EDITION
24/25

# LINE SCAN CAMERAS


Schäfter+Kirchhoff

## About Schäfter+Kirchhoff

Schäfter+Kirchhoff was founded over 65 years ago. The company started with classic lens design and customized optical solutions. The focus has gradually shifted to today's product lines: polarization-maintaining fiber optics, lasers for machine vision, as well as line scan cameras and scanner systems.

Schäfter+Kirchhoff GmbH has its headquarters in Hamburg, Germany. From here, high-quality optical products are developed, manufactured and shipped to customers around the world.

Our customers use our products to conduct basic research, work on quantum computers, they are Nobel Laureates, investigate corrosion phenomena, and so much more. We are a supplier to globally important industry sectors including automotive, solar, aerospace, and semiconductor. Our components are integral part of key technologies driving the global economy.

A major focus is the winning combination of high optical and mechanical precision. This is the basis for the high quality, stability and durability of our products. We are committed to providing the highest quality and reliability possible, a goal continuously improving because of our quality control system.

Extensive know-how and highly qualified, dedicated employees are the driving force of our company. Research and development, manufacturing and technical sales all have a strong technical background and are closely linked, ensuring an exchange at an equal level and a fast and efficient response to customer needs.

Schäfter+Kirchhoff

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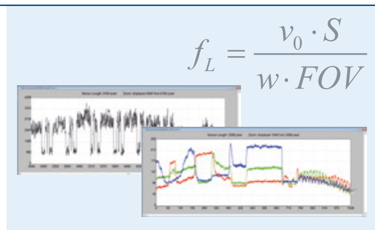



## Line Scan Cameras



## Accessories and Software

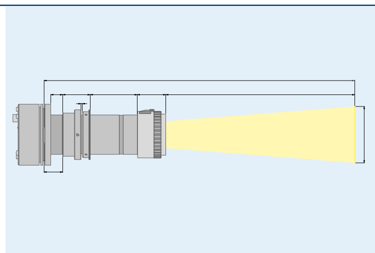






## Customized Line Scan Camera Configurations





# Introduction

# Introduction to Line Scan Cameras

# What are Line Scan Cameras?

**Technotes and Fundamentals**
For more information, please refer to the extensive technotes section on: www.sukhamburg.com/support/technotes.html

Line scan cameras are semiconductor cameras used in many industrial environments. The single photosensitive line sensor contains – depending on type – up to 22800 picture elements (pixels). Light energy incident on the sensor is transformed into an electric signal for digitization within the camera.

At 8-bit resolution, the A/D converter transmits the output voltage of each pixel into one of 256 brightness levels, at 12-bit resolution into 4096 brightness levels.

Color line scan cameras provide three separate line signals for Red, Green and Blue with either 3 x 8-bit or 3 x 12-bit per pixel. The digitized output signal is transfered to a computer via various interfaces according to requirements, e.g. Gigabit Ethernet or USB 3.0.

**The advantages of a line scan camera include**

- high optical resolution of up to 8160 pixels (monochrome) or 3 x 7600 pixels (color RGB)
- high speed of up to 54 kHz line frequency
- flexible parameter setting for the line scans
- synchronizing of each individual line, as well as the triggering of frames
- when focused on the zenith of cylindrical objects, the line scan camera delivers sharp, distortion-free images of the external surface during rotation
- flexible image height from 1 up to 64000 lines per image
- continuous scanning of endless materials such as foils or paper without a time limit.



## Image Acquisition

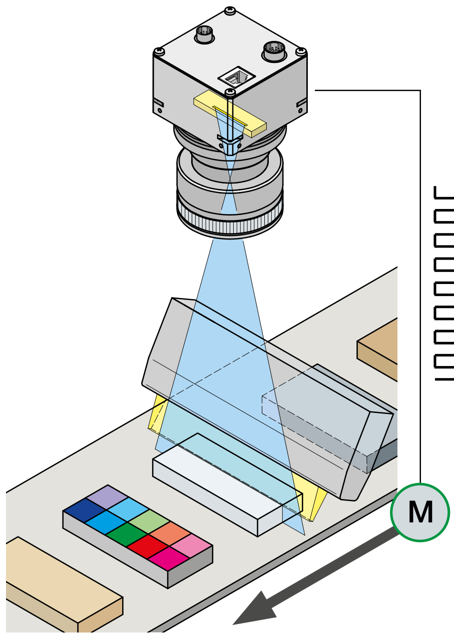
The image produced by a line scan camera is one-dimensional and represents the brightness profile of an object, captured at the current position of the line sensor. A two-dimensional image is generated by performing a scanning movement of either the object or the camera, during which the individual line signals are transferred to the computer and assembled one by one into a 2D image.

### Improving the image

High image quality can only be achieved with the appropriate combination of line scan camera, high resolution lens, appropriate lighting and a precise motor unit, whether rotary or linear drive or a conveyer belt. For an image to be correct in all proportions, the scanning speed and the image acquisition process must be highly synchronized and this is most easily achieved by adjusting the transport speed to the line frequency of the camera. However, in practice, it is usually the transport speed and the image resolution that are constraining and these predefine the line frequency and ultimate choice of line camera.

At constant transport speeds, such as when examining objects on a conveyor belt, a line scan camera can be allowed to operate in a free-running mode. Where there are velocity fluctuations or discordant movements then external triggering of the line scan camera is required. The trigger pulses, e.g. from an encoder, are equidistant and independent of the movement velocity so that the camera will be triggered after a constant travelled distance.

This precise synchronization guarantees images with a reproducible resolution and correct aspect ratio.




The production of a 2D image requires precise synchronization of the line camera sensor and the speed of transport of the object.

The line frequency $f_L$ can be calculated for a given object speed $v_0$ and field width $FOV$, sensor length $S$ and pixel width $w$ from

$$f_L = \frac{v_0 \cdot S}{w \cdot FOV} \quad (1)$$



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# Line Scan Camera Applications

Generally, the applications can be grouped into one-dimensional or two-dimensional measuring tasks.

For one-dimensional applications, the measured result is extracted from the pixel information of an individual line scan. Measurements of two-dimensional images require moving either the object or the line sensor.

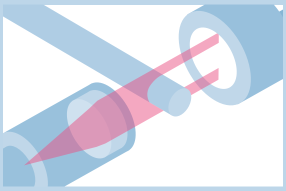
### Camera Application:

**1-dimensional**

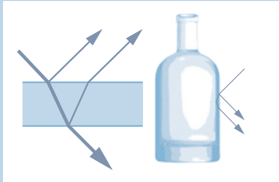
- Signal generation: individual line scan
- Examples: measurement of width, rod diameter, edge positions, glass thickness.

**2-dimensional**

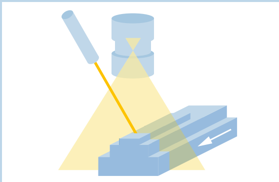
- Several line scans are combined to produce a 2D image (frame)
- Examples: surface inspection, endless webbing inspection, texture analysis, scanning.



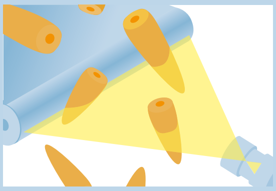
**Laser shadow boundaries**
Determination of rod diameters, by evaluation of shadow boundaries excited by the laser beam



**Glass thickness measurement**
Partial reflections at surfaces reach the line scan sensor with distinct timing off-sets that are related to glass thickness.

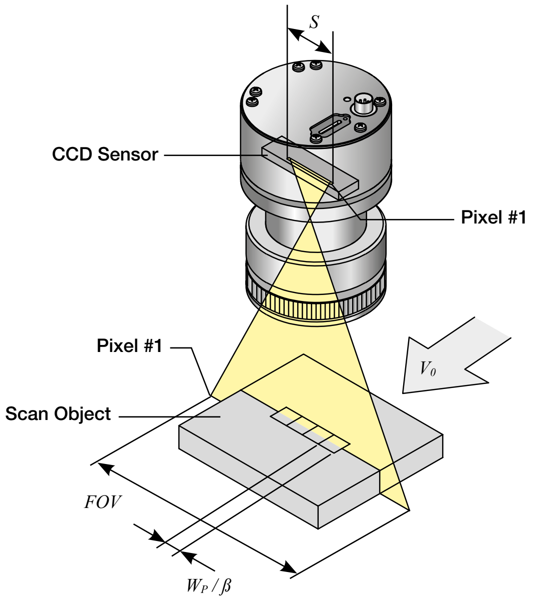


**Conveyor belt**
A line scan camera can provide height information during object transit using laser triangulation



**Screening installation**
Objects are sorted according to size or for defects as they drop through a line scan camera field

## Optical Resolution




The native resolution of an optical line scan camera is defined by the number of pixels – the row of photosensitive elements in the sensor line. Line scan cameras are available with more than 8000 pixels.

The resolution of the scanner system is determined by the objective lens chosen and the scale of the image $\beta'$, as a function of the ratio of image size ($FOV$, field of view) to object size $S$:

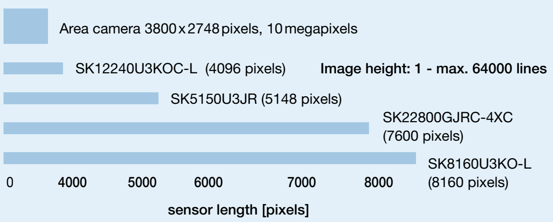
$$\beta' = \frac{S}{FOV} \quad (2)$$

$$p' = \frac{w}{\beta'} \quad (3)$$

Also, to maintain the correct aspect ratio for an image, the pixel resolution $p'$, (3) in the direction of the sensor X-axis must be identical to that in the direction of the transport Y-axis, perpendicular to the sensor. The resolution in the direction of transport is a function of transport speed and the line frequency of the camera as determined in Equation (1).

An identical resolution in both the X and Y-axis directions is an absolute prerequisite for the accurate geometrical measurement of the surface characteristics of the test object. The optical resolution of the scanner system is often reported in dots per unit length, usually dots per inch or dpi.

### Comparison: a conventional area camera and various line scan cameras



# Synchronization

## Synchronization of line scan cameras

In practice, a line scan camera has to be externally synchronized in order to obtain distortion-free images, e.g. triggered by an encoder.

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

1. **Line synchronization:**
   A TTL signal at the LINE SYNC input triggers each individual exposure of the sensor line by line.
2. **Frame synchronization:**
   The recording of a set of lines (frame) representing a two-dimensional image is triggered by a TTL signal at the FRAME SYNC input.

**Line Syncronization Modes:**

**FreeRun** / 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 the 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.

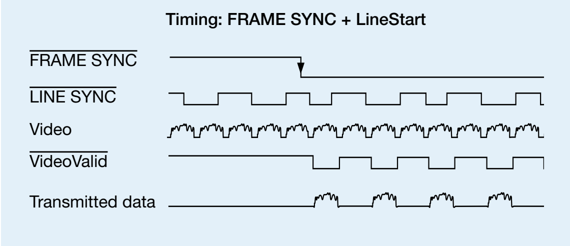
Limitation: The period duration of the trigger signal must be longer than the exposure time used.

**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.

**Frame Synchronization**

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.



# Blooming – Anti-Blooming

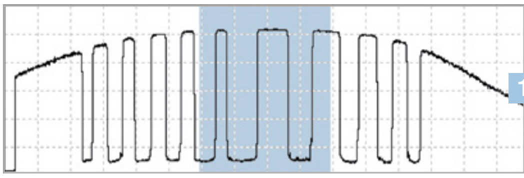
### Blooming and Anti-Blooming Correction

When the line sensor is saturated from excessive illumination and cannot accumulate more charges, the overloaded pixels transfer some of the excess charge to adjacent pixels – an effect termed blooming. Blooming leads to the corruption of the geometrical assignment of both the signal and the image generated by the line sensor.

A line scan camera with an anti-blooming sensor can effectively dissipate the surplus charge arising from over-exposure by using a ‘drain gate’. The less exposed neighboring pixels are no longer corrupted. Over-exposures of up to 30-fold can be drained successfully, depending on the pixel frequency and spectral range of the line sensor.

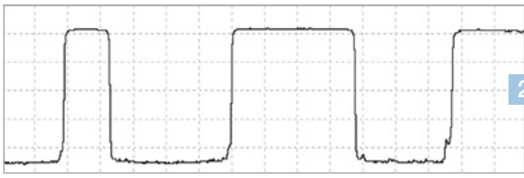
Line scan camera signal from a bar code using a midtone incident light and the SK2048U3JR line scan camera without an anti-blooming sensor.

1 Line signal with enhanced illumination of the central range



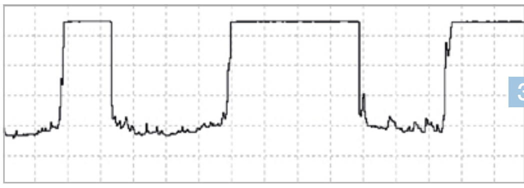
1

2 Zoom of the signal depicted in 1 showing the steep signal edge



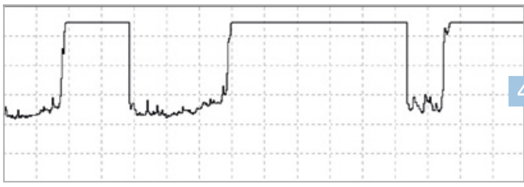
2

3 Extension of the integration time by a factor of 3.81 produces edges that are no longer vertical and have noticeable shoulders – the blooming of the sensor has begun



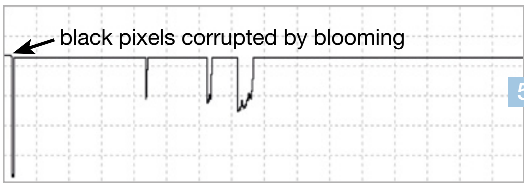
3

4 Over-exposure caused by too large an integration time leads to severe signal and data corruption when using line scan cameras without anti-blooming



4

5 Extreme over-exposure floods the dark pixels of the sensor, the offset control is disturbed and the line scan camera produces an attenuated signal

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# Features Selection Criteria

**In addition to the interface, other important technical features of the cameras should be considered when selecting a camera for the required application.**

Technical considerations include:

- Pixel number
- Pixel size
- Sensor length
- Maximum line rate
- Anti-blooming
- Integration control
- Dynamic range
- Spectral sensitivity

Quick and efficient product selection with the Product Configurator:
www.sukhamburg.com

## Pixel number / line rate:

**A high optical resolution is obtained from a large number of pixels. However, the line rate of the chosen camera must be high enough to reach this resolution in the scanning direction at a given scanning speed.**

## Sensor length:

**A suitable lens must be available for the specified sensor length and desired magnification.**

## Anti-blooming:

Blooming from the transfer of excess charges from oversaturated pixels to adjacent pixels can cause signal broadening and signal loss. Cameras with an anti-blooming function drain the excess charge and restore favorable signal characteristics.

