SK12240U3KOC-LB

Color Line Scan Camera

4080 x 3 pixels 10 x 10 µm², line frequency up to 4.80 kHz

Color line scan camera (Triple-Line) with 3 x 4080 RGB pixels, 4.8 kHz maximum line rate, anti blooming and integration control.

Instruction Manual

Sample Configuration

1 CCD line scan camera
SK12240U3KOC-LB
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

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:

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!

Contents

1 Introduction

1.1 Intended Purpose and Overview

The SK line scan camera series is designed for a wide range of vision and inspection applications in industrial and scientific environments. The SK12240U3KOC-LB is highly portable and the robustly attached dedicated connections enable external synchronization of the camera and the output of data to the USB 3.0 port of the computer.

The USB 3.0 connection supplies power to the camera and the camera is hot-pluggable, providing the greatest degree of flexibility and mobility. The computer does not require a grabber board, allowing a laptop to be used when space or weight restrictions are also at a premium.

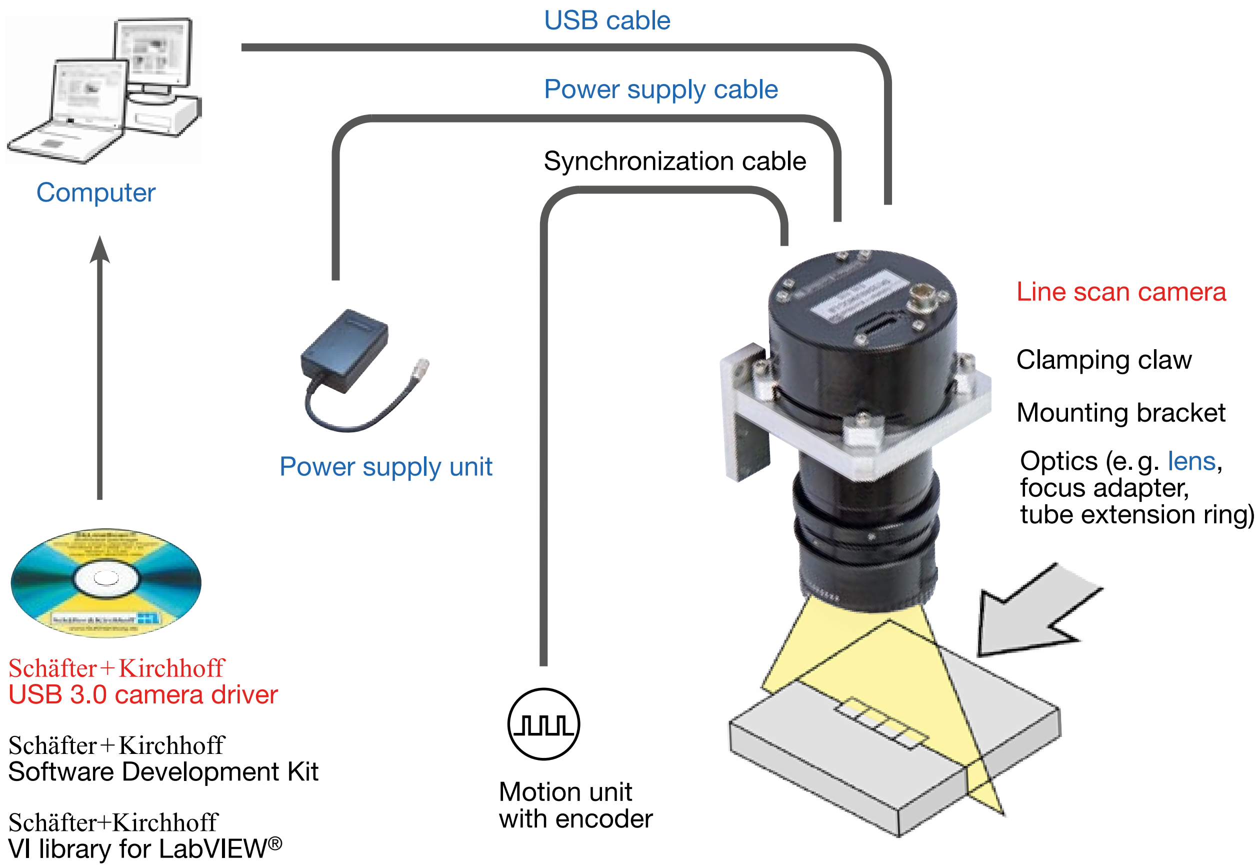
Once the camera driver and the SkLineScan® program have been loaded from the SK91USB3-WIN CD then the camera can be parameterized. The parameters, such as integration time, synchronization mode or shading correction, are permanently stored in the camera even after a power-down or disconnection from the 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 ***3.1 Software: SkLineScan (p. 10)***.

1.2 System Setup at a Glance

red: SK12240U3KOC-LB 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. 4 GB, depending on the size of acquired images
- USB 3.0 interface. With a USB 2.0 interface, there are limitations, see footer.
- High-performance video card, PCIe bus
- Operating Systems:
  Windows 7 / 8.1 / 10 (64 or 32-bit) or
  Linux kernel 3.13 or higher

1.4 SK12240U3KOC-LB Line Scan Camera - Specifications

Sensor category	CCD Color Sensor
Sensor type	KLI-4104
Pixel number	4080 x 3
Pixel size (width x height)	10 x 10 μm^2
Pixel spacing	10 µm
Line spacing, line sequence	90 µm, green (G) - red (R) - blue (B)
Active sensor length	40.8 mm
Anti-blooming	x
Integration control	x
Shading correction	x
Line synchronization modes	Line Sync, Line Start, Exposure Start, Exposure Active
Frame synchronization	x
Pixel frequency 2)	60 / 30 MHz
Maximum line frequency 1)	4.80 kHz
Integration time	0.01 ... 20 ms
Dynamic range	1:2500 (rms)
Spectral range	400 ... 700 nm
Video signal	color 8/12 Bit digital
Interface	USB 3.0
Voltage	5V DC (1.1A)
Power consumption 2)	5.5 W
Casing	Ø65 mm x 53.7 mm (Case type AT3L)
Objective mount	M45x0.75
Flange focal length	19.5 mm
Weight	0.2 kg
Permissible casing temperature	+5 ... +45°C

1) This camera is USB 2.0 downward compatible with the following limitation:
When connected to a USB 2.0 interface, the pixel data transfer rate is limited to 20 MByte/s and the line frequency is limited accordingly.

2) The maximum power supplied by an USB 3.0 interface is 4.5 Watt. This is sufficient up to a pixel frequency of 60 MHz.
When operated at 100 MHz pixel frequency or when connected to an USB 2.0 interface an external 5 V DC power supply unit is required (see section ***Accessories***).

The camera must be mounted thermally coupled so that the acceptable casing temperature is not exceeded during operation. Therefore applies to the thermal resistance of the bracket or heat sink:

$$R_{thHS} \leq \frac{\theta_{amb} - \theta_{casing}}{P_{camera}}$$

where

R_{thHS} [K/W] = thermal resistance of the bracket or heat sink

θ_{amb} [°C] = ambient temperature

θ_{casing} [°C] = temperature of the camera casing (not to be confused with the internal camera temperature that is queried and output with the request command I32)

P_{camera} [W] = camera power consumption

2 Installation and Setup

2.1 Mechanical Installation: Dimensions, Mounting Options, and Heat Dissipation

Mounting Options

When mounting the camera, pay attention to the following:

- Mechanical stability to avoid vibrations.
- Good thermal coupling for cooling the housing. The power consumption and the maximum housing temperature of the camera are specified in section ***1.4 - Specifications***.

The best fixing point of the camera is the collar for the mounting bracket SK5105-L (available as an accessory).

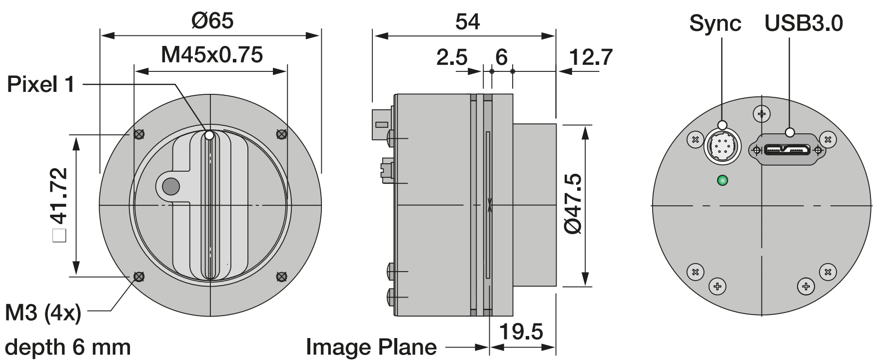
Four threaded holes M3 x 6.5 mm provide further options for customized brackets.

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.

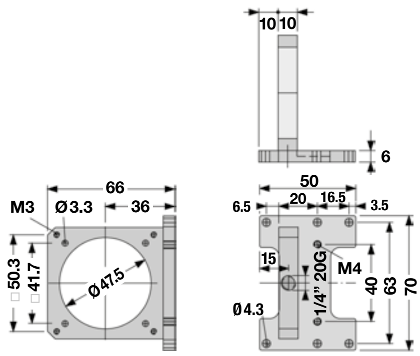
Optics Handling

- 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 AT3L



Mounting bracket SK5105-L

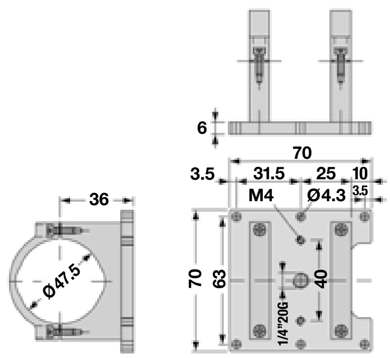


Clamping set SK5101

Set of 4 pcs. clamping claws incl. hex socket screws (EN ISO 4762–M3x12)

Mounting system SK5105-2L

for cameras with a tube extension > 52 mm



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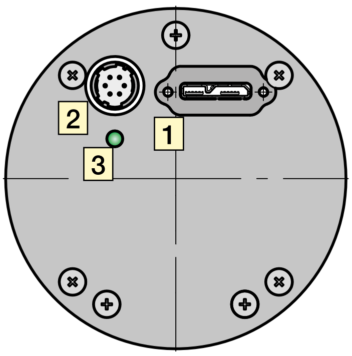
2.2 Electrical Installation: Connections and I/O Signals

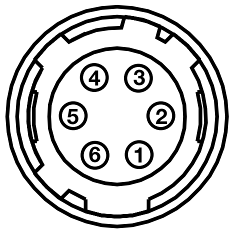
- The USB 3.0 interface provides data transfer, camera control and power supply capabilities to the SK12240U3KOC-LB line scan camera. The operating power can also be fed into socket 2. This is only mandatory when the camera is operated at 60 MHz or when it is connected to an USB 2.0 interface.
- If you want to operate the camera in FREE RUN trigger mode the connection is completed with the USB 3.0 cable provided the power supply is ensured.
- For any kind of synchronized operation the external trigger signal(s) have to be wired to socket 2 in addition. A frame synchronization signal and two separate line synchronization signals can be handled. The various trigger modes are particularly described in section ***Synchronization of the Image Acquisition with the Feed Rate of the Object (p. 18)***

All Schäfter+Kirchhoff USB 3.0 line scan cameras can be operated with a USB 2.0 interface. Note that there might be limitations in terms of the maximum data transfer rate. The details for your camera can be found in section ***1.4 Line Scan Camera - Specifications (p. 5)***.
If the power consumption of the camera exceeds 4.5 Watt (USB 3.0) or 2.5 Watt (USB 2.0), then connect an external source to socket 2.



1 **Data and power**
USB 3.0 socket type µB with threaded holes for locking screws

2 **Synchronization and power ***
Power: 5.5 W
Socket: Hirose series 10A, male 6-pin



Pin	Signal	Pin	Signal
1	Line Sync B	4	+5 V *
2	+15 V *	5	Line Sync A
3	Frame Sync	6	GND

* from external power supply unit
Line Sync A/B and Frame Sync: TTL levels

3 **Status indicator**

●	off	no power, check connection to the external power supply unit
●	red	power on
●	green	power on, firmware is loaded, camera is ready

Accessories (see also *Accessories (p. 36)***):**

USB 3.0 cable SK9020.3
For connecting socket 1 with the PC or USB hub. Standard length 3.0 m

Power Supply Unit PS051515
Input: 100-240 VAC, 0.8 A, 50/60 Hz IEC 320 C14 coupler
(for IEC C13 power cord)
Output: +5 V DC, 2.5 A / +15 V DC, 0.5 A / -15 V DC, 0.3 A
Cable length 1 m, with Lumberg connector KV60, female 6-pin
(for power cable SK9015.x or SK9016.x)

Power Cable SK9015.xMF
Use this cable to feed external supply voltage into socket 2.
Connectors:
Hirose plug HR10A, female 6 pin (camera side)
Lumberg SV60, male 6-pin connector (for supply voltage)
Length 1.5 m (standard) or 0.2 m

Combined Synchronization and Power Cable SK9016.1.5
Use this cable to feed external synchronization signals *and* supply voltage into socket 2.
Connectors:
Hirose plug HR10A, female 6 pin (camera side)
Lumberg SV60, male 6-pin connector (for supply voltage)
Phoenix 6 pin connector incl. terminal block (for synchronization signals)
Standard length 1.5 m

2.3 USB3 Connections and SkLineScan Software Installation

This section is a quick reference for installing the **SkLineScan** adjustment and configuration software and to set up the USB3 camera driver. 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 **SK91USB3-WIN**.

