Color Line Scan Camera SK6288CKOC

3 x 2096 pixels, 14 µm x 14 µm, 60/30 MHz pixel frequency

Camera	SK6288CKOC
Sensor	Triple Line Sensor
Type	KLI-2113
Pixel number	3 x 2096 (B-G-R)
Pixel size	14 µm x 14 µm
Pixel spacing	14 µm
Line spacing (B-G-R)	112 µm
Active length	29.3 mm
Anti-Blooming	no
Integration Control	yes
CDS [1]	yes
Pixel frequency	60 / 30 MHz
Line frequency max	9.28 kHz
Line frequency min	0.05 kHz
Integration time max	20 ms [2]
Integration time min	0.010 ms
Dynamic range	1:2500 (1 MHz, no Integration control)
Spectral range	400–700 nm
Video signal	8-bit / 12-bit
Interface	Interface: Camera Link
Voltage	+5 V, +15 V
Power consumption	3.5 W
Casing (W x H x D)	65 mm x 65 mm x 73 mm
Objective mount	M45 x 0.75
Weight	0.2 kg
Working temperature	+5°C to +45°C

[1] CDS = Correlated Double Sampling. Noise-reduction technology, increase of photosensitivity.
[2] Longer exposure times are possible in trigger mode "exposure active".

1 **Smart line scan camera SK6288CKOC** Interface: Camera Link with

2 Clamp set SK5102

3 Mounting bracket SK5105

4 Photo lens Nikon AF 1:1.4/f'=50 mm, M45x0.75 thread, with locking bridge for fixing focus and aperture

Contents

Schäfter + Kirchhoff GmbH
Kieler Str. 212, 22525 Hamburg, Germany • Tel: +49 40 85 39 97-0 • Fax: +49 40 85 39 97-79 • info@SuKHamburg.de • www.SuKHamburg.de

1. Introducing the SK6288CKOC Color Line Scan Camera

The successful use of the line scan camera requires that the complete optical system is properly set up, especially the location of the illumination, the degree of focus of the objective and the aperture setting. The most critical factor is the perpendicular alignment of the sensor axis either with the object to be measured or the direction of its relative travel when scanned.

Data acquisition requires that the grabber board conforms to the CameraLink™ standard. The grabber board provides the Start-Of-Scan (SOS) signals and thereby determines the exposure time and line frequency of the camera.

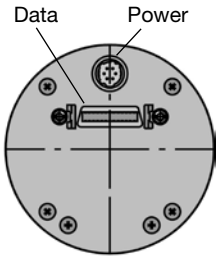
The configuration program **SkCLConfig** allows the full parameterization of the camera settings, such as gain, offset and pixel frequency, via the CameraLink™ serial port interface. **SkCLConfig** uses the *clser ***. dll* driver that is supplied with the CameraLink grabber board and personalized applications can also be developed using the SDKs available from the grabber board producers.

Schäfter+Kirchhoff supplies the operating program **SkLineScan®** for certified grabber boards, including µEnable III from Silicon Software, National Instruments PCI-1428, DALSA X64 XCelera-CL and the Matrox Solios.

The zoom function of the **SkLineScan** oscilloscope display of the line camera signal accelerates the optimal parameterization of the camera and alignment of the optical system. **SkLineScan** can be customized for a particular grabber board on request.

The cameras are supplied precalibrated, with factory settings for gain and offset that can be changed according to requirements using the supplied software. Significant losses in signal quality do accrue when the gain or offset parameters are set incorrectly. The gain and offset values in current use are stored in the camera in non-volatile memory and are immediately available when the camera is reactivated or switched on again.

2. Connections and I/O Signals



Data Connector:
Mini-D ribbon,
female 26-pin

Power Connector:
Hirose series HR10A,
female 6-pin

Power Connector: Hirose series HR10A, female 6-pin

+ 5 V	± 5%	ca. 300 mA	(30 MHz Clock)
		ca. 430 mA	(60 MHz Clock)
+15 V	± 5%	ca. 35 mA	

Signal	Pin	Signal	Pin
+ 15 V	1	+ 5 V	4
+ 15 V	2	GND	5
+ 5 V	3	GND	6

Data Connector: Mini-D ribbon, female 26-pin

Signal	Pin		Pin	Signal
GND	1	o o	14	GND
X0-	2	o o	15	X0+
X1-	3	o o	16	X1+
X2-	4	o o	17	X2+
Xclk-	5	o o	18	Xclk+
X3-	6	o o	19	X3+
SerTC+	7	o o	20	SerTC-
SerTFG-	8	o o	21	SerTFG+
CC1	9	o o	22	CC1+
CC2+	10	o o	23	CC2-
CC3-	11	o o	24	CC3+
CC4+	12	o o	25	CC4-
GND	13	o o	26	GND