## Integration control:

Line scan frequency is inversely proportional to exposure time; while the charges from a finished line scan are read out, the next line scan is being exposed. Thus, the minimum exposure period is achieved at the maximum line scan frequency. Integration control can act as a shutter by truncating the accumulation of charges and ending the line scan period. For high light intensities, over-exposure and blooming can also be avoided using integration control.

## Dynamic range and digitalization depth:

Depending on the sensor used, line scan cameras are characterized by their dynamic range (signal-to-noise ratio). Some digital line scan cameras can be operated with either 8 or 12-bit digitalization depths.

## Spectral sensitivity:

The spectral sensitivity of the line scan camera must be appropriate to the wavelengths of the light source used and the optical properties of the measured object.

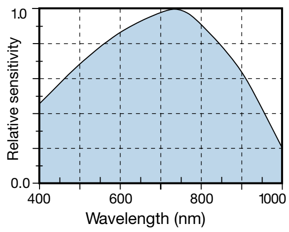
Cameras used for laser-based measurement systems have different spectral sensitivities than a color scanning system.

Because of these spectral sensitivity characteristics, some RGB sensors requires a UV/IR blocking filter when used in daylight.

## Relative spectral sensitivity of various line scan cameras

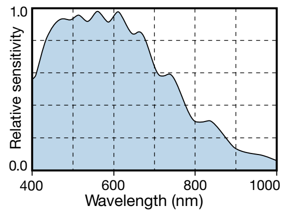
**Camera series ..SD, ..SH**

with typical spectral sensitivity of silicon



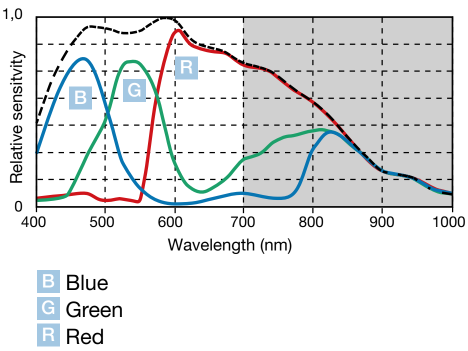

**Camera series ..JR**

with increased blue-green sensitivity




**Color cameras (exemplary)**

For a color sensor with RGB sensitivity, the spectral detection can be limitedto only the visible range of 400 –700 nm by **using a UV/IR blocking filter**



# Common Camera Interfaces

The choice of interface determines some of the basic functional features of the line scan camera such as maximum cable length and maximum line frequency. This decision should therefore be included in the type selection at an early stage.

Schäfter+Kirchhoff supplies line scan cameras with GigE Vision as well as USB 3.0 interface. CameraLink is also available for some types on request. The table below summarizes the main features of these interfaces.

**GigE Vision**

- GigE Vision™ and Gen<i>CAM™ standards ensure third party hard and software compatibility
- Large distances between camera and PC possible
- Power over Ethernet (PoE) is supportet

**USB 3.0**

- High performance line scan cameras, suitable for mobile measurement systems
- Does not require an external power supply for power consumptions up to 4.5 W

**Camera Link**

- Industry-common standard for machine vision
- Very high transfer speeds
- Requires separate CameraLink grabber

| | | GigE Vision | USB 3.0 | Camera Link |
|---|---|---|---|---|
| **Properties** | | | | |
| Max Cable Length | | 100 m | 3 m, up to 100 m with fiber optical cable extension | 10 m |
| Max Pixel Frequency | | 120 MHz | 150 MHz | 3 x 70 MHz |
| External Synchronization | Line Sync | ✓ | ✓ | ✓ |
| | Frame Sync | ✓ | ✓ | ✓ |
| | Sync Divider | ✓ | ✓ | — |
| Number of Devices | | up to 255 | up to 127 | up to 4 |
| Grabber Board | | — | — | Camera Link Frame Grabber |
| Required PC interface | | GigE | USB 3.0 | |
| External Power Supply | | required / dispensable when Power over Ethernet is used | not required | required |
| **Available Software** | | | | |
| Image Aquisition and Configuration Tools | Windows | SkGEVTool | SkLineScan-U3-WIN | SKCLconfig tool |
| | LabView | NI-IMAQdx | | Grabber dependent |
| | Linux | SkLineScan-GEV-LX | SkLineScan-U3-LX | |
| Software Development Kit (SDK) | Windows | SK91GEV-WIN | SK91USB3-WIN | Grabber dependent |
| | LabView | 3rd party, e.g. CVB, Halcon, NI-IMAQdx | on request | |
| | Linux | SK91GEV-LX | SK91USB3-LX | |
| **Software Compatibility** | | | | |
| Gen<i>CAM™ | | ✓ | — | Grabber dependent |

# How to Order – Using the Product Configurator

## Using the Product Configurator

### Fast and easy selection of line scan cameras on www.sukhamburg.com

The new product configurator for line scan cameras, helps select products based on a number of technical s pecifications and narrows down the search to a few relevant products that meet the customer's need.

- Sliders/check boxes for different parameters like e.g pixel number, pixel dimension or max. line frequency etc.
- Selection of camera interface (GigE, GigEVision, Camera Link or USB 3.0)
- Selection of monochrome or color sensor
- Selection of lens mount
- Special features like active sensor length, integration control, anti-blooming, TDI, Extended gray scale

**Technical details can be compared 1:1 by using the product comparison function.**

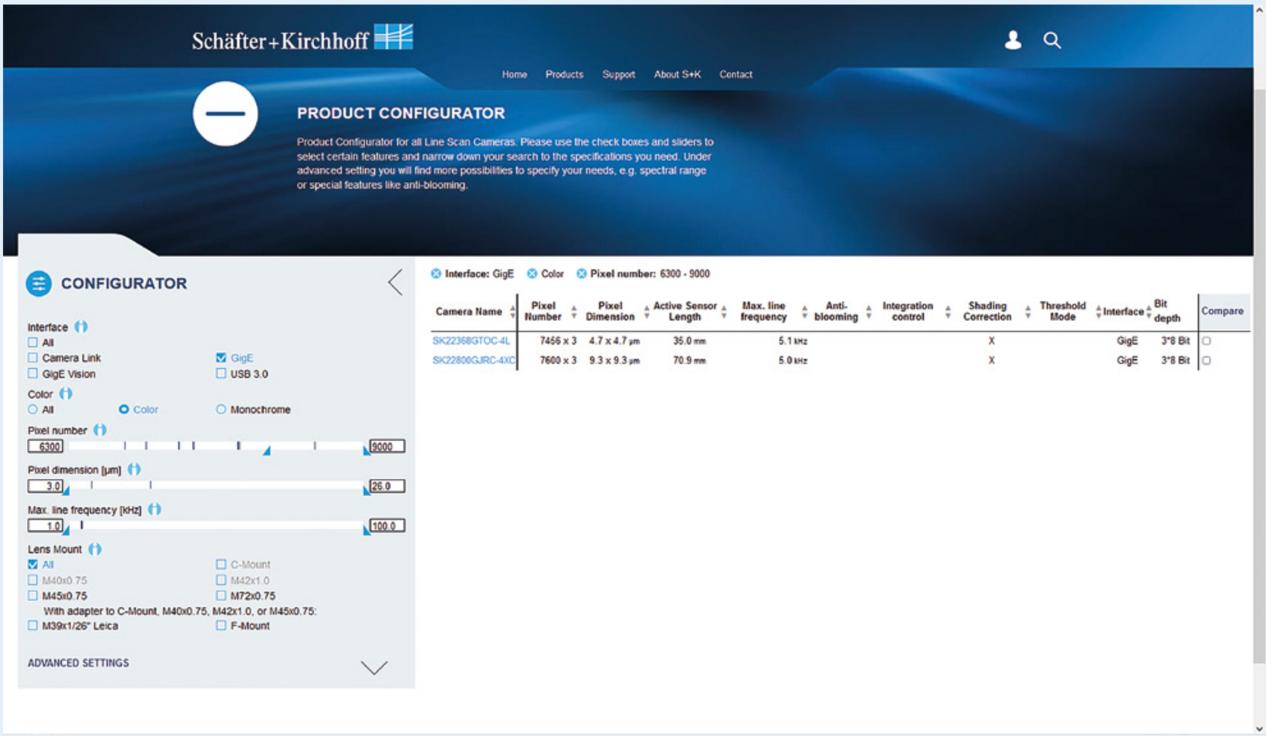
**The detailed specific product pages include:**

- Detailed description
- Up-to-date technical data, download of data sheets
- Technical drawings including step files (step files for registered users only)
- Adequate accessories including tools, adapters etc.
- Extensive technotes section
- FAQs

Using the product configurator, all camera parameters can be found on the specific product pages.

The data on the website is updated frequently. If you want the latest information on our line scan cameras, please refer to www.sukhamburg.com/products/linescancamera.html

**Example of the Product Configurator (https://www.sukhamburg.com/products/linescancameras/configurator.htm)**



# Setting up a Line Scan Camera System



**Lens focusing performed using the oscilloscope display**

The real-time display of the line scan camera signal facilitates the focusing of the camera lens. This display can even be used to focus a line scan camera system when making measurements in two dimensions.
Variations in edge steepness at dark-bright transitions and modulations in the line scan signals provide a useful mechanism for establishing the correct focus (see figure). Initial focusing is performed with a fully opened aperture, when the depth of field is at its smallest and the sensitivity of focus adjustment is at its largest. The integration time can also be shortened to provide a sufficiently sensitive low amplitude signal.

**Evaluation of a correct focus setting by using the line scan signal**

A Line scan camera out of focus:
edges are indistinct, signal peaks are blurred with low modulation of high frequency densities

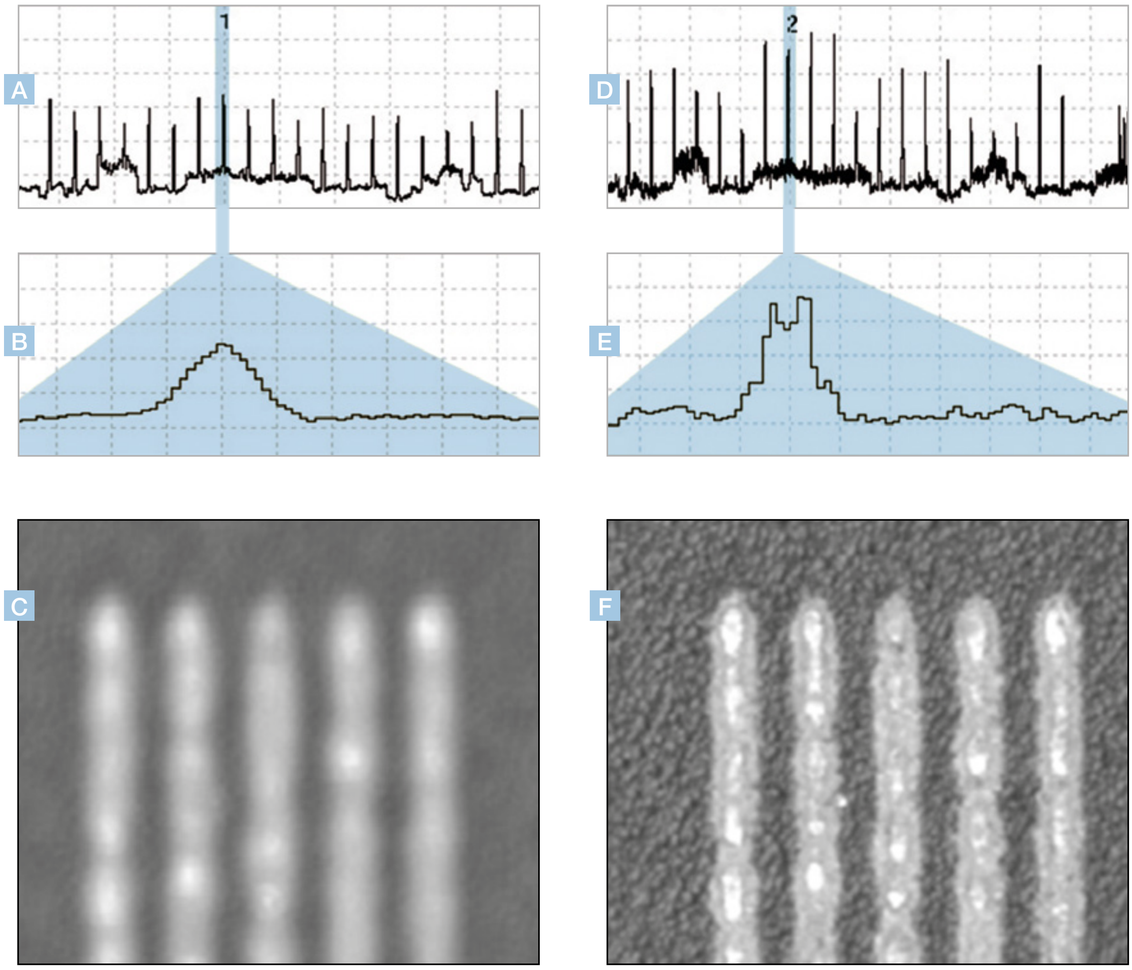
B Zoom of highlighted area in A

C Area scan with focus settings A and B

D Line scan camera signal with optimal focus setting:
dark-bright transitions have sharp edges, highly modulated signal peaks with high frequency density variations

E Zoom of highlighted area in D

F Area scan with focus settings D and E



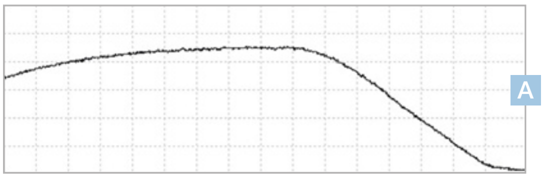
# Sensor Alignment and Shading Correction

## Sensor alignment

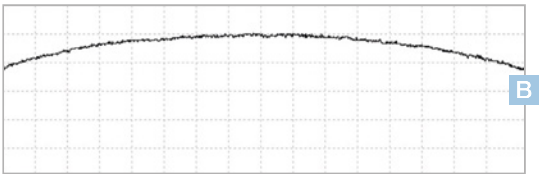
For linear illumination sources, rotating the line sensor results in asymmetric vignetting.

The camera and illumination optics can be aligned optimally by monitoring the object illumination using the oscilloscope display.

A Sensor and illumination optics rotated in apposition




B Sensor and illumination optics aligned properly




## Shading correction and white balance

All lenses show some vignetting as a function of the field angle. Hence, even with homogeneous object illumination, the signal intensity of the image decreases with increasing image height.

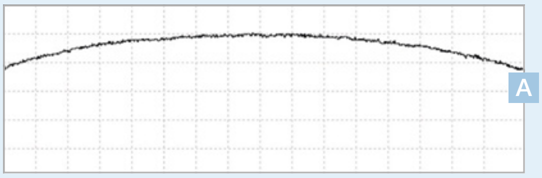
Shading correction (or flat field compensation) is used to compensate for lens vignetting A as well as for inhomogeneity in the illumination. Shading correction is achieved by performing a white balance calibration during illumination of a homogeneous white target.