Step 1: Install **SkLineScan**. The setup program will automatically install the Schaefter+Kirchhoff USB3 Line Scan Camera Driver.

Step 2: Plug in the USB3 connection cable to the camera. if appropriate switch on the external power supply.

Step 3: Start the **SkLineScan** program.

SkLineScan Installation and Automatic Camera Driver 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:

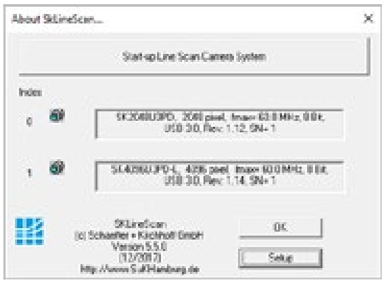
SkLineScan-USB3-Win_x64.msi
SkLineScan-USB3-Win_x86.msi
SK91USB3-Win_x64.msi
SK91USB3-Win_x86.msi

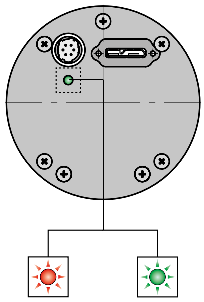
Then start the applicable installation file manually. This will set up the Schäfter+Kirchhoff **SkLineScan** camera control and adjustment tool as well as the USB3 Line Scan Camera Driver.

SkLineScan Start-up

- Start SkLineScan.
- A start-up dialog box pops up and displays the connected camera(s) that have been automatically detected. It also indicates the active USB standard. The optimum performance is provided by USB 3.0.
- The camera LED changes from red to green color light.

Desktop Icon



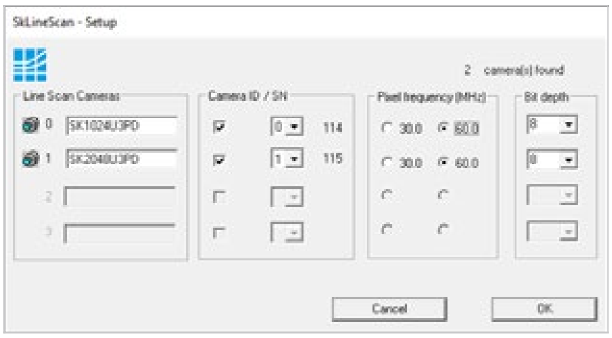


Camera Setup

Use the Setup dialog for

- activating/deactivating a connected USB3 camera (activated device is ticked)
- changing the pixel frequency
- setting the bit depth of the video signal to 8 or 12-bit

In USB 2.0 mode the lower pixel frequency and 8-bit video signal is recommended

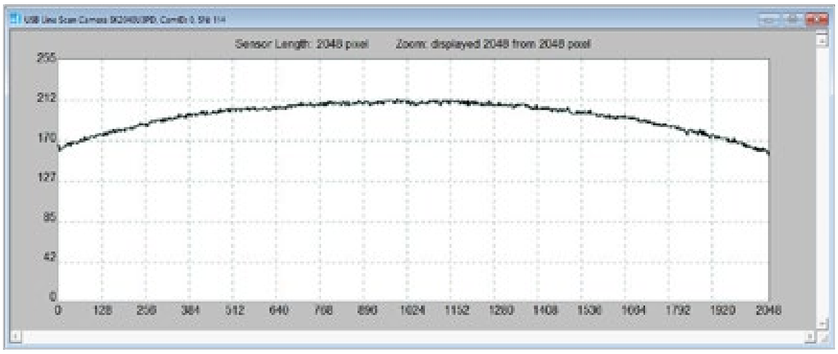


SkLineScan Setup dialog

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/supporte.html***.

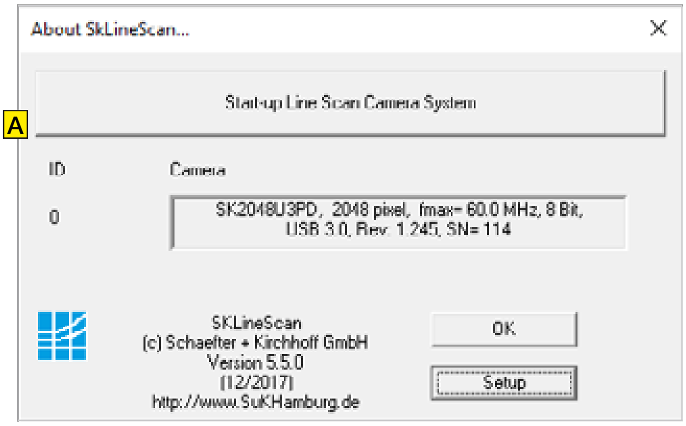
> Detailed instructions on how to obtain optimal image data and use the data with the Schäfter+Kirchhoff software package can be found in the ***SkLineScan Software Manual***.
>
> The most common functions of the line scan camera can be controlled by menu items and dialog boxes.
>
> In the "Camera Gain / Offset Control" dialog there is a command line for entering further control commands.

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.

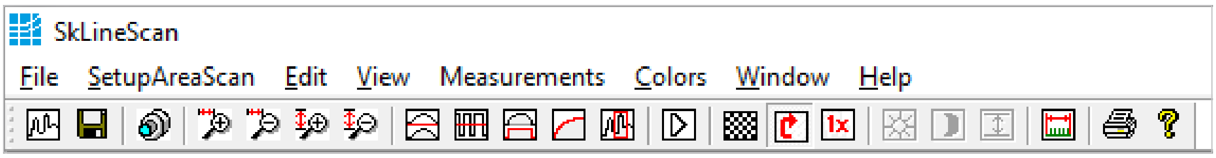
If the SK12240U3KOC-LB camera is identified correctly, confirm with "OK". The "Signal window" graphicaly showing the intensity signals of the sensor pixels (oscilloscope display) will open. It is responsive in real-time and the zoom function can be used to highlight an area of interest. The oscilloscope display is ideally suited for parameterizing the camera, for evaluating object illumination, for focussing the image or for aligning the line scan camera correctly.

A



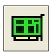
SkLineScan: Start-up dialog

Function Overview: SkLineScan Toolbar

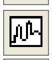


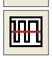
SkLineScan: Toolbar

 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

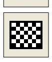
  Zooming in and out

 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]

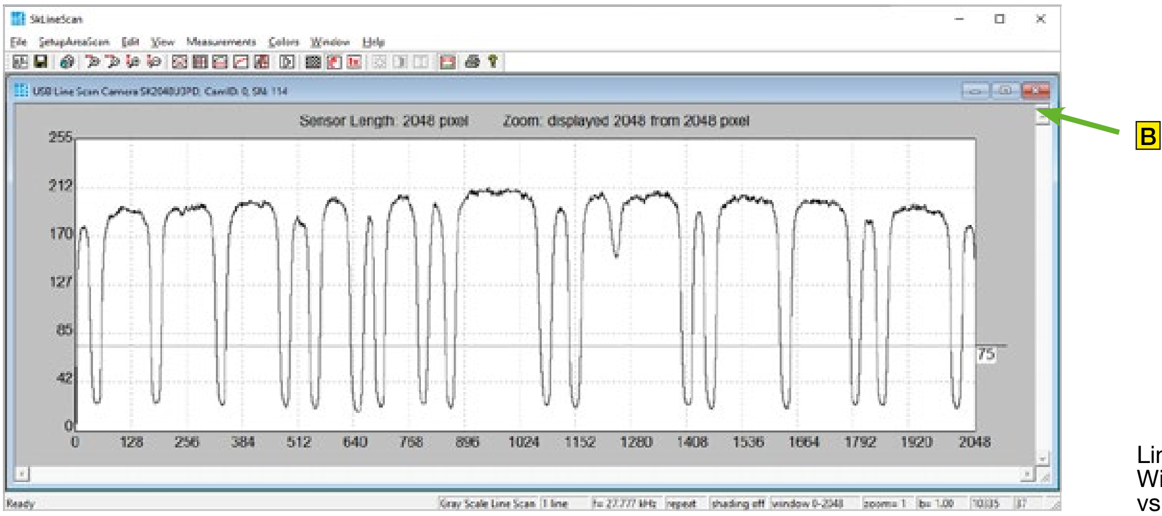
 "Gain/Offset Control" dialog, also for commands input [Shif+F4]

 New area scan

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.



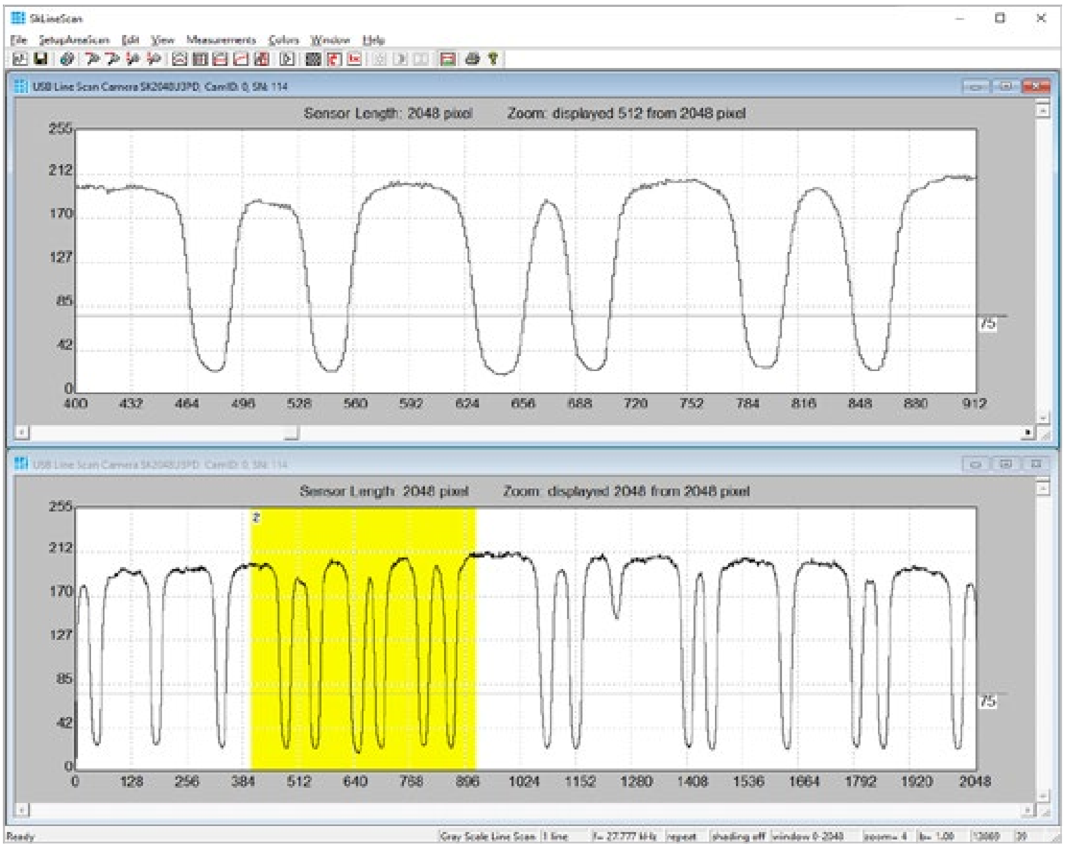
Line scan in Signal Window: brightness vs. pixel number

- **Zoom Function**

With a high number of sensor pixels, details are lost due to the limited number of display pixels. With the zoom function you select a part of the sensor for the detailed display. The possible magnification ranges up to the representation of the intensity signal of individual pixels.

- **Window Split Function**

The signal window can be divided horizontally into two areas. Use the slider **B** at the top of the vertical scroll bar. If you then use the zoom function in one frame, the selected section in the other frame will be highlighted in yellow.



Line scan in split signal window: The upper frame shows an enlarged 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.