3. Interface

Camera control

Signal Name	I/O	Type	Description
TRIG1	I	RS644	CC1 - Synchronization input (SOS)
TRIG2	I	RS644	CC2 - Start Integration period in dual synchro modus (only cameras with Integration Control)
CLK_IN	I	RS644	CC3 - External pixel frequency (optional)

I = Input, O = Output, IO = Bidirectional, P = Power/Ground, NC = not connected
Warning: CC4 is not used.

Video data

The differential LVDS signals X0-X3 and XCLK are reserved for the transmission of high-speed video data from the camera to the grabber board. The video data is transmitted using numerous serial channels simultaneously, according to the protocol for the channel link chipset from National Semiconductor.
The CameraLink standard defines the names of the pixel signals, the description of the signal level and the pin assignments and pinout of the chip.

Signal Name	I/O	Type	Description
D[0–11]	O	RS644	Pixel data, 00 = LSB, 11 = MSB
STROBE	O	RS644	Output data clock Data are valid for a rising edge
LVAL	O	RS644	Line Valid, active High Signal

I = Input, O = Output, IO = Bidirectional, P = Power/Ground, NC = not connected
Warning: FVAL and DVAL are not used here as defined in the CameraLink standard.
FVAL is always set to the value = 0 (low).
DVAL is always set to the value = 11 (high).
For a single output, the data is output as ODD (multiplex).

Bit allocation 12-bit data (F12)

Bit	DS90CR285 Pin Name	Bit	DS90CR285 Pin Name	Bit	DS90CR285 Pin Name	Bit	DS90CR285 Pin Name
D 0	Tx0	D 7	Tx5	NC	Tx19	NC	Tx14
D 1	Tx1	D 8	Tx7	NC	Tx20	NC	Tx10
D 2	Tx2	D 9	Tx8	NC	Tx21	NC	Tx11
D 3	Tx3	D10	Tx9	NC	Tx22	STROBE	TxCLK
D 4	Tx4	D11	Tx12	NC	Tx16	LVAL	Tx24
D 5	Tx6	NC	Tx15	NC	Tx17		
D 6	Tx27	NC	Tx18	NC	Tx13		

Bit allocation 8-bit data (F8)

Bit	DS90CR285 Pin Name	Bit	DS90CR285 Pin Name	Bit	DS90CR285 Pin Name	Bit	DS90CR285 Pin Name
D 0	Tx0	D 7	Tx5	NC	Tx19	NC	Tx14
D 1	Tx1	NC	Tx7	NC	Tx20	NC	Tx10
D 2	Tx2	NC	Tx8	NC	Tx21	NC	Tx11
D 3	Tx3	NC	Tx9	NC	Tx22	STROBE	TxCLK
D 4	Tx4	NC	Tx12	NC	Tx16	LVAL	Tx24
D 5	Tx6	NC	Tx15	NC	Tx17		
D 6	Tx27	NC	Tx18	NC	NC		

The bit allocation conforms to the CameraLink Standard basic configuration.

Serial communication

Signal Name	I/O	Type	Description
SerTFG	O	RS644	Differential pair for serial communications to the grabber board
SerTC	O	RS644	Differential pair for serial communications from the grabber board

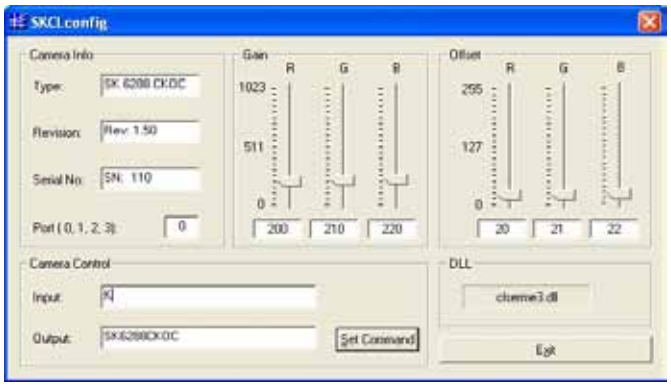
The CameraLink interface supports two LVDS signal pairs for communication between the camera and grabber board, which conform with the RS232 protocol for asynchronous communication:

– full duplex, no handshake

– 9600 baud, 8-bit, no parity bit, 1 stop bit.