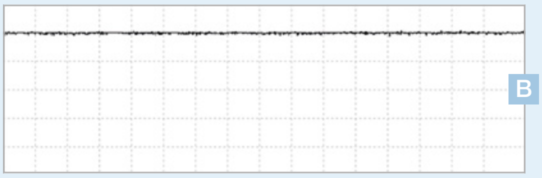
An individual gain for each pixel is obtained by scaling each value to a normalized maximum signal. The oscilloscope display now shows a homogeneous intensity distribution along the entire length of the line sensor B.

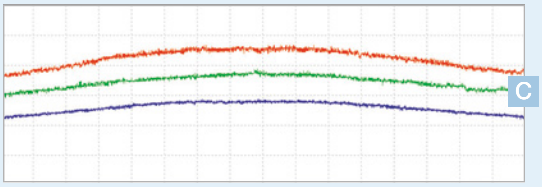
The shading correction procedure is also used for white balance calibrations in color line scan cameras. The different sensitivities of the individual color channels of the sensor are compensated for, as well as any color inhomogeneity arising from the illumination source.

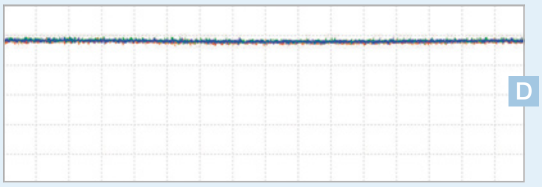
The SkLineScan software package provides all necessary functions for the performance of shading correction and white balance.

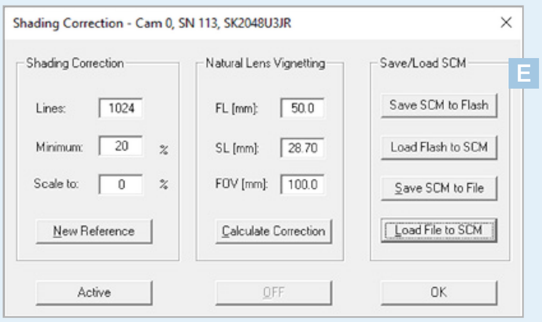
For individual software needs, library functions for shading correction and white balance are provided in the SDKs for the various interfaces.




### Shading correction and white balance

- A A monochrome line scan camera signal of a homogeneous white calibration target showing signal trimming caused by either lens vignetting or inhomogeneous object illumination
- B Monochrome line scan camera signal after shading correction
- C Signal from a color line scan camera of a homogeneous white calibration target showing the effect of trimming on red, green and blue signals
- D Color line scan signal after shading correction
- E Pop-up window for performing shading correction in the SkLineScan software allows white balance calibration to be performed automatically or manually

Schäfter+Kirchhoff

# Line Scan Cameras

# Line Scan Cameras

# Line Scan Cameras – Our Focus

### What you can expect from a Schäfter+Kirchhoff line scan camera

Schäfter+Kirchhoff was one of the pioneers in the line scan camera industry, launching its first product in the 1980s. Our initial product offerings were CCD line scan cameras that provided an analog signal display on oscilloscope, later that included PC interface cards.

We have always concentrated on line scan cameras in particular, and the specific advantages they offer our customers. Typical advantages include a high optical resolution, synchronizing of each individual line, as well as the triggering of frames, sharp, distortion-free images of the external surface during rotation, flexible image height, and continuous scanning of endless materials such as foils or paper without a time limit.

**Our primary focus has always been: It is essential to have reliable hardware and well-matched components in order to ensure optimal image data.**

Gigabit Ethernet RJ-45 connection with locking screws

USB 3.0 Micro-B connection with locking screws

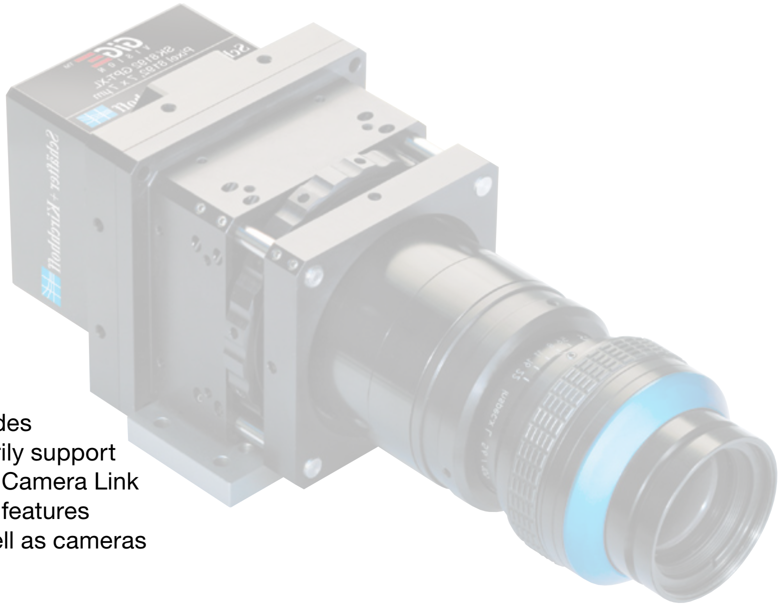
### High Quality and Reliability

All our cameras are equipped with a robust, industrial-grade aluminum housing. The product is resistant to shock, ensures rapid heat dissipation, and has good EMC properties.

Our stable mounting solutions, which include adjustment options at precisely the right points, ensure vibration-free images. Our in-house mechanical production capabilities allow us to provide individual solutions within a reasonable delivery time.

For customized application, we layout the image configuration and select the right tube, adapter, and lens components as part of our service.

Manufacturers of durable industrial machinery in particular have placed their trust in us for decades, as we take care of suitable replacement solutions when the procurement situation requires it.



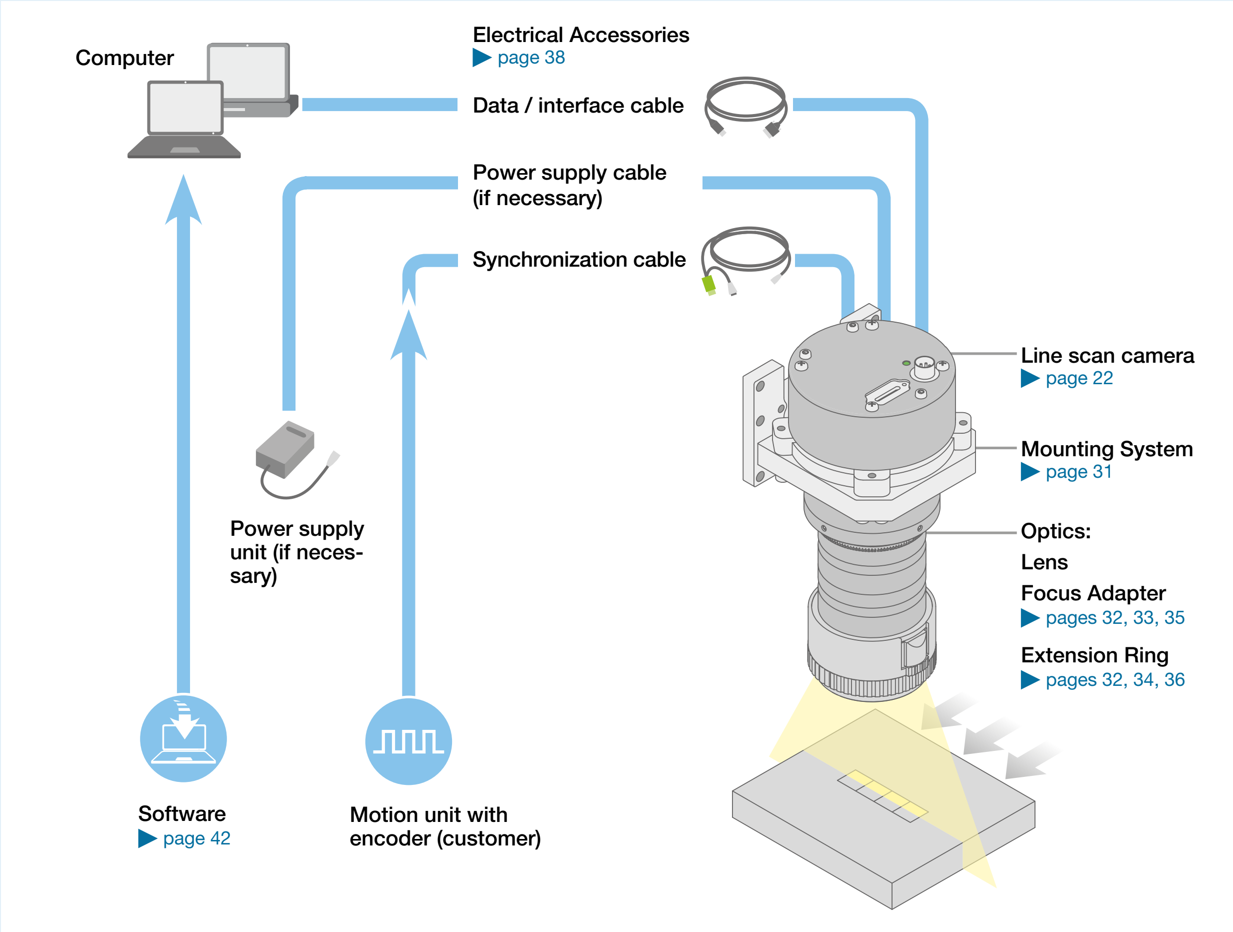
### This Line Scan Camera Catalogue

Our current line of line scan cameras includes monochrome and color models. We primarily support GigE and USB interfaces, and can provide Camera Link cameras upon request. Our product range features models with proven CCD technology as well as cameras with modern CMOS sensors.

This catalogue showcases our recommended models for new applications and projects. For spare parts or individual items, please refer to our website or contact us directly.

Detailed data sheets, up-to-date technical information, technical drawings including step files, accessories, extensive technotes section and FAQs:
**www.sukhamburg.com**

# Components of a Line Scan Camera System



# Overview Line Scan Camera Types

## Order Options

| Pos. | Order Code | monochrome color | Sensor Technology | Interface | Pixels | Active Length [mm] | Pixel Size [µm] | Max. Line Frequency [kHz] | Grayscale/ Colordepth | SNR | Lens Mount | Casing |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **Camera Series DR** | | | | | | | | | | | |
| 1 | SK8k-U3DR4 NEW! | monochrome | CMOS | USB 3.0 | 8192 | 28.67 | 3.5 x 3.5 | 43.4 | 8/10 Bit | 220:1 | M45x0.75 | NT3 |
| 2 | SK4k-U3DR7C NEW! | color | CMOS | USB 3.0 | 4096 x 2 | 28.67 | 7 x 7 | 43.4 | 8 Bit | 220:1 | M45x0.75 | NT3 |
| | **Camera Series JR** | | | | | | | | | | | |
| 3 | SK2048U3JR | monochrome | CCD | USB 3.0 | 2048 | 28.70 | 14 x 14 | 4.7 | 8/12 Bit | 350:1 | M40x0.75 | AT2 |
| | **Camera Series HA** | | | | | | | | | | | |
| 4 | SK1024U3HA | monochrome | CCD | USB 3.0 | 1024 | 8.19 | 8 x 8 | 52.6 | 8/12 Bit | 310:1 | C-Mount | AT1 |
| 5 | SK2048U3HA | monochrome | CCD | USB 3.0 | 2048 | 16.38 | 8 x 8 | 52.6 | 8/12 Bit | 310:1 | C-Mount | AT1 |
| | **Camera Series SH** | | | | | | | | | | | |
| 6 | SK512U3SH | monochrome | CCD | USB 3.0 | 512 | 7.17 | 14 x 14 | 35.7 | 8/12 Bit | 350:1 | C-Mount | AT1 |
| 7 | SK1024U3SH | monochrome | CCD | USB 3.0 | 1024 | 14.30 | 14 x 14 | 27.0 | 8/12 Bit | 350:1 | C-Mount | AT1 |
| 8 | SK1024MVSH | monochrome | CCD | GigE Vision | 1024 | 14.30 | 14 x 14 | 27.0 | 8/12 Bit | 350:1 | C-Mount | RG1 |
| 9 | SK2048MVSH | monochrome | CCD | GigE Vision | 2048 | 28.70 | 14 x 14 | 14.1 | 8/12 Bit | 350:1 | M40x0.75 | RG2 |
| 10 | SK2048U3SH | monochrome | CCD | USB 3.0 | 2048 | 28.70 | 14 x 14 | 14.0 | 8/12 Bit | 350:1 | M40x0.75 | AT2 |

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# Standard Line Scan Cameras – USB Interface and CMOS Sensor

## M45x0.75

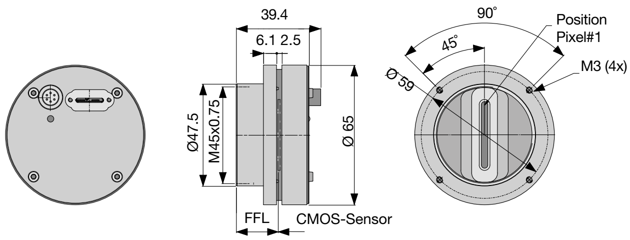
**Types:**

| |
|---|
| SK8k-U3DR4 |
| SK4k-U3DR7C |

NEW!