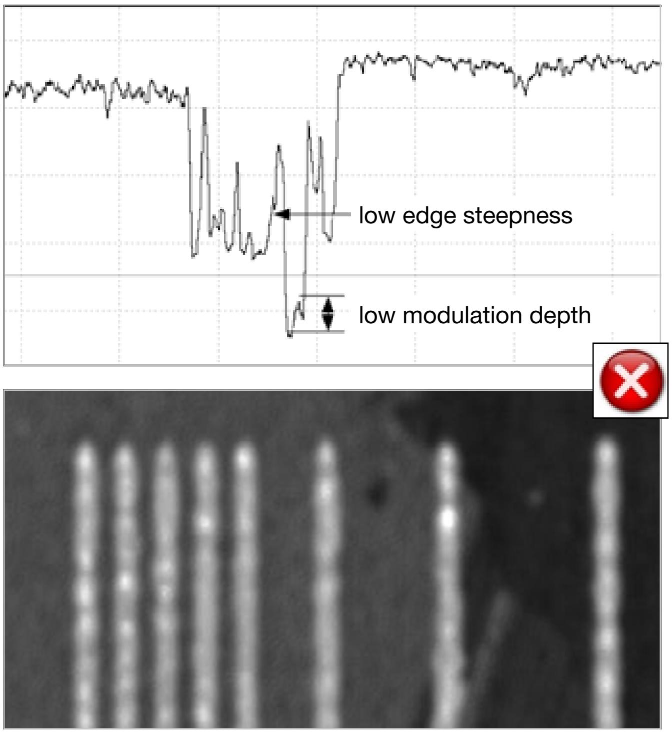
Start with the signal window / oscilloscope display. Any changes in the optical system or camera parameters are displayed in real-time when using an open dialog box.

Lens Focussing

The real time Signal Window 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.

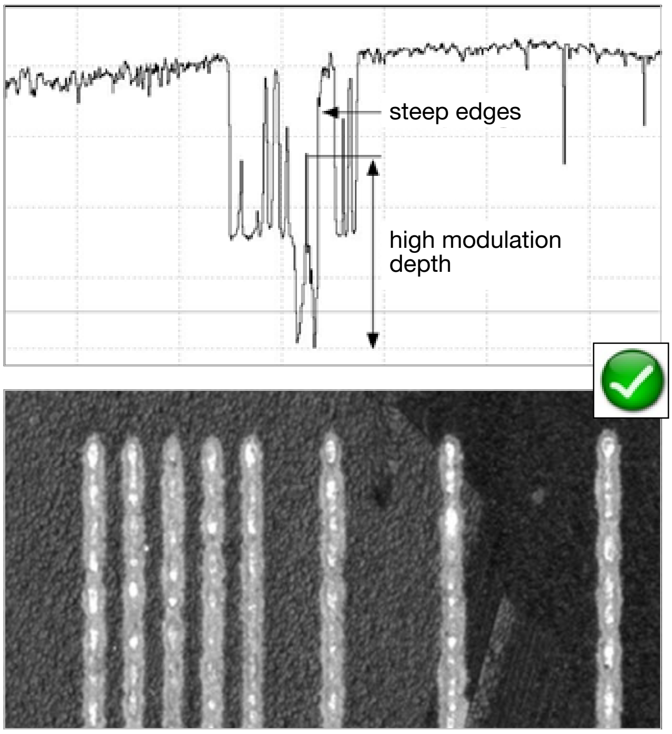
Adjust the focus with the aperture fully open to limit the depth of field and enhance the effects of changing the working distance.

If the sensor is overloaded when the aperture is fully open, the easiest way to reduce the signal amplitude is to shorten the integration time, as described in section *Optimum brightness adjustment, Integration Time (p. 17)*.



Out-of-focus:

- Low edge steepness
- Signal peaks are blurred
- High spatial frequencies with low modulation depth



Optimum focus:

- Dark-bright transitions with steep edges
- Large modulation in the signal peaks
- High spatial frequencies with high modulation depth

Sensor Alignment

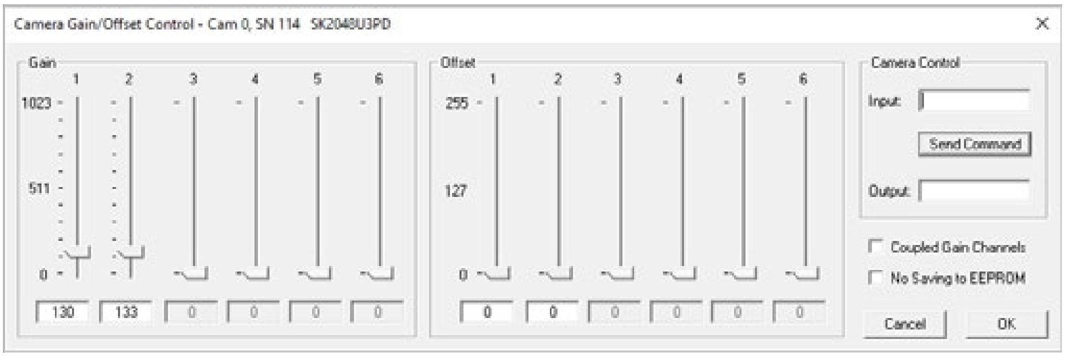
If you are using a linear light source, check the alignment of the light source and sensor before shading correction, as rotating the line sensor will result in asymmetric vignetting.

Sensor and line lighting slightly twisted in relation to each other, asymmetric vignetting

Sensor and line lighting aligned in parallel, symmetric vignetting

Gain/Offset Adjustment

The cameras are supplied with factory-set gain/offset. Open the "Gain/Offset Control" dialog to adjust 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. If "Coupled Gain Channels" is checked, all channels are set synchronously with one slider.

Enter commands for advanced software functions in the 'Camera Control' field (see page *10*).

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.

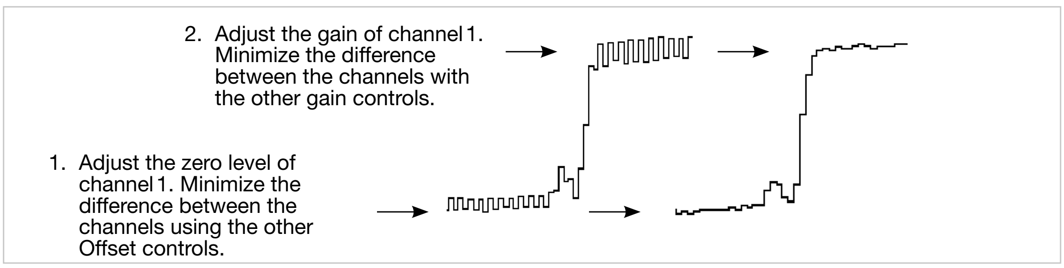
A slight signal noise should be visible in the zero baseline.

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.



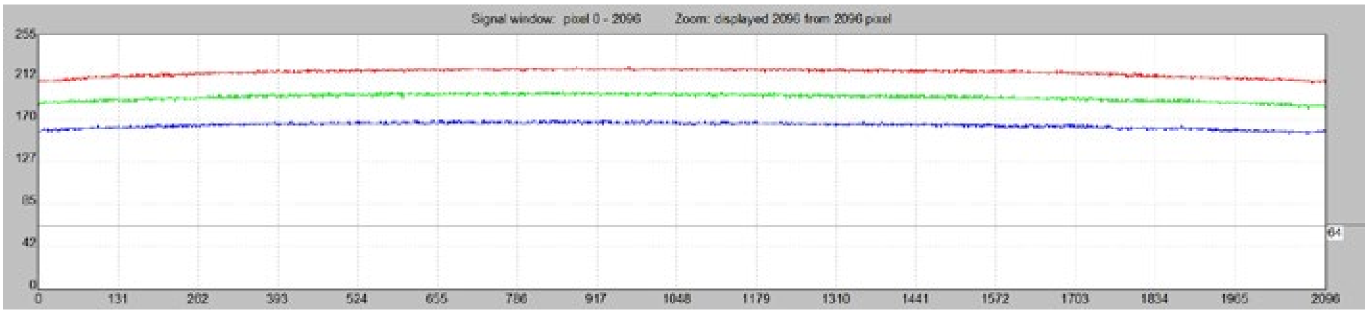
Offset and gain adjustment for more than one gain/ offset channel

White Balance and Shading Correction

Shading Correction compensates for non-uniform illumination and 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. The result is a leveled signal along the full sensor length. A shading correction with a balanced RGB sensitivity ensures a natural color reading. 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.

Step 1: White Balancing

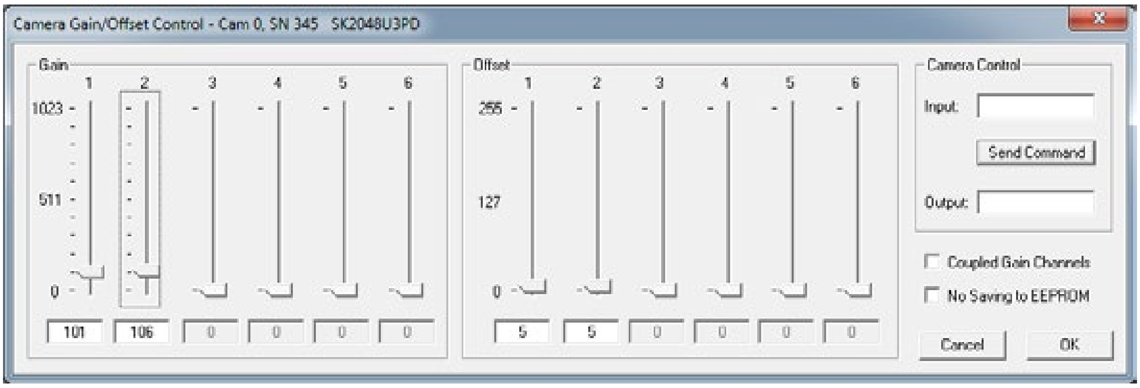
- Use a homogeneous white object, e.g. a white sheet of paper, to acquire the RGB line signals.



Color line signal with separated RGB curves

White Balancing by Gain Adjustment

- Open the "Gain/Offset Control" dialog. Use the gain sliders to adjust all three curves to the same level. Some camera models provide two gain/offset channels - thus two sliders - per color.



"Gain/Offset Control" Dialog

White Balancing by Individual Integration Time Control

In some circumstances, it is not possible to adjust the white balance using the gain setting because of:

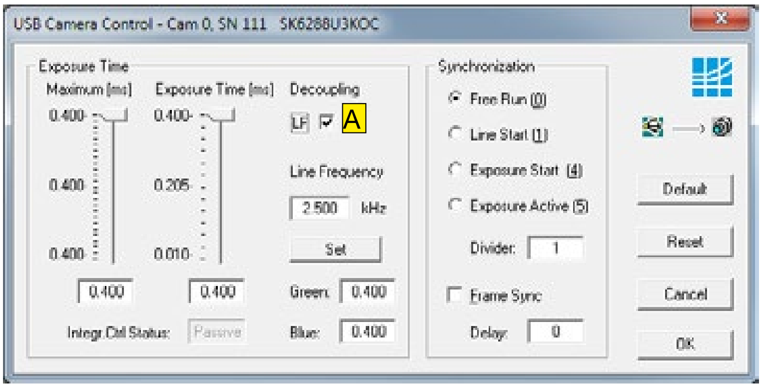
- dynamic limitations from a very intensive or weak illumination,
- undesired changes in noise level.

This approach is only available for camera models providing **Integration Control** function, see camera specifications page *5*.

For such situations, an individual adjustment of integration times for the Red, Green, and Blue channels is available, for a general description of the integration time adjustment, see section *Optimum brightness adjustment, Integration Time (p. 17)*.

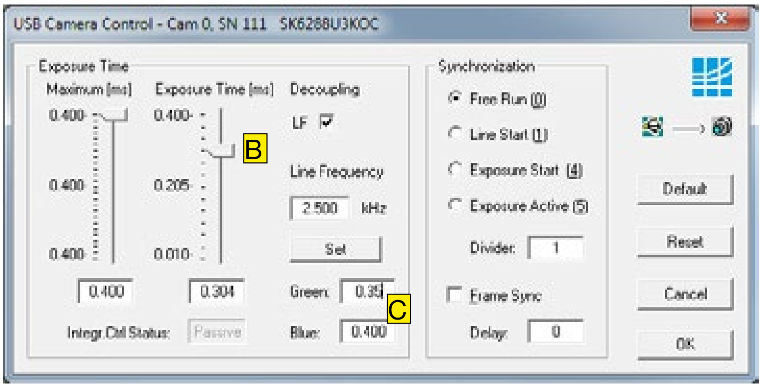
Check that the weakest color signal is higher than about 70%. If necessary, adjust the line frequency or the illumination intensity accordingly.

