SK22368GTFC-4L

Color Line Scan Camera

7456 x 3 pixels 4.7 x 4.7 µm², line frequency up to 5.13 kHz

Instruction Manual

Sample Configuration

1 CCD line scan camera
SK22368GTFC-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

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

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!

1 Introducing the SK22368GTFC-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 SK22368GTFC-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:

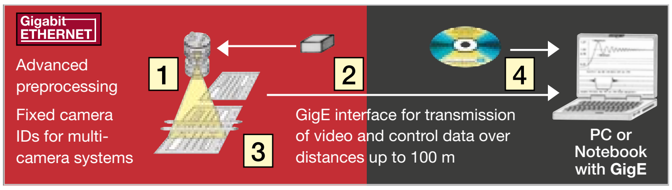
- customer-specific I/O signals in addition to the video signal
- special preprocessing algorithms can be implemented in the camera
- consistent attribution of camera IDs in multi-camera operations
- SDK from Schäfter+Kirchhoff with the SkLineScan operating program, libraries and examples.

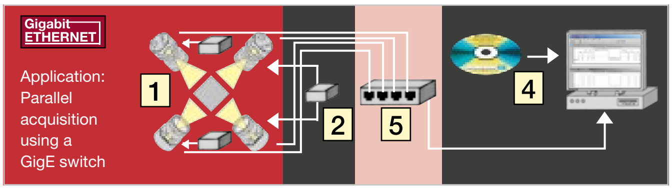
Features	Gigabit ETHERNET
Shading Correction	yes
Programmable Lookup Table	yes
Thresholding	yes
Window Function (ROI)	yes
Line Trigger, Frame Trigger	yes
Frame Trigger Delay	yes
Threshold Trigger	yes
Advanced Synchronization Ctrl.	yes
Integration Control for R, G, B	yes
Decoupling of line frequency	yes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

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 *3 Camera Control and Performing a Scan (p. 12)*.



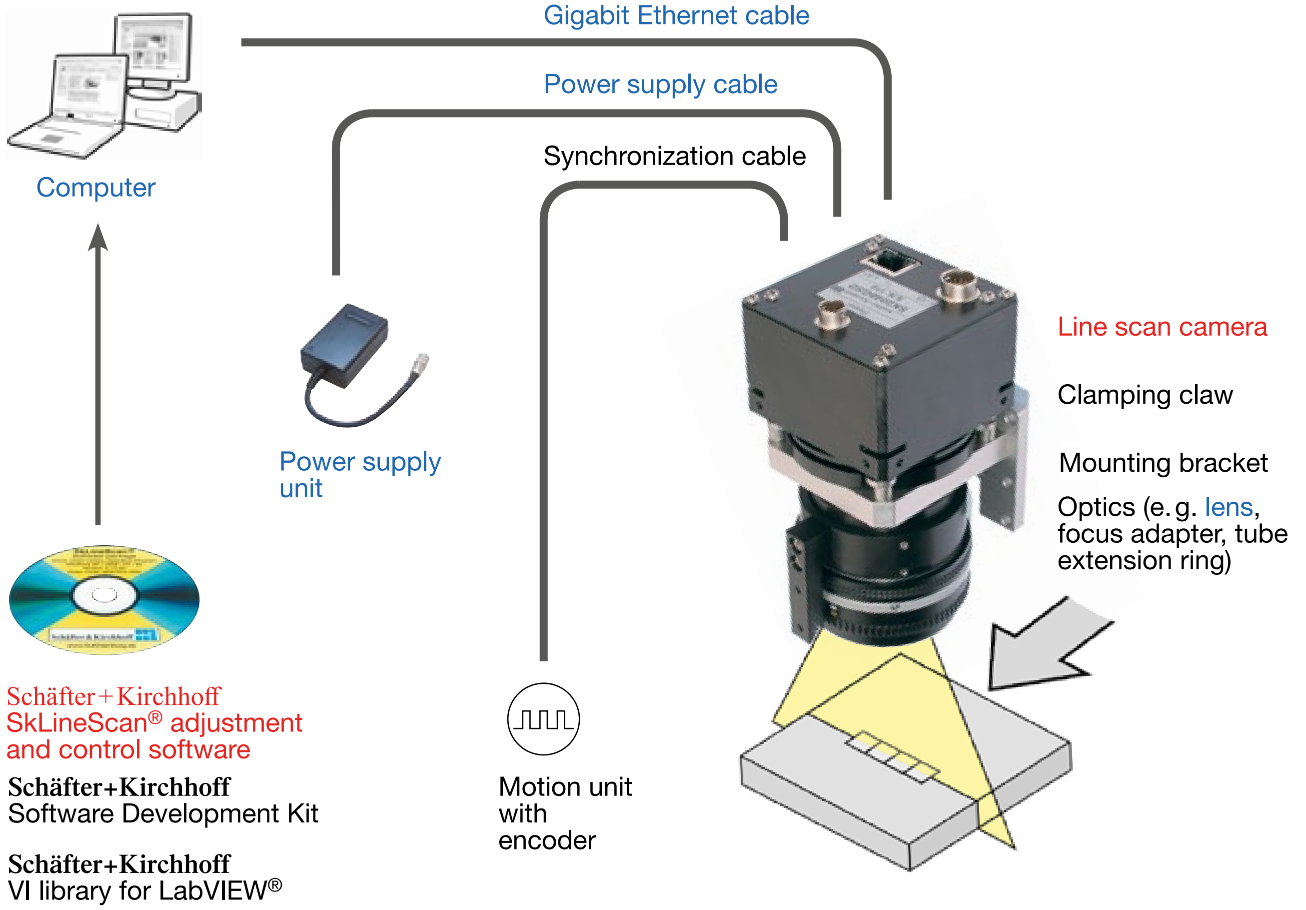


1	CCD line scan camera	4	Software, SDKs and eBus driver
2	Power supply	5	GigE switch
3	Illumination		

1.2 System Setup at a Glance

red: SK22368GTFC-4L scope of delivery
blue: accessories for minimum system configuration
black: optional accessories

For accessory order details see *Accessories (p. 38)*.



1.3 SK22368GTFC-4L Line Scan Camera - Specifications

Sensor category	CCD Color Sensor
Sensor type	TCD2724DG-1
Pixel number	7456 x 3
Pixel size (width x height)	4.7 x 4.7 µm^2
Pixel spacing	4.7 µm
Line spacing, line sequence	18.8 µm, red (R) - green (G) - blue (B)
Active sensor length	35.04 mm
Anti-blooming	no
Integration control	no
Shading correction	yes
Line synchronization modes	Line Start, Exposure Start
Frame synchronization	yes
Pixel frequency	120 / 60 MHz
Maximum line frequency	14.10 / 4.72 kHz
Integration time	0.195 ... 20 ms
Dynamic range	1:1150 (rms)
Spectral range	350 ... 700 nm
Video signal	color 3*8 Bit digital
Interface	GigaBit Ethernet
Voltage	18 - 36 V DC
Power consumption	6.5 W @120 MHz
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
Admissable casing temperature	+5 ... +45°C
Revision level camera	2.62
Revision level interface control	1.5

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).

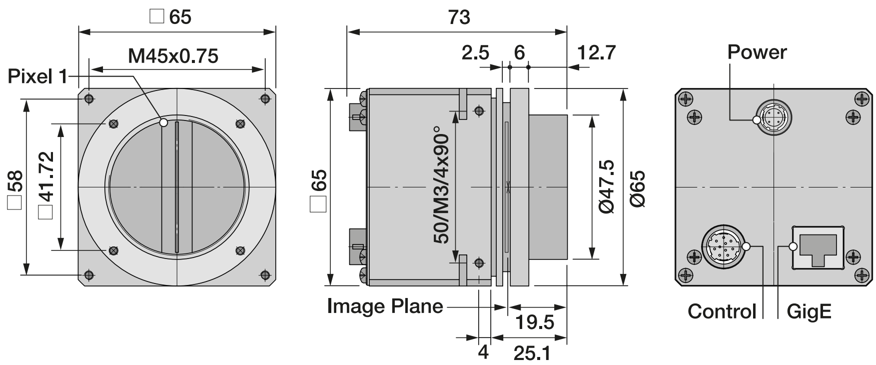
Four threaded holes M3 x 6.5 mm provide further options for customized brackets.

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.

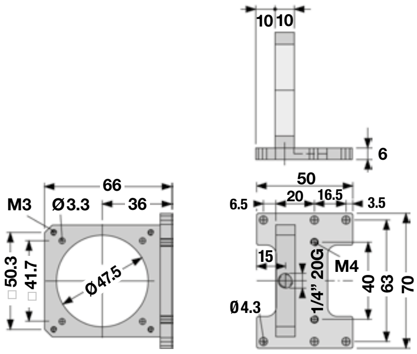
Optics Handling

- 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 BG3



Mounting bracket SK5105-L

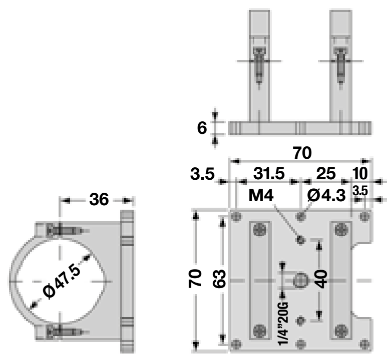


Clamping set SK5101

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

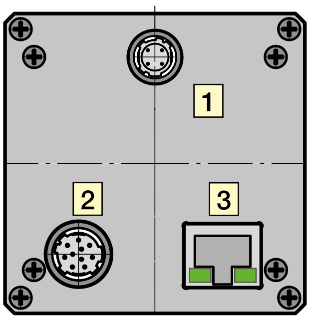
Mounting system SK5105-2L

for cameras with a tube extension > 52 mm

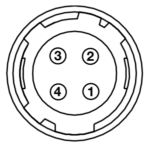


2.2 Electrical Installation: Connections and I/O Signals

- For the SK22368GTFC-4L line scan camera-data transfer and camera control is provded by the Gigabit Ethernet interface 3. Use a CAT6 twisted-pair cable to connect the camera to a PC; the maximum cable length is 100 m.
- 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 Image Acquisition with the Feed Rate of the Object (p. 19)*



1 **Power +24 V**

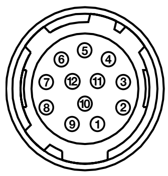


Hirose series 10A, male 4-pin

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

Total power: 6.5 W @120 MHz

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

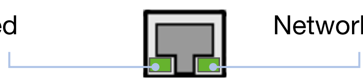
*) Signal Specification (TTL)

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**
RJ-45 connector for Gigabit Ethernet cable

Status indicators

Network connection speed



Network activity

Network connection speed		Network activity	
off	no connection, 10 Mbyte/s connection, or 100 Mbyte/s connection	off	no connection
on	1 Gbyte/s connection	on	connected
		flash light	data is being transmitted or received

Accessories *(see also Accessories (p. 38))*:

Network Cable CAT6.x
For connecting socket 3 with the PC Ethernet interface. Both ends with RJ45 connectors.