4. Camera Control and SkCLConfig

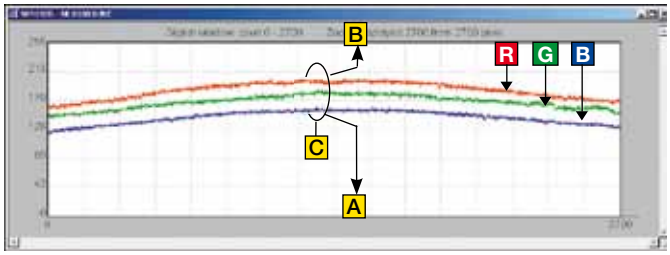
The configuration program **SkCLConfig** is shipped with all **Schäfter+Kirchhoff** cameras and enables the adjustment of line scan camera parameters, such as gain, offset and pixel frequency, via the serial connector of the CameraLink interface. The software uses the *clser***.dll* supplied with the CameraLink grabber board or a choice is made from the installed *clser*.dll* list using **Select**. On startup, the camera declares information about type, revision and serial number. If the camera type field is empty then switch off, check the connections and restart.



To set and read camera parameters:

Operation	Description
Gnnnn<CR>	Set Gain Chan1 (Red) 0-24 dB
Bnnnn<CR>	Set Gain Chan2 (Green) 0-24 dB
Hnnnn<CR>	Set Gain Chan3 (Blue) 0-24 dB
Jnnnn<CR>	Set Gain Chan4 0-24 dB
Ommm<CR>	Set Offset Chan1 (Red)
Pmmm<CR>	Set Offset Chan2 (Green)
Qmmm<CR>	Set Offset Chan3 (Blue)
Ummm<CR>	Set Offset Chan4
F8<CR>	Output Format: 8-bit data
F12<CR>	Output Format: 12-bit data
C30<CR>	Camera Clock: 30 MHz
C60<CR>	Camera Clock: 60 MHz
CC3<CR>	Camera Clock external at CC3 (max. 60 MHz / optional)
T0<CR>	Test pattern off
T1<CR>	Test pattern on,
M1<CR>	Trigger Mode: External Trigger CC1
M2<CR>	Free Run with maximum line rate
M3<CR>	External Trigger & Integration CC1-input, optional
M4<CR>	External Trigger CC1, Integration CC2- input, optional
I<CR>	returns camera identification
K<CR>	returns SK type number
R<CR>	returns Revision number
S<CR>	returns Serial number
I4<CR>	returns Camera Clock Low Freq.
I5<CR>	returns Camera Clock High Freq.
I6<CR>	Ga1:xxxxx<CR> ret.Gain Chan1
I7<CR>	Ga2:xxxxx<CR> ret.Gain Chan2
I10<CR>	Ga3:xxxxx<CR> ret.Gain Chan3
I11<CR>	Ga4:xxxxx<CR> ret.Gain Chan4
I8<CR>	Of1:xxxxx<CR> ret.Offset Chan1
I9<CR>	Of2:xxxxx<CR> ret.Offset Chan2
I12<CR>	Of3:xxxxx<CR> ret.Offset Chan3
I13<CR>	Of4:xxxxx<CR> ret.Offset Chan4
Range of values:	nnnn = 0 .... 1023 mmm = 0 ... 255

Camera commands are entered into the 'Input' field of the configuration tool and executed with the 'Set Command'.



4.1 Gain / Offset and Shading Correction

The camera is shipped prealigned with gain and offset factory settings. On startup, the RGB sliders register the gain and offset values already stored in the camera. Customized settings for gain or offset can be programmed using the **SkLineScan** software:

A Offset

After blocking all light reaching the line sensor, bring the individual video signals close to zero using the R, G and B offset sliders. The line signal should be just visible in the oscilloscope display.

B Gain

Now fully illuminate the sensor and move the R, G and B gain sliders to provide a slight overexposure for maximum signal clipping (for 8-bit: 255 or slightly above, for 12-bit: 4095).

The parameter settings are stored within the list using **Select** and are retained for immediate subsequent use even after a complete shut down.