NT3

| | |
|---|---|
| Lens mount: | M45x0.75 |
| Seat for bracket: | Ø 47.5 mm |
| Flange focal length: | FFL = 19.5 mm |

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mono chrome | CMOS

### SK8k-U3DR4

**Monochrome line scan camera, CMOS sensor, spectral range 400 to 800 nm, 43.4 kHz line rate, anti blooming and integration control.**

| | |
|---|---|
| Pixels, dimensions | 8192, 3.5 x 3.5 µm² |
| Sensor length | 28.67 mm |
| Max. line frequency | 43.4 kHz |
| Pixel frequencies | 200 MHz |
| Exposure time | 0.023 ... 20 ms |
| Spectral range | 400 ... 800 nm |
| Dynamic range | 1:1000 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8/10 Bit |

| | |
|---|---|
| **Lens mount** | **M45x0.75** |
| Camera Casing | NT3 |

| | |
|---|---|
| Supply Voltage | USB |
| Power | 2.2 W |

RGB | CMOS

### SK4k-U3DR7C

**Color line scan camera, CMOS sensor, Bayer pattern, spectral range 400 to 800 nm, 43.4 kHz line rate, anti blooming and integration control.**

| | |
|---|---|
| Pixels, dimensions | 4096 x 2, 7 x 7 µm² |
| Sensor length | 28.67 mm |
| Max. line frequency | 43.4 kHz |
| Pixel frequencies | 200 MHz |
| Exposure time | 0.023 ... 20 ms |
| Spectral range | 400 ... 800 nm |
| Dynamic range | 1:1000 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8 Bit |

| | |
|---|---|
| **Lens mount** | **M45x0.75** |
| Camera Casing | NT3 |

| | |
|---|---|
| Supply Voltage | USB |
| Power | 2.8 W |

# Standard Line Scan Cameras – USB Interface and CCD Sensor

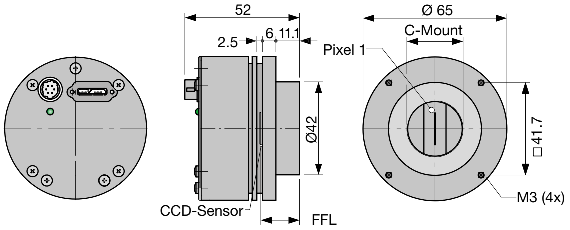
## C-Mount

**Types:**

| |
|---|
| SK512U3SH |
| SK1024U3HA |
| SK1024U3SH |
| SK2048U3HA |

AT1

| | |
|---|---|
| Lens mount: | C-Mount |
| Seat for bracket: | Ø 42 mm |
| Flange focal length: | FFL = 17.5 mm |

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mono chrome | CCD

### SK512U3SH

**Line scan camera with 35.7 kHz maximum line rate, large dynamic range, anti blooming and integration control.**

| | |
|---|---|
| Pixels, dimensions | 512, 14 x 14 µm² |
| Sensor length | 7.17 mm |
| Max. line frequency | 35.7 kHz |
| Pixel frequencies | 30 or 15 MHz |
| Exposure time | 0.01 ... 20 ms |
| Spectral range | 200 ... 1000 nm |
| Dynamic range | 1:2000 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8/12 Bit |

| | |
|---|---|
| **Lens mount** | **C-Mount** |
| Camera Casing | AT1 |

| | |
|---|---|
| Supply Voltage | USB (500 mA) |
| Power | 2.5 W |

mono chrome | CCD

### SK1024U3HA

**Line scan camera, high speed with 52.63 kHz maximum line rate, spectral range of 200 to 1000 nm.**

| | |
|---|---|
| Pixels, dimensions | 1024, 8 x 8 µm² |
| Sensor length | 8.19 mm |
| Max. line frequency | 52.6 kHz |
| Pixel frequencies | 120 or 90 MHz |
| Exposure time | 0.01 ... 20 ms |
| Spectral range | 200 ... 1000 nm |
| Dynamic range | 1:2500 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8/12 Bit |

| | |
|---|---|
| **Lens mount** | **C-Mount** |
| Camera Casing | AT1 |

| | |
|---|---|
| Supply Voltage | USB (800 mA) |
| Power | 3.3 W |

mono chrome | CCD

### SK1024U3SH

**Line scan camera with 27 kHz maximum line rate, large dynamic range, anti blooming and integration control.**

| | |
|---|---|
| Pixels, dimensions | 1024, 14 x 14 µm² |
| Sensor length | 14.30 mm |
| Max. line frequency | 27.0 kHz |
| Pixel frequencies | 30 or 15 MHz |
| Exposure time | 0.01 ... 20 ms |
| Spectral range | 200 ... 1000 nm |
| Dynamic range | 1:2500 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8/12 Bit |

| | |
|---|---|
| **Lens mount** | **C-Mount** |
| Camera Casing | AT1 |

| | |
|---|---|
| Supply Voltage | USB (500 mA) |
| Power | 2.5 W |

# Standard Line Scan Cameras – USB Interface and CCD Sensor

**mono chrome** **CCD**

## SK2048U3HA

Line scan camera, high speed with 52.63 kHz maximum line rate, spectral range of 200 to 1000 nm.

| | |
|---|---|
| Pixels, dimensions | 2048, 8 x 8 µm² |
| Sensor length | 16.38 mm |
| Max. line frequency | 52.6 kHz |
| Pixel frequencies | 120 or 90 MHz |
| Exposure time | 0.01 ... 20 ms |
| Spectral range | 200 ... 1000 nm |
| Dynamic range | 1:2500 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8/12 Bit |

| **Lens mount** | **C-Mount** |
|---|---|
| Camera Casing | AT1 |

| Supply Voltage | USB (800 mA) |
|---|---|
| Power | 3.3 W |

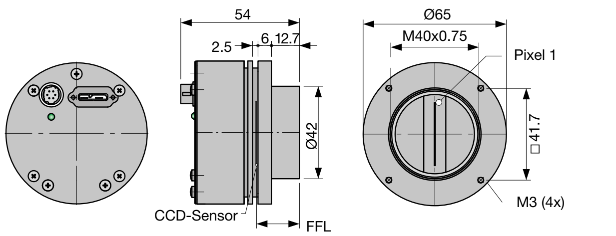
## M40x0.75

**Types:**

| |
|---|
| SK2048U3JR |
| SK2048U3SH |

**AT2**

Lens mount: M40x0.75
Seat for bracket: Ø 42 mm
Flange focal length: FFL = 19.5 mm

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**mono chrome** **CCD**

## SK2048U3JR

Line scan camera with high sensitivity and 4.69 kHz maximum line rate.

| | |
|---|---|
| Pixels, dimensions | 2048, 14 x 14 µm² |
| Sensor length | 28.70 mm |
| Max. line frequency | 4.7 kHz |
| Pixel frequencies | 10 or 0 MHz |
| Exposure time | 0.01 ... 20 ms |
| Spectral range | 400 ... 900 nm |
| Dynamic range | 1:1000 (rms) |
| Special features | Integration control |
| Pixel data format | 8/12 Bit |

| **Lens mount** | **M40x0.75** |
|---|---|
| Camera Casing | AT2 |

| Supply Voltage | USB (350 mA) |
|---|---|
| Power | 1.8 W |

**mono chrome** **CCD**

## SK2048U3SH

Line scan camera with large dynamic range and 14.3 kHz maximum line rate, anti blooming and integration control.

| | |
|---|---|
| Pixels, dimensions | 2048, 14 x 14 µm² |
| Sensor length | 28.70 mm |
| Max. line frequency | 14.0 kHz |
| Pixel frequencies | 30 or 15 MHz |
| Exposure time | 0.01 ... 20 ms |
| Spectral range | 200 ... 1000 nm |
| Dynamic range | 1:2500 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8/12 Bit |

| **Lens mount** | **M40x0.75** |
|---|---|
| Camera Casing | AT2 |

| Supply Voltage | USB (600 mA) |
|---|---|
| Power | 3 W |

# Standard Line Scan Cameras – GigE Interface and CCD Sensor

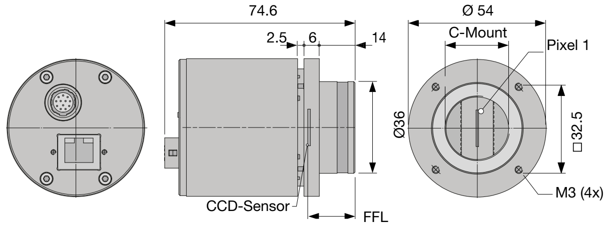
## C-Mount

**Types:**

SK1024MVSH

Lens mount: C-Mount
Seat for bracket: Ø 36 mm
Flange focal length: FFL = 17.5 mm

RG1

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mono chrome | CCD

### SK1024MVSH

**Line scan camera with large dynamic range and 27 kHz maximum line rate, anti blooming and integration control.**

| | |
|---|---|
| **Lens mount** | **C-Mount** |
| Camera Casing | RG1 |

| | |
|---|---|
| Supply Voltage | 8 - 16 V DC |
| Power | 3.9 W |

| | |
|---|---|
| Pixels, dimension | 1024, 14 x 14 µm² |
| Sensor length | 14.30 mm |
| Max. line frequency | 27.0 kHz |
| Pixel frequencies | 30 or 20 MHz |
| Exposure time | 0.01 ... 20 ms |
| Spectral range | 200 ... 1000 nm |
| Dynamic range | 1:2500 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8/12 Bit |
| | |

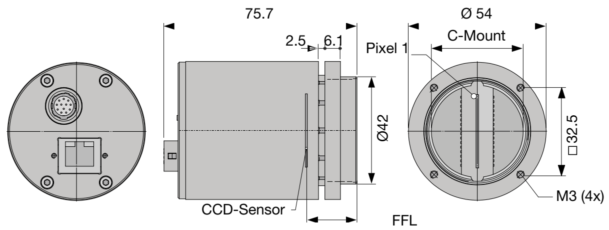
## M40x0.75

**Types:**

SK2048MVSH

Lens mount: C-Mount
Seat for bracket: Ø 42 mm
Flange focal length: FFL = 19.5 mm

RG2

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mono chrome | CCD

### SK2048MVSH

**Line scan camera with large dynamic range and 14.1 kHz maximum line rate, anti blooming and integration control.**

| | |
|---|---|
| **Lens mount** | **M40x0.75** |
| Camera Casing | RG2 |

| | |
|---|---|
| Supply Voltage | 8 - 16 V DC |
| Power | 4.4 W |

| | |
|---|---|
| Pixels, dimensions | 2048, 14 x 14 µm² |
| Sensor length | 28.70 mm |
| Max. line frequency | 14.1 kHz |
| Pixel frequencies | 30 or 20 MHz |
| Exposure time | 0.01 ... 20 ms |
| Spectral range | 200 ... 1000 nm |
| Dynamic range | 1:2500 (rms) |
| Special features | Anti blooming, integration control |
| Pixel data format | 8/12 Bit |
| | |

Schäfter+Kirchhoff

# Accessories and Software

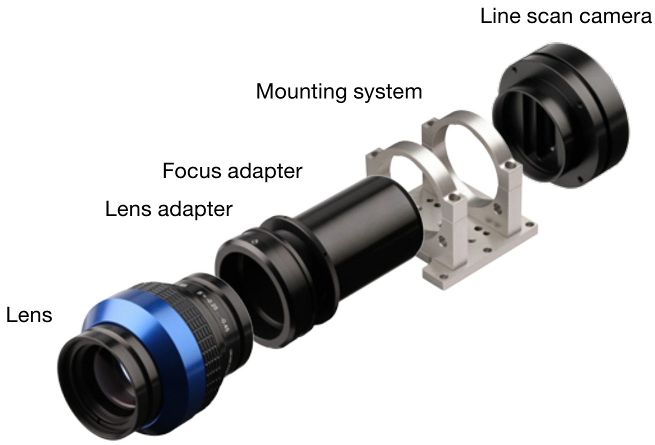
# Accessories and Software

# Mechanical Accessories – Basics

A typical line scan camera set-up consists of several individual elements. Theroratically only camera, a mount and a lens are necessary. However, the specific optical layout may call for particular distances between the camera and the lens, there needs to be a possibility for focus adjustment and the lens might have a different mount than the other components. To account for this, different adapters are necessary.

A typical line scan set-up then consists of:

- Line scan camera
- Mounting bracket
- Optional extension rings to enlarge the distance between lens and camera
- Focus adapter for adjusting the focus setting
- Lens adapter for attaching lenses with differing mounts
- Lens

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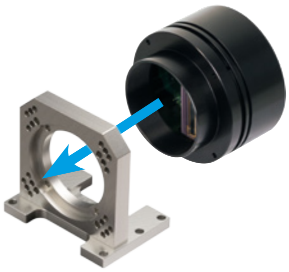
# Mounting Accessories – Mounting Brackets

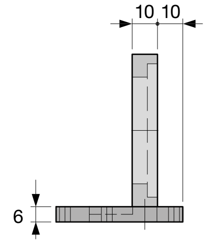
## Mounting System SK5105

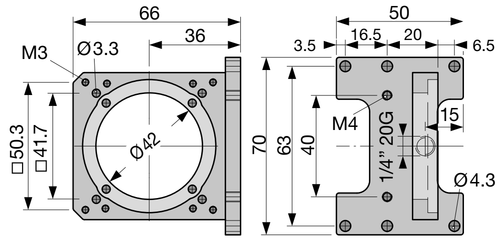
Camera mounting bracket Ø42.0 mm for C-Mount or M40x0.75-mount line scan cameras with outer diameter up to Ø65 mm and mounting dimension Ø42 mm.
Made from naturally anodized aluminum.
Matching clamping claws: Order Code SK5101



**Order Code**

SK5105



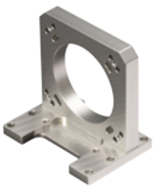




**Suitable for Camera Types:**

| | | | |
|---|---|---|---|
| SK2048U3JR | SK2048U3HA | SK1024U3SH | SK2048MVSH |
| SK1024U3HA | SK512U3SH | SK1024MVSH | SK2048U3SH |

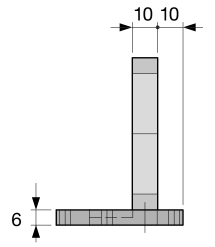
## Mounting System SK5105-L

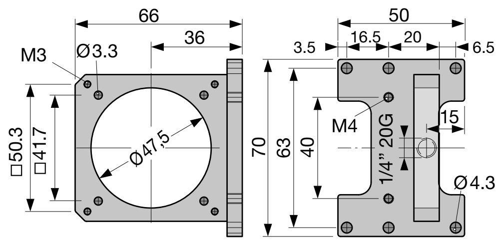
Camera mounting bracket Ø47.5 mm for M45x0.75-mount line scan cameras with outer diameter up to Ø65 mm and mounting dimension Ø47.52 mm, camera can be used from both sides. Made from naturally anodized aluminum.
Matching clamping claws:  Order Code SK5101



**Order Code**

SK5105-L




**Suitable for Camera Types:**

| |
|---|
| SK8k-U3DR4 |
| SK4k-U3DR7C |

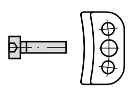
## Clamping Set SK5101

Clamping set of 4 pcs. suitable for mounting brackets type SK5105 and SK5105-L.
The clamps can also be combined with customer-specific mounting brackets.
Made from naturally anodized aluminum with stainless steel screws.

**Order Code**

SK5101

Clamp



Allen screw
DIN 912–M3x12

# Mechanical Accessories for Cameras with C-Mount

**Suitable for Camera Types:**

| | | |
|---|---|---|
| SK1024U3HA | SK512U3SH | SK1024MVSH |
| SK2048U3HA | SK1024U3SH | |

Detailed data sheets, up-to-date technical information, technical drawings including step files, accessories, extensive technotes section and FAQs:
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### Focus Adapters Cameras with C-Mount

The focus adapter has a variable length and is used for focus adjustment, i.e. the adjustment of the distance between the camera sensor and the lens in order to obtain a sharp image.

**Order Options**

| Pos. | Order Code | Rotatable | Mount 1, male (camera side) | Mount 2, female (lens side) | Min. optical length [mm] | Max. optical length [mm] |
|---|---|---|---|---|---|---|
| 1 | FA22-C | - | C-Mount | M39x1/26" | 22.0 | 33.0 |

Further adapters on request.