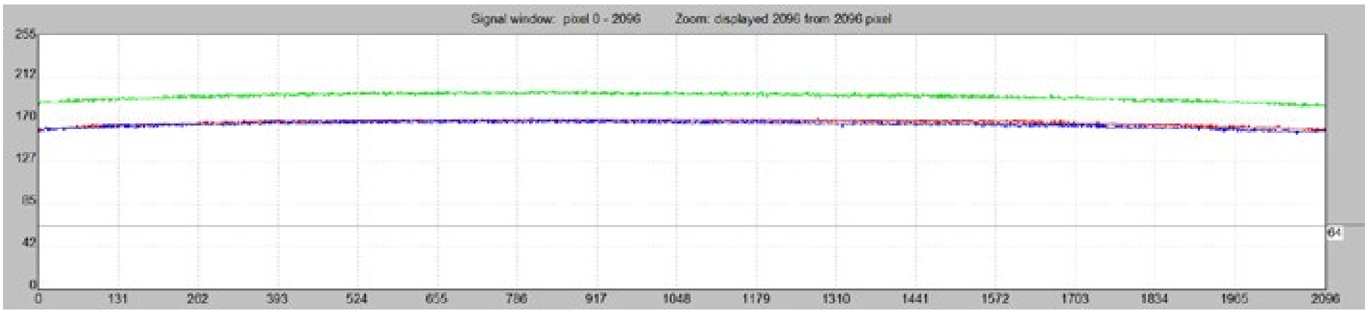
Tick the box "Decoupling LF" A in the "Camera Control" dialog.



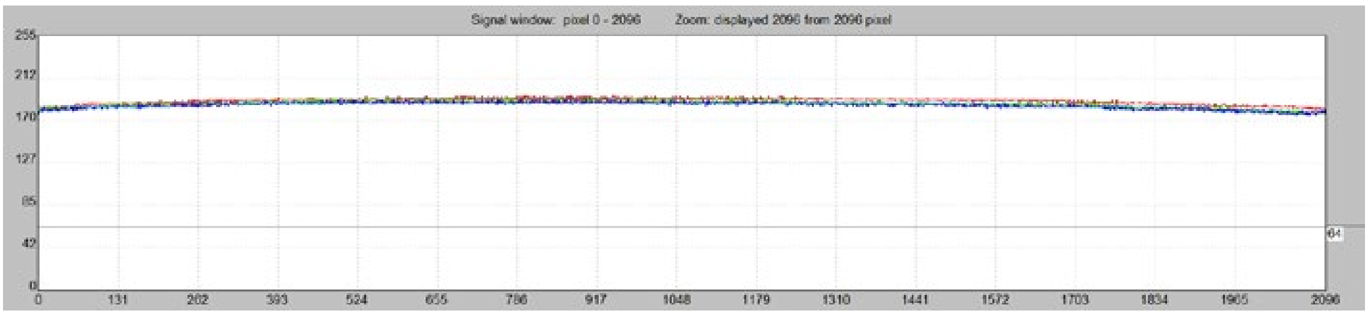
Reduce the integration times for the two color channels with the higher signals in order to align the Red, Green and Blue channels to the same level.

The Red channel is adjusted using the slider "Exposure Time". B
For the Green and Blue channels, enter the exposure time into the respective boxes. C





Color line signal with the Red signal adjusted to that of the Blue channel; the Green channel is still separate



Color line signal with balanced RGB curves

Step 2: Obtaining the Shading Correction Data

The shading correction refrence data that is stored in the shading correction memory (SCM) can be obtained in two ways:

a) Using a white homogeneous background

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

  Use the entries in the left column to obtain shading correction reference data from a white homogeneous background.
- Use a homogeneous white object to acquire the reference data, e.g. a white sheet of paper.
- Either take a 2-dimensional scan ("Area Scan Function" [F3]) or

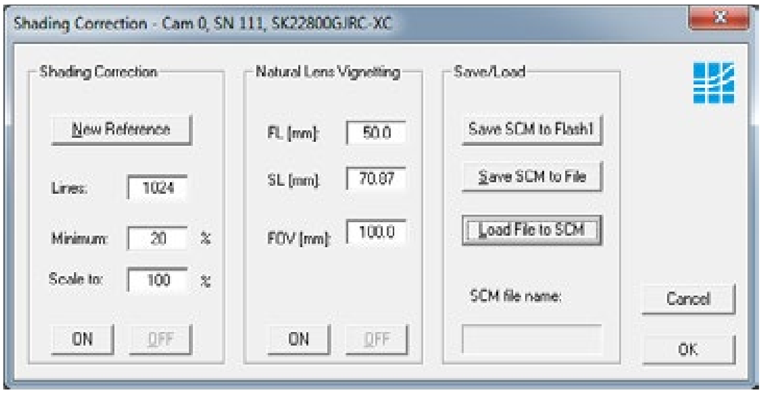
  use a single line signal that was averaged over a number of single line scans.
- To suppress any influence from the surface structure, move the imaged object during the image acquisition.
- Input the scale range:

  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.
- Click on button **New Reference**
- Click on **Save SCM to Flash** to save the SCM reference signal in the flash memory of the camera



Shading Correction dialog

Parameters for correction of natural lens vignetting:

FL	=	Focal Length of the lens in mm
SL	=	Sensor Length in mm
FOV	=	Field Of View in mm

Save SCM to Flash	Save the SCM reference signal in the flash memory of the camera
ON	Activate Shading Correction with the reference signal that is stored in the SCM.
OFF	Switch off Shading Correction. This does not affect the content of the camera SCM buffer or the camera flash memory.
Save SCM to File	The SCM reference signal will be stored in a file.
Load File to SCM	A stored reference signal will be loaded into the SCM of the camera. If the load process completes then the Shading Correction is active.

b) Analytic compensation of natural lens vignetting

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

  Use the entries in the middle column to calculate the reference data based on the imaging setup.
- Enter the parameters focal length (FL), sensor length (SL) and field of view (FOV) according to your setup.

  The implemented algorithm will compensate the natural lens vignetting.
- Click on **Save SCM to Flash** to save the SCM reference signal in the flash memory of the camera

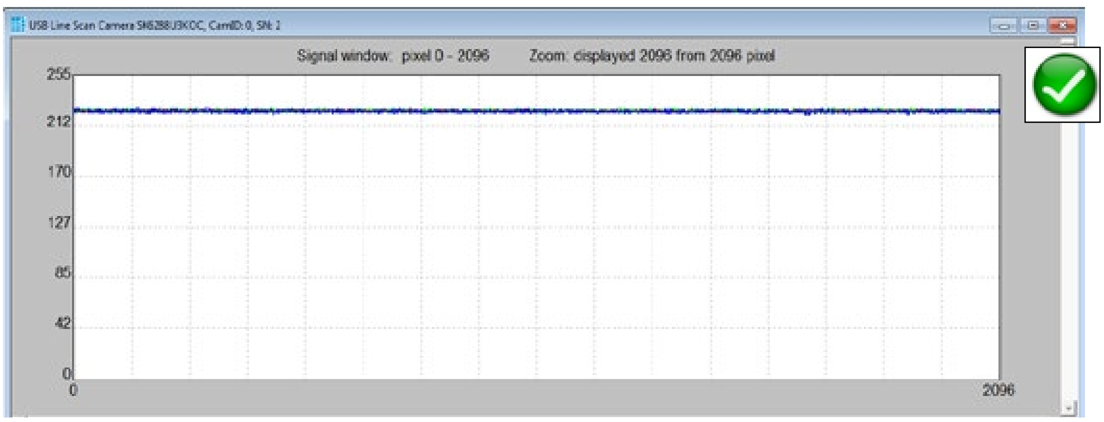
Power-down and Power-up Behaviour

The shading correction memory (SCM) buffer is a volatile memory. Its content is lost on power-off.

Once the reference signal is copied from the SCM to the camera flash memory, it will persist even after a power-down. On a re-start, this data will be restored automatically from the flash memory back into the SCM.

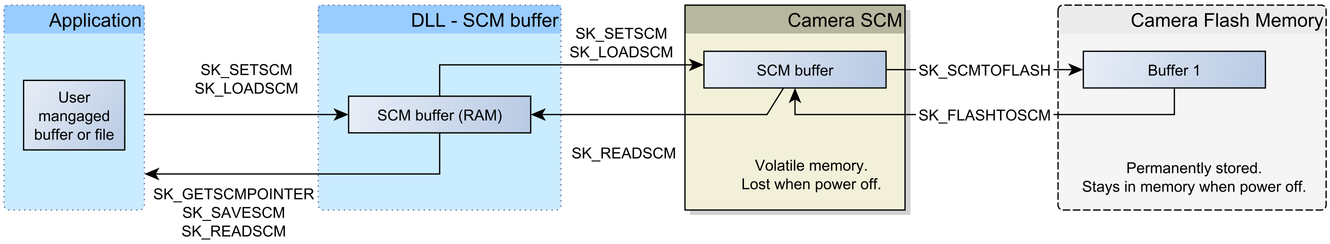
The shading correction status on shutting down - active or not active - will be retained and automatically restored on power-up.

Color line signal with separated RGB curves after Gain Adjustment and Shading Correction



Shading Correction Memories and API Functions

As an alternative to the user dialog, a new shading correction reference signal can also be generated using API (Application Programming Interface) functions. The relationship between the memory locations and the related API functions are shown in the following figure. The API functions are included in the SK91USB3-WIN software package. For more information, refer to the ***SK91USB3-WIN manual***.



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

Optimum brightness adjustment, Integration Time

The brightness distribution of the line signal is influenced not only by the integration time, but also by the illumination and the aperture setting. It should be noted that the aperture setting affects the depth of field and thus the overall quality of the image.

The line signal is optimal if the signal from the brightest area of the object corresponds to 95% of the maximum output value. At 8-bit digitizing depth, 256 brightness levels are available, at 12-bit 4096. In this setting, optimum signal sensitivity is achieved and overexposure or even blooming is avoided.

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

- 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.
- For cameras with integration control function (shutter), it is possible to shorten the integration time without increasing the line frequency. This integration control mode is activated as soon as the maximum line frequency of the camera is reached by shortening the integration time or by checking **Decoupl. LF** and thus the integration time is decoupled from the line frequency.

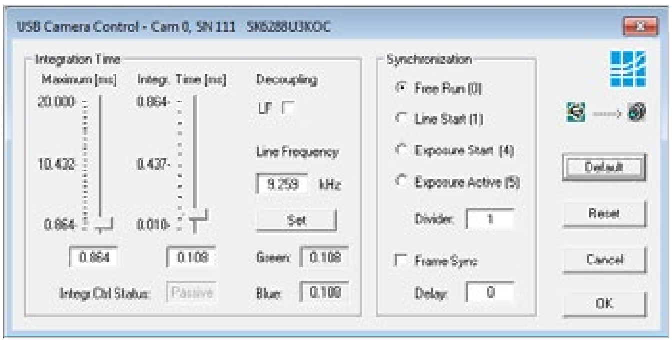
The **Default** button sets the integration time to the minimum exposure period that is determined from the maximum line frequency.

Reset restores the start values.

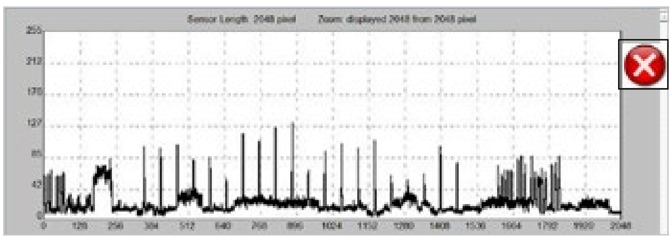
Cancel closes the dialog without changes.

OK stores the integration time values and closes the dialog.

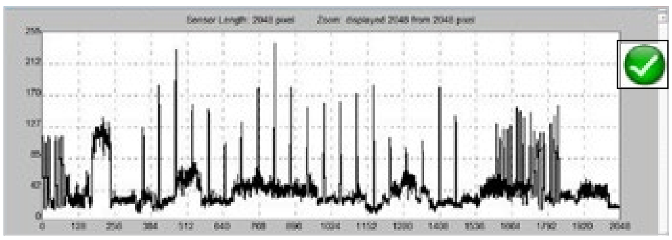
For synchronization settings, see section *Synchronization of the Image Acquisition with the Feed Rate of the Object (p. 18)*.



SkLineScan Camera Control dialog



A camera signal with insufficient level: The integration time is too short, since only about 50% of the gray levels are used.



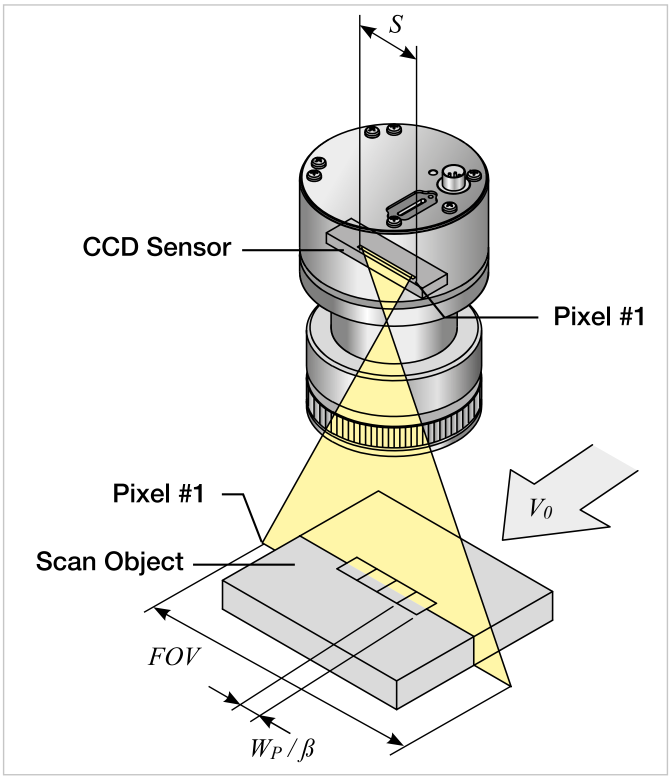
Optimized level of the camera signal after increasing the integration time by a factor of 4 to 95 % of the available scale.