C Shading Correction: White Balance

Shading correction is a procedure used for compensating for the potential sources of variation in the signal, whether caused by lens vignetting or variations in pixel sensitivity or illumination. A reference signal for the shading correction is obtained by taking an image of a plain white surface, so that each individual pixel can be compensated for algorithmically to provide a maximum overall intensity and an idealized flat signal. Alternatively, the R, G and B gain sliders can be used to regulate the signal.

The shading correction reference values are permanently stored in the designated shading correction memory (SCM) in the camera, for future use, and can be switched on and off according to demand.

4.2 Illumination and Exposure

An exposure is illumination of the line scan sensor for a set period of time. The light sensitive elements of the sensor transform the radiation into freed charges. The time period of accumulation of these charges during one exposure is called the **Integration Time**. The accumulated charges are read out of the sensor, pixel-by-pixel, using a scrolling shift register. This total process of integration time and read-out is termed the **Exposure Period** T_E. The speed of data read-out is determined by the pixel frequency (MLCK).

The reciprocal of the maximum line frequency determines the minimum exposure period. In continuous mode, the next exposure is simply begun at the time of read-out of the previous exposure and the charges accumulated at each camera pixel are transformed into appropriate voltage values for further use. In trigger mode, the time between the positive edges of two consecutive SOS signals detemines the exposure period.

Cameras with **Integration Control** can regulate the integration time within an exposure period (shutter mechanism). The line frequency is not increased thereby, as the total exposure time remains the same.

$$T_E = \frac{N + N_P}{f_P} \qquad f_L = \frac{1}{T_E}$$

T_E = exposure period — f_L = line scan frequency
N = number of pixels — N_P = passive pixels of the sensor
f_P = pixel frequency

The maximum line frequency of the SK6288CKOC camera is 9.28 kHz and the programmable exposure period ranges from 0.11 ms to 20.0 ms.

The minimum exposure period is the time interval between two SOS signals and must be at least the length of N = 3 x 2096 pixel clocks, plus the sensor-dependent number of passive pixels Nρ= 176 (for the SK6288CKOC camera).

Example: SK6288CKOC, 60 MHz pixel frequency

T_E = (3 x 2096 +176) / 60 MHz = **0.108 ms**

f_L = 1 / 0.108 ms = **9.28 kHz**

4.3 Integration Control

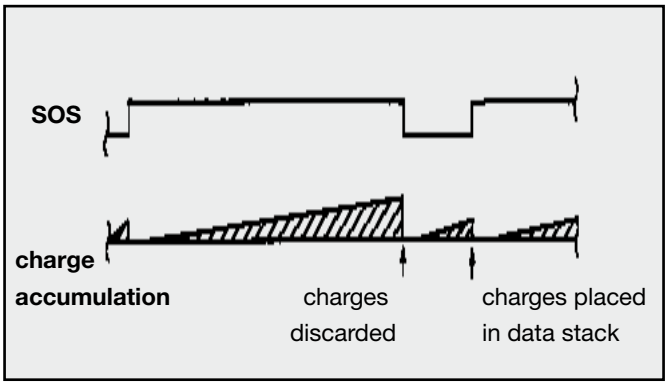
In the normal use of the line scan camera at lower pixel frequencies, the SOS signals between two exposure periods are set at 'high' and the integration time and exposure time are essentially the same.

Integration control is a function that extends the 'high' pulse of the SOS signal over a programmable number of pixel clocks. Within an illumination cycle, this results in a delay before the accumumulation of charge can begin.

The integration time T_A is shortened to the difference between the minimum pixel frequency for an illumination cycle (N + Nρ) and the programmed number of pixel clocks required for the extension of the 'high' pulse of the SOS signal (SOSL).

The line frequency is not increased by using integration control and the total exposure time remains the same.

