imaging Procedure and the Object Scan Velocity, p. 18*.

### Synchronization of the Imaging Procedure and the Object Scan Velocity

- A two-dimensional image is generated by moving either the object or the camera. The direction of the translation movement must be orthogonal to the sensor axis of the CCD line scan camera.
- To obtain a proportional image with the correct aspect ratio, a **line-synchronous transport** with the laterally correct pixel assignment is required. The line frequency and the constant object velocity have to be coordinated.
- In cases of a variable object velocity or particularly high accuracy requirements then an **external synchronization** is necessary. The various **synchronization modes** are described below.



The optimum object scan velocity is calculated from:

$$V_O = \frac{W_P \cdot f_L}{\beta}$$

If the velocity of the object carrier is not adjustable then the line frequency of the camera must be adjusted to provide an image with the correct aspect ratio, where:

$$f_L = \frac{V_O \cdot \beta}{W_P}$$

- $V_O$  = object scan velocity
- $W_P$  = pixel width
- $f_L$  = line frequency
- $S$  = sensor length
- $FOV$  = field of view
- $\beta$  = magnification
- =  $S / FOV$

#### Example 1:

Calculating the object scan velocity for a given field of view and line frequency:

- Pixel width = 14  $\mu$ m
- Line frequency = 4.73 kHz
- $S$  = 28.7 mm
- $FOV$  = 50 mm

$$V_O = \frac{14 \mu\text{m} \cdot 4.73 \text{ kHz}}{(28.7 \text{ mm} / 50 \text{ mm})} = 115 \text{ mm/s}$$

#### Example 2:

Calculating the line frequency for a given field of view and object scan velocity:

- Pixel width = 14  $\mu$ m
- Object scan velocity = 100 mm/s
- $S$  = 28.7 mm
- $FOV$  = 50 mm

$$f_L = \frac{100 \text{ mm/s} \cdot (28.7 \text{ mm} / 50 \text{ mm})}{14 \mu\text{m}} = 4.1 \text{ kHz}$$

## Synchronization Modes

The synchronization mode determines the timing of the line scan. Synchronization can be either performed internally or triggered by an external source, e.g. an encoder signal.

The line scan camera can be externally triggered in two different ways:

### 1. Line-triggered synchronization:

Each single line scan is triggered by the falling edge of a TTL signal supplied to LINE SYNC A input.

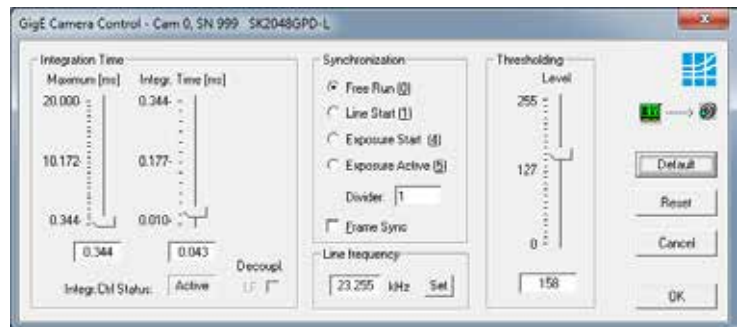
The SK2048GJR-4L line scan camera facilitates advanced synchronization control by a second trigger input LINE SYNC B. For a detailed description, see *Advanced Synchronization Control, p. 22*

### 2. Frame-triggered synchronization:

A set of lines resulting in a 2-dimensional frame or image is triggered by the falling edge of a TTL signal on FRAME SYNC input.

Schäfter + Kirchhoff differentiates several trigger modes identified by a number, which can be selected in the control dialog as appropriate.

- Open the 'Camera Control' dialog [F4] to configure the synchronization. The trigger mode settings are available in the middle frame.
- Frame- and line-triggered synchronization can be combined. Tick the 'Frame Sync' box to activate the frame synchronization mode.
- The Trigger Control stage is followed by a Trigger Divider stage inside the camera. Enter the division ratio into the 'Divider' field.



Camera Control dialog

### Free Run / SK Mode 0

The acquisition of each line is internally synchronized (free-running) and the next scan is started automatically on completion of the previous line scan. The line frequency is determined by the programmed value.

### LineStart / SK Mode 1

On an external trigger, the currently exposed line will be read out at the next internal line clock. The start and duration of exposure are controlled internally by the camera and are not affected by the trigger. The exposure time is programmable and the trigger does not affect the integration time. The line frequency is determined by the trigger clock frequency.

Restriction: The period of the trigger signal must be longer than the exposure time used.

### ExposureStart / SK Mode 4 (only available when camera supports integration control)

A new exposure is started exactly at the time of external triggering and the current exposure process will be interrupted. The exposure time is determined by the programmed value. The exposed line will be read out with the next external trigger. The trigger clock frequency determines the line frequency.

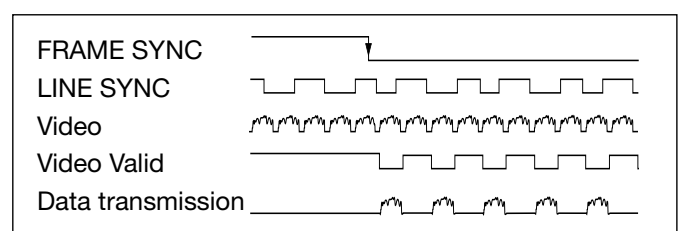
Restriction: The period of the trigger signal must be longer than the exposure time used.

### ExposureActive / SK extSOS (Mode 5)

The exposure time and the line frequency are controlled by the external trigger signal. This affects both the start of a new exposure (start-of-scan pulse, SOS) and the reading out of the previously exposed line.

### FrameTrigger / SK FrameSync

The frame trigger synchronizes the acquisition of a 2D area scan. The individual line scans in this area scan can be synchronized in any of the available line trigger modes. The camera suppresses the data transfer until a falling edge of a TTL signal occurs at the FRAME SYNC input. The number of lines that defines the size of the frame must be programmed in advance.