### Extension Rings Type EXT for C-Mount

- Black anodized
- Different lengths 5 to 40 mm
- Spacer washer (thickness 0.5 or 1 mm) for short extension

For large image scales up to macro imaging (magnification about 1:1), the integral lens focus extension or the extension of the focus adapter is usually not sufficient. The camera tube is then lengthened with extension rings to fit.

**Order Code**

| | |
|---|---|
| EXT-0.5 | thickness 0.5 mm (spacer washer) |
| EXT-1 | thickness 1.0 mm (spacer washer |
| EXT-5 | length 5 mm |
| EXT-10 | length 10 mm |
| EXT-20 | length 20 mm |
| EXT-40 | length 40 mm |
| EXT-6 | 6-piece set of lengths from 0.5 to 40 mm |

The indicated lengths are optical path lengths.
Each extension ring has an inner thread and an outer thread at the opposite end.

# Mechanical Accessories for Cameras with M40x0.75-Mount

**Suitable for Camera Types:**

| | |
|---|---|
| SK2048U3JR | SK2048U3SH |
| SK2048MVSH | |

Detailed data sheets, up-to-date technical information, technical drawings including step files, accessories, extensive technotes section and FAQs:
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## Focus Adapters and Lens Adapters for Cameras with M40x0.75-Mount

The focus adapter has a variable length and is used for focus adjustment, i.e. the adjustment of the distance between the camera sensor and the lens in order to obtain a sharp image.
A lens adapter is used to attach a lens with a differing mount.

### Order Options

| Pos. | Order Code | Rotatable | Mount 1, male (camera side) | Mount 2, female (lens side) | Min. optical length [mm] | Max. optical length [mm] |
|---|---|---|---|---|---|---|
| | **Focus adapters** (variable length) for focus adjustment | | | | | |
| 1 | FA22-40 | - | M40x0.75 | M39x1/26" | 22.0 | 32.0 |
| 2 | FA22R-40 | x | M40x0.75 | M39x1/26" | 28.0 | 39.0 |
| 3 | FA22RL-40 | x | M40x0.75 | M39x1/26" | 34.7 | 44.7 |
| 4 | FA10-AC38-40 | x | M40x0.75 | V38 | 9.0 | 19.0 |
| 5 | FA11-AC38-40 | x | M40x0.75 | V38 | 27.0 | 38.0 |
| | **Lens adapters** (fixed length) for lens mount | | | | | |
| 6 | AOC-CM-40 | - | M40x0.75 | C-Mount | -2.0 | -2.0 |
| 7 | AOC-F-40-R2 | - | M40x0.75 | F-Mount | 27.0 | 27.0 |

Further adapters on request.

# Mechanical Accessories with M39x1/26"-Mount (Leica)

## Suitable for Focus Adapters:

| | | |
|---|---|---|
| FA22-40 | FA11-45 | FA22RL-45 |
| FA22R-40 | FA16-45 | |
| FA22RL-40 | FA22R-45 | |

Detailed data sheets, up-to-date technical information, technical drawings including step files, accessories, extensive technotes section and FAQs:
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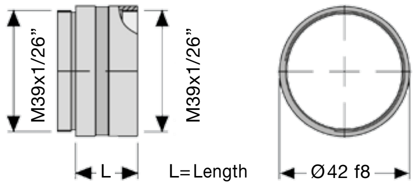
## Extension Rings Type ZR for M39x1/26"-Mount (Leica)

- Black anodized
- Different lengths 10 to 50 mm

For large image scales up to macro imaging (magnification about 1:1), the integral lens focus extension or the extension of the focus adapter is usually not sufficient. The camera tube is then lengthened with extension rings to fit. If required, several intermediate rings can be mounted one behind the other. For vibration-free mounting of long tubes, the camera is attached to the tube with the mounting system SK5105-2.



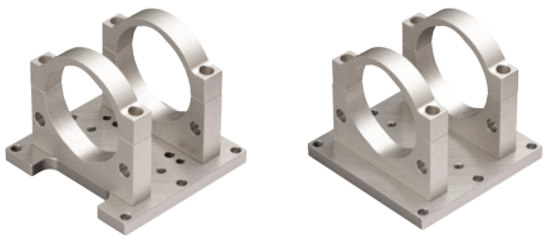

**Order Code**

| | |
|---|---|
| ZR-10 | length 10 mm |
| ZR-15 | length 15 mm |
| ZR-20 | length 20 mm |
| ZR-50 | length 50 mm |

The indicated lengths are optical path lengths. Each extension ring has an inner thread and an outer thread at the opposite end.

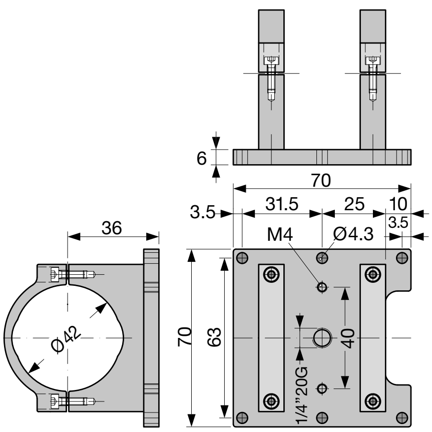
## Mounting System SK5105-2

Mounting system Ø42.0 mm
for camera configurations with tube lengths > 55 mm using extension rings type ZR.
Made from naturally anodized aluminum.



**Order Code**

SK5105-2



# Mechanical Accessories for Cameras with M45x0.75-Mount

**Suitable for Camera Types:**

| |
|---|
| SK8k-U3DR4 |
| SK4k-U3DR7C |

Detailed data sheets, up-to-date technical information, technical drawings including step files, accessories, extensive technotes section and FAQs: **www.sukhamburg.com**

www

## Focus Adapters and Lens Adapters for Cameras with M45x0.75-Mount

The focus adapter has a variable length and is used for focus adjustment, i.e. the adjustment of the distance between the camera sensor and the lens in order to obtain a sharp image.
A lens adapter is used to attach a lens with a differing mount.

### Order Options

| Pos. | Order Code | Rotatable | Mount 1, male (camera side) | Mount 2, female (lens side) | Min. optical length [mm] | Max. optical length [mm] |
|---|---|---|---|---|---|---|
| | **Focus adapters** (variable length) for focus adjustment | | | | | |
| 1 | FA16-45 | - | M45x0.75 | M39x1/26'' | 16.0 | 26.0 |
| 2 | FA22R-45 | x | M45x0.75 | M39x1/26'' | 22.0 | 32.0 |
| 3 | FA22RL-45 | x | M45x0.75 | M39x1/26'' | 28.2 | 38.2 |
| 4 | FA6-AC38-45 | x | M45x0.75 | V38 | 4.0 | 10.0 |
| 5 | FA22R-45-S3 | x | M45x0.75 | V38 | 14.5 | 24.5 |
| 6 | FA11-AC38-45 | x | M45x0.75 | V38 | 20.0 | 31.0 |
| 7 | FA11-M45-AC46-L2 | x | M45x0.75 | V46 | 69.5 | 80.5 |
| | **Lens adapters** (fixed length) for lens mount | | | | | |
| 8 | AOC-CM-45 | - | M45x0.75 | C-Mount | -2.0 | -2.0 |
| 9 | AOC-F-45-R2 | - | M45x0.75 | F-Mount | 27.0 | 27.0 |
| 10 | AC48-45-L3 | x | M45x0.75 | V48 | 10.0 | 10.0 |

Further adapters on request.

Accessories and Software

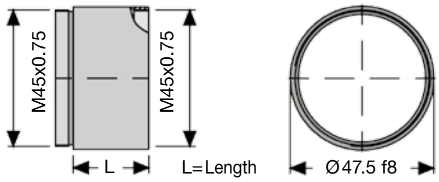
09-2024 E Mounting-Tube-Accessories.indd • Page 35

# Mechanical Accessories for Cameras with M45x0.75-Mount

## Extension Rings Type ZR-L for M45x0.75

- Black anodized
- Different lengths 10 to 87 mm

For large image scales up to macro imaging (magnification about 1:1), the integral lens focus extension or the extension of the focus adapter is usually not sufficient. The camera tube is then lengthened with extension rings to fit. If required, several intermediate rings can be mounted one behind the other. For vibration-free mounting of long tubes, the camera is attached to the tube with the mounting system SK5105-2L.



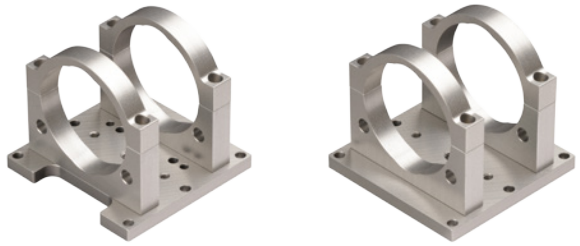

**Order Code**

| | |
|---|---|
| ZR-L10 | length 10 mm |
| ZR-L15 | length 15 mm |
| ZR-L25 | length 24.5 mm |
| ZR-L60 | length 60 mm |
| ZR-L87 | length 87 mm |

The indicated lengths are optical path lengths. Each extension ring has an inner thread and an outer thread at the opposite end.

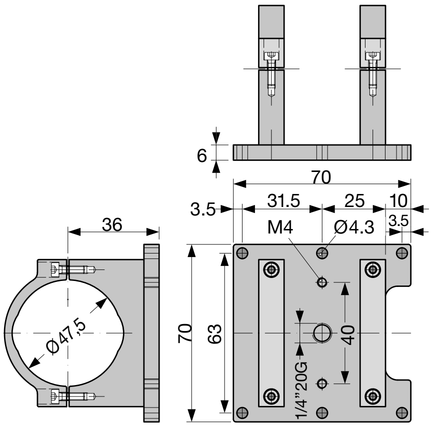
## Mounting System SK5105-2L

Mounting system Ø47.5 mm for camera configurations with tube lengths > 55 mm using extension rings type ZR-L
Made from naturally anodized aluminum.



**Order Code**

SK5105-2L



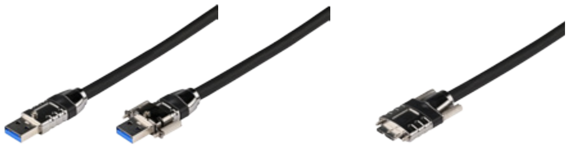
Schäfter+Kirchhoff

# Cables for Cameras with USB 3 Interface

**USB 3 Interface Cable (Power and Data)**

**SK9020**

Connection cable for USB3 Line Scan Cameras,
connectors plug A (straight) - plug Micro-B (straight, locking screws)



**Order Code**

SK9020.1 1 m length
SK9020.2 2 m length
SK9020.3 3 m length
SK9020.5 5 m length
Other lengths on request.

**USB 3 Interface Cable (Power and Data)**
**angled connector**

**SK9020-TB**

Connection cable for USB3 Line Scan Cameras,
connectors plug A (straight) - plug Micro-B (locking screws,
TB-angled, i.e. transversal position B)

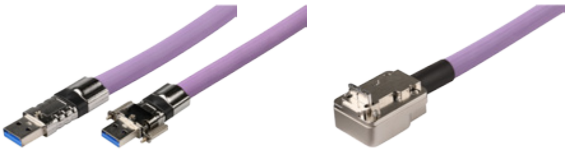
**Order Code**

SK9020.2-TB 2 m length
SK9020.3-TB 3 m length
Other lenghts and variants on request.

**USB 3 Interface Cable (Power and Data)**
**For use in cable carriers and harsh environments,**
**angled connection**

**SK9020S-TA**

Connection cable for USB3 Line Scan Cameras
HiFlex cable, min. static bending radius 57 mm
connectors plug A (straight) - plug Micro-B (locking screws,
TA-angled, i.e. transversal position A)



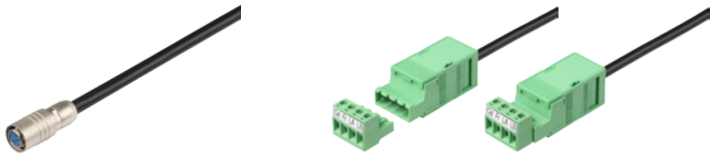
**Order Code**

SK9020S.2-TA 2 m length
Other lengths and variants on request.

### Synchronization Cable

**SK9026**

Cable for external synchronization of line scan cam. with USB3.0 interface, connectors Hirose HR10A 6pin (straight) - Phoenix 4pin

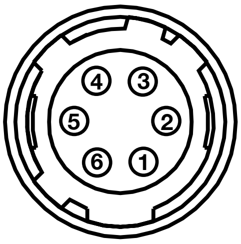


**Order Code**

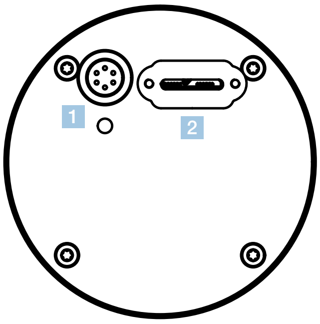
| | |
|---|---|
| SK9026.1 | 1 m length |
| SK9026.3 | 3 m length |
| SK9026.5 | 5 m length |
| SK9026.10 | 10 m length |

Other lengths and variants on request.

### Connections and I/O Signals




| Pin | Signal |
|---|---|
| 1 | Line Sync B |
| 2 | not connected |
| 3 | Frame Sync |
| 4 | not connected |
| 5 | Line Sync A |
| 6 | GND |




1 **Synchronization**
Connector type: Hirose series 10A, male 6-pin
Sync signals: TTL levels

2 **USB 3 Interface, Data and Power**
Connector type: USB 3.0 socket Micro-B, threaded holes for locking screws

If the image acquisition does not need to be synchronized with a motion or drive system, connector 1 remains unused.

## Cables for Cameras with GigE Vision Interface



### GigE Interface Cable

**CAT6**

Network cable for Gigabit Ethernet, data transfer and Power over Ethernet (PoE), CAT6, shielded, halogen-free, RJ45 connectors, straight

**Order Code**

| | |
|---|---|
| CAT6.3 | 3 m length |
| CAT6.5 | 5 m length |
| CAT6.10 | 10 m length |
| CAT6.20 | 20 m length |

### GigE Interface Cable
### Angled connector at one end

**CAT6-TA**

Network cable for Gigabit Ethernet, data transfer and Power over Ethernet (PoE), CAT5e, connectors RJ45 (straight) - RJ45 (TA-angled, i.e. transversal position opposite to clip)

**Order Code**

CAT6.5-TA 5 m length
Other lengths on request.

### GigE Interface Cable
### Industrial standard

**CAT6IndE**

Network cable for Gigabit Industrial Ethernet, data transfer and Power over Ethernet (PoE), CAT6, RJ45 connectors, straight

**Order Code**

| | |
|---|---|
| CAT6IndE.1 | 1 m length |
| CAT6IndE.20 | 20 m length |

Other lengths on request.