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

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**.

Step 1: Install **SkLineScan**

Step 2: If the Gigabit network interface controller (NIC) has an INTEL PRO/1000 chip then install the **High Performance Driver**

Step 3: Plug in the CAT6 network cable to the camera and switch on the power supply.

Step 4: Check the network connection.

Step 5: Start the **SkLineScan** program.

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
SkLineScan-GigE-Win_x86.msi
SK91GigE-Win_x64.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

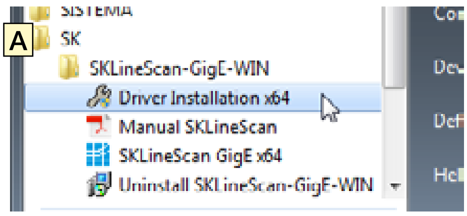
a) High Performance Driver for Intel PRO/1000 Chip

- **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. Under *Windows10* proceed as described in the section "Standard GigE Network Adapters" below.**

Open the program menue 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”.**

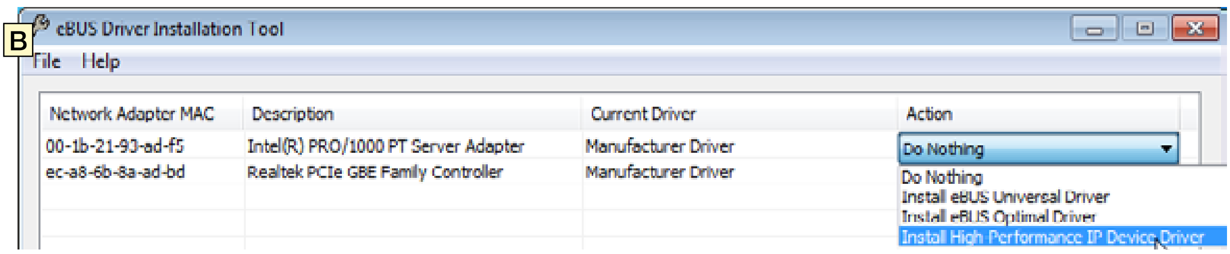
A



Start Driver Installation Tool from **Start Menue**

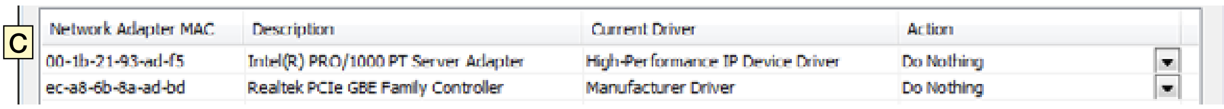
The eBUS driver installation tool window B will show up to list the available network adapters and the currently installed network drivers in the system.

B



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

C



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

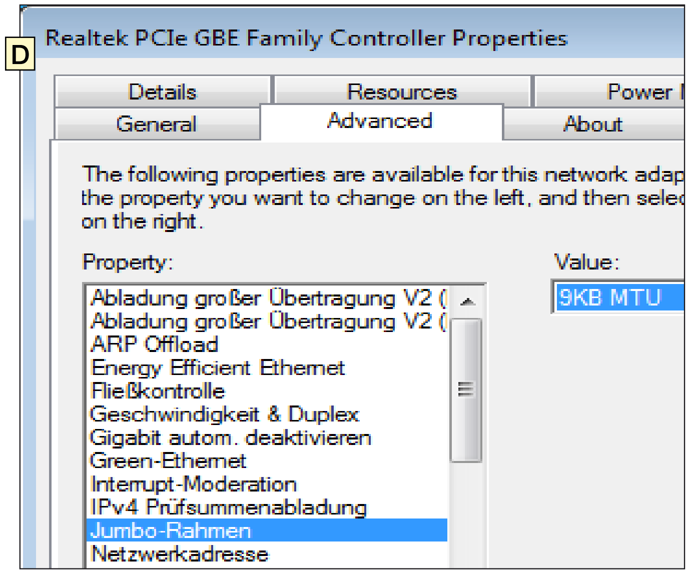
b) Standard GigE Network Adapters

- **For non-Intel PRO/1000 network adapters or for Intel PRO/1000 network adapters under *Windows 10* 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

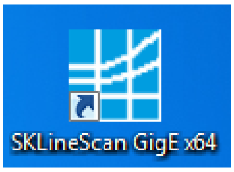
LAN adapters for GigE cameras that do not work with the High Performance Driver must use a fixed IP address, e.g. 192.168.0.99.



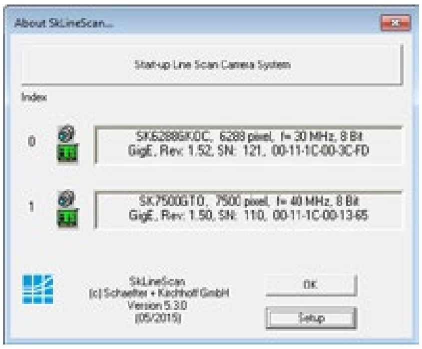
Network Controller Properties: Note, the terms can differ depending on the installed Ethernet card and driver.

SkLineScan Start-up

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



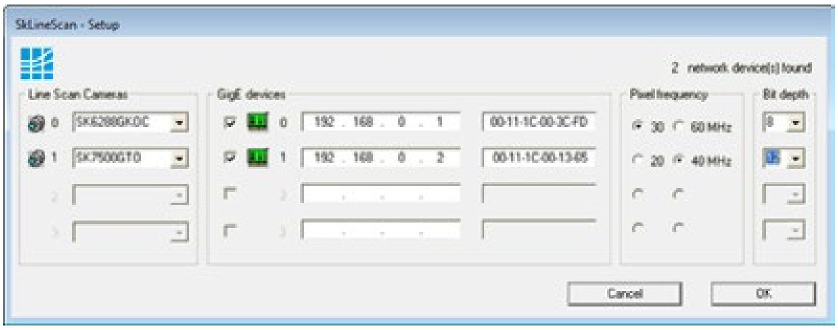
Desktop Icon



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.



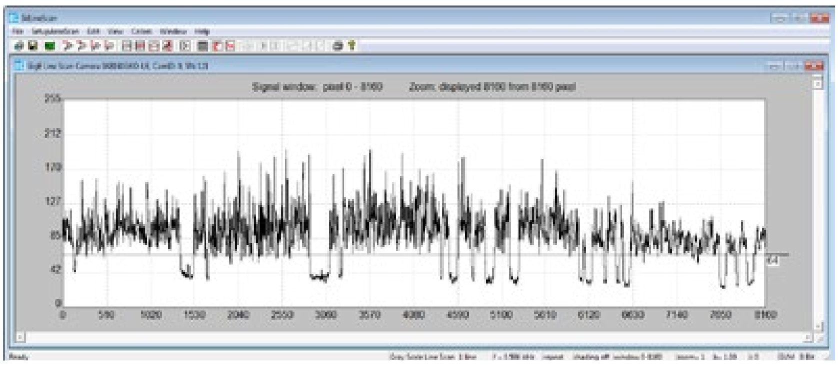
SkLineScan Setup dialog

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/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.

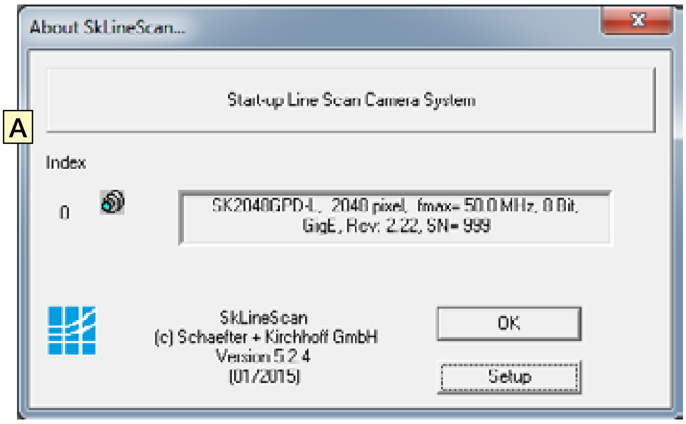
In the "Camera Gain / Offset Control" dialog there is a command line for entering further control commands.

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.