Combined frame and line synchronization

## 4 Advanced SkLineScan Software Functions

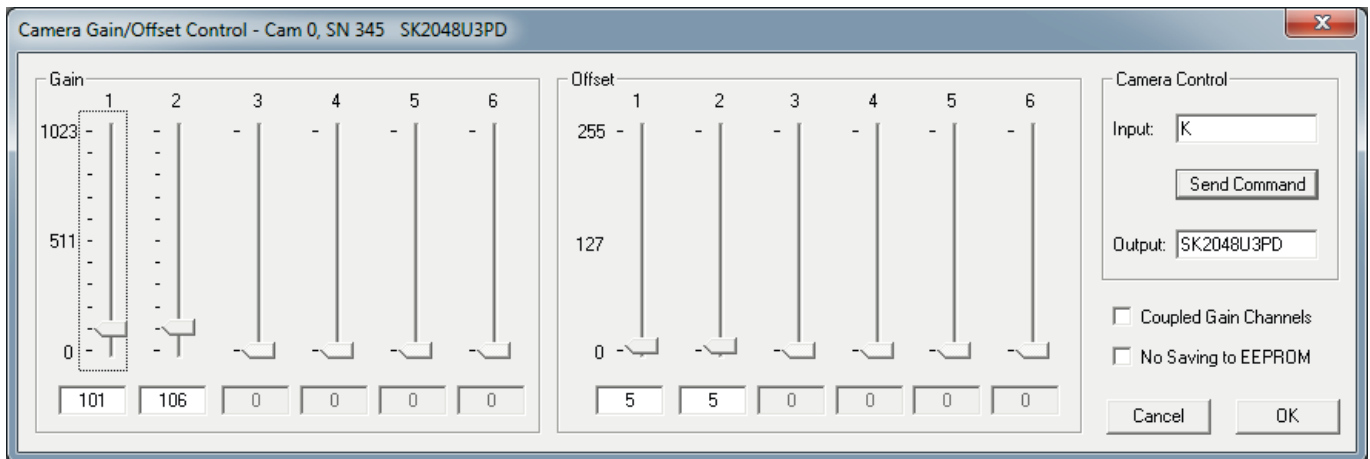
### 4.1 Camera Control by Commands

In addition to user dialog inputs, the SkLineScan software also provides the option to adjust camera settings, such as gain, offset, trigger modes, by sending control commands directly.

Similarly, current parameters, as well as specific product information, can be read from the camera using the request commands. All set and request commands are listed in the tables below.

- The commands are entered in the 'Input' field in the 'Camera Control' section of the "Camera Gain/Offset Control" user dialog, [Shift+F4].
- In the 'Output' field, either the acknowledgement of the set commands (0=OK, 1=not OK) or the return values of the request commands are output.

The parameter settings are stored in the non-volatile flash memory of the camera and are available after a rapid start-up, even after a complete shut down or loss of power.



Gain/Offset Control dialog: Camera Control input and output in the right section



## ■ Set Commands

Set Operation	Description
Goooo<CR>	gain setting 0-24 dB
Oppp<CR>	offset setting
F0<CR>	Output Format: threshold addr. (13 bit ) no noise reduction
F1<CR>	Output Format: threshold addr. (13 bit ) with noise reduction
F8<CR>	output format: 8 bit video data
F10<CR>	output format: 10 bit video data
F12<CR>	output format: 12 bit video data
C10<CR>	camera clock: 10 MHz data rate
T0<CR>	test pattern off / SCM off
T1<CR>	test pattern on (turns off with power off)
T2<CR>	shading correction on
T3<CR>	auto program Shading Correction / SCM on
T4<CR>	copy flash memory 1 to SCM
T5<CR>	save SCM to flash memory 1
T6<CR>	video out = SCM data
T7<CR>	copy Flash Memory 2 to SCM Memory
T8<CR>	save SCM Memory to Flash Memory 2
Lppp<CR>	set threshold level
M0<CR>	line trigger mode0: internal all lines
M1<CR>	line trigger mode1: extern trigger, next line
M2<CR>	line trigger mode0: internal all lines and set max line rate
M3<CR>	Pleora sync modes
M5<CR>	line trigger mode5: extern SOS, all Lines
Axxxx<CR>	SCM address (xxxx = A0-2047)
Dxxxx<CR>	SCM data (xxxx = 0-4095) and increment SCM address
Eyyyyy<CR>	Frames / Multiframe (yyyyy = 0-32767)
EFyyyyy<CR>	external Frame Trigger Delay (yyyyy = 0-32767 lines)
Nyyyyy<CR>	Lines/Frame (yyyyy = 1-32767)
SLUT<CR>	enable LUT
RLUT<CR>	disable LUT
Wyyyyy<CR>	line clock frequency (yyyyy = 20-4694) (Hz)
Xyyyyy<CR>	exposure time (yyyyy = 10-20000) (µs)
Vyyyyy<CR>	extern sync divider (yyyyy = 1-32767)
Yppp<CR>	set sync control (ppp = 255)