### GigE Interface Cable
### Industrial standard, lockable plug connector at camera side

**CAT6IndE SL/LL**

Network cable for Gigabit Industrial Ethernet, data transfer and Power over Ethernet (PoE), CAT6, connectors RJ45 (straight, shielded) - RJ45 (straight, screw lock, latch lock)

**Order Code**

| | |
|---|---|
| CAT6IndE.2SL/LL(ST) | 2 m length |
| CAT6IndE.5SL/LL(ST) | 5 m length |
| CAT6IndE.20SL/LL(ST) | 20 m length |

Other lengths on request.

## Combined Power and Synchronization Cable

**SK9025**

Combined synchronization and power cabel for line scan cameras GigE (MV series), connector Hirose HR10A 12pin (straight) - other end ferrules

**Order Code**

SK9025.5 5 m length
SK9025.20 20 m length
Other lengths on request.

## Combined Power and Synchronization Cable For use in cable carriers and harsh environments

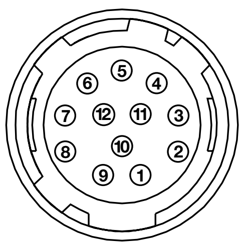
**SK9025S**

Combined synchronization and power cabel for line scan cameras GigE (MV series), for permanently moving use, flame-retardant, oil-resistant, halogen-free, connector Hirose HR10A 12pin (straight) - other end ferrules

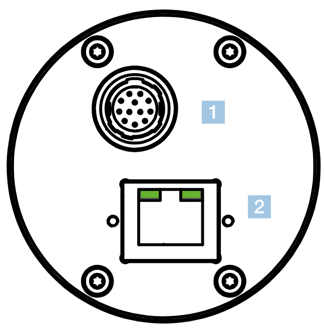
**Order Code**

SK9025S.1 1 m length
SK9025S.20 20 m length
Other lengths on request.

## Connections and I/O Signals




| Pin | Signal |
|---|---|
| 1 | GND $V_S$ |
| 2 | Supply Voltage $V_S$ |
| 3, 4, 11 | Camera Select Setting |
| 5 | GND |
| 6 | LineSyncB IN+ |
| 7 | FrameSync IN- |
| 8 | FrameSync IN+ |
| 9 | LineSyncA IN- |
| 10 | LineSyncA IN+ |
| 12 | LineSyncB IN- |




1 **I/O Connector and Power 24 V DC**
Connector type: Hirose series 10A, male 12-pin
Power $V_S$: min. +18 V, max. +36 V
Sync signals: RS422

2 **GigE-Interface, Data and Power over Ethernet (PoE)**
Connector type: RJ-45

The cameras can be supplied with operating voltage either via connection 1 or 2.

If no external synchronization is required for image acquisition and Power over Ethernet (PoE) is used, the cameras can be operated with a single connection cable.

### Camera Select

Two cameras connected to the network can be distinguished using the SkCamID parameter in the Device Feature List.

The SkCamID is defined by the bridges set in the connector according to this scheme:

| Pin # | Bridges for Camera Select | | |
|---|---|---|---|
| | 0 | 1 | 2 |
| 3 | | | |
| 4 | | | |
| 11 | | | |

# Software for Line Scan Cameras

**SkLineScan program and Software Development Kit (SDK)**

- The software is available for line scan cameras with a GigE or USB 3.0 interface
- Operation program SkLineScan for setup and simple scanning tasks
- SDK with API and class library for the development of customized application software
- Examples in C/C++ can be used as templates for developing custom programs
- Supported operating systems are Windows 10 (32- or 64-bit), Windows 11, and Linux kernel 3.13+

```
int CCameraInit::Camera(int CamID, DWORD IPaddr, DWORD Subnet)
{
    if (SK_GETDEVICES() < CamID + 1)
        return SK_RESULT_DEVICE_ERROR;
    if (IPaddr != 0)
    {
        // set IP address
        if (SK_SETIPADDRESS(CamID, IPaddr, Subnet)
            != SK_RESULT_OK)
            return SK_RESULT_NETWORK_ERROR;
    }
    int result = 1;
    result = SK_INITCAMERA(CamID);
    if (result != SK_RESULT_OK)
        return SK_RESULT_DEVICE_ERROR;
}
```

## SkLineScan Application Program

The Schäfter+Kirchhoff SkLineScan program is designed for the start-up and control of their line scan cameras. All functions of the connected cameras can be checked.

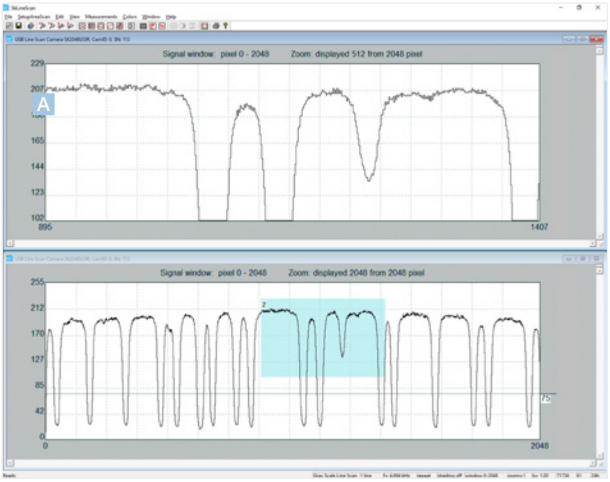
The user can adjust the total optical system of camera, lens and illumination by using the real-time display of the line signal A .

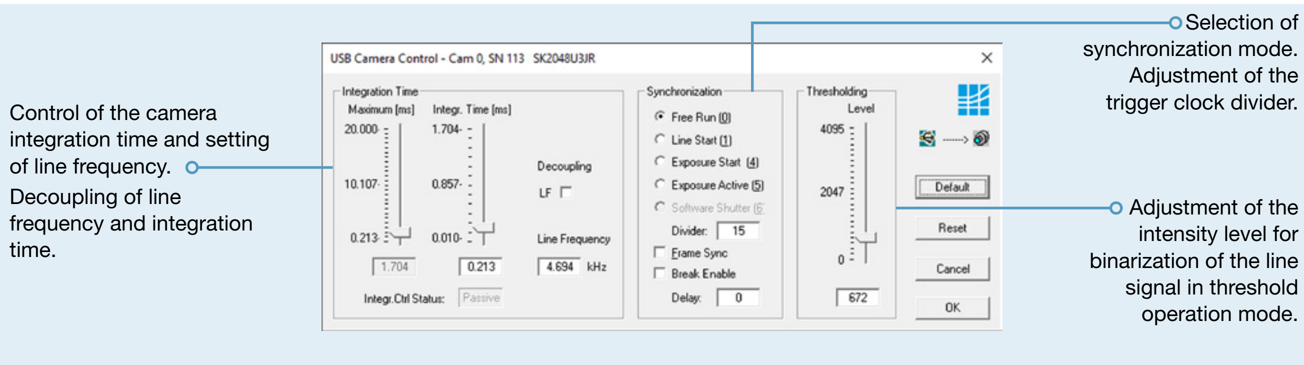
The operating parameters of the camera can be changed interactively during signal acquisition.

Each individual pixel of the line signal can be displayed by using the zoom or scroll functions and signal images can be saved.

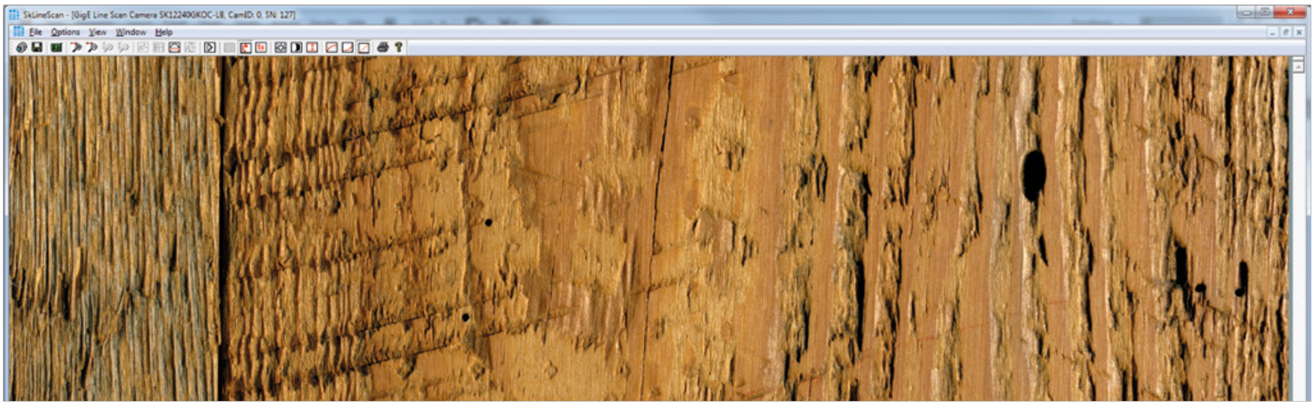
The program also enables a two-dimensional area scan of a surface to be acquired by accumulating repetitive line scans from the line scan camera.

The SkLineScan program is free for downloading from the support area of the Schäfter+Kirchhoff homepage.



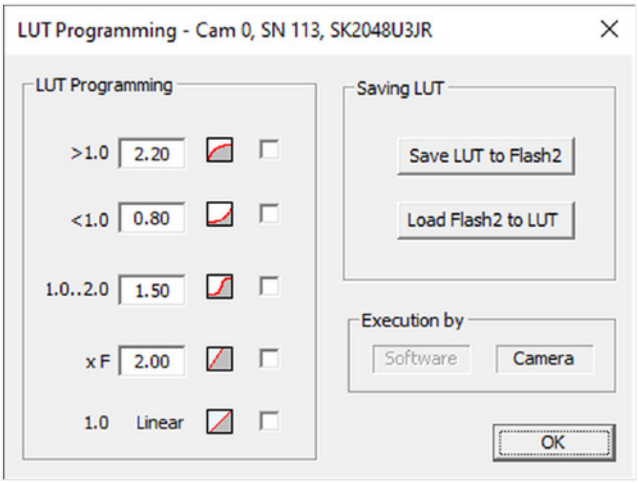

**A color area scan using the SkLineScan program**



# SkLineScan Application Program



All of the settings adjusted using the SkLineScan program are saved inside the camera when the program is closed. The adjustments for shading correction, lookup table, gain, offset, integration time, etc can be performed using the SkLineScan program and are available when the camera is controlled by a customized application. Previously stored parameters are used on start-up and these parameters can be changed during the running of an application. This is useful when adding a Lookup Table or a Shading Correction profile into the camera memory.




The Lookup Table (LUT) within the camera can be used for pre-processing the signal data. By programming a transformation function, brightness values of the camera can be converted to their corrected values. The transformation of image data can be useful in obtaining better imaging results, such as providing more contrast or higher dynamic range.

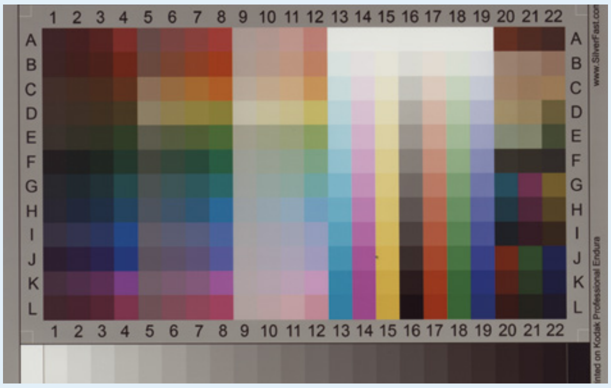
The SkLineScan program supports Gamma Correction (convex: gamma > 1.0, concave: gamma < 1.0), and Linear Function with a factor. The Linear LUT with a factor of 1.0 provides the unaltered image data.

The desired transformation function can be activated by inputting the appropriate parameter and clicking on the icon or tick box.

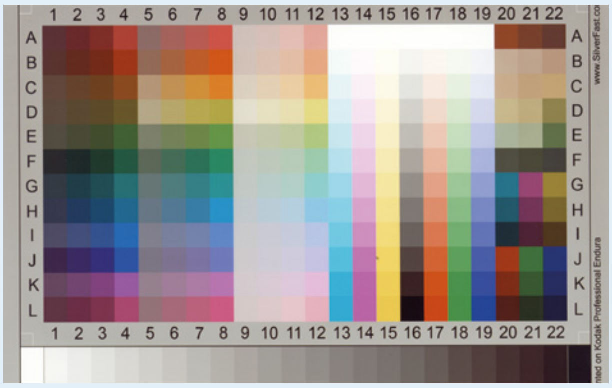
If the camera does not support LUT programming, the transformation can be performed downstream using software.

Press the “Save LUT to Flash2” button to save the currently used LUT in the non-volatile memory of the camera.

## Application: Gamma correction for color images

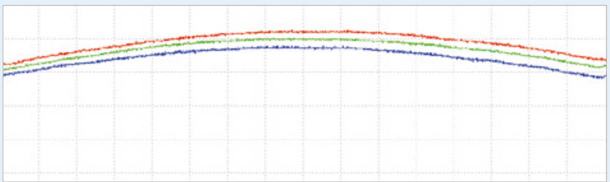


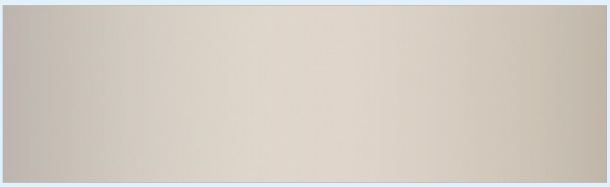
A color image of an it8-target without correction where dark colors are difficult to differentiate



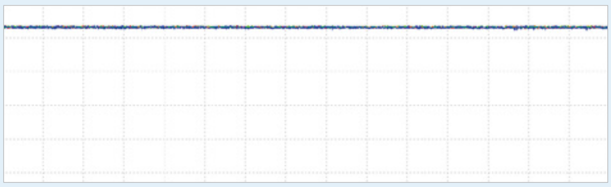
Using the Gamma Correction 2.2, dark colors are brighter and more distinct

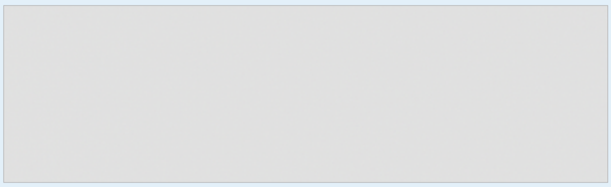
## Application: Shading Correction and White Balance





RGB raw signal and area scan without white balance





Line signal and area scan with active white balance

# Software Development Kit (SDK)

**Schäfter+Kirchhoff offers an SDK with API DLLs and C++ class libraries for GigE and USB 3.0 cameras for the development of customized application software. The SDK also contains examples in C/C++ as a template for the development of individually customized applications. Source code comments and a manual complete the camera programming environment.**

**The SDK package consists of a core and API:**

## 1. Core

The core is required to drive the line scan camera and consists of the device driver and the base DLLs. By using the core, developers can build an efficient installation package for their software. A developer is free to integrate the core within any customized application software for an end customer.