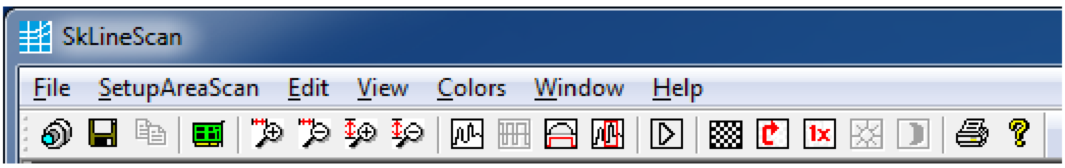
If the SK22368GTFC-4L camera is identified correctly, confirm with "OK". The "Signal window" graphicaly showing the intensity signals of the sensor pixels (oscilloscope display) will open. It is responsive in real-time and the zoom function can be used to highlight an area of interest. The oscilloscope 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



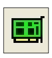
SkLineScan: Start-up dialog

Function Overview: SkLineScan Toolbar

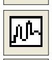


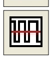
SkLineScan: Toolbar

 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

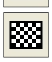
  Zooming in and out

 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]

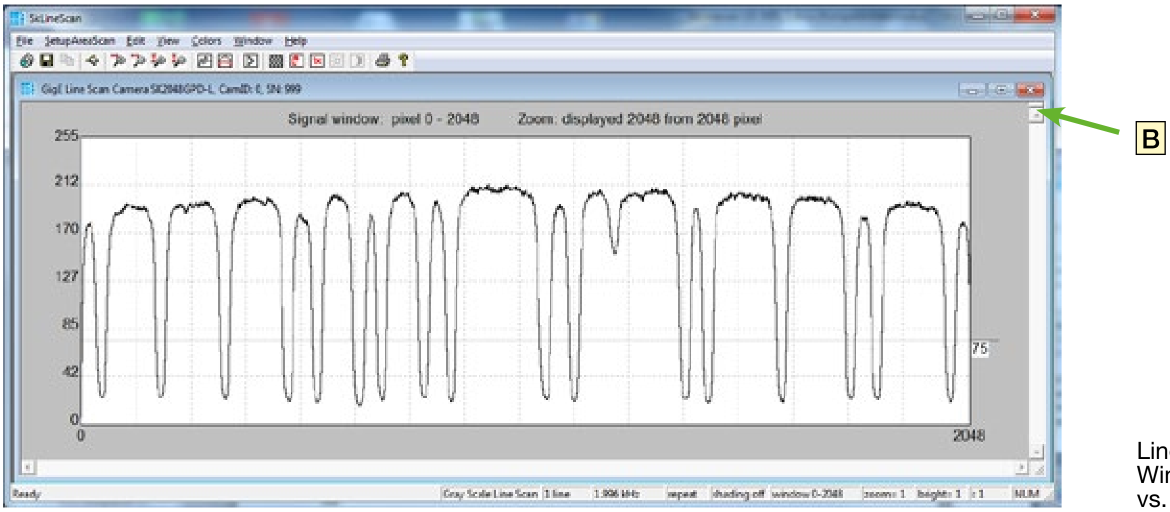
 "Gain/Offset Control" dialog, also for commands input [Shif+F4]

 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.



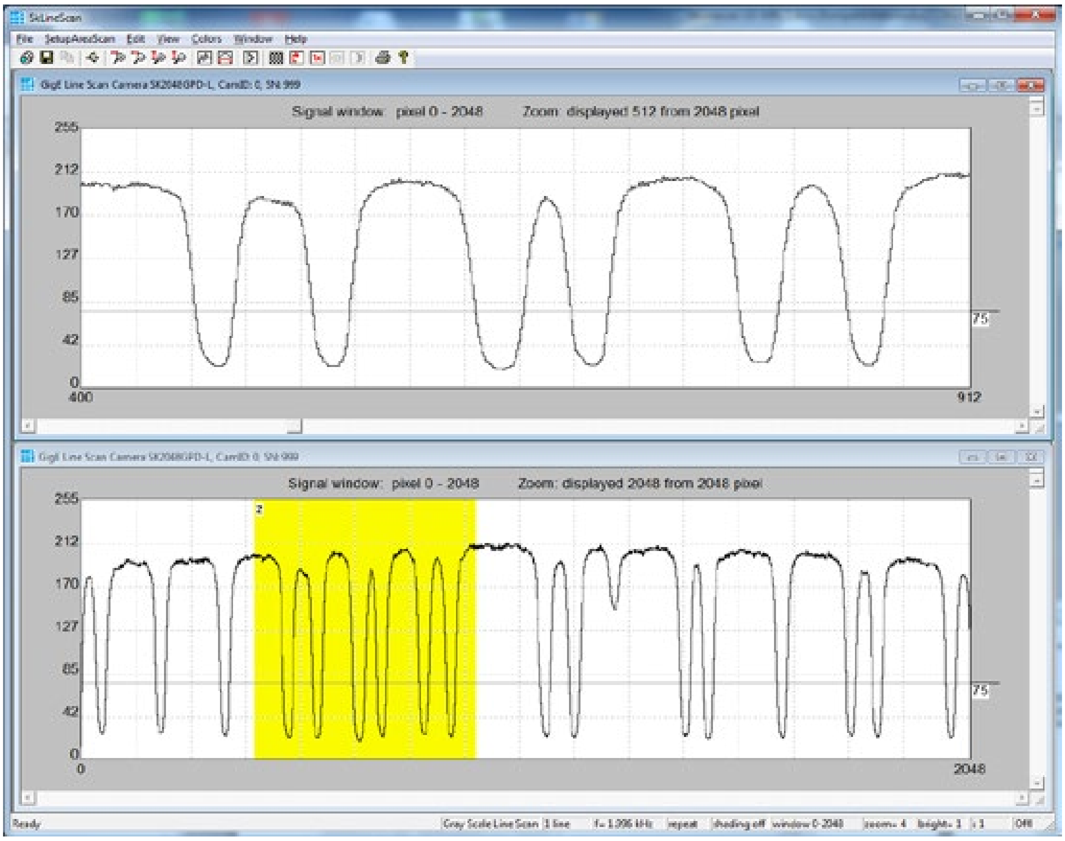
Line scan in Signal Window: brightness vs. pixel number

- **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.

Schäfter+Kirchhoff

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.

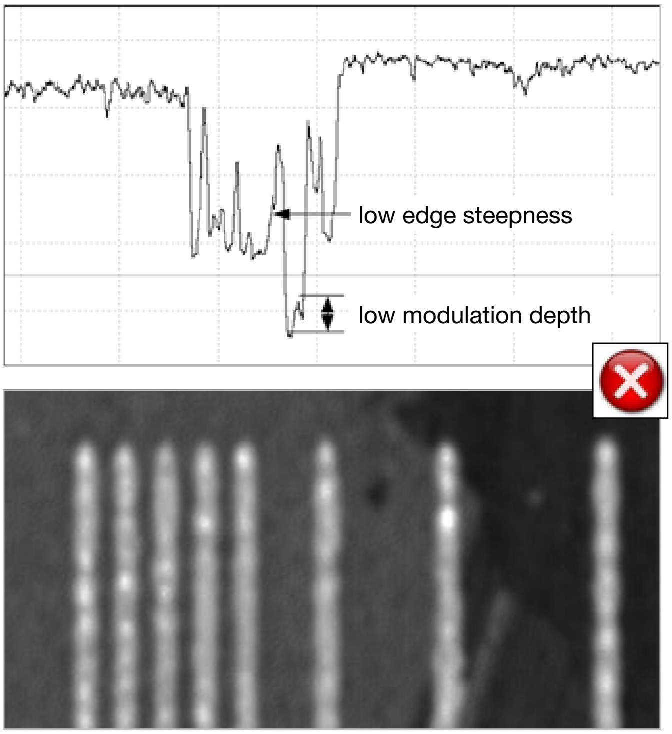
Start with the signal window / oscilloscope display. Any changes in the optical system or camera parameters are displayed in real-time when using an open dialog box.

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.

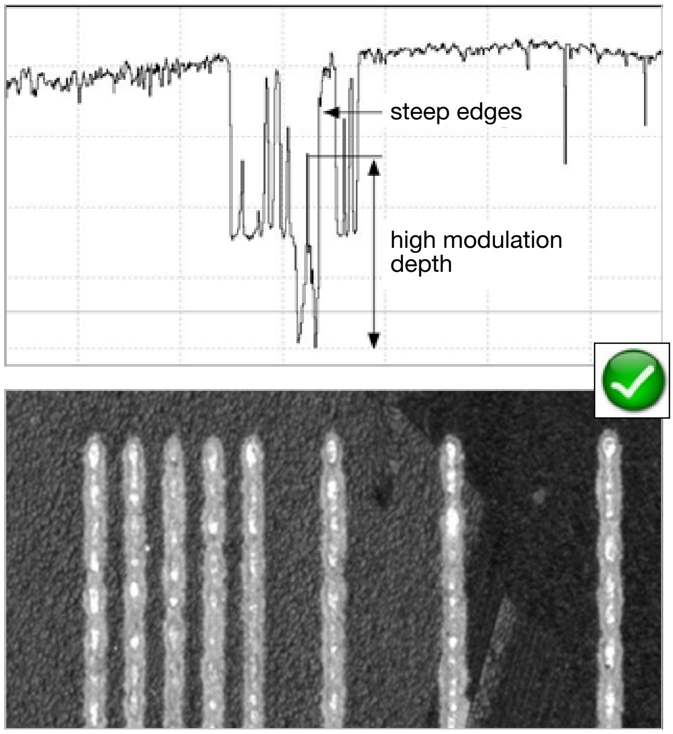
Adjust the focus with the aperture fully open to limit the depth of field and enhance the effects of changing the working distance.

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. 18)*.



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

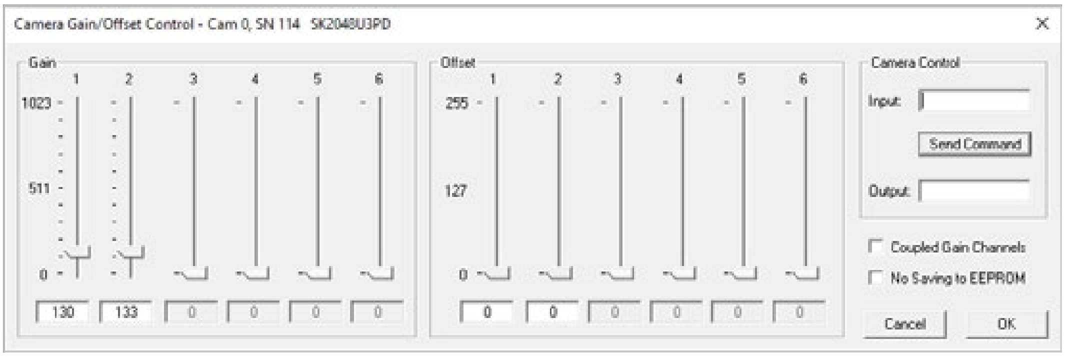
If you are using a linear light source, check the alignment of the light source and sensor before shading correction, as rotating the line sensor will result in asymmetric vignetting.