## ■ Request Commands

Request	Return	Description
K<CR>	SK2048GJR-4L	returns SK type number
R<CR>	Rev2.50	returns Revision number
S<CR>	SNr00163	returns Serial number
I<CR>	SK2048GJR-4L Rev2.50 SNr00163	camera identification eadout
I1<CR>	VCC: yyyyy	returns VCC (1=10mV)
I2<CR>	VDD: yyyyy	returns VDD (1=10mV)
I3<CR>	moo: yyyyy	returns mode of operation
I4<CR>	CLo: yyyyy	returns camera clock low frequency (MHz)
I5<CR>	CHi: yyyyy	returns camera clock high frequency (MHz)
I6<CR>	Ga1: yyyyy	returns gain
I8<CR>	Of1: yyyyy	returns offset
I14<CR>	THL: yyyyy	returns threshold level
I19<CR>	Tab: yyyyy	returns video channels
I20<CR>	CLK: yyyyy	returns selected clock frequency (MHz)
I21<CR>	ODF: yyyyy	returns selected output data format
I22<CR>	TRM: yyyyy	returns selected trigger mode
I23<CR>	SCO: yyyyy	returns shading corr. on/off
I24<CR>	Exp: yyyyy	returns exposure time
I25<CR>	miX: yyyyy	returns min. exposure time (µs)
I26<CR>	LCK: yyyyy	returns line frequency (Hz)
I27<CR>	maZ: yyyyy	returns max. line frequency (Hz)
I28<CR>	TSc: yyyyy	returns Sync Divider
I29<CR>	SyC: yyyyy	returns Sync Control
I30<CR>	Lin: yyyyy	returns Lines/Frame
I31<CR>	DXT: yyyyy	returns DXT on/off
I32<CR>	Tmp: yyyyy	returns Video Board Temper.
I33<CR>	FSD: yyyyy	returns Frame Trigger Delay
I36<CR>	WPL: yyyyy	returns Window Pixel Length
I37<CR>	WFP: yyyyy	returns Window First Pixel
I38<CR>	LUT: yyyyy	returns LUT on/off

LUT: Lookup Table  
SCM: Shading Correction Memory  
SOS: Start of Scan

Range of values:  
oooo = 0 ... 1023  
ppp = 0 ... 255  
xxxx = 4 digits integer value as ASCII  
yyyyy = 5 digits integer value as ASCII

Acknowledgement for all set commands:  
0 = OK, 1 = not OK

### 4.2 Advanced Synchronization Control

The basic synchronization function makes use of the trigger input LINE SYNC A. The trigger mode is determined by the settings in the "Camera Control" dialog, e.g. LineStart (1) or ExposureStart (4).

Advanced trigger functions are provided by combining LINE SYNC A with a second trigger input LINE SYNC B. The operation mode is controlled by the entries in the **Sync Control Register (SCR)**.

Use control commands to write to or to read from the Sync Control Register:

**Yppp<CR> set sync control**  
 with ppp = 0...255 (decimal)  
 Return value: 0 = OK; 1 = not OK

**I29<CR> return sync control**  
 Return value: SyC:yyyyy (5-digits integer value as ASCII)

**Example:**

Y232  
 ppp = 232(dec) = 11101000(bin)  
 new SCR value: 11101000 → **E**

#### Advanced Trigger Functions and Sync Control Register Settings

- Basic synchronization function, 'Camera Control' dialog settings are valid → **A**
- Detection of direction → **B, C, D, E**
- Trigger pulses are valid only in one direction, trigger pulses in the other direction are ignored → **B**
- Trigger on 4 edges → **D, E**
- Suppression of machine-encoded jitter, programmable hysteresis for trigger control → **E**

Sync Control Register (SCR)	SyC7	SyC6	SyC5	SyC4	SyC3	SyC2	SyC1	SyC0
default	x	x	x	x	x	x	0	0
pixel #1 data = external trigger input states	x	x	x	x	x	x	0	1
pixel #1 data = Linecounter (8 bit)	x	x	x	x	x	x	1	0
pixel #1, #2 data = ext. trigger states (3 bit) + line counter (13 bit)	x	x	x	x	x	x	1	1
ExSOS and Sync at LINE SYNC A (Mode5)	x	x	x	x	x	0	x	x
ExSOS at LINE SYNC B, Sync at LINE SYNC A (Mode5)	x	x	x	x	x	1	x	x
Jitter Hysteresis off	x	x	x	0	0	x	x	x
Jitter Hysteresis 4	x	x	x	0	1	x	x	x
Jitter Hysteresis 16	x	x	x	1	0	x	x	x
Jitter Hysteresis 64	x	x	x	1	1	x	x	x
Sync 1x Enable	x	x	0	x	x	x	x	x
Sync 4x Enable	x	x	1	x	x	x	x	x
Sync up Enable / down disable	x	0	x	x	x	x	x	x
Sync up/down Enable	x	1	x	x	x	x	x	x
Sync Ctrl. Disable, SyC3...SyC6 without function	0	x	x	x	x	x	x	x
Sync Control Enable	1	x	x	x	x	x	x	x
	128	64	32	16	8	4	2	1

For diagnostic purposes, the present state of external trigger inputs (LINE SYNC A, LINE SYNC B, FRAME SYNC) or the internal line counter can be output instead of pixel #1 and/or pixel #2 data.

SCR	Pixel #1 Data (lowByte)	Pixel #2 Data (lowByte)
xxxxxx00	intensity	intensity
xxxxxx01	D7 = FRAME SYNC D6 = LINE SYNC A D5 = LINE SYNC B D4 ... D0 = 0	intensity
xxxxxx10	internal line counter (8 bit)	intensity
xxxxxx11	D7 = FRAME SYNC D6 = LINE SYNC A D5 = LINE SYNC B D4 ... D0 = line counter (bit 12 ... 8)	internal line counter (bit 7 ... 0)