Synchronization of the Image Acquisition with the Feed Rate of the Object

A line scan camera produces a two-dimensional image by moving either the object or the camera. The direction of the translation movement must be orthogonal to the sensor axis of the line scan camera.

In order to obtain an image with the correct aspect ratio, a line synchronous feed is required. With RGB color sensors, the color sequence of the individual sensor lines must also be taken into account when processing the sensor data. The software development kits from Schäfter+Kirchhoff contain easy-to-use functions for this purpose.

If the object speed is variable or the accuracy requirements are high, external synchronization is required. The various synchronization modes are described in the next section.



The optimal scan speed for a given line frequency is calculated as follows:

$$V_O = \frac{W_P \cdot f_L}{ß}$$

If the scanning speed is fixed, the line frequency must be adjusted accordingly in order to obtain the correct aspect ratio in the image:

$$f_L = \frac{V_O \cdot ß}{W_P}$$

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

Example 1:

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

Pixel width	= 10 µm
Line frequency	= 4.80 kHz
S	= 40.8 mm
FOV	= 70 mm

$$V_O = \frac{10\,\mu m \cdot 4.80\,kHz}{(40.8\,mm / 70\,mm)}$$

$$= 82\,mm/s$$

Example 2:

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

Pixel width	= 10 µm
Scan velocity	= 80 mm/s
S	= 40.8 mm
FOV	= 70 mm

$$f_L = \frac{80\,mm/s \cdot (40.8\,mm / 70\,mm)}{10\,\mu m}$$

$$= 4.7\,kHz$$

Synchronization Modes

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

There are two different synchronization functions that can be applied together or individually:

1. **Line synchronization:**

The falling edge of a TTL signal at the LINE SYNC A input triggers each individual exposure of the sensor line by line.

The SK12240U3KOC-LB line scan camera enables extended synchronization control by means of a second trigger input LINE SYNC B. A detailed description can be found .under ***Advanced Synchronization Control, S. 24***.

2. **Frame synchronization:**

The recording of a set of lines (frame) representing a two-dimensional image is started by the falling edge of a TTL signal at the FRAME SYNC input.

Free Run / SK Mode 0

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

LineStart / SK Mode 1

After an external trigger pulse, the currently exposed line is read out at the next internal line clock. The start and duration of the exposure are controlled internally by the camera and are not affected by the trigger pulse. The exposure time is programmable. The line frequency is determined by the frequency of the trigger signal.

Limitations: The period of the trigger signal must be longer than the exposure time used. Between the external trigger signal and the internally generated line clock, jitter occurs in the range of the exposure time.

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

A new exposure is started exactly at the point in time of the external trigger pulse. The exposure time is determined by the programmed value. The exposed line is read out after the exposure time has elapsed. The frequency of the trigger signal determines the line frequency.

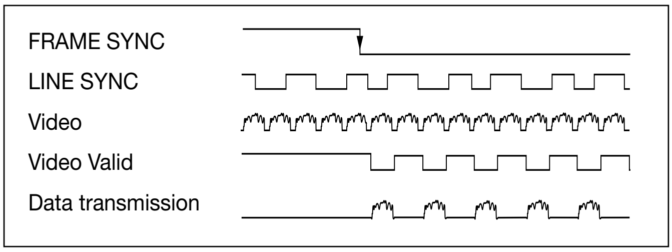
Restriction: The period duration of the trigger signal must be longer than the exposure time used.

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 readout of the previously exposed line.

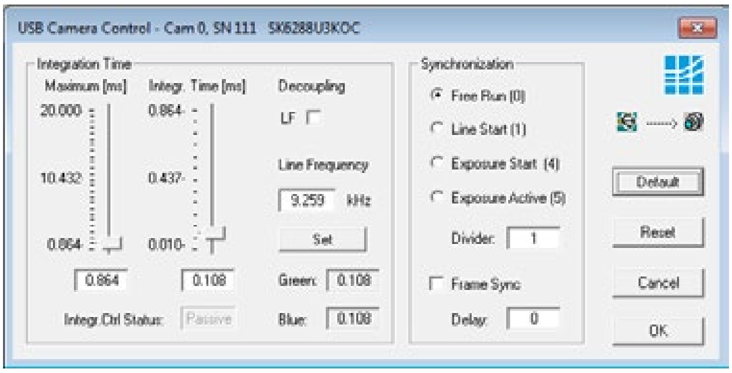
FrameTrigger / SK FrameSync

The camera suppresses the data transfer until a falling edge of a TTL signal occurs at the FRAME SYNC input. This starts the acquisition of a 2D area scan. The number of image lines must be programmed in advance. Any of the available line synchronization modes can be used for the individual line scans.

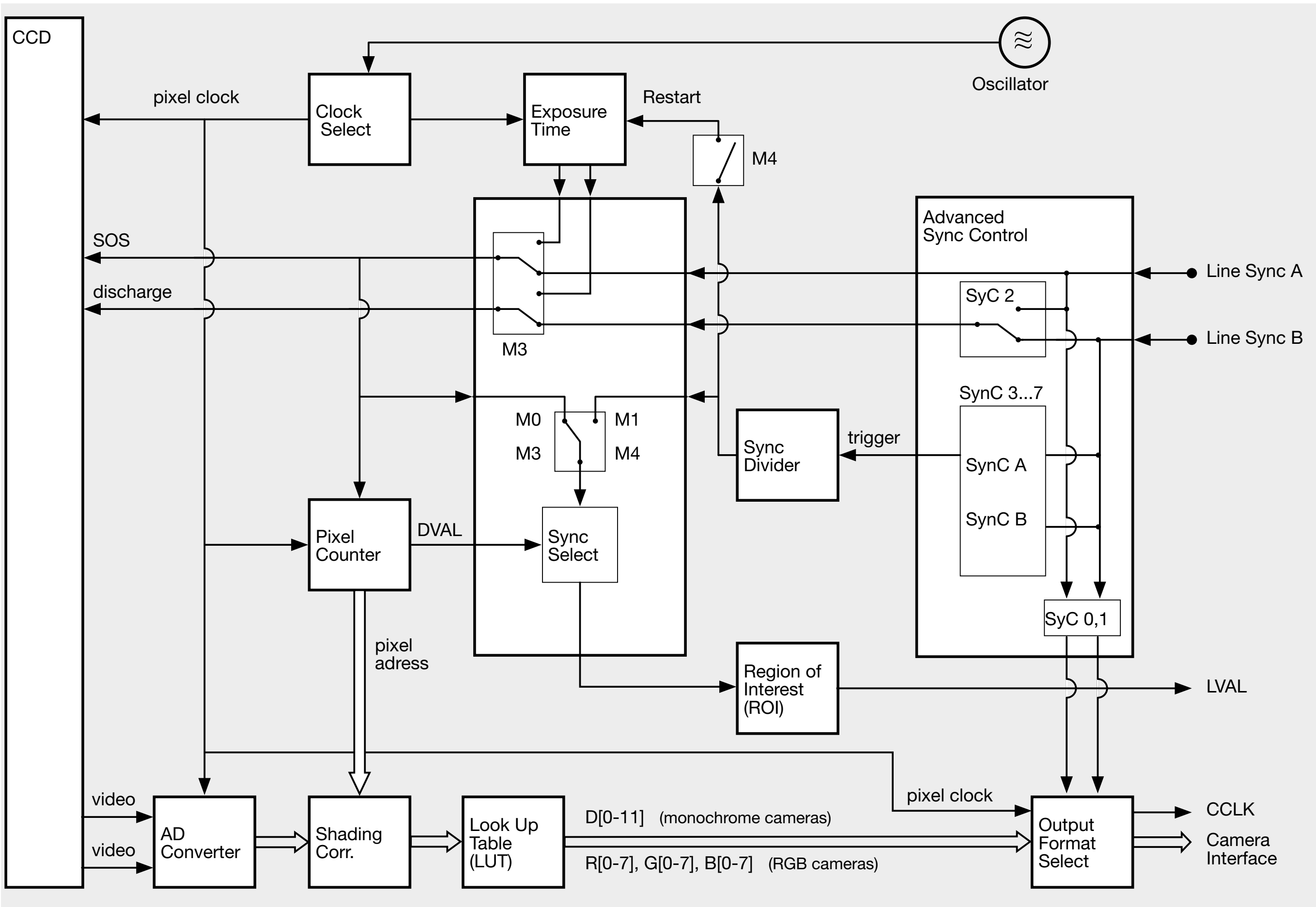


Combined frame and line synchronization

- To configure synchronization, open the **Camera Control** dialog. [F4]
- Within the **Synchronization** frame, select one of the numbered line synchronization modes.
- Within the camera, the trigger control stage is followed by a divider stage with which the trigger frequency can be divided by integer dividers. Enter the division ratio in the **Divider** field.
- Select the **Frame Sync** check box to activate frame synchronization. In the **Delay** field, enter the delay time in milliseconds.



Camera Control dialog

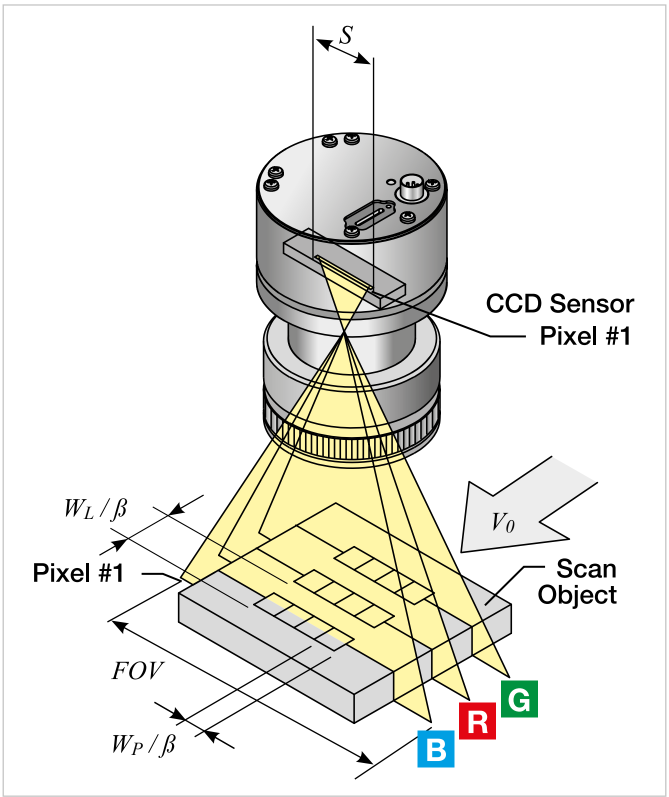


Functional diagram of the Camera Control System

RGB Sensors: 2D Imaging and Pixel Allocation

The three lines of the implemented triple line sensor are sensitive for the primary colors green (G), red (R) and blue (B). For the spectral sensitivity characteristics, see section ***5 Sensor Information***. The pixel width W_P is 10 µm and the line spacing W_L of 90 µm is 9 times the pixel width.

During object travel, an object point reaches the green (G) line sensor first. If the object is translated by one pixel height per clock pulse then after 9 lines the red (R) pixels are exposed. After another 9 lines then the blue (B) pixels have been covered and all color information has been acquired.



V_O: object scan velocity

W_P: pixel width = pixel height H_P (for sensors with square pixels)

W_L: line spacing

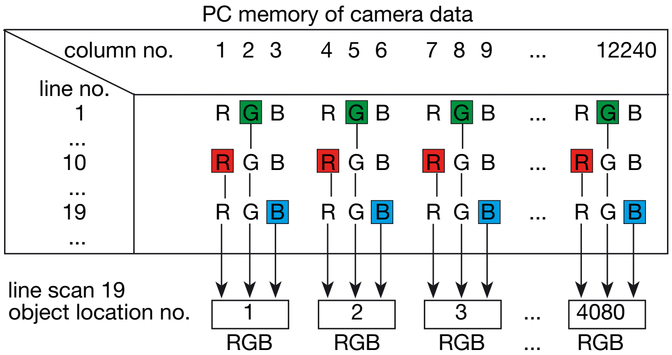
S: sensor length

FOV: field of view

β: magnification = S / FOV

The Camera SK12240U3KOC-LB outputs the green (G), red (R) and blue (B)-information sequentially in one single video output signal.

The color information originating from the different parts of the object is stored in the buffer of the PC and subsequently reallocated correctly.