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 *12*).

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.

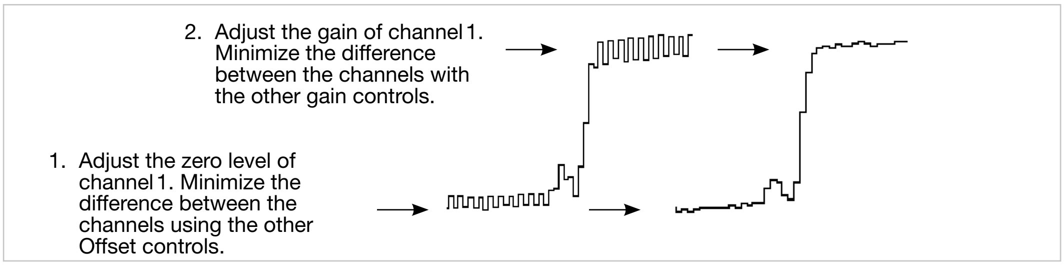
A slight signal noise should be visible in the zero baseline.

2. Gain

Illuminate the sensor with a slight overexposure in order to identify the amplitude 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.



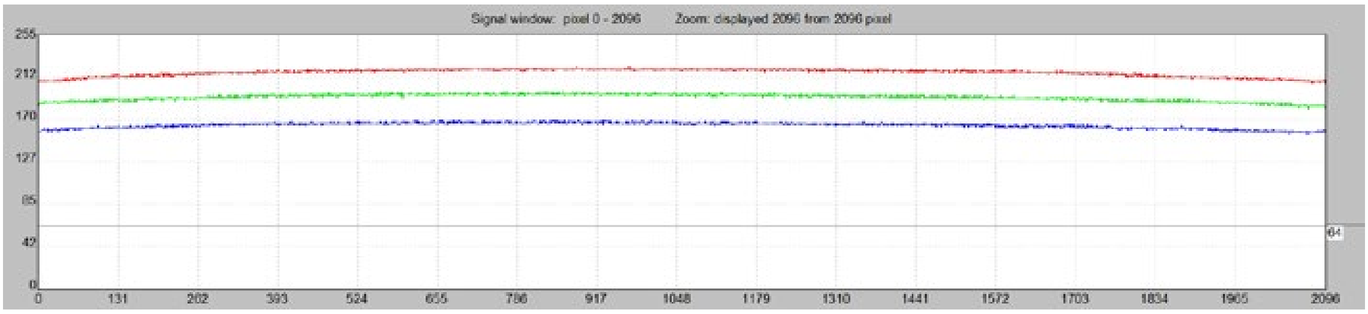
Offset and gain adjustment for more than one gain/offset channel

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

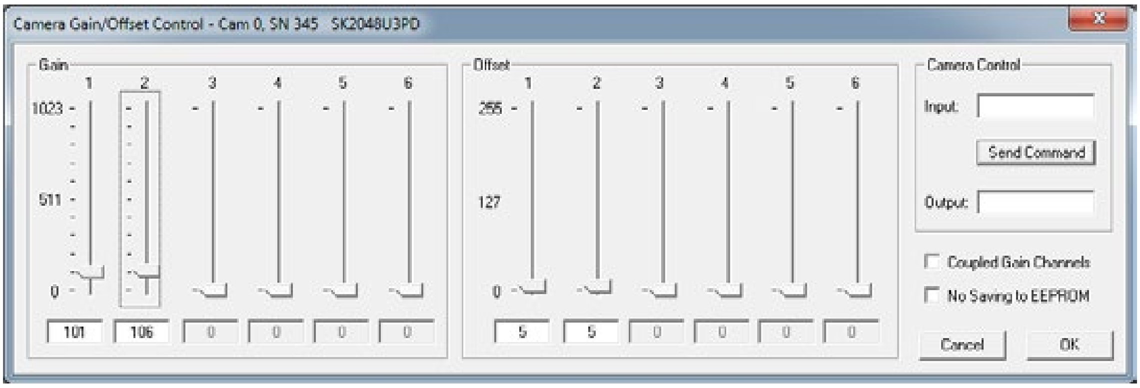
- Use a homogeneous white object, e.g. a white sheet of paper, to acquire the RGB line signals.



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

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

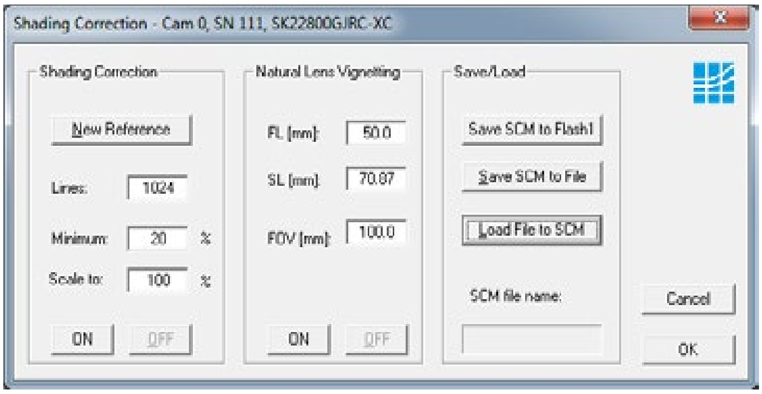
  A typical appropriate value is 90% of the full intensity range. The result will be a homogeneous line at 230 (= 90% 255) for an 8-bit intensity scale.
- Click on button **New Reference**
- Click on **Save SCM to Flash** to save the SCM reference signal in the flash memory of the camera

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



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.

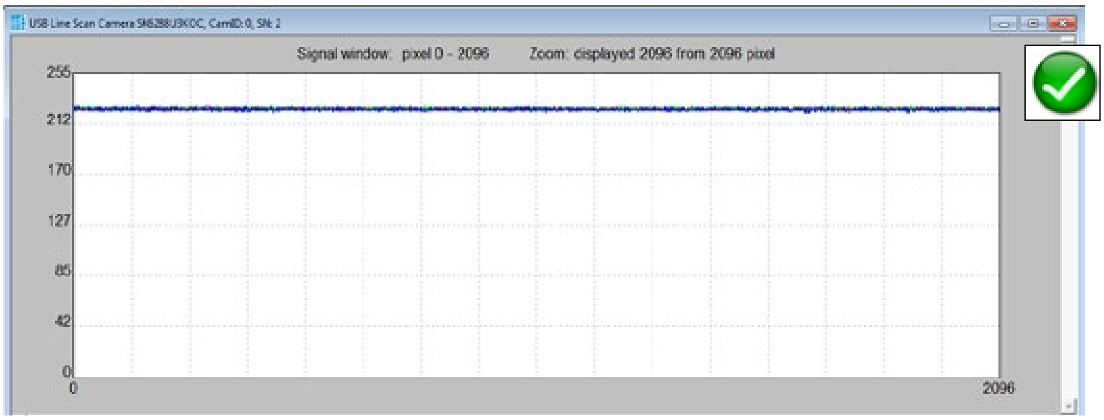
Power-down and Power-up Behaviour

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.

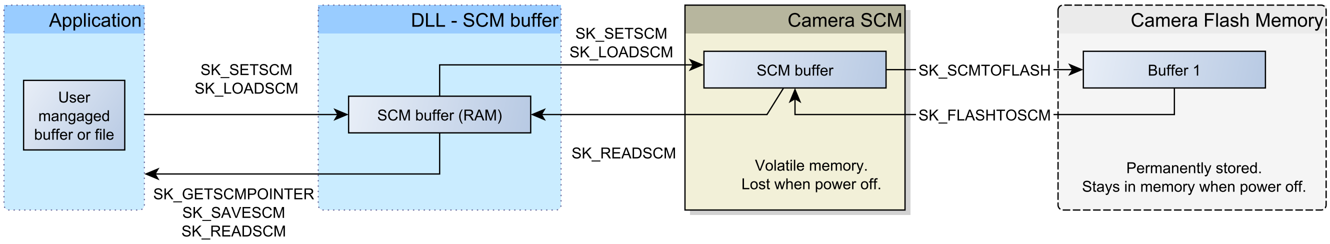
The shading correction status on shutting down - active or not active - will be retained and automatically restored on power-up.

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.

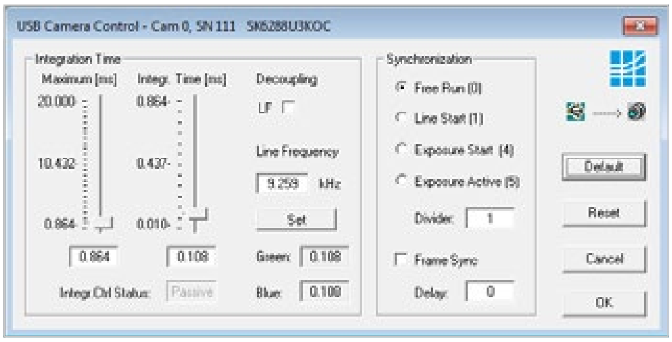
The **Default** button sets the integration time to the minimum exposure period that is determined from the maximum line frequency.

Reset restores the start values.