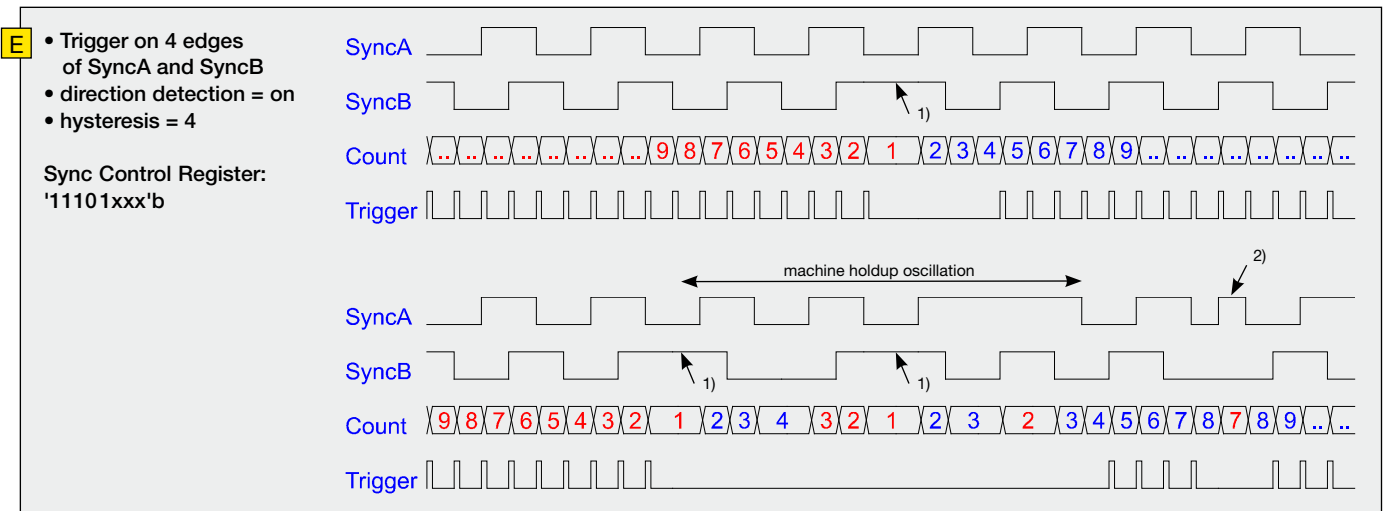
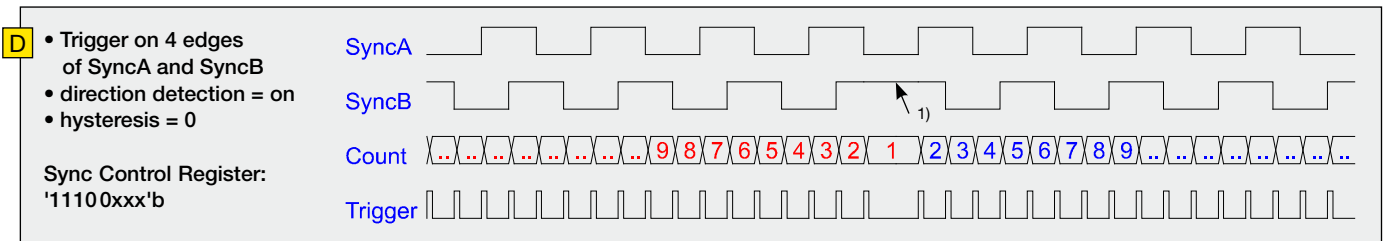
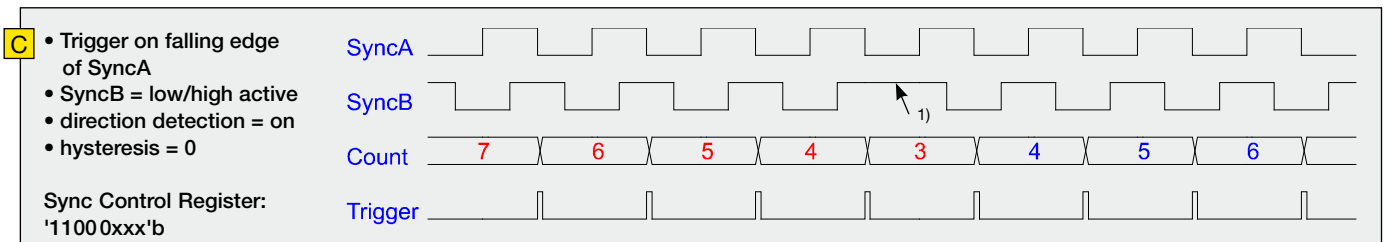
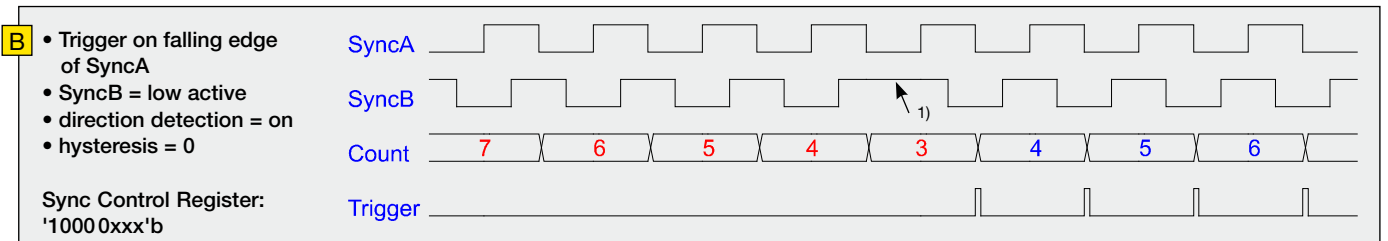
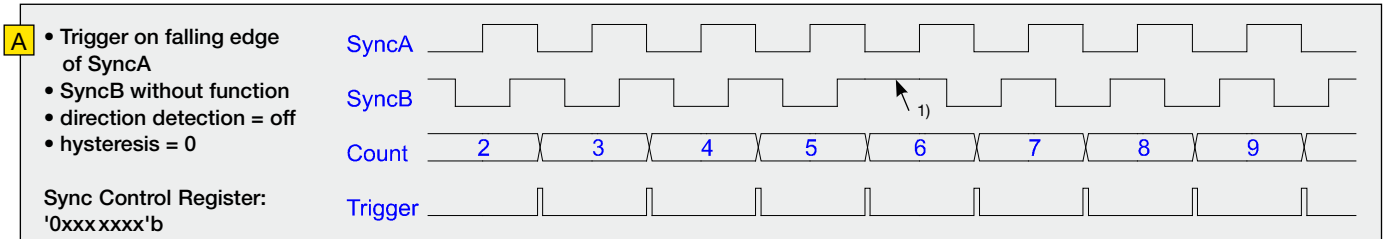


### ■ Example Timing Diagrams of Advanced Synchronization Control

Annotations:

- SyncA = LINE SYNC A (external line synchronization input, I/O connector)
- SyncB = LINE SYNC B (external line synchronization input, I/O connector)
- Count = internal counter
- Trigger = Generated trigger pulses from the Trigger Control stage. The signal goes to the Trigger Divider stage inside the camera. For setting the divider, use the Vyyyyy<CR> command or the 'Divider' input field in the **4.1 Camera Control by Commands, p. 20**.