Generating the color information of object locations for display

Triple line sensors require a precise synchronous translation of the object for the correct allocation of pixels. Also, the transport direction has to conform to the sequence of the line acquisition: first green (G) then red (R) and blue (B).

Images with color convergence aberrations are generated, when these conditions are not met.

Monochrome font pattern

A line synchronous object transport

B asynchronous transport of the object causes color convergence aberration

4 Advanced Camera Control Functions

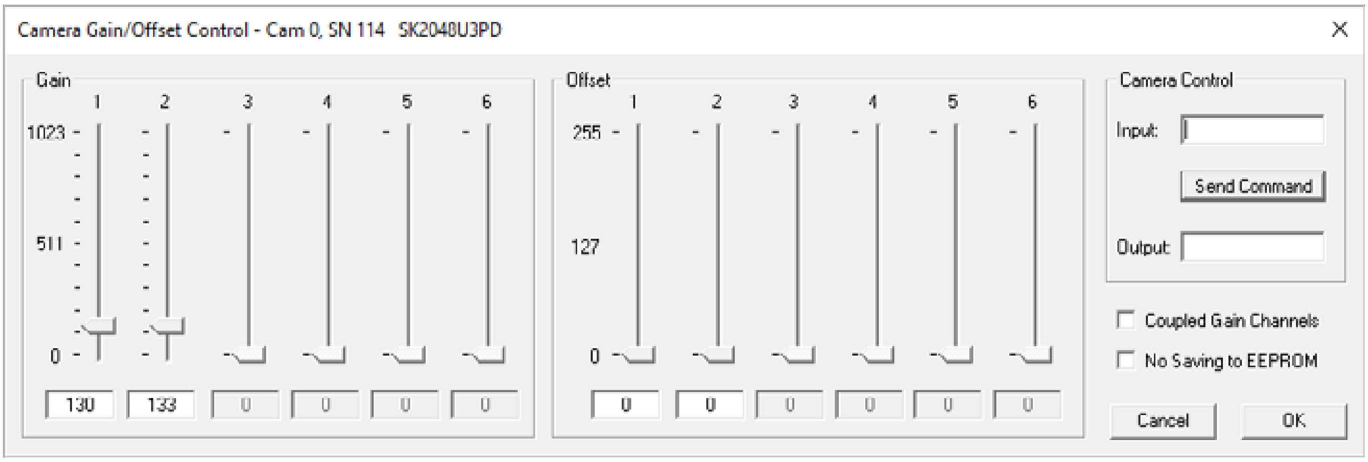
4.1 Camera Control by Commands

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
G*oooo*<CR>	gain 1 (red odd) setting 0-24 dB
B*oooo*<CR>	gain 2 (red even) setting 0-24 dB
H*oooo*<CR>	gain 3 (green odd) setting 0-24 dB
O*ppp*<CR>	offset 1 (red odd) setting
P*ppp*<CR>	offset 2 (red even) setting
Q*ppp*<CR>	offset 3 (green odd) setting
F8<CR>	output format: 8 bit output data
F12<CR>	output format: 12 bit output data
C60<CR>	camera clock: 60 MHz data rate
C30<CR>	camera clock: 30 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 LUT Memory
T8<CR>	save LUT Memory to Flash Memory 2
T9<CR>	output data = LUT data
L*ppp*<CR>	set threshold level
M0<CR>	line trigger mode0: free run (no triggering) at selected line rate
M1<CR>	line trigger mode1: extern trigger, next line
M2<CR>	line trigger mode0: free run (no triggering) at maximum line rate
M4<CR>	line trigger mode4: external triggering and restart
M5<CR>	line trigger mode5: extern SOS, all lines
Mx+8	frame trigger external, start on falling edge
Mx+16	frame trigger external, active low
A*xxxx*<CR>	SCM address (xxxxx = A0-A12239) or LUTM (xxxxx = A32768-A36863)
D*xxxx*<CR>	Memory data (*xxxx* = 0-4095), increment memory address counter
E*yyyyy*<CR>	frames / multiframe (*yyyyy* = 0-32767)
EF*yyyyy*<CR>	external frame trigger delay (*yyyyy* = 0-32767 lines)
N*yyyyy*<CR>	lines / frame (*yyyyy* = 1-32767)
W*yyyyy*<CR>	line clock frequency (*yyyyy* = 50-4800) [Hz]
WL*yyyyy*<CR>	Window Pixel length (*yyyyy* =1-Line length)
WF*yyyyy*<CR>	Window First Pixel (*yyyyy* = 1-Line length)
X*yyyyy*<CR>	exposure time (*yyyyy* = 10-20000) [µs]
X*yyyyy*<CR>	exposure time (*yyyyy* = 10-20000) [µs] or if DXT=on: exposure time red (*yyyyy* = 10-20000) [µs]
XG*yyyyy*<CR>	exposure time green (*yyyyy* = 10-20000) [µs]
XB*yyyyy*<CR>	exposure time blue (*yyyyy* = 10-20000) [µs]
V*yyyyy*<CR>	extern sync divider (*yyyyy* = 1-32767)
Y*ppp*<CR>	set sync control (*ppp* = 255)
SCOG<CR>	enable COG (coupling of gain settings)
RCOG<CR>	disable COG (coupling of gain settings)

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

SDXT<CR>	enable DXT (decoupling of line clock frequency and exposure time)
RDXT<CR>	disable DXT (decoupling of line clock frequency and exposure time)
SLUT<CR>	enable LUT
RLUT<CR>	disable LUT
SNES<CR>	enable NES (no EEPROM save)
RNES<CR>	disable NES (no EEPROM save)
RESET<CR>	reset Memory to manufacturer default

Request Commands

Request	Return	Description
K<CR>	*SK12240U3KOC-LB*	returns **SK** type number
R<CR>	*Rev. 1.24*	returns **R**evision number
S<CR>	*SNr00163*	returns **S**erial number
I<CR>	*SK12240U3KOC-LB Rev. 1.24 SNr00163*	camera identification readout
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>	Ga: *yyyyy*	returns gain 1
I7<CR>	Ga2: *yyyyy*	returns gain 2
I8<CR>	Of: *yyyyy*	returns offset 1
I9<CR>	Of2: *yyyyy*	returns offset 2
I10<CR>	Ga3 *yyyyy*	returns gain 3
I12<CR>	Of3: *yyyyy*	returns offset 3
I14<CR>	THL: *yyyyy*	returns threshold level
I19<CR>	Tab: *yyyyy*	returns number of 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
I39<CR>	KST: *yyyyy*	returns Status

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

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)**.

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

Y*ppp*<CR>	**set SCR** 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 (SCR) 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 jitter in the encoder signal, 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 Hysterese off	x	x	x	0	0	x	x	x
Jitter Hysterese 4	x	x	x	0	1	x	x	x
Jitter Hysterese 16	x	x	x	1	0	x	x	x
Jitter Hysterese 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)
*xxxxxx*00	intensity	intensity
*xxxxxx*01	D7 = FRAME SYNC D6 = LINE SYNC A D5 = LINE SYNC B D4 ... D0 = 0	intensity
*xxxxxx*10	internal line counter (8 bit)	intensity
*xxxxxx*11	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

Annotations:

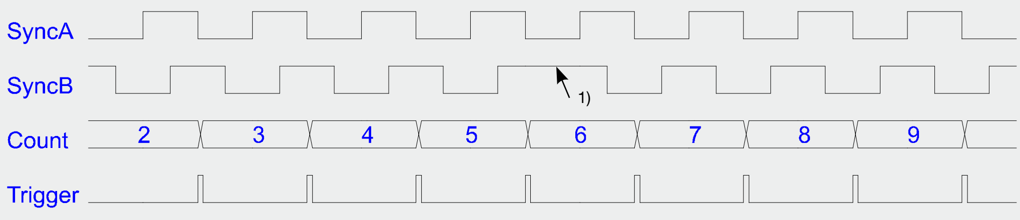
SyncA	=	LINE SYNC A (external line synchronization input, I/O connector)
SyncB	=	LINE SYNC B (external line synchronization input, I/O connector)
Count	=	internal counter
Trigger	=	Generated trigger pulses from the Trigger Control stage. The signal goes to the Trigger Divider stage inside the camera. 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

A

- Trigger on falling edge of SyncA
- SyncB without function
- direction detection = off
- hysteresis = 0

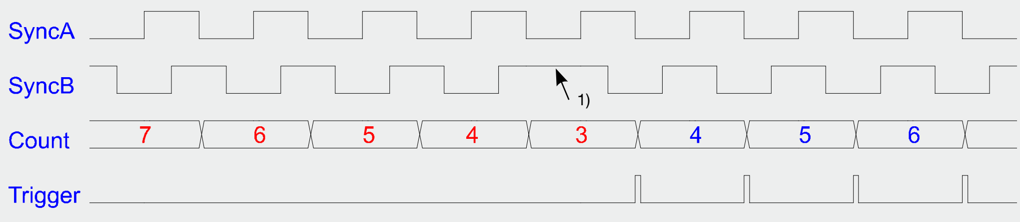
Sync Control Register:
'0xxx xxxx'b



B

- Trigger on falling edge of SyncA
- SyncB low active
- direction detection = on
- hysteresis = 0

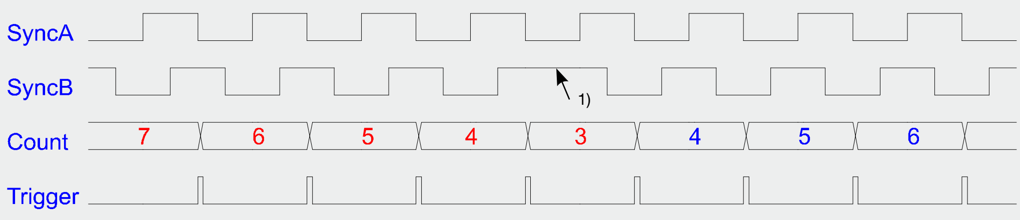
Sync Control Register:
'1000 0xxx'b



C

- Trigger on falling edge of SyncA
- SyncB low/high active
- direction detection = off
- hysteresis = 0

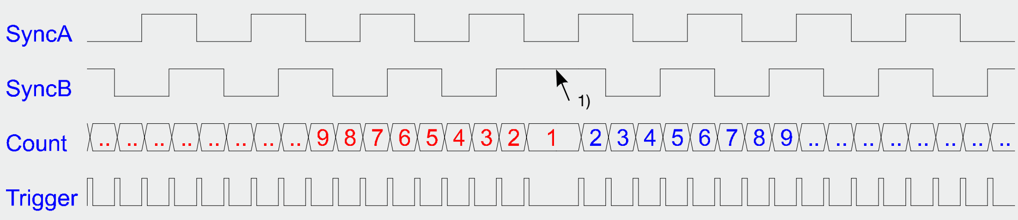
Sync Control Register:
'1100 0xxx'b



D

- Trigger on 4 edges of SyncA and SyncB
- direction detection = off
- hysteresis = 0

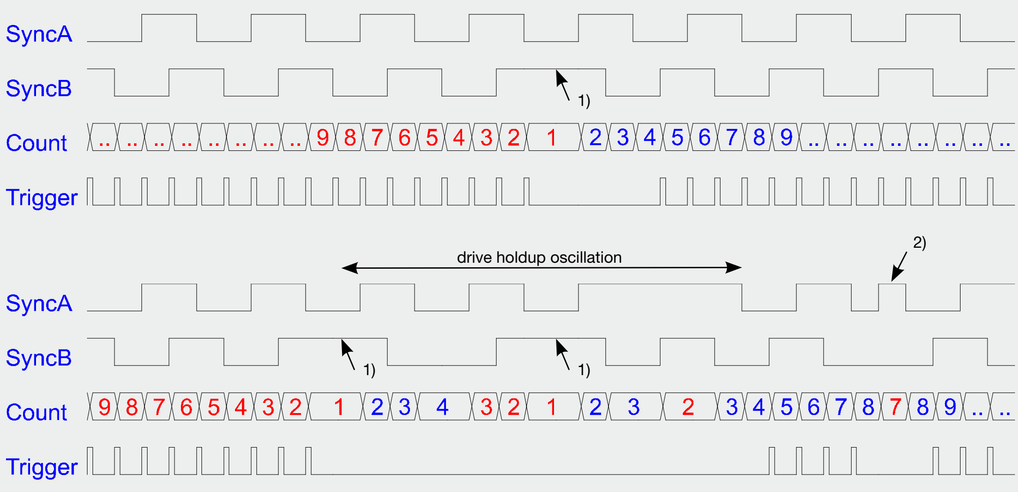
Sync Control Register:
'1110 0xxx'b



E

- Trigger on 4 edges of SyncA and SyncB
- direction detection = off
- hysteresis = 4

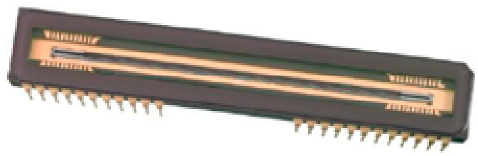
Sync Control Register:
'1110 1xxx'b



5 Sensor Information

Manufacturer: TRUESENSE Imaging, Inc.
Type: KLI-4104
Data source: KLI-4104 Image Sensor, Device Performance Specification, Revision 2.0 PS-0051

a) Summary Specification



Description

The KLI-4104 Image Sensor is a multi-spectral, linear solid-state image sensor for color scanning applications where fast operation and high resolution are required. The imager consists of three parallel linear photodiode arrays, each with 4080 active photosites for the output of red, green and blue (R, G, and B) signals. The sensor contains a fourth channel for luminance information. This array has 8160 pixels segmented to transfer out data through one of four luminance outputs. This device offers high sensitivity, high data rates, low noise and negligible lag. Individual electronic exposure control for each of the Chroma and the Luma channel is provided, allowing the KLI-4104 sensor to be used under a variety of illumination conditions.