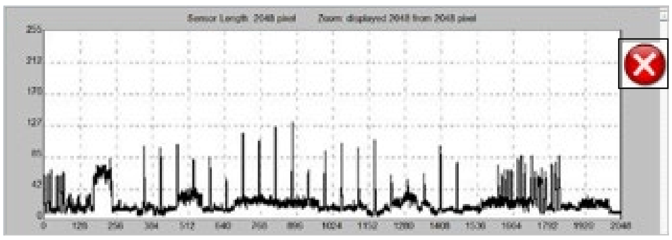
Cancel closes the dialog without changes.

OK stores the integration time values and closes the dialog.

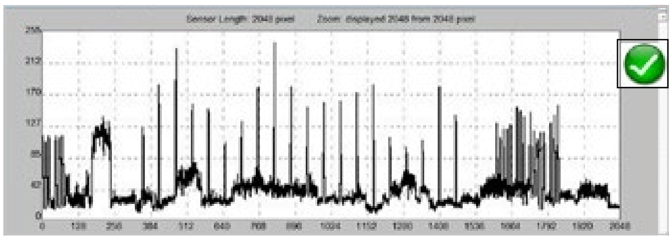
For synchronization settings, see section *Synchronization of the Image Acquisition with the Feed Rate of the Object (p. 19)*.



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.



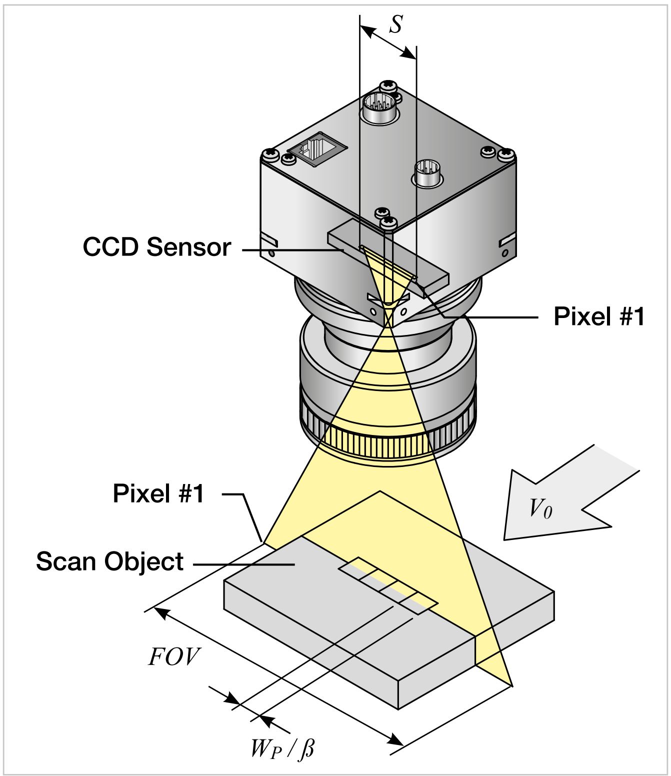
Optimized level of the camera signal after increasing the integration time by a factor of 4 to 95 % of the available scale.

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:

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

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

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

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

Example 1:

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

Pixel width	= 4.7 µm
Line frequency	= 5.13 kHz
S	= 35.04 mm
FOV	= 60 mm

$$V_O = \frac{4.7\,\mu m \cdot 5.13\,kHz}{(35.04\,mm / 60\,mm)} = 41\,mm/s$$

Example 2:

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

Pixel width	= 4.7 µm
Scan velocity	= 40 mm/s
S	= 35.04 mm
FOV	= 60 mm

$$f_L = \frac{40\,mm/s \cdot (35.04\,mm / 60\,mm)}{4.7\,\mu m} = 5\,kHz$$

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 SK22368GTFC-4L 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. 26***.

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.

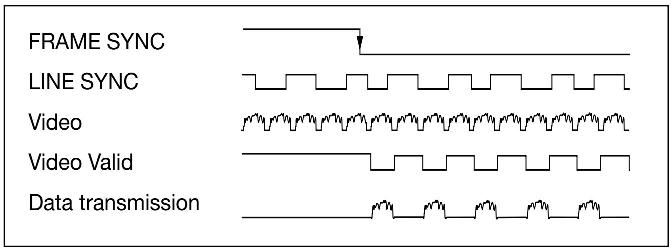
Restriction: The period duration of the trigger signal must be longer than the exposure time used.

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.

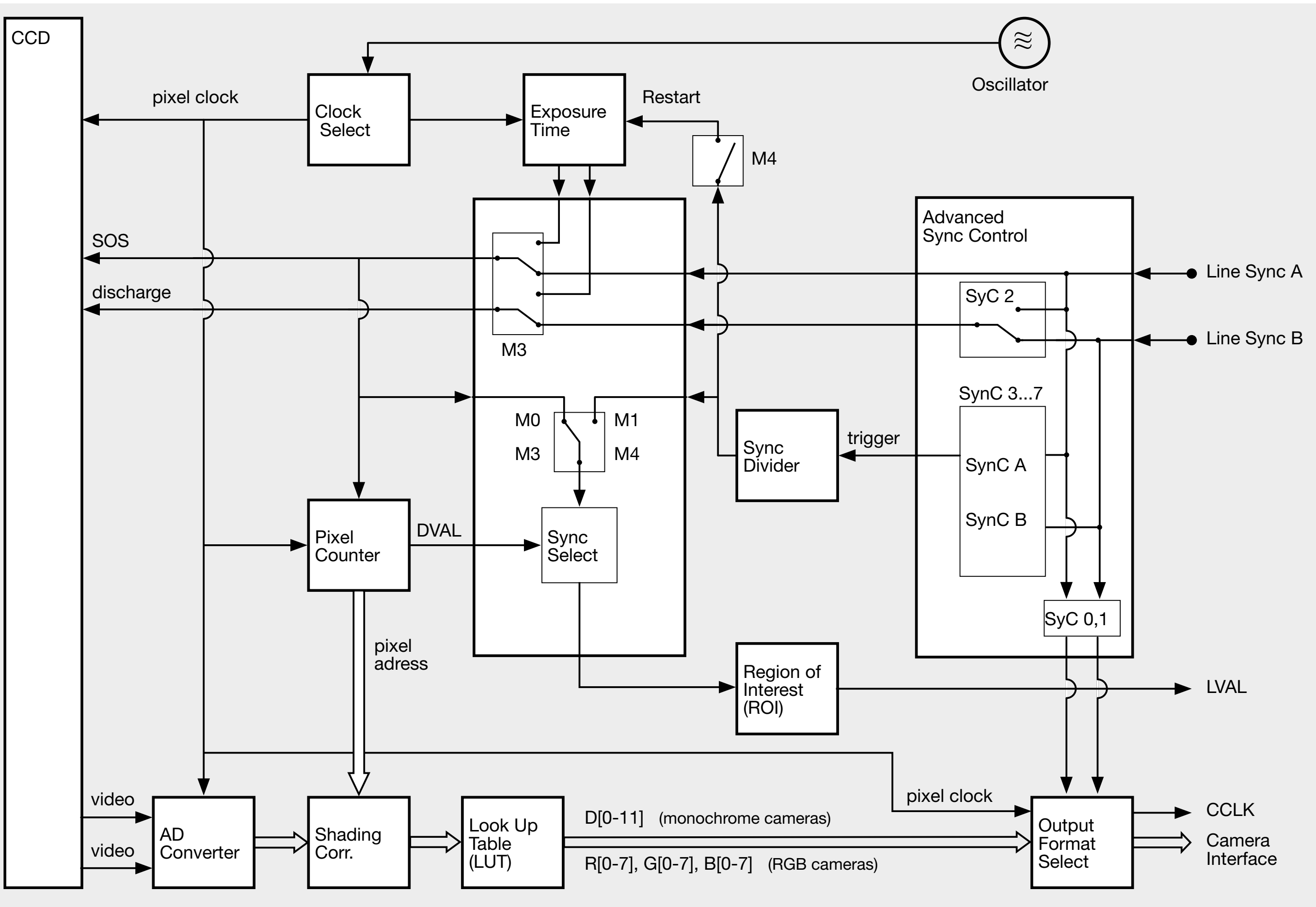
FrameTrigger / SK FrameSync

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

The configuration of the synchronization, i.e. setting the synchronization mode for line triggering, activating frame triggering, setting the frame trigger delay time, is done either by parameters in the Camera Head Feature or Custom Feature section of the ***GigEVision Device Feature List (see section 4)***, or via serially transmitted commands (see ***Advanced Camera Control Functions, section 5***).

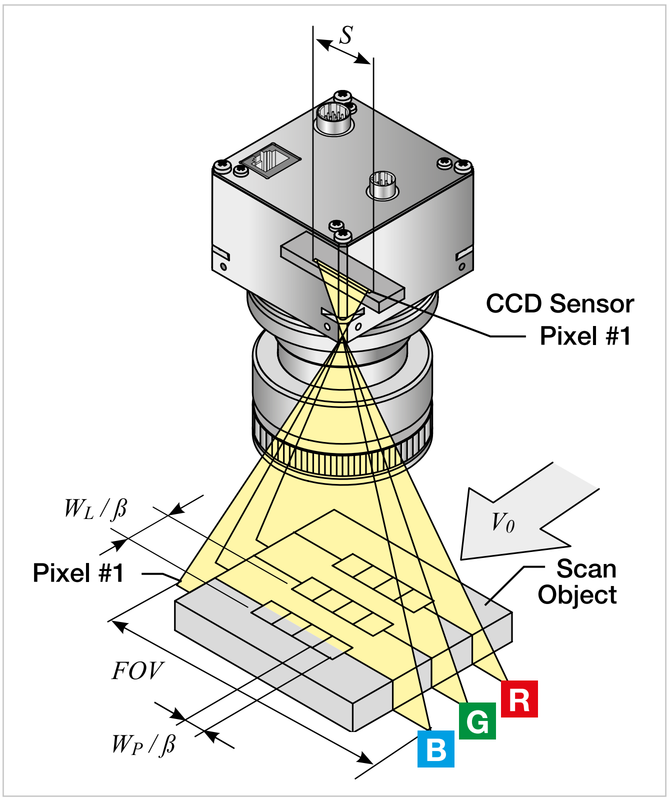


Functional diagram of the Camera Control System

RGB Sensors: 2D Imaging and Pixel Allocation

The three lines of the implemented triple line sensor are sensitive for the primary colors red (R), green (G) and blue (B). For the spectral sensitivity characteristics, see section ***5 Sensor Information***. The pixel width W_P is 4.7 µm and the line spacing W_L of 18.8 µm is 4 times the pixel width.