## 2. Application Programming Interface (API)

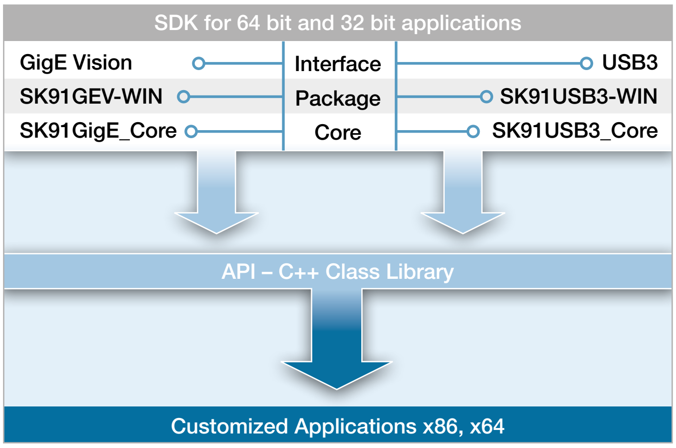
The API contains a C++ class library as well as compilable projects with example source code. The supported development environment is Microsoft Visual Studio 2017, 2019 and 2022.

Supported operating systems are Windows® 10/11, and Linux®.

### Why an SDK despite compatibility with the Vision standard?

The SDK considerably simplifies handling if your application requires the following functions:

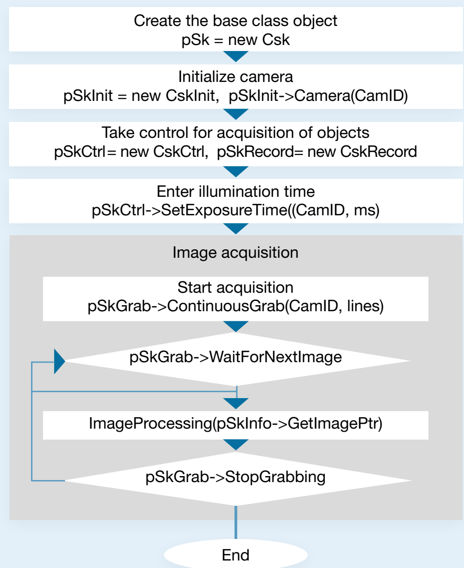
- Capturing large images, even continuously
- External line and frame triggering, also with direction or slip detection
- Shading correction (SC) or lookup table (LUT)




| | |
|---|---|
| **Csk – Base class** | |
| struct sk_interface | Communication structure for the driver |
| **CskInit: Csk – Initializing class** | |
| ::Camera | Initializing the camera |
| ::AllocBuffer | Allocate memory in the user area |
| ::FreeBuffer | Release memory |
| ::SetUserBufferPtr | Set pointer to user buffer |
| **CskCtrl: Csk – Control class** | |
| ::SetIntegrationTime | Set integration time (ms) |
| ::SetLineFrequency | Set line frequency (kHz) |
| ::SetSyncMode | Set synchronization mode |
| ::SetGain | Set camera gain |
| ::SetOffset | Set camera offset |
| **CskRecord: Csk – Acquisition class** | |
| ::SingleLineScan | Get a single line scan |
| ::AreaScan | Acquire a 2D scan |
| ::ContinuousGrab | Start continuous grab |
| ::GetImage | Get single image from a continuous grab |
| ::StopContinuousGrab | Stop continuous grab |
| **CskView: Csk – View class** | |
| ::LineScanView | Display a line scan signal |
| ::AreaScanView | Display an area scan |
| **CskInfo: Csk – class** | |
| ::GetCamType | Name of current camera |
| ::GetPixWidth | Number of current camera pixels |
| ::GetLineFrequency | Current line frequency in kHz |
| ::GetUserBufferPtr | Pointer to data set in user memory |

* Examples from the class library containing more than 60 ways to control a GigE line scan camera

### Flow of camera image acquisition




## Software Products

| Product | Interface | Operating System | Price |
|---|---|---|---|
| **SkLineScan Operating Program** | | | |
| SkGEVTool | GigE Vision | Windows 10/11 | on request |
| SkLineScan-GEV-LX | GigE Vision | Linux® | on request |
| SkLineScan-U3-WIN_x64_x86 | USB 3.0 | Windows 10/11 | https://www.sukhamburg.com/products/details/SKLineScan |
| SkLineScan-U3-LX_x64_x86 | USB 3.0 | Linux® | https://www.sukhamburg.com/products/details/SKLineScan |
| **Software Delelopment Kit (SDK)** | | | |
| SK91GEV-WIN | GigE Vision | Windows 10/11 | on request |
| SK91GEV-LX | GigE Vision | Linux® | on request |
| SK91USB3-WIN | USB 3.0 | Windows 10/11 | on request |
| SK91USB3-LX | USB 3.0 | Linux® | on request |

Schäfter+Kirchhoff

# Examples – Camera Configurations

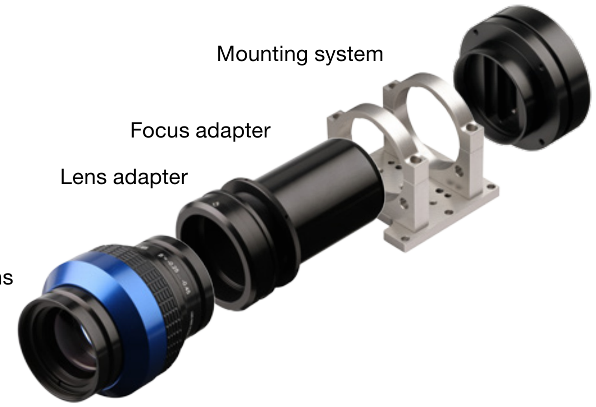
# Customized Line Scan Camera Configurations

# Customized Line Scan Camera Configurations

In its decades of experience, Schäfter+Kirchhoff has developed a wide range of specialized line scan camera configurations.

Each application comes with their own range of specifications for the optical system layout. Usually the desired resolution and the field of view (FOV)  or the scanning velocity determine the choice of lens and the necessary accessories including focus adapter, lens adapters, extension rings and mouting brackets.

Here are some examples of our wide range of customized line scan camera configurations for  both industrial and laboratory environments.



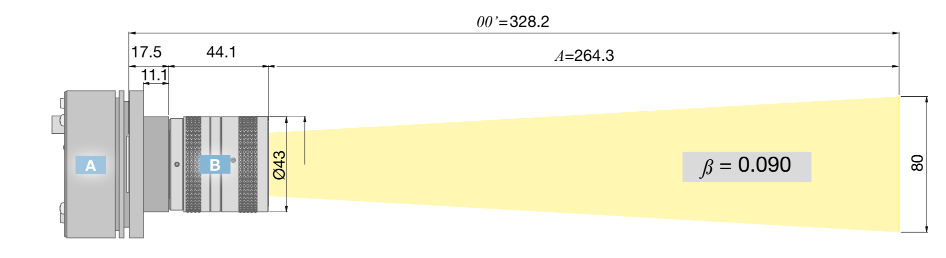

Customer-specific choice of  line scan camera, imaging optics and accessories.
**Contact us to find the best optical system layout for your application.**

## Example - Line Scan Camera SK512U3SH with Lens MeVis-C1.6/25 for Field of View 80 mm

| Technical Data | |
|---|---|
| **Resolution** | 160 µm/pixel (163 dpi) |
| **Field of view** | 80 mm |
| **Sensor** | monochrome line scan camera,<br>512 pixels, 14 x 14 µm²,<br>line rate max. 35.7 kHz |
| **Lens** | MeVis-C1.6/25 |

Customer-specific choice of  line scan camera, imaging optics and accessories.
**Contact us to find the best optical system layout for your application.**

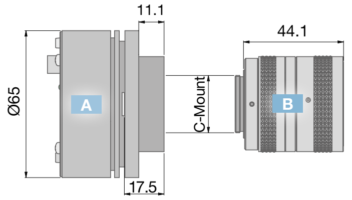
**Configuration Example: Line Scan Camera SK512U3SH with Lens MeVis-C1.6/25 for Field of View 80 mm**




| | |
|---|---|
| Sensor length $S$ | 7.17 mm |
| FOV length $L$ | 80 mm |
| Magnification $\beta$ | 0.090 |
| Focal length $f$ | 24.6 mm |
| $HH$ | 1.9 mm |
| $OO$ | 328.2 mm |

$\beta$ calculated from F2,
$OO$  calculated from F5
(see page 53)

**System Components**




| A  Camera | B  Lens |
|---|---|
| **Order Code** | **Order Code** |
| SK512U3SH | MeVis-C1.6/25 |

The Schäfter+Kirchhoff line scan cameras which can be used with C-Mount lenses have a corresponding female C-Mount (1“/32 TPI) thread.

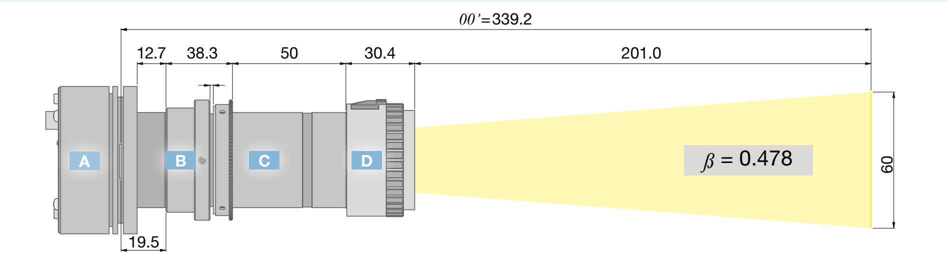
No additional components are required if the working distance A is larger than the minimum specified in the corresponding lens data.

# Example - Line Scan Camera SK2048U3SH with Lens Apo-Rodagon D2 4.0/75mm for Field of View 60 mm

| Technical Data | |
|---|---|
| Resolution | 36 µm/pixel (708 dpi) |
| Scan width (Field of view) | 60 mm |
| Sensor | monochrome line scan camera,<br>2048 pixels, 14 x 14 µm²,<br>line rate max. 14 kHz |
| Lens | Apo-Rodagon D2 4.0/75mm |


Customer-specific choice of line scan camera, imaging optics and accessories.
**Contact us to find the best optical system layout for your application.**

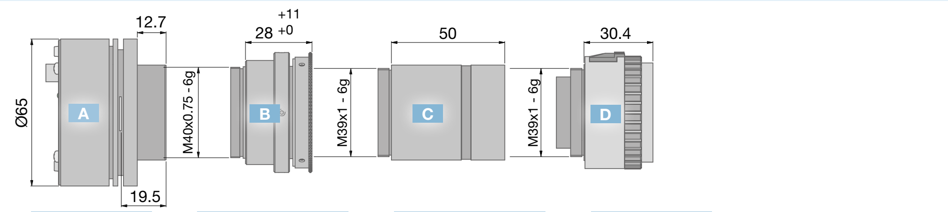
## Configuration Example: Line Scan Camera SK2048U3SH with Lens Apo-Rodagon D2 4.0/75mm for Field of View 60 mm




Sensor length: 28.7 mm
Field of View: 60 mm
Magnification $\beta$ 0.478
Focal length: 74.7 mm
Flange focal length: 72.1 mm
$HH$ : -2.1 mm
$OO$ : 339.2 mm

$\beta$ calculated from F2,
*$OO$ calculated from F5
(see page 53)

### System Components




| A Camera | B Focus Adapter | C Extension Ring | D Lens |
|---|---|---|---|
| **Order Code** | **Order Code** | **Order Code** | **Order Code** |
| SK2048U3SH | FA22R-40 | ZR50 | Apo-Rodagon D2 4.0/75mm |

Scan and macro lenses require a focus adapter for focusing and one or more additional extension rings. Extension rings and the focus adapter together provide the tube length LT (see page 53, F4):
LT = 72.1+35.7-19.5 mm
= 88.3 mm
= 50 + 38.3 mm



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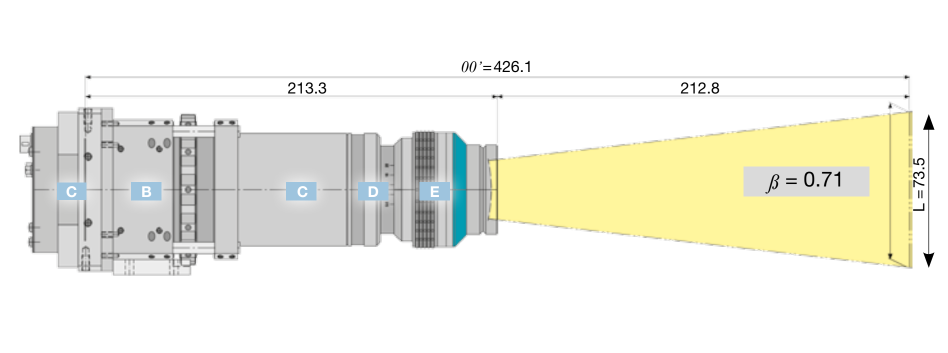
# Example - Line Scan Camera SK7500U3TO-XL with Lens inxpec.x L 5.6/105 for Field of View 73.5 mm

| Technical Data | |
|---|---|
| Resolution | 9.8 µm/pixel (2592 dpi) |
| Scan width (Field of view) | 73.5 mm |
| Sensor | monochrome line scan camera,<br>7500 pixels, 7 x 7 µm²,<br>line rate max. 5.2 kHz |
| Lens | inxpec.x L 5.6/105 |

CUSTOM

Customer-specific choice of line scan camera, imaging optics and accessories.
**Contact us to find the best optical system layout for your application.**

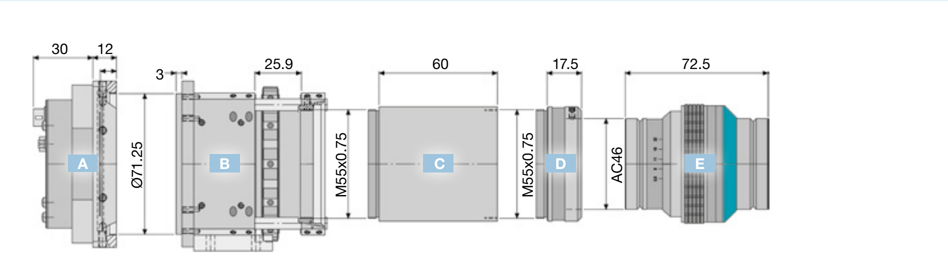
## Configuration Example: Line Scan Camera SK7500U3TO-XL with Lens inxpec.x L 5.6/105 for Field of View 73.5 mm




| | |
|---|---|
| Sensor length: | 52.5 mm |
| Field of View: | 73.5 mm |
| Magnification $\beta$ | 0.71 |
| Focal length: | 105.4 mm |
| $HH$ : | -7.5 mm |
| $OO$ : | 426.1mm |

$\beta$ calculated from F2,
*$OO$ calculated from F5
(see page 53)

## System Components




| A Camera | B Focus Adapter | C Extension Ring | D Lens Adapter | E Lens |
|---|---|---|---|---|
| **Order Code** | **Order Code** | **Order Code** | **Order Code** | **Order Code** |
| SK7500U3TO-XL | FA26-S55 | ZR55-60 | AC46-55 | inspec.x L 5.6/105 |

Scan and macro lenses require a focus adapter for focusing and one or more additional extension rings.
Depending on the lens mount (V-Mount in this example), additional lens adapters may be necessary.
Extension rings, the focus adapter, and the lens adapter together provide the tube length LT (see page 53, F4):

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**Technotes and Fundamentals**
For more information, please refer to the extensive technotes section on:
www.sukhamburg.com/support/technotes.html



The two defining parameters for a line scan camera application are the width of the object and the required resolution. For an object of 80 mm width that must be inspected at a resolution of 20 µm then the camera sensor requires at least 4000 pixels (80/0.020 = 4000).