Features

- Quad-linear array (G, R, B, L)
- High resolution: Luma (monochrome) array with 5 µm pixels with 8160 count.
- Luma channel has 4 outputs approaching 120 MHz data rate.
- High resolution: color (RGB) array with 10 µm pixels with 4080 count.
- Each color channel has 1 output approaching 30 MHz data rate.
- No Image Lag
- Two-Phase Register Clocking
- On-ship Dark Reference
- Electronic exposure control

Applications

- Machine vision

Parameter	Value
Total Number of Pixels	3 x 4134 Chroma, 1 x 8292 Luma
Number of Effective Pixels	3 x 4128 Chroma, 1 x 8276 Luma
Number of Active Pixels	3 x 4080 Chroma, 1 x 8160 Luma
Pixel Size	10 µm (H) x 10 µm (V) Chroma, 5 µm (H) x 5 µm (V) Luma
Pixel Pitch	10 µm Chroma, 5 µm Luma
Inter-Array Spacing, G to R R to B B to L	 90 µm (9 lines effective) 90 µm (9 lines effective) 122.5 µm (12.25 lines effective)
Chip Size	50.5 mm (H) x 1.1 mm (V)
Saturation Signal	121,000 electrons Chroma, 110,000 electrons Luma
Quantum Efficiency	62%(B), 62%(G), 80%(R), 85%(L)
Output Sensitivity	Chroma -14 µV/electron Luma -11 µV/electron
Responsivity (R/G/B/L)	17(B), 20(G), 32(R), 27(L) V/µJ/cm^2
Total Read Noise	120 electrons
Dark Current	Chroma 0.007 pA/pixel Luma 0.0008 pA/pixel
Dark Current Doubling Temperature	9 °C
Dynamic Range @ 30 MHz Data Rate	60 dB (chroma) 60 dB (luma)
Photoresponse Non-uniformity	5% Peak-Peak
Charge Transfer Efficiency	0.99999/Transfer
Total Number of Pixels	3x4134 Chroma 1x8292 Luma

The above parameters are specified for operation at 25 °C, unless noted otherwise.

b) Imaging Performance

- Imaging Performance Operational Conditions

Specifications given under nominally specified operating conditions for the given mode of operation at 25 °C, fCLK = 1 MHz, AR cover glass, color filters where applicable, no exposure control (line time = integration time), and an active load as shown in Figure 14, unless otherwise specified. See notes for further descriptions.

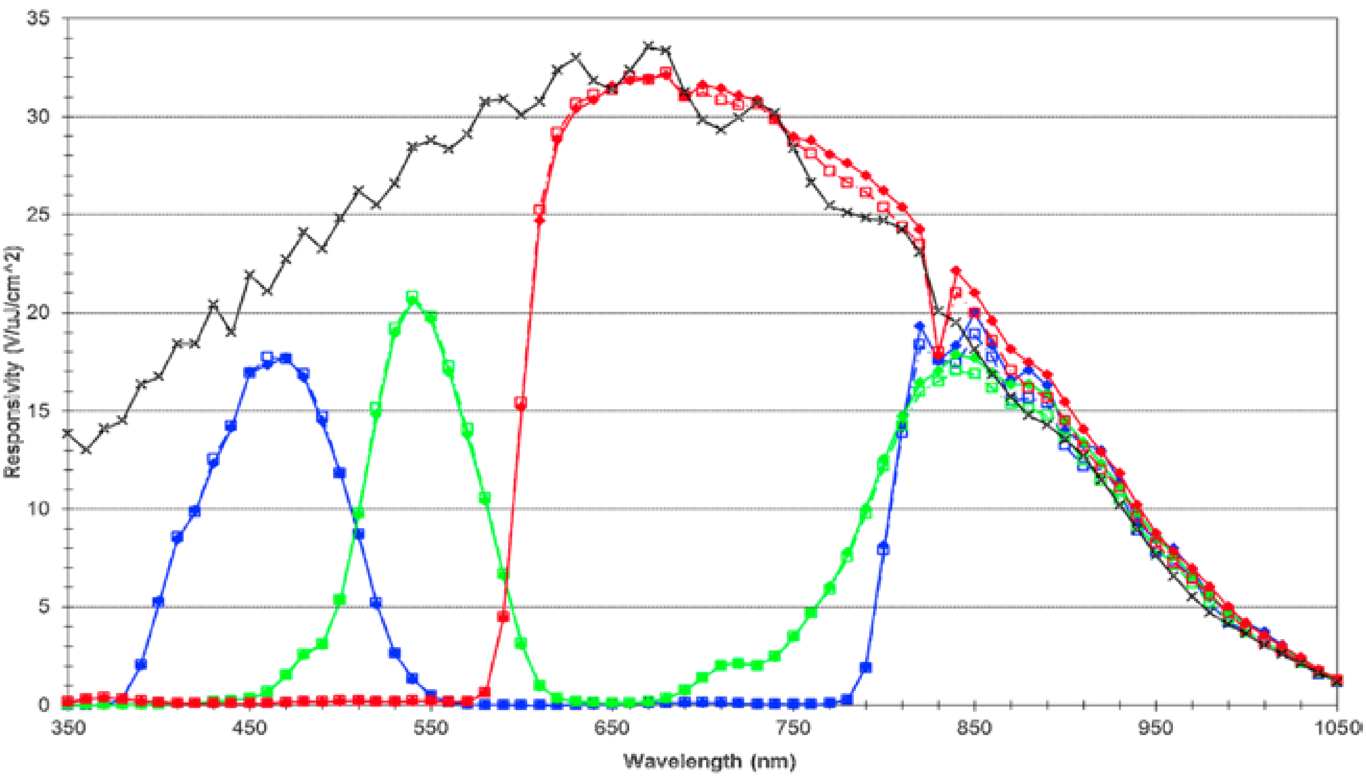
- Imaging Performance Specifications - Chroma Channels

Description	Symbol	Min.	Nom.	Max.	Units	Notes	Verification Plan
Saturation Output Voltage, Chroma	Vsat	1.5	1.7		Vp-p	1, 8, 9, 17	die[21]
Output Sensitivity, Chroma	ΔVo/ΔNe		14		$\mu V/e^-$	8, 9	design[22]
Saturation Signal Charge, Chroma	Ne, sat		121K		electrons	1, 8, 9	design[22]
Responsivity Blue @ 460 nm Green @ 550 nm Red @ 650 nm	R		17 20 32		$V/\mu J/cm^2$	2, 8, 9 ± 10 % ± 10 % ± 10 %	design[22]
Dynamic Range, Chroma	DR		60		dB	3	design[22]
Dark Signal Non-Uniformity, Chroma	DSNU		2	16	mV		die[21]
DC Gain, Amplifier, Chroma	ADC		0.74				design[22]
Dark Current, Chroma @ 40 °C	Idark		0.007	2	pA/pixel	14, 17	die[21]
Charge Transfer Efficiency, Chroma @ 30 MHz Data Rate Charge Transfer Efficiency, Chroma @ 2 MHz Data Rate	CTE	0.999995	0.999992 0.999997			4, 19	design[22] die[21]
Lag, Chroma @ 30 MHx Data Rate Lag, Chroma @ 2 MHx Data Rate	L		1 0.005		%	15	design[22] die[21]
DC Output, Offset, Chroma	Vo, dc		8.6			8, 9	design[22]
Photoresponse Non-Uniformity, Chroma Low Frequency	PRNU, Low		4	15	% p-p	5, 19	die[21]
Photoresponse Non-Uniformity, Chroma Medium Frequency	PRNU, Medium		4	15	% p-p	6, 19	die[21]
Photoresponse Non-Uniformity, Chroma High Frequency	PRNU, High		4	15	% p-p	7, 19	die[21]
Smear Smear, Chroma @ 450 nm Smear, Chroma @ 500 nm Smear, Chroma @ 550 nm Smear, Chroma @ 600 nm Smear, Chroma @ 650 nm	Smear		0.03 0.05 0.1 0.2 0.3		%		design[22]
Response Non-Linearity	RNL		3		%	16	design[22]
Darkfield Defect, Chroma Brightpoint	Dark Def			0	Allowed	11, 17	die[21]
Brightfield Defect, Chroma Dark or Bright	Bfld Def			3	Allowed	10, 12, 19	die[21]
Exposure Control Defects, Chroma Channels	Exp Def			64	Allowed	10, 13, 20 Figure 11	die[21]

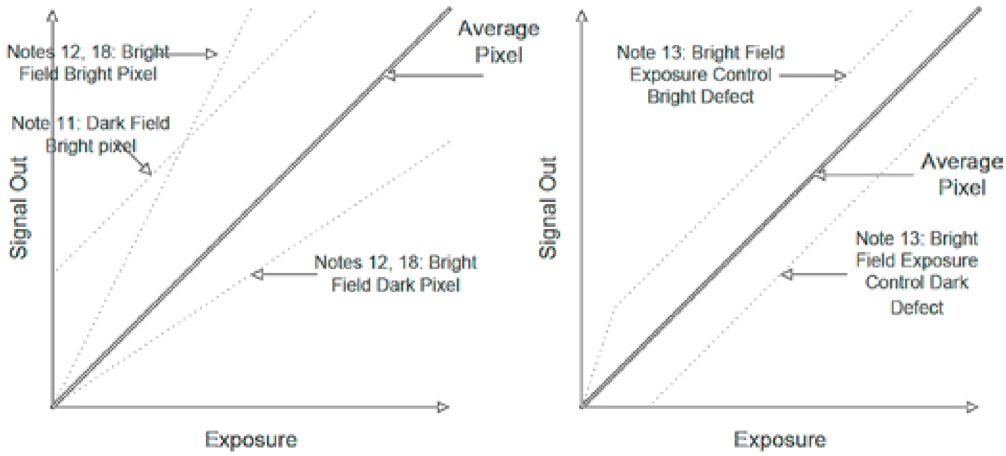
- Imaging Performance Specifications - Luma Channels

Description	Symbol	Min.	Nom.	Max.	Units	Notes	Verification Plan
Saturation Output Voltage, Luma	Vsat	1.0	1.3		Vp-p	1, 8, 9, 17	die[21]
Output Sensitivity, Luma	ΔVo/ΔNe		11.5		μV/e^-	8, 9	design[22]
Saturation Signal Charge, Luma	Ne, sat		110K		electrons	1,8, 9	design[22]
Responsivity, Luma (550 nm)	R		6.5		V/μJ/cm^2	2, 8, 9 (± 10 %)	die[21]
Dynamic Range, Luma	DR		60		dB	3	design[22]
Dark Signal Non-Uniformity, Luma	DSNU		2	16	mV	17	die[21]
DC Gain, Amplifier, Luma	ADC		0.74				design[22]
Dark Current, Luma @ 40 °C	Idark		0.0008	0.02	pA/pixel	14, 17	die[21]
Charge Transfer Efficiency, Luma @ 30 MHz Data Rate Charge Transfer Efficiency, Luma @ 2 MHz Data Rate	CTE	0.999995	0.999997 0.999997			4, 19	design[22] die[21]
Lag, Luma @ 30 MHx Data Rate per Luma Channel Lag, Luma @ 2 MHz Data Rate per Luma Channel	L		1 0.3		%	15	die[21]
DC Output, Offset, Luma	Vodc		8.6		Volts	8, 9	design[22]
Photoresponse Non-Uniformity, Luma Low Frequency	PRNU, Low		4	10	% p-p	5, 19	die[21]
Photoresponse Non-Uniformity, Luma Medium Frequency	PRNU, Medium		4	10	% p-p	6, 19	die[21]
Photoresponse Non-Uniformity, Luma High Frequency	PRNU, High		4	10	% p-p	7, 19	die[21]
Smear @ 550 nm	Smear		0.12		%		design[22]
Response Non-Linearity	RNL		3.4		%	16	design[22]
Darkfield Defect, Luma Brightpoint	Dark Def			0	Allowed	11, 17	die[21]
Brightfield Defect, Luma Dark or Bright	Bfld Def			6	Allowed	17, 18, 19	die[21]
Exposure Control Defects, Luma Channels	Exp Def			128	Allowed	13, 20 Figure 11	die[21]