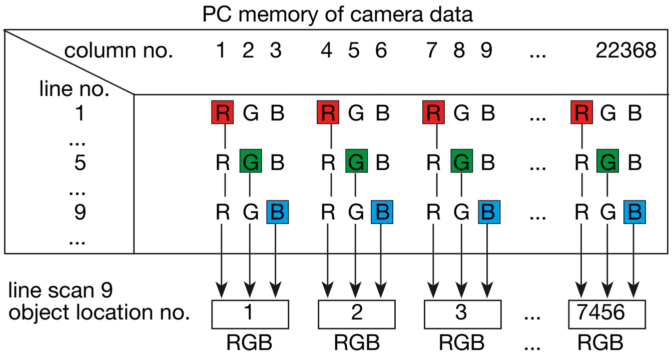
During object travel, an object point reaches the red (R) line sensor first. If the object is translated by one pixel height per clock pulse then after 4 lines the green (G) pixels are exposed. After another 4 lines then the blue (B) pixels have been covered and all color information has been acquired.



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 SK22368GTFC-4L outputs the red (R), green (G) 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 red (R) then green (G) 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

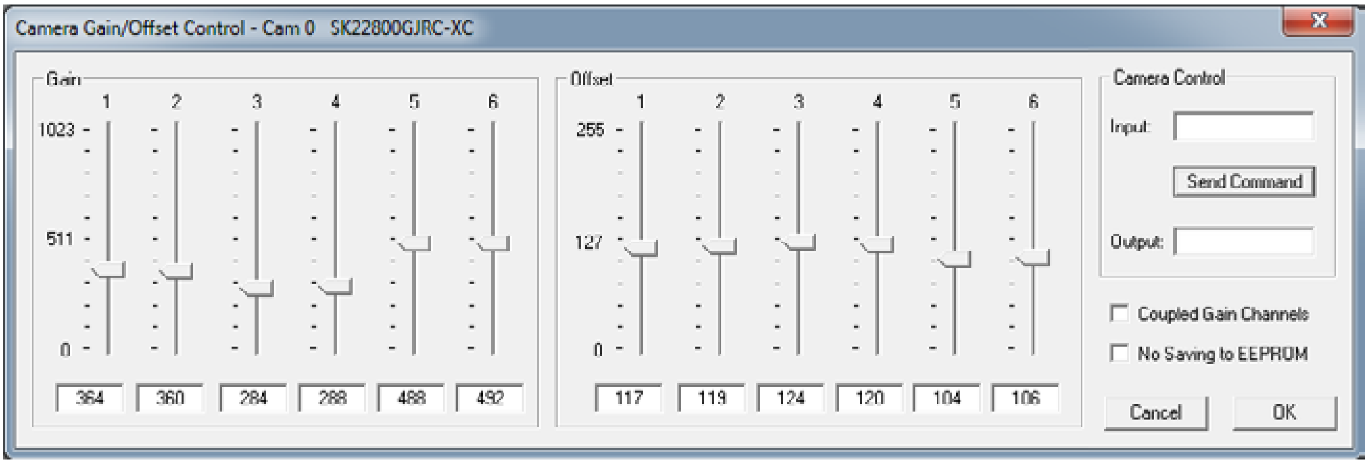
4.1 Camera Control by Commands

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
Goooo<CR>	gain 1 (red odd) setting 0-24 dB
Boooo<CR>	gain 2 (red even) setting 0-24 dB
Hoooo<CR>	gain 3 (green odd) setting 0-24 dB
Joooo<CR>	gain 4 (green even) setting 0-24 dB
[oooo<CR>	gain 5 (blue odd) setting 0-24 dB
@oooo<CR>	gain 6 (blue even) setting 0-24 dB
Oppp<CR>	offset 1 (red odd) setting
Pppp<CR>	offset 2 (red even) setting
Qppp<CR>	offset 3 (green odd) setting
Uppp<CR>	offset 4 (green even) setting
]ppp<CR>	offset 5 (blue odd) setting
_ppp<CR>	offset 6 (blue even) setting

F24<CR>	output format: 3x8 bit output data
F25<CR>	output format: 3x12 bit output data
C120<CR>	camera clock: 120 MHz data rate
C60<CR>	camera clock: 60 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

Set Operation	Description
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
M3<CR>	Pleora sync modes
M5<CR>	line trigger mode5: extern SOS, all lines
A*xxxx*<CR>	SCM address (A*xxxx* = A0-A[22367]) or LUTM (A*xxxx* = A32768-A36863)
D*xxxx*<CR>	SCM 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)
V*yyyyy*<CR>	extern sync divider (*yyyyy* = 1-32767)
Y*pppp*<CR>	set sync control (*ppp* = 0-4095)
W*yyyyy*<CR>	line clock frequency (*yyyyy* = 50-5130) [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* = 195-20000) [µs]
SCOG<CR>	enable COG (coupling of gain settings)
RCOG<CR>	disable COG (coupling of gain settings)
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

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

Request Commands

Request	Return	Description
K<CR>	*SK22368GTFC-4L*	returns SK type number
R<CR>	*Rev.2.62*	returns Revision number
S<CR>	*SNr00163*	returns Serial number
I<CR>	*SK22368GTFC-4L Rev.2.62 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
I11<CR>	Ga4 *yyyyy*	returns gain 4
I12<CR>	Of3: *yyyyy*	returns offset 3
I13<CR>	Of4: *yyyyy*	returns offset 4
I14<CR>	Ga5 *yyyyy*	returns gain 5
I15<CR>	Ga6 *yyyyy*	returns gain 6
I16<CR>	Of5: *yyyyy*	returns offset 5
I17<CR>	Of6: *yyyyy*	returns offset 6
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
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 B D5 = LINE SYNC A D4 ... D0 = 0	intensity
*xxxxxx*10	internal line counter (8 bit)	intensity
*xxxxxx*11	D7 = FRAME SYNC D6 = LINE SYNC B D5 = LINE SYNC A D4 ... D0 = line counter (bit 12 ... 8)	internal line counter (bit 7 ... 0)

Example Timing Diagrams

Annotations:

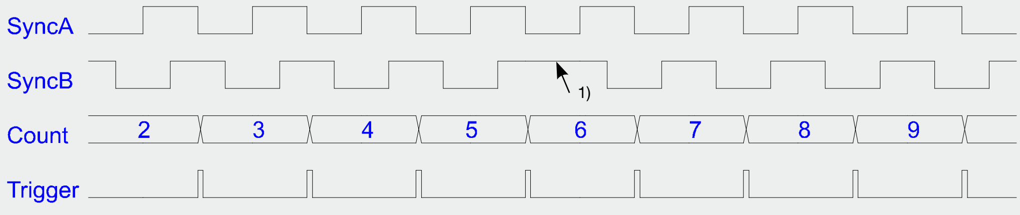
SyncA	=	LINE SYNC A (external line synchronization input, I/O connector)
SyncB	=	LINE SYNC B (external line synchronization input, I/O connector)
Count	=	internal counter
Trigger	=	Generated trigger pulses from the Trigger Control stage. The signal goes to the Trigger Divider stage inside the camera.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