- 1) direction changed
- 2) glitch



Line Scan Camera SK2048GJR-4L Manual (09.2016) • skimed\_CameraControl0\_Advanced-SyncCtrl\_ML.indd (09.2016)

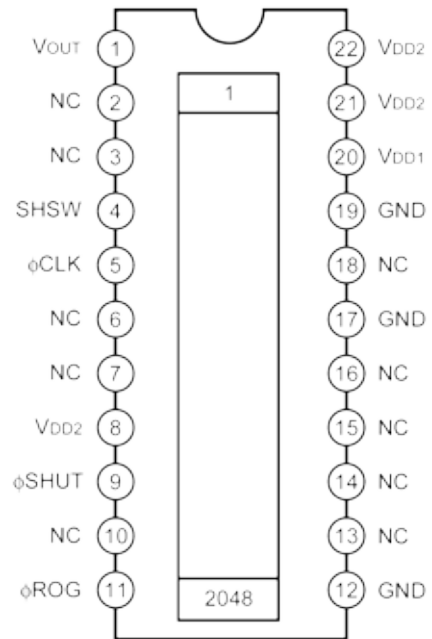
5 Sensor Information

Manufacturer: Sony  
 Type: ILX751  
 Data source: Sony ILX751B Linear Sensor Document E97X25B97-PS

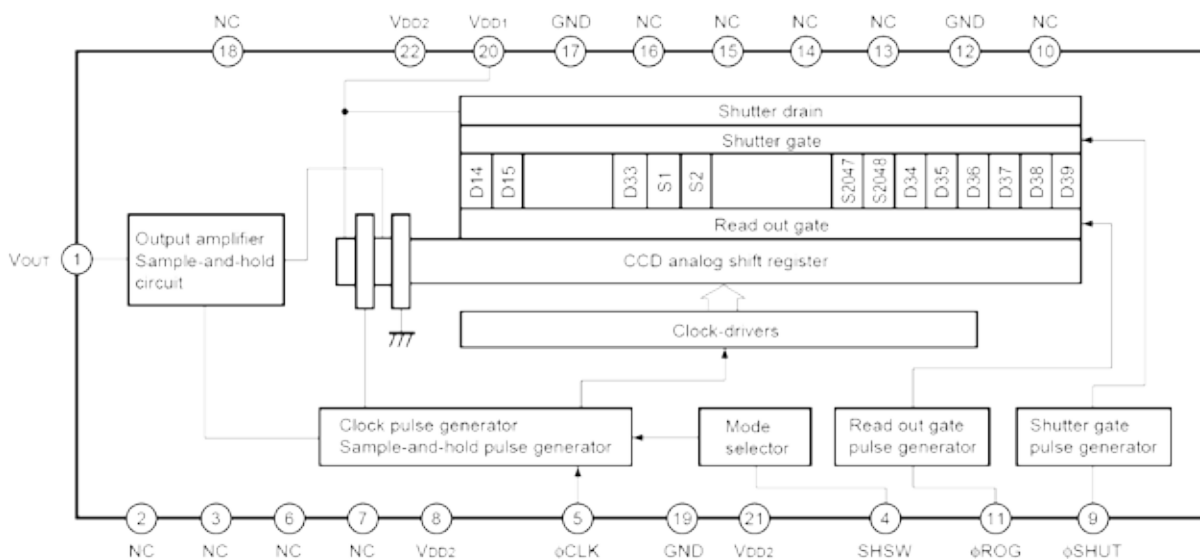
Features

- Number of effective pixels: 2048 pixels
- Pixel size: 14µm × 14µm (14µm pitch)
- Built-in timing generator and clock-drivers
- Shutter function
- Ultra low lag
- Maximum clock frequency: 5MHz

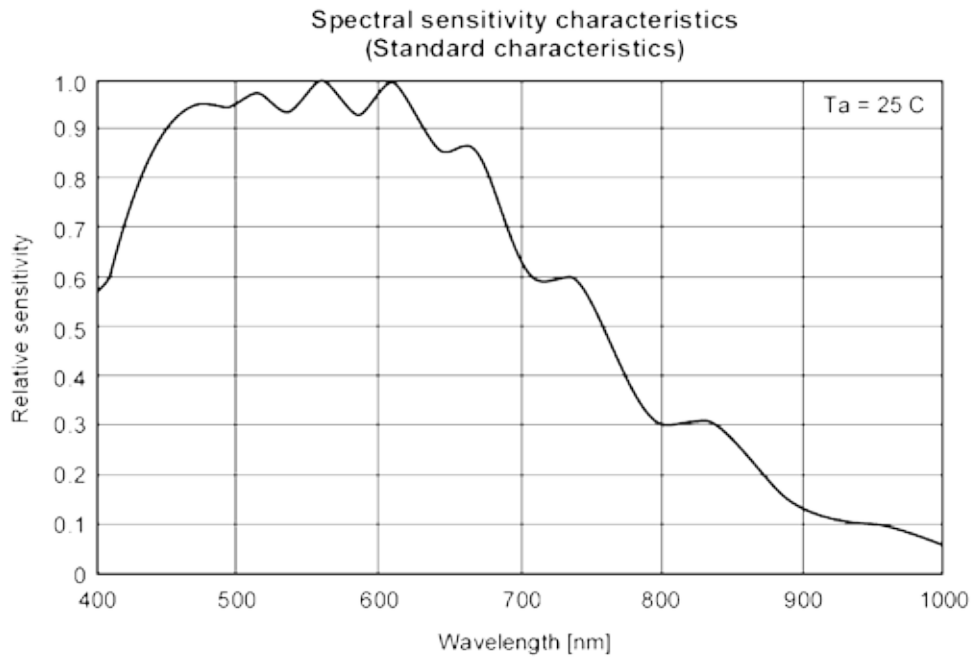
Pin Configuration (Top View)