c) KLI-4104 Image Sensor Responsivity



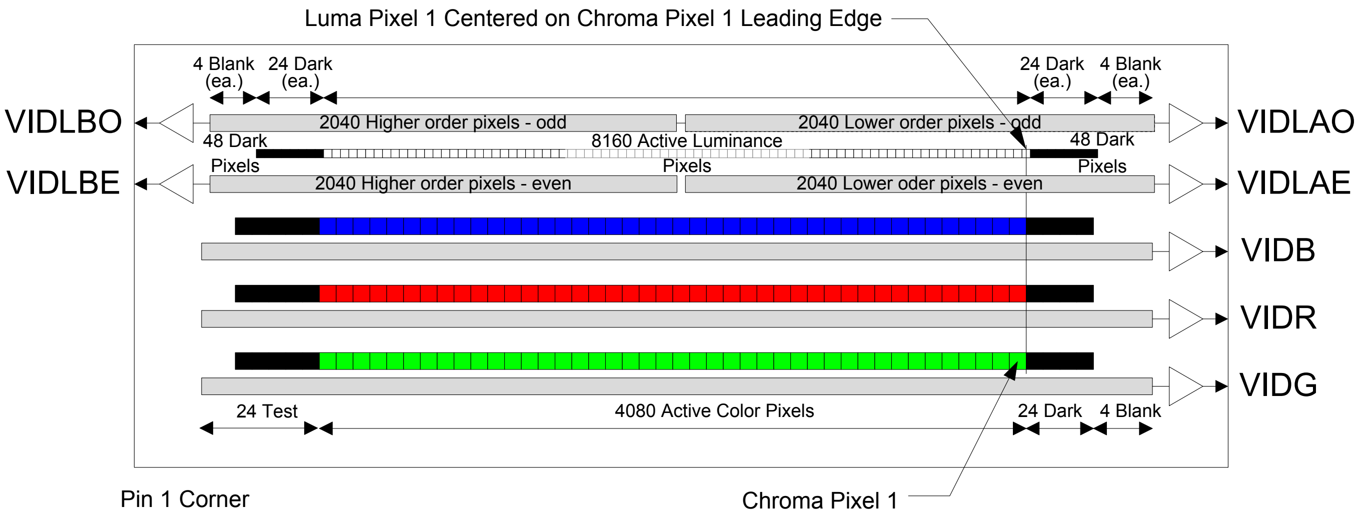
d) Defect Pixel Classification



e) Notes

1. Defined as the maximum output level achievable before linearity or PRNU performance is degraded beyond specification
2. With color filter. Values specified at filter peaks. 50% bandwidth = ±30 nm. Color filter arrays become transparent after 710 nm. It is recommended that a suitable IR cut filter be used to maintain spectral balance and optimal MTF. See Figure 12.
3. As measured at 30 MHz data rate. This device utilizes 2-phase clocking for cancellation of driver displacement currents. Symmetry between φ1 and φ2 phases must be maintained to minimize clock noise.
4. Measured per transfer. For a chroma line: (0.99999) * 8268 = 0.92065. For a luma line: (0.99999) * 2092 = 0.97930.
5. Low frequency response is measured across the entire array with a 1000 pixel-moving window and a 5 pixel median filter evaluated under a flat field illumination.
6. Medium frequency response is measured across the entire array with a 50 pixel-moving window and a 5 pixel median filter evaluated under a flat field illumination.
7. High frequency response non-uniformity represents individual pixel defects evaluated under a flat field illumination. An individual pixel value may deviate above or below the average response for the entire array. Zero individual defects allowed per this specification.
8. Increasing the current load (nominally 4.7 mA) to improve signal bandwidth will decrease these parameters.
9. If resistive loads are used to set current, the amplifier gain will be reduced, thereby reducing the output sensitivity and net responsivity.
10. Defective pixels will be separated by at least one non-defective pixel within and across the color channels.
11. Pixels whose response is greater than the average response by the specified threshold, (16 mV). See Figure 11.
12. Pixels whose response is greater or less than the average response by the specified threshold, (±15%). See Figure 11.
13. Pixels whose response deviates from the average pixel response by the specified threshold, (4.5 mV for chroma, 5.5 mV for luma), when operating in exposure control mode with an integration time that is 50% of the line time. See Figure 11. If dark pattern correction is used with exposure control, the dark pattern acquisition should be completed with exposure control actuated. Dark current tends to suppress the magnitude of these defects as observed in typical applications, hence line rate changes may affect perceived defect magnitude. Measured at 1 MHz data rate.
14. Dark current doubles approximately every +9 °C.
15. Residual charge in the first field after transfer is used to determine lag measurement.
16. Nominal value was measured at an output of 1.5 V signal level at 30 MHz. Expect linearity to be better than 10% over the entire range.
17. As measured at 1 MHz data rate.
18. Pixels whose response is greater or less than the average response by the specified threshold, (±10%). See Figure 11.
19. As measured at 1 MHz data rate and with an average output level of 70% VSat.
20. As measured at 1 MHz data rate and with an average output level of 100 mV. With the exposure control active - the timing is adjusted so exposure time = 50% * integration time.

f) Block Diagram



g) Channel Alignment

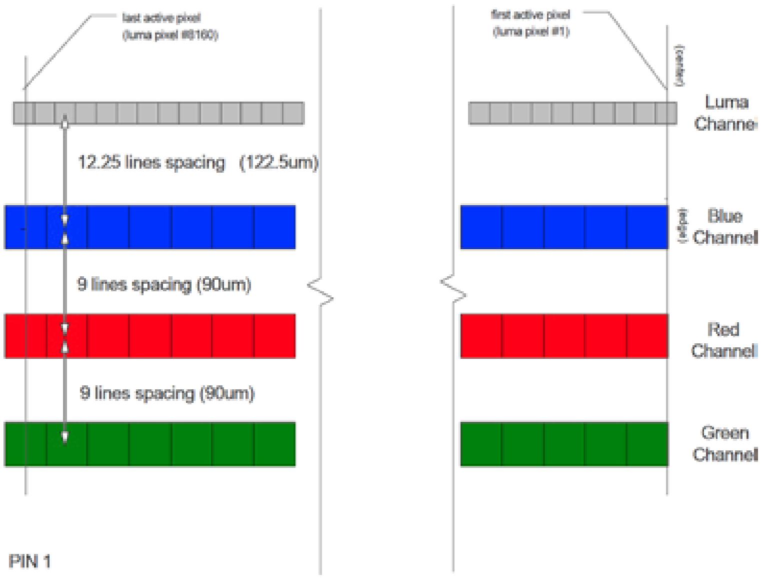
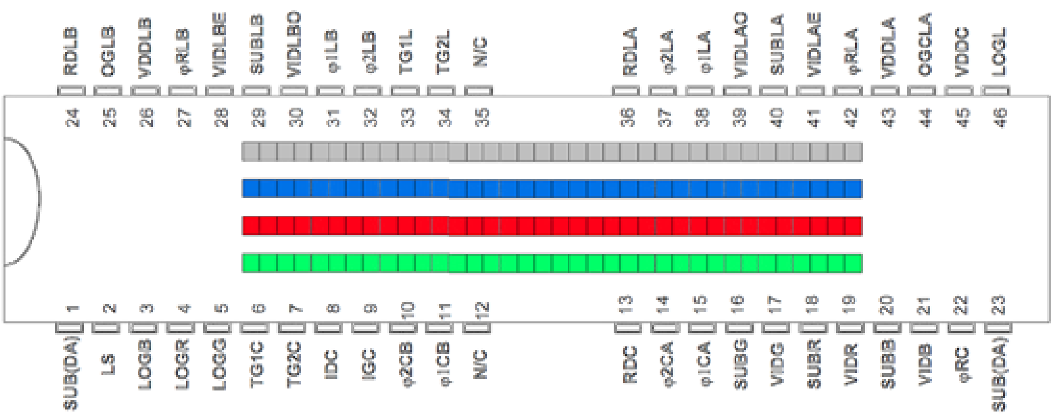


Figure 2: Channel Alignment Diagram



Blooming

If by overexposure too many charge carriers are produced in one or several photosensitive elements (pixels) of the line sensor, the transport register is „flooded“ with charge carriers, and also the following register bins are charged over the saturation limit. This spreading of a local overexposure along a line is called „blooming“. In the resulting video signal an overexposed area includes too many pixels. In that area the geometric mapping between image and object is not correct.

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 12 000 pixels, ranging from 4 to 14 µm 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

SoI (Start of Integration)

In addition to → ***SoS***, cameras with → ***Integration Control*** function generate an internal SoI-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

DIN EN 55011:2009 + A1:2010 / Group 1 / Class A

Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement

Class B limits (devices for usage in domestic establishments) are met with an additional ferrite attached to the USB connector cable (camera side).

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 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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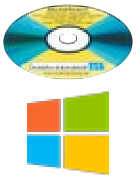
Software



Software

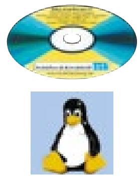
SK91USB3-WIN **Order Code**

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

SK91USB3-LV VI **Order Code**

VI-Library for LabVIEW®, requires **SK91USB3-WIN**



Software

SK91USB3-LX **Order Code**

SDK from *Schäfter + Kirchhoff* including the **SKLineScan** operating program, as well as libraries and examples.

Operating systems:
Linux kernel 3.13 or higher

Accessories

USB 3.0 cable SK9020.x

Camera connector: USB 3.0 plug, type micro-B, with safety lock screws

PC connector: USB 3.0 plug, type A (also fits into a USB 2.0 type A socket)

SK9020.x **Order Code**

3 = 3 m cable length (standard)
5 = 5 m cable length

Power supply unit PS051515

Input: 100-240 VAC, 0.8 A, 50/60 Hz
IEC 60320 C14 coupler (for IEC C13 power cord)
Output: +5 V DC, 2.5 A / +15 V DC, 0.5 A / -15 V DC, 0.3 A
Cable length: 1 m, with Lumberg connector KV60, female 6-pin

PS051515 **Order Code**

Power cord IEC 60320 C13, 1.5 m, 10 A, 250 V AC

PC150DE **Order Code**
DE = Europe / **US** = USA, Canada, Japan / **UK** = United Kingdom

USB 3.0 active extension cable USB3.EXT.A2A...

Hybrid cable (copper/fiber), power supply by another USB-connection, cable lenght up to 100 m on request.

Connectors:
USB 3.0 plug and socket, with locking screws

USB3.EXT.A2Ax **Order Code**

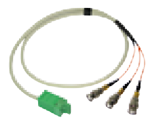
20 = 20 m cable length
30 = 30 m
50 = 50 m
other lengths up to 100 m on request

Combined Synchronization and Power Cable SK9016.1.5

Applicable when a power supply in addition to the USB interface is required. Shielded cable, length 1.5 m.

Connectors: Hirose plug HR10A, female 6 pin, (camera side), Lumberg SV60, male 6-pin connector (for supply voltage), Phoenix 6 pin connector incl. terminal block (for synchronization signals)

SK9016.1.5 **Order Code**



Adapter cable for sync signals CAB-AD Sync-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

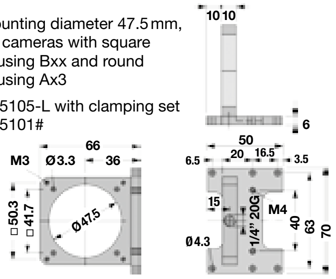
CAB-AD Sync-BNC-1 **Order Code**

M2 **Mounting Bracket SK5105-L**

Order Code
SK5105-L

Mounting diameter 47.5 mm, for cameras with square housing Bxx and round housing Ax3

SK5105-L with clamping set SK5101#



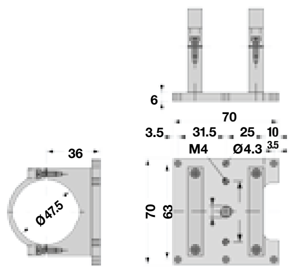
MC **Clamping Set SK5101**

Order Code
SK5101

M4 **Mounting System SK5105-2L**

Order Code
SK5105-2L

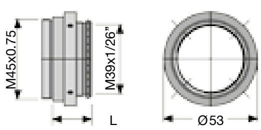
For camera configurations with tube length > 55 mm using extension rings **ZR-L**



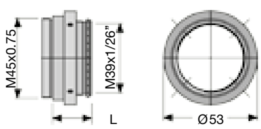
FA3 **Focus adapter L-Mount (M39x1/26" Leica)**

any rotation angle adjustable (V-groove)
attachement 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**

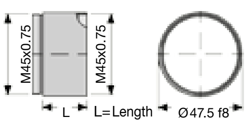
Attachment thread:
45 = M45x0.75
40 = M40x0.75
32 = M32x0.75
C = C-Mount 1"-32-TP

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



Schäfter+Kirchhoff