$$T_A = \frac{(N + N_P) - SOSL}{f_P}$$

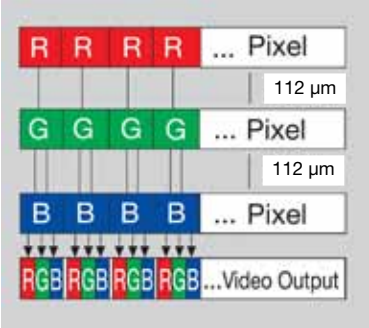


The principle of Integration Control

5. RGB Sensors: 2D Imaging and Pixel Allocation

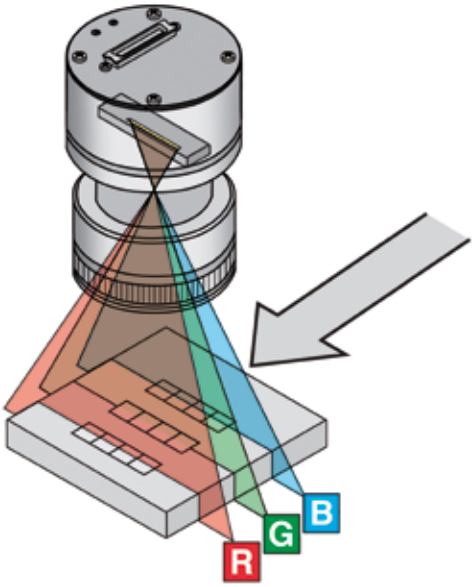
Triple line sensors have 3 separate sensor lines for the primary colors red, green and blue and can achieve extremely high optical resolutions. The SK6288CKOC color line scan camera has 3 x 2096 pixel triple line sensors of red, green and blue.

The distance between the sensor lines is 8 times the pixel height, so the inter-sensor distance is 112 µm for a pixels of 14 µm.



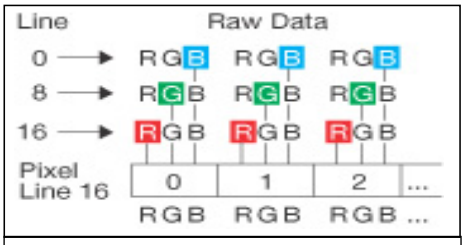
A two-dimensional color image is generated by moving the object or the camera, ensuring that the sensor properties, the travel direction and speed are all accounted for:

$$\text{object velocity} = \frac{\text{pixel width} \bullet \text{magnification}}{\text{exposure time}}$$

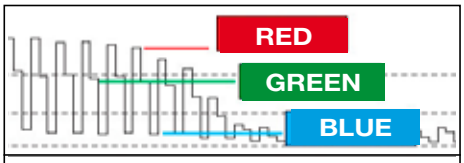


During object travel, an object point reaches the blue line sensor first. If the object is translated by one pixel height per clock pulse then after 8 lines the green pixels are exposed. After another 8 pixels then the red pixels have been covered and all color information has been acquired.

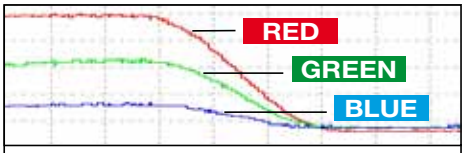
The color information originating from the different parts of the object is stored in the buffer of the PC and subsequently reallocated correctly.



Allocation of color information



Signal display - RGB sequentially



Signal display - RGB splitting

Triple line sensors require a precise synchronous translation of the object for the correct allocation of pixels A. When these conditions are not met then images with color convergence aberrations are generated B.

Monochrome font pattern
A line synchronous object transport
B asynchronous transport of the object causes color convergence aberration

6. Control Signals and Timing Diagram

Input Control Signals

The control signals needed to run the CCD line scan camera are "Clock" (MCLK) and "Start Of Scan" (SOS). The clock signal is generated internally by a 60 MHz oscillator, which can be reduced to 30 MHz using a frequency divider. The clock signal can also be supplied from an external source if required.

Because these signals are used to trigger the camera, they should be of the highest quality.

The frequency of the 'SOS' signal determines the number of lines that are read per second. On the rising edge of this signal, the accumulated charges in the sensor pixels of the analog shift register are read out with each beat of the clock signal.