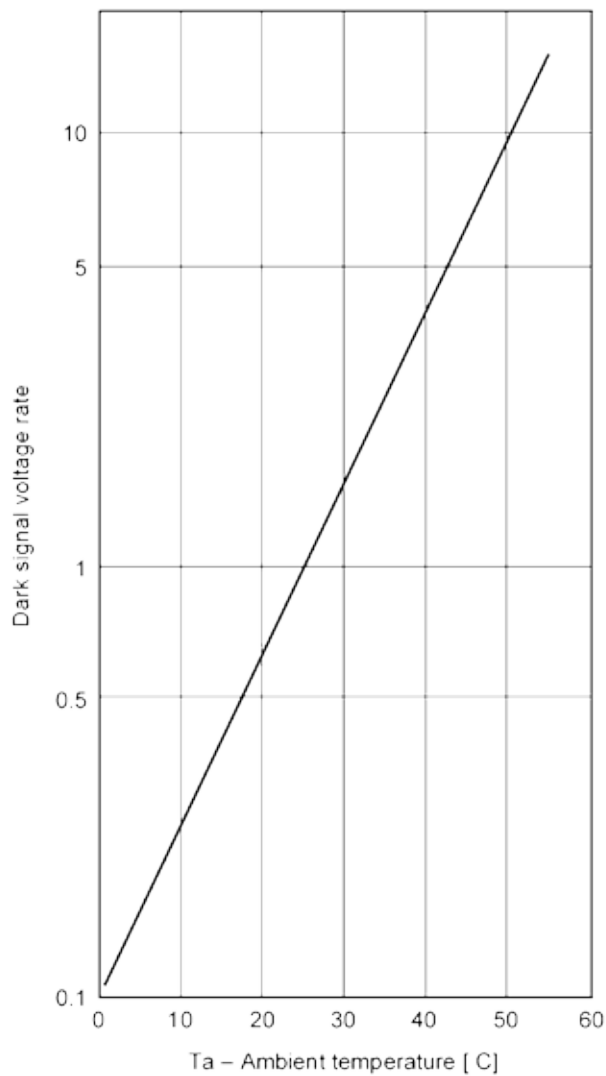
Block Diagram



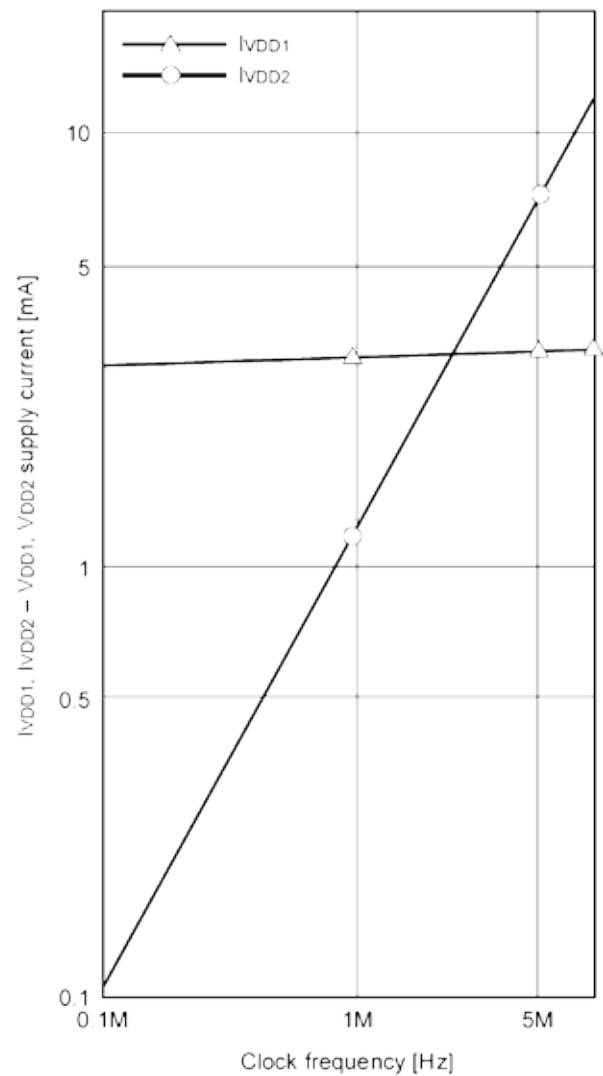
### Example of Representative Characteristics



Dark signal voltage rate vs. Ambient temperature  
(Standard characteristics)



VDD1, VDD2 supply current vs. Clock frequency  
(Standard characteristics)



**Electrooptical Characteristics**

(Ta = 25°C, VDD1 = 9V, VDD2 = 5V, Clock frequency = 1MHz, Light source = 3200K, IR cut filter: CM-500S (t = 1.0mm))