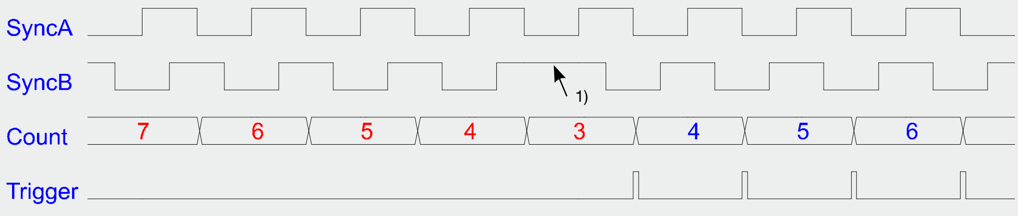
Sync Control Register:
'0xxx xxxx'b



B

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

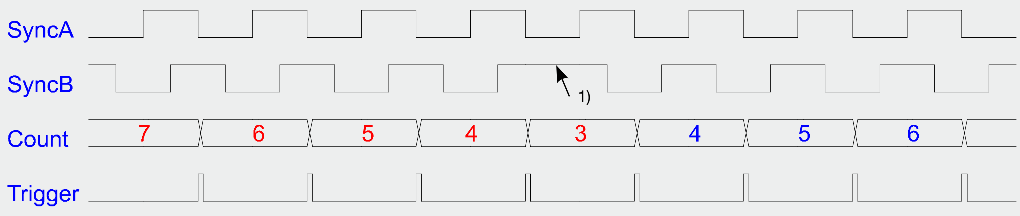
Sync Control Register:
'1000 0xxx'b



C

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

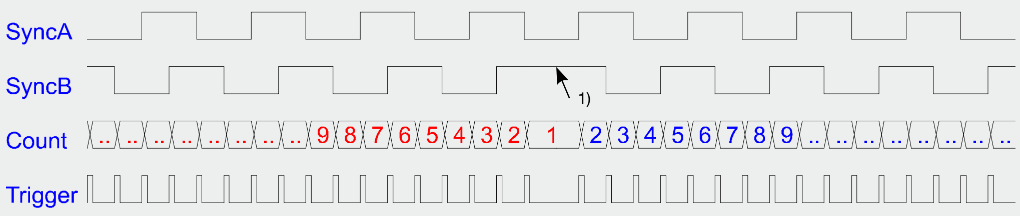
Sync Control Register:
'1100 0xxx'b



D

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

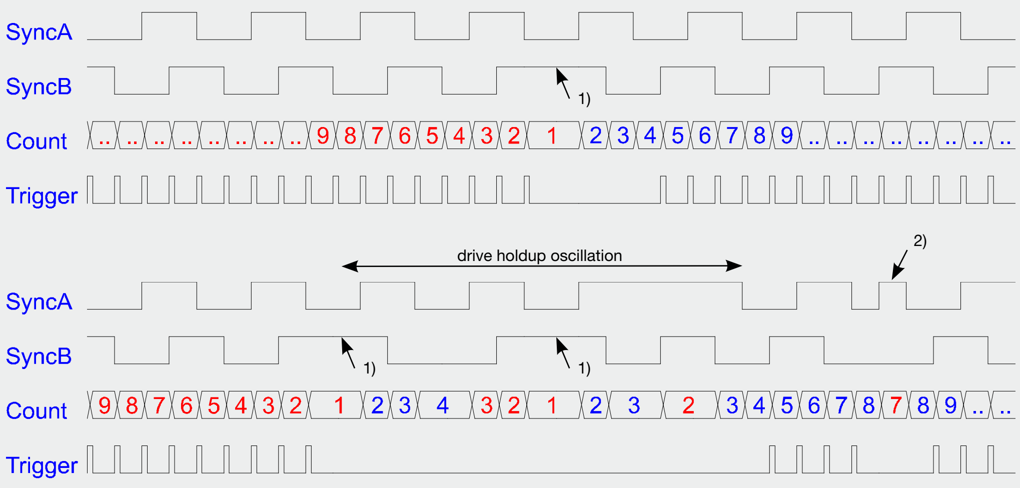
Sync Control Register:
'1110 0xxx'b



E

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

Sync Control Register:
'1110 1xxx'b



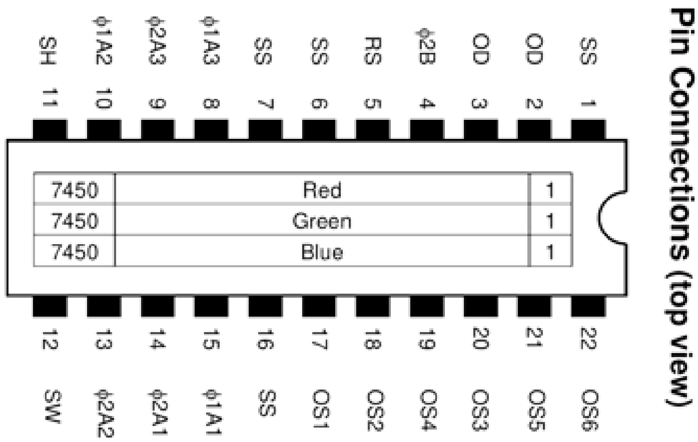
5 Sensor Information

Manufacturer: TOSHIBA Corporation
Type: TCD2724DG-1
Data source: TOSHIBA CCD Linear Image Sensor CCD (Charge Coupled Device) TCD2724DG-1, 2019-01-15

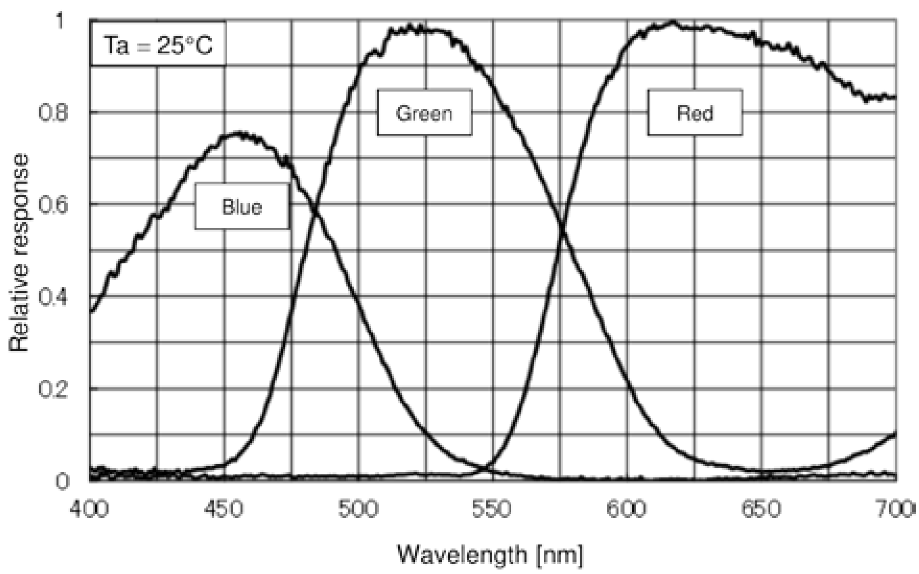
a) Features

- Number of image sensing elements: 7450 elements × 3 lines
- Image sensing elements size: 4.7 µm by 4.7 µm on 4.7 µm center
- Photo sensing region: High sensitive PN photodiode
- Clock: 2-phase (3.3 V)
- Power supply voltage: 10 V (typ.)
- Distance between photodiode array: 18.8 µm (4 lines) R array – G array, G array – B array
- Internal circuit: Clamp circuit, sample and hold circuit, low input capacitance
- Package: 22-pin CERDIP
- Color filter: Red, Green, Blue

b) RGB filter arrangement



c) Typical Spectral Response



d) Optical/Electrical Characteristics

Optical/Electrical Characteristics

Ta = 25°C, V_{OD} = 10 V, V_ϕ = V_{RS} = V_{SH} = 3.3 V (pulse), f_ϕ = 1.0 MHz,
t_{INT} (integration time) = 10 ms, light source = A light source + CM500S (t = 1.0 mm)

Characteristics		Symbol	Min	Typ.	Max	Unit	Note
Sensitivity Enable sample and hold	Red	R_R	9.0	12.8	16.6	V/lx·s	(Note 2)
	Green	R_G	10.5	15.0	19.5		
	Blue	R_B	3.6	5.2	6.8		
Sensitivity Disable sample and hold	Red	R_R	10.0	14.3	18.6		
	Green	R_G	11.8	16.9	22.0		
	Blue	R_B	4.0	5.8	7.5		
Photo response non uniformity		PRNU (1)	—	5	20	%	(Note 3)
		PRNU (3)	—	3	12	mV	(Note 4)
Saturation output voltage		V_{SAT}	1.2	1.8	—	V	(Note 5)
Saturation exposure		SE	0.05	0.1	—	lx·s	(Note 6)
Dark signal voltage		V_{DRK}	—	0.5	6	mV	(Note 7)
Dark signal non uniformity		DSNU	—	10	12	mV	(Note 8)
DC power dissipation		P_D	—	700	1050	mW	—
Total transfer efficiency		TTE	92	97	—	%	—
Output impedance		Z_O	—	0.2	0.5	kΩ	—
DC output signal voltage		V_{OS}	3.7	5.2	6.7	V	(Note 9)
Random noise (Enable sample and hold)		$N_{D\sigma}$	—	1.4	—	mV	(Note 10)
Random noise (Disable sample and hold)			—	1.1	—		

Note 2: Sensitivity is defined for each color of signal outputs average when the photosensitive surface is applied with the light of uniform illumination and uniform color temperature.

Note 3: PRNU (1) is defined for each color on a single chip by the expressions below when the photosensitive surface is applied with the light of uniform illumination and uniform color temperature, where measured approximately 600 mV of signal output.

$$\text{PRNU (1)} = \frac{\Delta X}{\overline{X}} \times 100\ (\%)$$

$\overline{X}$: Average of total signal outputs
ΔX: The maximum deviation from $\overline{X}$

Note 4: PRNU (3) is defined as the maximum voltage with next pixel, where measured approximately 50 mV of signal output.

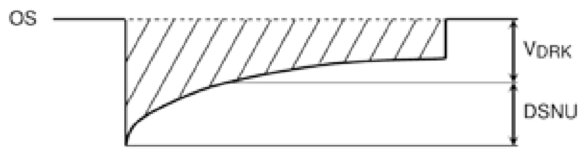
Note 5: V_{SAT} is defined as the minimum saturation output voltage of all effective pixels.

Note 6: Definition of SE:

$$SE = \frac{V_{SAT}}{R_G}$$

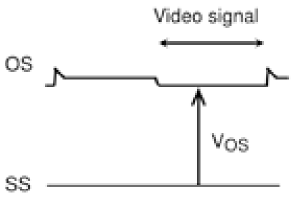
Note 7: V_{DRK} is defined as average dark signal voltage of all effective pixels.

Note 8: DSNU is defined by the difference between average value (V_{DRK}) and the maximum value of the dark voltage.

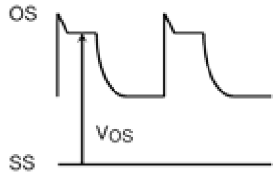


Note 9: DC output signal voltage is defined as follows.
Video signal with sample and hold represents the dummy outputs period.

Enable sample and hold

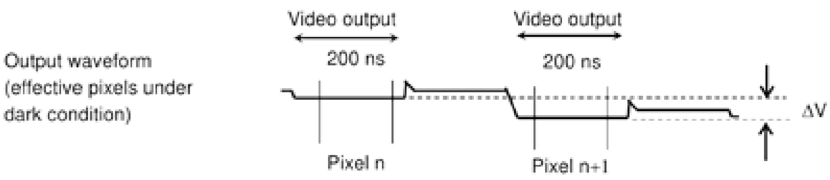


Disable sample and hold

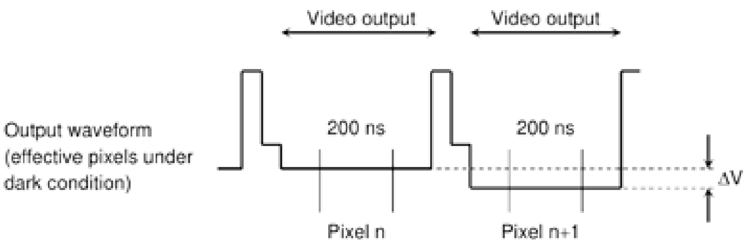


Note 10: Random noise is defined as the standard deviation (sigma) of the output level difference between two adjacent effective pixels under no illumination (i.e. dark condition) calculated by the following procedure.