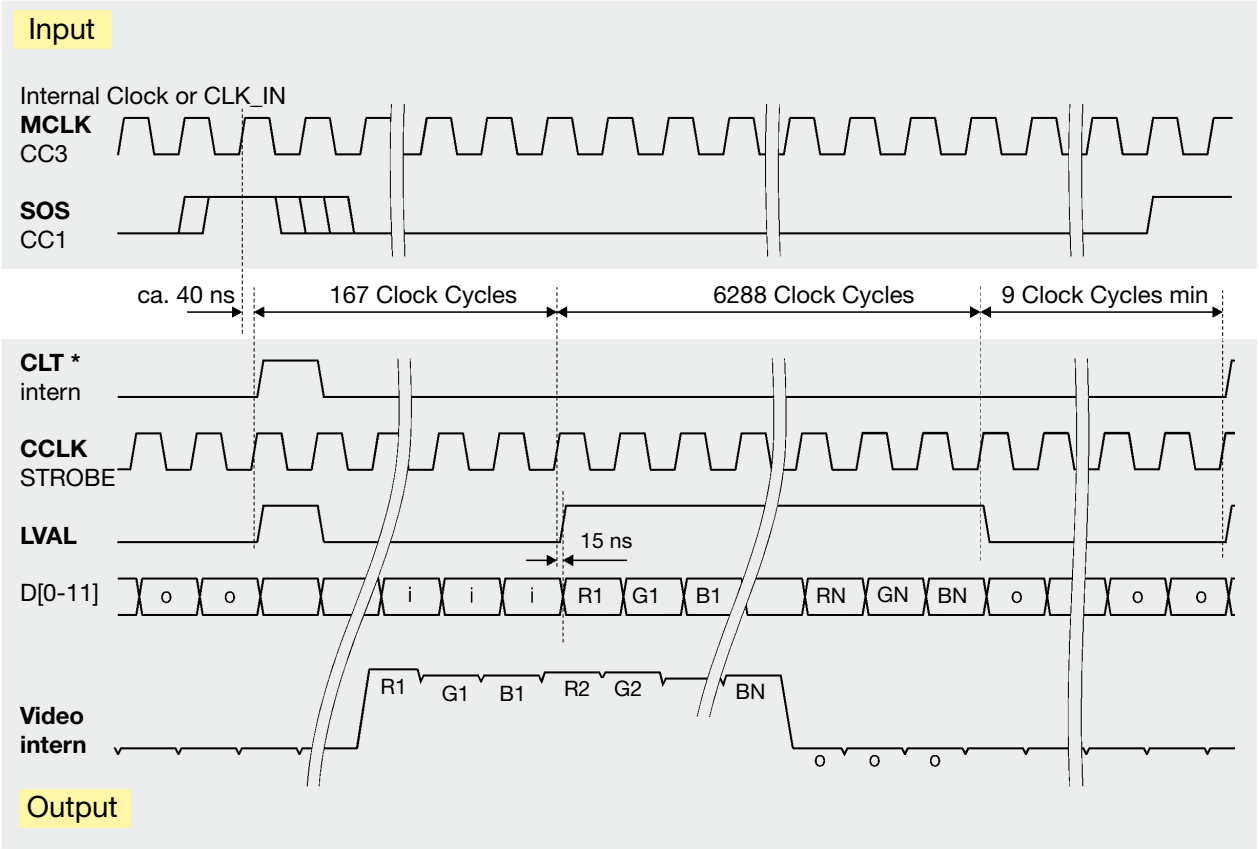
Thus, the frequency of the clock signal determines the speed at which the charges of the individual pixels of the line sensor appear in the camera video output. At each positive edge, the accumulated charges of the subsequent pixels are released as video output.

The Clock and 'SOS' signals do not have be synchronized. However, the clock frequency should be sufficiently slow to allow two successive 'SOS' signals to be read out from the line camera. The SK6288CKOC camera requires 6464 clock pulses for a line scan to be read out completely. Larger numbers of clock pulse can be used without restriction.

MCLK: Master Clock in: determines the frequency of pixel transfer, maximally 60 MHz.

SOS: Start Of Scan: minimum pulse length of 30 ns.

The frequency of the SOS signal is directly controlled by the line frequency of the camera. The rising edge of the 'SOS' signal is the start of the signal accumulation process. The accumulated charges within the sensor are transferred to the analog transport registers in parallel with the sensor line information.



* CLT = Camera Line Transfer (internal line camera signal). The black value signal is 4 to 36 pixels prior to pixel no.1.