Item	Symbol	Min.	Typ.	Max.	Unit	Remarks
Sensitivity	R	(30)	40	(50)	V/(lx · s)	Note 1
Sensitivity nonuniformity	PRNU	—	2.0	(8.0)	%	Note 2
Saturation output voltage	VSAT	(1.5)	1.8	—	V	—
Dark voltage average	VDRK	—	0.3	(2.0)	mV	Note 3
Dark signal nonuniformity	DSNU	—	0.5	(3.0)	mV	Note 3
Image lag	IL	—	0.02	—	%	Note 4
Dynamic range	DR	—	6000	—	—	Note 5
Saturation exposure	SE	—	0.045	—	lx · s	Note 6
9V supply current	IVDD1	—	4.0	(8.0)	mA	—
5V supply current	IVDD2	—	1.8	(5.0)	mA	—
Total transfer efficiency	TTE	92.0	97.0	—	%	—
Output impedance	Zo	—	600	—	Ω	—
Offset level	Vos	—	4.0	—	V	Note 7
Shutter lag	SHUT	0	1.0	(5.0)	%	Note 8

**Note)**

1. For the sensitivity test light is applied with a uniform intensity of illumination.
2. PRNU is defined as indicated below. Ray incidence conditions are the same as for Note 1.

$$PRNU = \frac{(V_{MAX} - V_{MIN})/2}{V_{AVE}} \times 100 [\%]$$

The maximum output is set to VMAX, the minimum output to VMIN and the average output to VAVE.

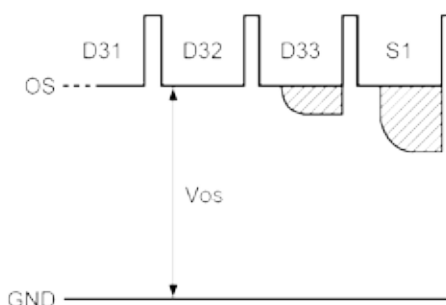
3. Integration time is 10ms.
4. VOUT = 500mV

$$5. DR = \frac{V_{SAT}}{V_{DRK}}$$

When optical accumulated time is shorter, the dynamic range gets wider because dark voltage is in proportion to optical accumulated time.

$$6. SE = \frac{V_{SAT}}{R}$$

7. Vos is defined as indicated below.



8. To stipulate the lag during shutter operation, use the formula below.  
Place the output voltage average value during shutter operation at  $V_{SHUT}$  and the output Voltage average value when the shutter is not in operation at  $V_{AVE}$ . (Refer to Fig. 5.)

$$SHUT = \frac{V_{SAT}}{R} \times 100 [\%]$$

Please note that the shutter pulse at this time accord with Fig.5.

## Glossary

### Blooming

Extended illumination of saturated pixels, which are not able to accumulate further charge due to long exposure, leads to charge overflow into adjacent pixels. This effect is called blooming. Blooming causes a corruption of the geometrical allocation of image and object in the line signal. CCD line scan cameras with anti-blooming sensors direct the abundant charge to a "drain gate". Charge overflow into adjacent, less illuminated pixels is prevented. Depending on pixel frequency and spectral range, overexposure up to factor of 50 can thus be handled.

### Exposure period

is the illumination cycle of a line scan sensor. It is the → *integration time* plus the additional time to complete the read-out of the accumulated charges and the output procedure. While the charges from a finished line scan are being read out, the next line scan is being exposed. The exposure period is a function of the pixel number and the → *pixel frequency*. The minimum exposure period of a particular line scan camera determines the maximum → *line frequency* that is declared in the specifications.

### Integration control

Cameras with integration control are capable of curtailing the → *integration* time within an → *exposure period*. This performs an action equivalent to a shutter mechanism.

### Integration time

The light-sensitive elements of the photoelectric sensor accumulate the charge that is generated by the incident light. The duration of this charge accumulation is called the integration time. Longer integration times increase the intensity of the line scan signal, assuming constant illumination conditions. The complete read-out of accumulated charges and output procedure determines the minimum → *exposure period*.

### Line frequency, line scan frequency

is the reciprocal value of the → *exposure period*. The maximum line frequency is a key criterion for line scan sensors as this is the limiting factor for the scan velocity.

### Optical resolution

Two elements of a line scan camera determine the optical resolution of the system: first, the pixel configuration of the line sensor and, secondly, the optical resolution of the lens. The worst value is the determining value. In a phased set-up, both are within the same range.

The optical resolution of the line sensor is primarily determined by the number of pixels and secondarily by their size and spacing, the inter-pixel distance. Currently available line scan cameras have up to 12000 pixels,

ranging from 4 to 14  $\mu\text{m}$  in size and spacing, for sensors up to 56 mm in length and line scan frequencies up to 83 kHz.

During a scanning run, the effective resolution perpendicular to the sensor orientation is determined by the velocity of the scan and by the → *line frequency*

### Pixel frequency

The pixel frequency for an individual sensor is the rate of charge transfer from pixel to pixel and its ultimate conversion into a signal.

### Region of Interest

A freely programmable window (region of interest, ROI) can be applied to the line sensor so that only the pixel information within the ROI can reach the memory.

By only illuminating these ranges, data volume and data processing is accelerated for both line and area scan acquisitions.

Constraint: the ROI memory allocation must be divisible by 8.

### Shading correction

→ *Shading Correction*, section 3.2

### SCM

Shading Correction Memory,

→ *Shading Correction Memories and API Functions*, section 3.2

### Sol (Start of Integration)

In addition to → *SoS*, cameras with → *Integration Control* function generate an internal Sol-signal that initiates the integration period.

### SoS (Start of Scan)

is an internally generated trigger signal for sequential control of the camera, The signal is induced either by an internal counter or by an external line synchronization signal, depending on the selected line synchronization mode.

→ *Synchronization*

→ *Advanced Synchronization Control*, section 4.2

### SkLineScan

is the software application from Schäfter + Kirchhoff for controlling and adjusting the line scan cameras,

→ *Software: SkLineScan*, section 3.1

## Synchronization

To obtain a proportional image with the correct aspect ratio, a line synchronous transport with the laterally correct pixel assignment is required. The → **Line frequency** and constant object velocity have to be compatible with each other.

