Table 1: Color Line Scan Cameras

<table>
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<tbody>
<tr>
<td>1</td>
<td>SK6288GKOC-L</td>
<td>1.92 kHz</td>
<td>8/12 Bit</td>
<td>14 x 16 μm</td>
<td>122 μm</td>
<td>23.8 mm</td>
<td>-</td>
<td>x</td>
<td>1:250</td>
<td>+5V, +12V</td>
<td>MG5</td>
<td>7400 (\mu A)</td>
<td>5.6/105</td>
<td>0.33</td>
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<tr>
<td>2</td>
<td>SK12420GKOC-CL</td>
<td>1.47 kHz</td>
<td>8/12 Bit</td>
<td>10 x 10 μm</td>
<td>90 μm</td>
<td>40.8 mm</td>
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<td>4.7 x 4.7 μm</td>
<td>18.6 μm</td>
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<td>-</td>
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<td>4</td>
<td>SK22800GJRC-XC</td>
<td>4.95 kHz</td>
<td>3’8 Bit</td>
<td>9.3 x 9.3 μm</td>
<td>9.3 μm</td>
<td>70.87 mm</td>
<td>-</td>
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<td>1:1000</td>
<td>+5V, +12V</td>
<td>FG7</td>
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Image acquisition

The acquisition of a color image is achieved by performing a scanning movement of the object or the camera, respectively. The precise synchronization of transport speed and image acquisition ensures the correct aspect ratio and reproducible resolution of the image. For a given object velocity \(v_{o}\) and field of view \(FOV\), the line frequency \(f_{L}\) can be calculated from the pixel width \(w\) and length of the sensor \(S\) using:

\[
f_{L} = \frac{v_{o} S}{w FOV}
\]

Compliance with conditions of formula F1 is also a prerequisite for accurate color mixing of the RGB colors in the image. Triple line sensors, especially, with their large line spacing produce color convergence errors when F1 is not applicable (Figures 1 and 2).

\[
F1: \quad \frac{1}{	ext{FOV}} = \frac{1}{S} + \frac{1}{w}
\]

Color line scan cameras are able to scan the surfaces of moving objects in color. Typical applications are:

- Surface inspection of wood, ores and minerals
- Scanning of books and documents
- Quality control of printing
- Sorting colored objects, in bulk

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- Quality control of printing
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- Color imaging in industries, especially, for the surface inspection of wood, ores and minerals.

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- Surface inspection of wood, ores and minerals
- Scanning of books and documents
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The sensors use red, green and blue (RGB) color-sensitive pixels. With up to 7600 pixels per color, very high optical resolutions are possible. A document in A3 size can be scanned at up to 650 dpi or 39 μm per pixel. For true-color imaging, hardware and software functions for white balance, black level correction and color correction are available. Color calibration using an IT8-target is also possible.
**Triple Line Sensors**

Line scan cameras are designated according to the number of line sensors as triple line, dual line or single line sensors. Schäfter + Kirchhoff offers most camera models with triple line sensors. Triple line sensors have three separate rows of sensors for the primary colors red (R), green (G) and blue (B). The positions of the R, G and B pixels are defined precisely and triple line sensors exhibit particularly high resolutions. The distance between the line sensors (line spacing) is generally 1, 2, 8 or 9-times the pixel height (h). This spatial distance in the translational direction is automatically corrected during production of the image. For exact color mixing, line synchronous image acquisition according to formula F1 and the direction of transport are particularly important. The color information of a picture with a delay line, Ld, of cycles is incomplete. The line delay Ld is twice the line spacing LS divided by the pixel height h, with both usually measured in microns:

\[ Ld = \frac{2 \cdot LS}{h} \]

Applications in which the transport velocity is not exactly known, such as when imaging bulk products, during free-fall or a photo-finish in a race, should use color line scan cameras with a low line spacing. This has the added advantage that the color convergence errors from the not perfectly synchronous signals are smaller and may be neglected.