i = isolation pixels, o = overclocking R = red, G = green, B = blue, N = 2096

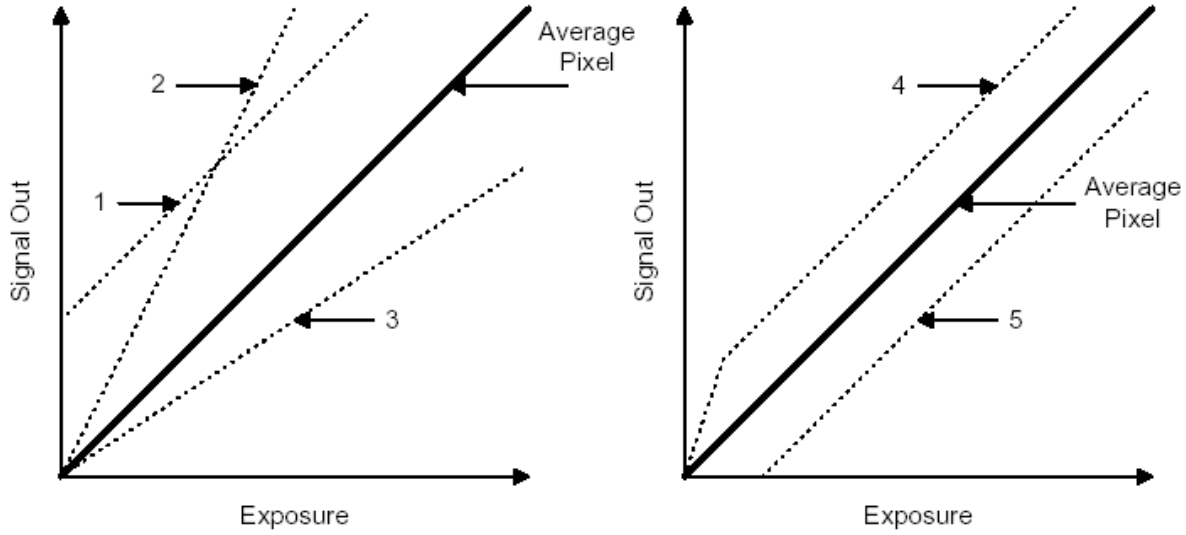
7. Sensor Performance Specifications

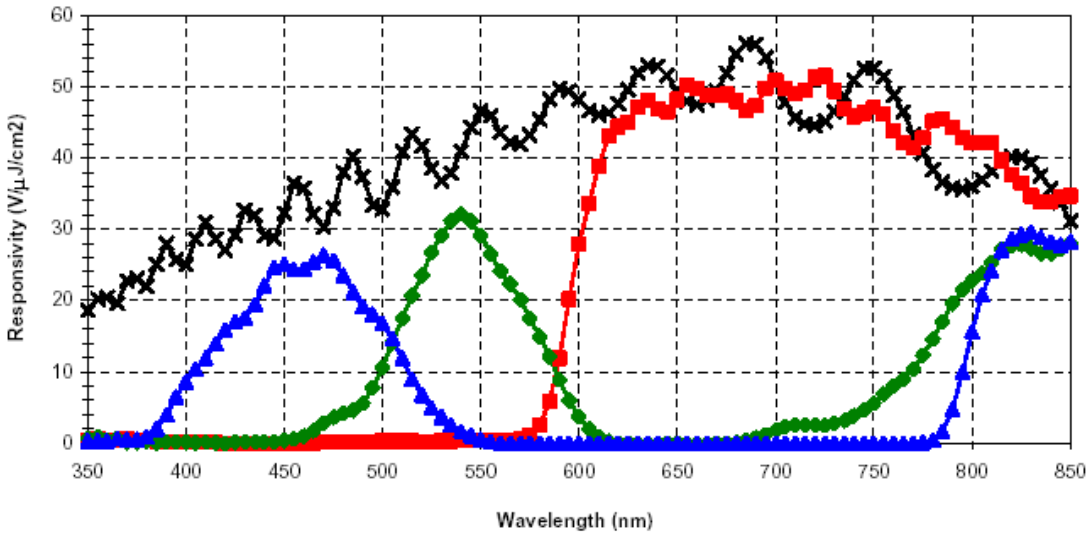
Producer: Eastman Kodak Company
Type: KLI-2113
Data source: Kodak Digital Science KLI-2113 Image Sensor - Technical Data

Representative Characteristics Test conditions: T = 25°C, f_{CLK} = 2 MHz, t_{int} =1.066 msec

Field	Defect Type	Threshold	Units	Notes	Number
Dark	Bright	8.0	mV	1, 2	0
Bright	Bright/Dark	10	%	1, 3	0
Bright	Exposure Control	4.0	mV	1, 4, 5	≤16

Notes:
1. Defective pixels will be separated by at least one non-defective pixel within and across channels.
2. Pixels whose response is greater than the average response by the specified threshold. See line 1 in figure below.
3. Pixels whose response is greater or less than the average response by the specified threshold. See lines 2 and 3 in figure below.
4. Pixels whose response deviates from the average pixel response by the specified threshold when operating in exposure control mode. See lines 4 and 5 in the figure below.
5. Defect coordinates are available upon request.