Subsequent criteria would include measurement rate, interface type and spectral sensitivity, which can lead to the selection of one or more suitable line scan camera types. The final selection task is determined by the choice of appropriate lens.

Each lens has specific properties and the major determinants are maximal sensor size and magnification range.

The maximal sensor size traditionally determines how it is used and thereby the lens category:

**CCTV or C-Mount lenses**
**for shorter sensors (< 22 mm)**

These were first used with surveillance (CCTV) cameras. Instead of the actual sensor size, manufacturers still use the old tube diameter specifications. For example, a 2/3" lens corresponds to a maximal sensor size of 11 mm, a 1" lens to a sensor of 16 mm.

CCTV lenses have a C-Mount (threaded connector) and an internal focusing mechanism.

Most are designed for distant objects and small magnifications. Macro versions for shorter distances are also available.

**Photo lenses**
**for the traditional film format of 24 mm x 35 mm**

Since vignetting at the corners was tolerated in many photo lens designs, most photo lenses should not be used for sensor sizes beyond 36 mm.

Photo lenses also have an internal focusing mechanism and are also designed for distant objects, i.e. small magnifications.

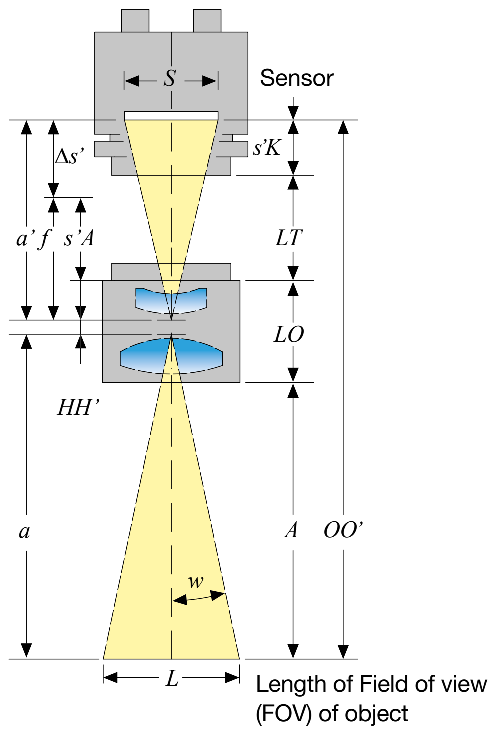
**Scan lenses and macro lenses**

These are designed for use with longer sensors and larger magnifications. Unlike CCTV and photo lenses, scan lenses do not have an internal focusing mechanism. Depending on the magnification, they often require a large distance between the sensor and the lens, which is achieved with extension tubes and a focus adaptor for focusing.

Within these categories of use, other parameter choices include the focal length of the lens, which determines the working distance and the required space, or the f-number, which determines the signal amplitude, the diffraction limit of resolution and, together with the magnification, the depth of focus.

The following collection of optical formulae is intended to help with the design of the imaging system and to provide preliminary information about the performance to be expected. The identifiers used are explained in Fig. 1.

**Figure 1:**
Schematic depiction of the imaging system and definition of variables used




| | |
|---|---|
| $f$ | Lens focal length (mm) |
| $S$ | Sensor length (mm) |
| $L$ | Length of Field of view (FOV) of object (mm) |
| $a$ | Object range (mm) |
| $a'$ | Image distance: Distance from sensor to $HH'$ (mm) |
| β | Magnification |
| $w$ | Field angle |
| $OO'$ | Distance from sensor to measured zone (mm) |
| $HH'$ | Principal point distance (mm) (can lengthen or shorten $OO'$) |
| $s'K$ | Camera flange length |
| $s'A$ | Flange focal length (mm) |
| $\Delta s'$ | Lens extension (mm) |
| $LT$ | Tube length consisting of focus adapter FA22-... and extension rings ZR... (mm) |
| $LO$ | Lens length (mm) |
| $A$ | Working distance (mm) |

# Optical System Layout - Basics

## F1: Imaging equation

Object range and image range are related by the imaging focal length. The formulae F3 to F6 are derived from

$$\frac{1}{a} + \frac{1}{a'} = \frac{1}{f}$$

## F2: Magnification β:

The magnification is defined as

$$\beta = \frac{\text{sensor length}}{\text{FOV length}} = \frac{S}{L} = \frac{a'}{a}$$

**Example:**

FOV length $L$ = 290 mm,
Sensor length $S$ = 28.7 mm:
$\beta = S/L$ = 28.7/290 = 1/10.1 = 0.099

## F3: Lens extension $\Delta s'$

For a very distant object ("at infinity"), the sensor has to be placed in the focal plane of the lens, i.e. a' = $f$. To focus a nearer object, the distance between lens and sensor has to be increased by using a lens extension

$$\Delta s' = f \cdot \beta$$

For C-Mount and Photo lenses, the lens extension is achieved by using their internal focusing mechanism, up to a specified minimum object distance. Extension rings are available for C-Mount lenses to increase the extension further and to focus nearer objects. This is a convenient solution but might impair imaging quality.

For scan and macro lenses, the solution is more complicated. The required tube length $LT$ is calculated from (F3) and (F4) and implemented with extension rings and with a focus adapter as well.

**Example 1:** Magnification β =0.099 and focal length $f$ = 50 mm:
$\Delta s'$= 50 mm x 0.099 = 4.95 mm

**Example 2:** In macro imaging with β = 1 (1:1 imaging),
the lens extension equals the focal length $f$.

## F4: Tube length $LT$

$LT$ = flange focal length + lens extension
(Camera flange length)
$LT = s'A + \Delta s' - s'K$

**Example:** Rodagon 4.0/80, focal length $f$ = 81 mm, β = 1/6,
$s'A$ = 74.7 mm, $s'K$ = 19.5 mm:
$\Delta s' = f\beta$ = 81 mm/ 6 = 13.5 mm
$LT$ = 74.7 mm + 13.5 mm - 19.5 mm
= 68.7 mm

| By using: | | |
|---|---|---|
| | focus adapter FA22-40 | 22.0 mm |
| | + focus adapter extension | 6.7 mm |
| | + 2x extension rings ZR20 | 40.0 mm |
| | **Total =** | **68.7 mm** |

## F5: Sensor to object distance $OO'$

With magnification β and focal length $f$ then:

$$OO' = \left(\beta + \frac{1}{\beta} + 2\right) \cdot f + HH'$$

For β ≤ 1/10 then $OO'$ approximates (1/β + 2) · $f + HH'$.

**Example 1:** Video lens B1614A, focal length $f$ = 16 mm,
$HH'$ = 3.85 mm, $L$ = 290 mm, $S$ = 13.3 mm:
$OO'$ = ($L/S$ + 2) · $f + HH'$
= (290/13.3 + 2) ·16 mm + 3.85 mm
= 384.7 mm (as an approximation)

**Example 2:** Rodagon 4.0/80, focal length $f$ = 81 mm,
$HH'$ = -2.5 mm, β = 1/6:
$OO'$ = (1/β+β+2)· $f + HH'$
= (1/6+6+2) · 81mm - 2.5 mm
= 658.7 mm

The value $OO'$ provides an indication of the required space (the length of camera housing attached to the sensor, without taking into account the space required for connectors and cables).

## F6: Calculation of focal length $f$

With magnification β and sensor to object distance $OO'$.
If there is a space restriction, the maximum focal length is calculated from the sensor to object distance $OO'$ by

$$f = \frac{OO'}{1/\beta + \beta + 2}$$

or for β< 0.1 approximately

$$f = \frac{OO'}{1/\beta + 2}$$

**Example:**

Magnification β = 0.099 and $OO'$ = 605 mm:
Focal length $f$ = 605 mm/ (10.1 + 2) = 50 mm

## F7: Field angle $w$

The field angle $w$ is determined by the sensor length $S$, the focal length $f$ and magnification β:

$$w = \arctan\left(\frac{S}{2 \cdot f \cdot (1+\beta)}\right)$$

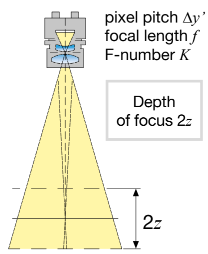
The field angle is used for calculating the edge intensity, F10.

## F8: Depth of focus

The depth of focus $2z$ is calculated from

$$2z = 2 \cdot \Delta y' \cdot K \cdot \frac{1}{\beta}\left(1 + \frac{1}{\beta}\right)$$

using the F-number $K$, the pixel pitch (mm) $\Delta y'$, and the magnification β.




**Example:** Pixel pitch $\Delta y'$ = 0.014 mm
1/magnification 1/β = 10
F-number $K$ = 4

then $2z$ = 2 · 0.014 mm · 4 · 10 · (1+10) = 12.3 mm

| F-number $K$ | 2 | 2.8 | 4 | 5.6 | 8 | 11 | 22 | 32 |
|---|---|---|---|---|---|---|---|---|
| Depth of Focus 2z (mm)* | 6.2 | 8.6 | 12.3 | 17.2 | 24.6 | 33.9 | 67.8 | 98.6 |
| Relative signal amplitude | 16 | 8 | 4 | 2 | 1 | 1/2 | 1/4 | 1/8 |

* for $\Delta y'$ = 0.014 mm and β = 1/10

# Optical System Layout - Basics

## F9: Effective F-number $K'$, relative signal amplitude

For small magnifications $\beta \leq 0.1$ when calculating signal amplitude or the limit of lens resolution caused by diffraction (see F11), the F-number $K$ (=focal length/aperture diameter) is replaced by an effective F-number $K'$ (=image distance/aperture diameter).

With a nominal F-number $K$ and small magnification $\beta$ the effective F-number $K'$ is calculated from:

$$K' = K \cdot (1 + \beta)$$

**Example:** Nominal F-number $K = 4$, magnification $\beta = 1$: effective F-number $K' = 2 \cdot K = 8$

The relative signal amplitude of two effective F-numbers is given by

Relative signal amplitude

$$R = \left(\frac{K'_2}{K'_1}\right)^2$$

For konstant $\beta$, the effect of stopping down a $K$=1.4 lens is as follows

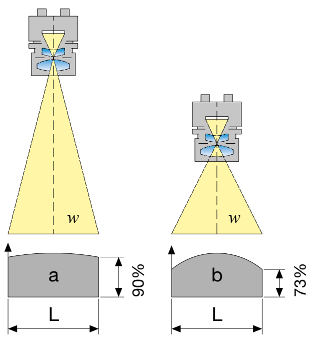
| F-number $K$ | 1.4 | 2.0 | 2.8 | 4.0 | 5.6 | 8 |
|---|---|---|---|---|---|---|
| Relative signal amplitude $R$ | 1 | 0.5 | 0.25 | 0.125 | 0.06 | 0.016 |

## F10: Edge intensity

The edge intensity of a line scan signal is determined by the illumination and the field angle $w$ (see F7).
Even for homogeneous illumination, the signal amplitude decreases towards the ends of the line:

$$\text{Edge intensity [\%]} = 100 \cdot \cos^4(w)$$

**Rule of thumb:** The focal length should be equal to or greater than the sensor length. In these examples, the edge intensities are 90% and 73% of the center intensity, respectively.




**Example:** Edge intensities calculated for two different field angles using the same sensor length $S$ = 28.7 and magnification $\beta$ = 0.25:

a) focal length $f$ = 50 mm
field angle $w$ = 13°
**edge intensity = 90%**

b) focal length $f$ = 28 mm
field angle $w$ = 22.3°
**edge intensity = 73%**

## F11: Diffraction limit

The resolution of a lens is limited by diffraction and declared using the effective F-number $K'$ (see F9).
The best possible resolution is achieved by closing the lens aperture by 1 to 2 steps, so that the lens resolution approaches the diffraction limit.
Adjacent image elements become distinguishable when their distance is:

$$\Delta y' \geq 2{,}4 \cdot \lambda \cdot K'$$

With the optical wavelength $\lambda$ for visible radiation is defined as 550 nm then:

| Effective F-number $K'$ | Diffraction limit Resolution* $\Delta y'_{min}$ [µm] |
|---|---|
| 2 | 2.6 |
| 2.8 | 3.7 |
| 4 | 5.3 |
| 5.6 | 7.4 |
| 8 | 10.8 |
| 11 | 14.5 |
| 16 | 21.1 |
| 22 | 29 |

*at wavelength $\lambda$ = 550 nm

**Example:** effective F-number $K'$ = 8
wavelength $\lambda$ = 550 nm
$\Delta y'_{min}$ = 10.6 µm

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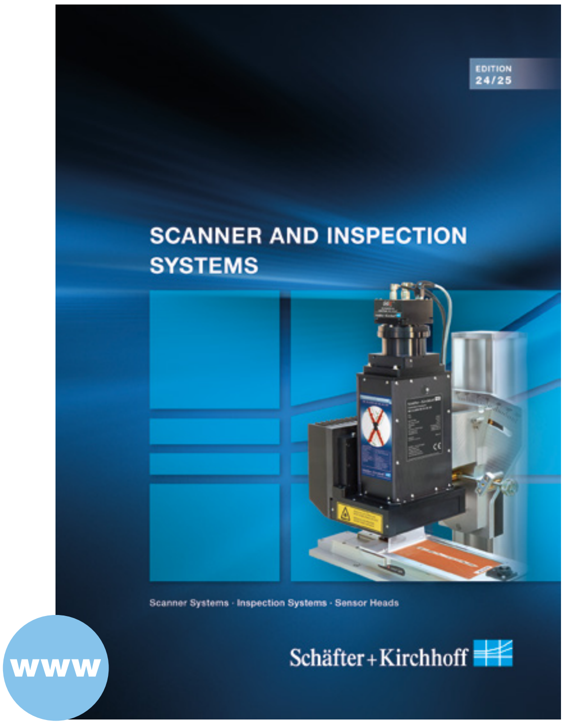


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