For more accurate requirements or with a variable object velocity, external synchronization is necessary.

→ *Synchronization of the Imaging Procedure and the Object Scan Velocity*, section 3.2

## Thresholding (monochrome cameras only)

The thresholding process generates a binary signal from the gray scale data, with values below the threshold yielding 0 and those above yielding 1. Only the pixel addresses of the location and threshold transition (from high→low or low→high) are transmitted, reducing data throughput.

Thresholding is particularly appropriate for measuring widths or edge positions, by simply masking the required pixel addresses.





**CE-Conformity**

The product complies with the following standards and directives:

**2014/30/EU**

EMC Directive

**DIN EN 61326-1:2013**

Electrical equipment for measurement, control and laboratory use – EMC requirements

Part 1: General requirements

**Warranty**

This manual has been prepared and reviewed as carefully as possible but no warranty is given or implied for any errors of fact or in interpretation that may arise. If an error is suspected then the reader is kindly requested to inform us for appropriate action.

The circuits, descriptions and tables may be subject to and are not meant to infringe upon the rights of a third party and are provided for informational purposes only.

The technical descriptions are general in nature and apply only to an assembly group. A particular feature set, as well as its suitability for a particular purpose, is not guaranteed.

Each product is subjected to a quality control process. If a failure should occur then please contact the supplier or Schäfter+Kirchhoff GmbH immediately. The warranty period covers the 24 months from the delivery date. After the warranty has expired, the manufacturer guarantees an additional 6 months warranty for all repaired or substituted product components. Warranty does not apply to any damage resulting from misuse, inappropriate modification or neglect. The warranty also expires if the product is opened. The manufacturer is not liable for consequential damage. If a failure occurs during the warranty period then the product will be replaced, calibrated or repaired without further charge. Freight costs must be paid by the sender. The manufacturer reserves the right to exchange components of the product instead of making a repair. If the failure results from misuse or neglect then the user must pay for the repair. A cost estimate can be provided beforehand.

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We reserve the right to improve or change specifications so that the system description and depictions in the Instruction Manual may differ in detail from the system actually supplied. The Instruction Manual is not covered by an update service.

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## Software



### Software

#### SK91GigE-WIN Order Code

SDK from Schäfter + Kirchhoff including the SKLineScan operating program, as well as API, C++ class library and examples.

Operating systems:  
Windows 7 / 8.1 / 10 - x64 and x86

#### SK91GigE-LV VI Order Code

VI-Library for LabVIEW®, requires SK91GigE-WIN



## Accessories



### CAT6 Network cable

Shielded CAT6 patch cable, halogen-free, both ends with RJ45 connectors for Gigabit Ethernet

#### CAT6.x Order Code

cable length 3 / 5 / 10 m or  
length according to choice,  
max. 100 m



### Power cable SK9014.xF

for GigE Vision™ line scan cameras with 24 VDC supply voltage.

Shielded cable with Hirose plug HR10A, female 6-pin (camera side), and open-ended line.

#### SK9014.xF Order Code

cable length 1.5 / 3 / 5 m



### External synchronization cable SK9024...

for line scan cameras with GigE / GigE Vision™ interface.

Shielded cable with Hirose plug HR10A, female 12 pin (camera side), and Phoenix 4 pin connector incl. terminal block.

#### SK9024.x Order Code

cable length 3 / 5 m  
Other lengths on request



### Adapter cable for sync signals CAB-ADSync-BNC-1

BNC/SMA (3x) to Line Scan Camera Synchronization Cable SK9016/SK9024/SK9026.

Shielded cable, length 0.25 m

#### Connectors:

- 1x Phoenix 4-pin connector
- 3x SMA plug (Line Sync A, Line Sync B, Frame Sync)
- 3x adapter SMA socket (outside threading) to BNC-plug

#### CAB-ADSync-BNC-1 Order Code

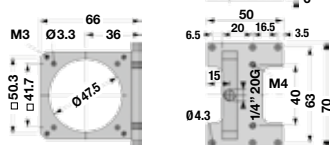
### M2 Mounting Bracket SK5105-L

For cameras with lens thread size M45x0.75

SK5105-L with clamping set SK5101#



Order Code  
SK5105-L



### MC2 Clamping Set SK5101



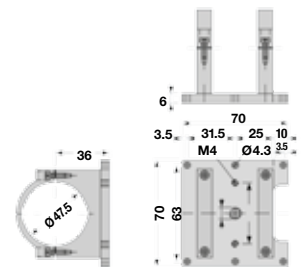
Order Code  
SK5101  
(set of 4 pcs.)

Allen screw  
DIN 912-M3x12

### M4 Mounting System SK5105-2L



Order Code  
SK5105-2L



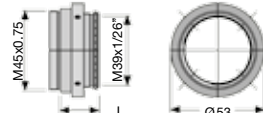
For camera configurations with tube length > 55 mm using extension rings **ZR-L**

### FA3 Focus adapter L-Mount (M39x1/26" Leica)

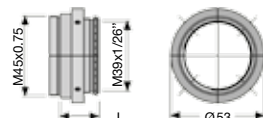
any rotation angle adjustable (V-groove)  
attachment thread M45x0.75, male



**FA22R-45** Order Code  
length L: 22 ... 32 mm



**FA22RL-45** Order Code  
length L: 29 ... 38 mm



### A3

### Lens Adapter F-Mount

for line scan cameras with case type **Axx** or **BGx**.



#### AOC-F-... Order Code

Attachment thread:  
45 = M45x0.75  
40 = M40x0.75  
32 = M32x0.75  
C = C-Mount 1"-32-TP

### ZR-L Extension rings M45x0.75

attachment threads M45x0.75 male/female

#### ZR-L.25 Order Code

15 = Length 15 mm  
25 = Length 25 mm  
60 = Length 60 mm  
87 = Length 87 mm