---

**Color acquisition with Triple Line Sensors**

The color line scan camera delivers the red (R), green (G) and blue (B) signals sequentially in a single line signal. Asynchronous transport during image acquisition results in inappropriate pixel designations and color convergence aberration (Figure 2).

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**Image acquisition with Dual Line Sensors**

2D image acquisition data, using a dual line color sensor signal with one line of 2048 green pixels and a second line with 1024 each of alternating red and blue pixels, can be produced by either:

1. using all green pixels once, and the red and blue pixels twice each, so that 2048 image points per line are generated, or
2. combining the red and blue pixel data with the mean of two adjacent green pixels so that 1024 image points per line are generated, which results in a lower resolution image than above.

---

**Color management of pictures with color fidelity**

Pictures with color fidelity require a color calibration of the line camera. This process requires a scanner system with a translation unit and the scanner software SKan-G from Schäfter+Kirchhoff (Figure 7).
Performing a white balance correction of the individual R, G and B components of the line signal results in the intensities of the three basic colors produced using a white template (sheet of paper) being matched over the entire sensor length.

First, a coarse adjustment of the RGB signals in the oscilloscope display of the line signal is performed using the Gain Controller in the Gain/Offset dialog. The red, green and blue curves are now coincident, A.

Second, the curved line signals can now be flattened, which counteracts any manifestations of lens vignetting, inhomogeneous illumination and non-uniformity of the sensor. A scan of a white template over a defined distance is performed to produce a 2D image. The software calculates a reference curve to correct for variations in brightness. The resulting look-up table is stored in the flash-memory of the camera and, thereafter, the correction is automatically applied within the camera. A new scan of the white template reveals a homogenous intensity distribution over the entire image. During this process, the software also corrects for template irregularities and dust flecks automatically.

**Color correction**

A white balance correction is not a guarantee of color fidelity for all colors in a colored template. Disturbances can arise from the spectral properties of the illumination unit or of the sensor, as well as from the whiteness properties of the template used for the white balance.

For effective color reproduction by the entire scanner, a standardized color calibration is necessary using an IT8-Target of defined size and color palette. The IT8-Target is imaged by the scanner and the software calculates an ICC-Profile on the basis of defined reference values. Subsequent scans can use this profile to produce images with reliable color fidelity.

The SKan-G software produces lossless pictures with an embedded ICC-Profile for storage in .png and other formats.

### White balance

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### Wood surface inspection with the color line camera

**SK22800GJRC-XC**

- Pixel: 3x7600 (RGB), 9.3 x 9.3 μm²
- Sensor length: 70.68 mm
- Line frequency: max. 4.93 kHz
- Interface: Gigabit Ethernet
- Measuring range: 320 mm x 2500 mm
- Resolution: 600 dpi, 42 μm/pixel
- Picture size: 7600 x 60000 pixel (24-bit), in the PC RAM
- Storage format: bmp, png with embedded ICC-Profile

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**Caption:**
- A. Line signal after RGB signal adjustment using a white template
- B. Area scan for determination of the reference signal for white balance
- C. Line signal after white balance
- D. Area scan of an IT8-Target with active white balance
Specialized application: Plug Scanner
SK-2096-USB3-Color
for automated bore plug inspection

Color line scan camera SK6288U3KOC, 3x 2096 pixel (RGB)
- For object length 50–75 mm
- Optical resolution 1050–700 dpi
- Object diameter of 25–50 mm

The bore plug scanner SK-2096-USB3-Color is a fully mobile surface-scanning macroscope that was specially developed by Schäfter+Kirchhoff for the investigation of smooth cylindrical objects, such as bore plugs.

Features:
- Rapid and precise exchange of test objects by using two rotating supports
- Simple adjustment of focus for objects with different diameters
- The new USB 3.0 interface enables the scanner to be transported and used almost anywhere
- A surface scan by simply pressing a switch or clicking a mouse button
- Automatic white balance
- One-click zooming for 1:1 depictions
- Printing and saving of complete or zoomed sections

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### Interface

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<tr>
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