Enable sample and hold



Disable sample and hold



1) Two adjacent pixels (pixel n and n+1) in one reading are fixed as measurement points.
2) Each of the output levels at video output periods averaged over 200 ns period to get V(n) and V(n+1)
3) V(n+1) is subtracted from V(n) to get ΔV.
   $\Delta V = V(n) - V(n+1)$
4) The standard deviation of ΔV is calculated after procedure 2) and 3) are repeated 30 times (30 readings).

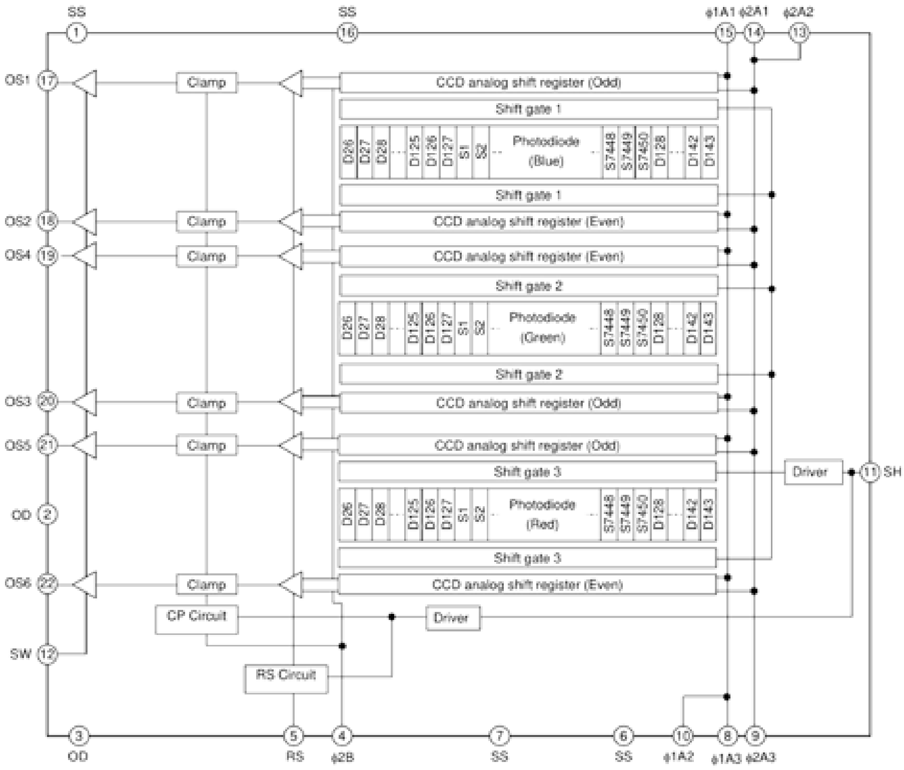
$$\overline{\Delta V} = \frac{1}{30}\sum_{i=1}^{30}|\Delta V_i| \qquad \sigma = \sqrt{\frac{1}{30}\sum_{i=1}^{30}\left(|\Delta V_i| - \overline{\Delta V}\right)^2}$$

5) Procedure 2), 3) and 4) are repeated 10 times to get sigma value.
6) 10 sigma values are averaged.

$$\bar{\sigma} = \frac{1}{10}\sum \sigma i$$

e) Circuit Diagram

Circuit Diagram



Pin Names

Pin No.	Symbol	Name	Pin No.	Symbol	Name
1	SS	Ground	22	OS6	Output signal 6 (Red(Even))
2	OD	Power supply	21	OS5	Output signal 5 (Red(Odd))
3	OD	Power supply	20	OS3	Output signal 3 (Green(Odd))
4	ϕ2B	Last stage transfer clock (phase 2)	19	OS4	Output signal 4 (Green(Even))
5	RS	Reset gate	18	OS2	Output signal 2 (Blue(Even))
6	SS	Ground	17	OS1	Output signal 1 (Blue(Odd))
7	SS	Ground	16	SS	Ground
8	ϕ1A3	Transfer clock 3 (phase 1)	15	ϕ1A1	Transfer clock 1 (phase 1)
9	ϕ2A3	Transfer clock 3 (phase 2)	14	ϕ2A1	Transfer clock 1 (phase 2)
10	ϕ1A2	Transfer clock 2 (phase 1)	13	ϕ2A2	Transfer clock 2 (phase 2)
11	SH	Shift gate	12	SW	Switch gate (Sample and hold output select)

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.

Disposal of Waste of Electrical and Electronic Equipment (WEEE)

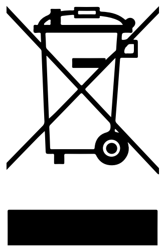
The products placed on the market by Schäfter+Kirchhoff can usually be repaired. Nevertheless, if the product is to be disposed of, please note that used electrical and electronic equipment must not be disposed of in household waste. Used devices must be collected separately and taken to an appropriate collection point.

In accordance with the legal requirements (WEEE Directive 2012/19/EU, Waste of Electrical and Electronic Equipment), Schäfter+Kirchhoff products have been recognized by the responsible German foundation EAR (Elektro- Altgeräte Register) as B2B (Business to Business) products. Schäfter+Kirchhoff is registered there under the WEEE Reg. No. DE 65963161.

In the commercial sector (B2B), disposal is subject to individual contractual agreements. However, Schäfter+Kirchhoff is willing to take back equipment that Schäfter+Kirchhoff has placed on the market within the EU, and to dispose of it properly.

Contact service@sukhambug.de to receive a return form or or download it at https://www.sukhamburg.com/documents/RMA-en.pdf

Note that we only take back products of Schäfter+Kirchhoff. Products from other manufacturers will be returned at the sender's expense. The return form is only used to assign the disposal to Schäfter+Kirchhoff. It is not a parcel label for free shipping. The shipment of the old device must be carried out by you independently and at your own expense.



We the Manufacturer

Schäfter+Kirchhoff GmbH
Kieler Straße 212
22525 Hamburg

Herewith declare that:

Product Description:	**Line Scan Camera**		
Product Family Name:	**Line Scan Cameras with GigE Interface**		
Product Types:	SK1024GJR-4	SK2048GSH-4L	SK16200GTOC-4L
	SK1024GSH-4	SK2048GJR-4L	SK22368GTFC-L
		SK2048GHA-4	SK22368GTFC-4L
		SK7500GTF-4XB	SK22800GJRC-4XC

are produced in accordance with the following:

2011/65/EU	Restriction of Hazardous Substances Directive (RoHS)	2011
2014/30/EU	Directive on the harmonisation of the laws of the Member States relating to electromagnetic compatibility	2014

Following harmonized standards applied:

DIN EN 61326-1	Electrical equipment for measurement, control and laboratory use - EMC requirements – Class A	2022
DIN EN 55011	Industrial, scientific and medical equipment - Radio-frequency disturbance characteristics - Limits and methods of measurement	2022
DIN EN 61010-1	Safety requirements for electrical equipment for measurement, control and laboratory use	2020

I hereby declare that the equipment named has been designed to comply with the relevant sections of the above referenced specifications, and complies with all applicable Essential Requirements of the Directives.

Hamburg, Sept 7, 2023
Place, Date

Managing Director, Dr. Ulrich Oechsner

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.

An EU Declaration of Conformity has been issued for this product.

Date of document publication: 08.09.2023

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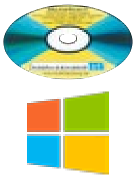
Software



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 V DC supply voltage.

Shielded cable with Hirose plug HR10A, female 4-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

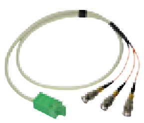
Power cable SK9014.xMF

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

Shielded cable with Hirose plug HR10A, female 4-pin (camera side), and XLR connector type NC6MXX.

SK9014.xMF Order Code

└── cable length 1.5 / 3 / 5 m



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

DE US UK

Power supply unit PS243005

Input: 100-240 VAC, 0.8 A, 50/60 Hz
IEC 60320 C14 coupler (for IEC C13 power cord)
Output: +24 V DC, 3.0 A
Cable length: 1 m, with XLR connector type NC6FXX

PS243005 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

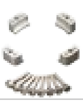
M2 **Mounting Bracket SK5105-L**

Order Code
SK5105-L

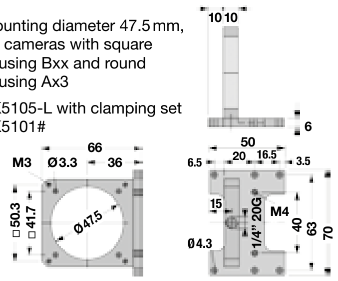
Mounting diameter 47.5 mm, for cameras with square housing Bxx and round housing Ax3

SK5105-L with clamping set SK5101#

MC **Clamping Set SK5101**



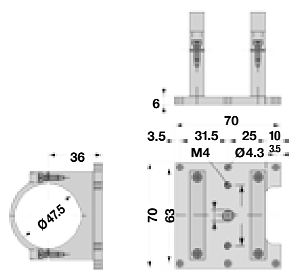
Order Code
SK5101



M4 **Mounting System SK5105-2L**

Order Code
SK5105-2L

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

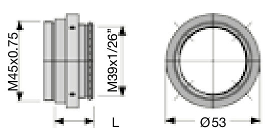


FA3 **Focus adapter L-Mount (M39x1/26" Leica)**

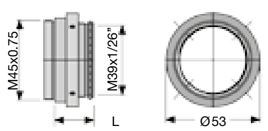
any rotation angle adjustable (V-groove)

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 24.5 mm
60 = Length 60 mm
87 = Length 87.5 mm