Electro-optical Characteristics

Specifications given under nominal operating conditions @ 25°C ambient, f_{CLK} =2 MHz and nominal external VIDn load resistors unless otherwise specified.

Symbol	Parameter	Min.	Nom.	Max.	Units	Notes
V_{sat}	Saturation Output Voltage		2.0		V_{p-p}	1, 7
$\Delta V_o/\Delta N_e$	Output Sensitivity		11.5		$\mu V/e^-$	7
$N_{e,sat}$	Saturation Signal Charge		170k		electrons	
R	Responsivity (@ 650nm)		50		$V/\mu J/cm^2$	2, 7
	(@ 540nm)		32		$V/\mu J/cm^2$	
	(@ 460nm)		25		$V/\mu J/cm^2$	
f_{-3dB}	Output Buffer Bandwidth		75		MHz	@ C_{LOAD} = 10 pF
DR	Dynamic Range		76		dB	3
I_{dark}	Dark Current		0.02		pA/pixel	4
CTE, η	Charge Transfer Efficiency		.99999		-	5
L	Lag		0.6	1	%	1st Field
$V_{o,dc}$	DC Output Offset	6	7	9	Volts	7
PRNU	Photoresponse Uniformity		5	10	% p-p	6
C_ϕ	Register Clock Capacitance		500		pF	/phase
C_{TG}	Transfer Gate Capacitance		400		pF	

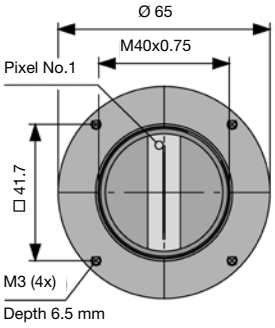
Notes:

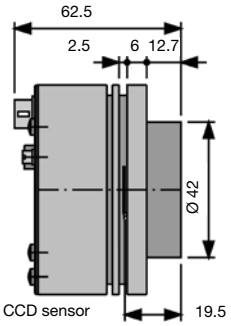
1. Defined as the maximum output level achievable before linearity or PRNU performance is degraded.
2. With color filter. Values specified at filter peaks. 50% bandwidth = ±30 nm.
3. This device utilizes 2-phase clocking for cancellation of driver displacement currents. Symmetry between $\phi 1$ and $\phi 2$ phases must be maintained to minimize clock noise.
4. Dark current doubles approximately every +9°C.
5. Measured per transfer. For total line h < $(.99999)^{4256}$ =0.96.
6. Low frequency response across array with color filter array.
7. Decreasing external VIDn load resistors to improve signal bandwidth will decrease these parameters.

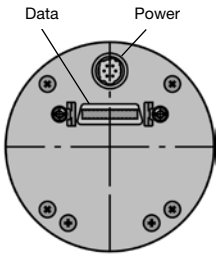
8. Dimensions

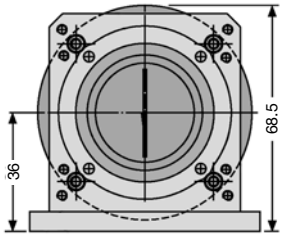
Line scan cameras with CameraLink interface

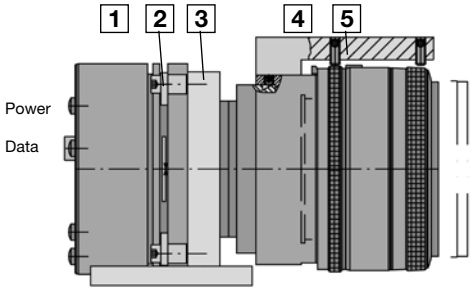
Casing group: AC2, AC3









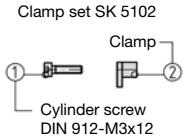


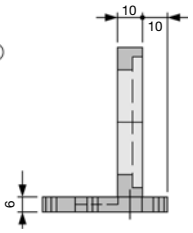
CCD line scan camera, digital

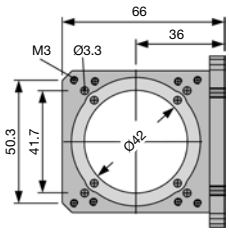
Lens thread: (AC2) M40x0.75
Distance to sensor: 19.5 mm
Data Connector: Mini-D ribbon, female 26-pin
Power Connector: Hirose series HR10A, female 6-pin

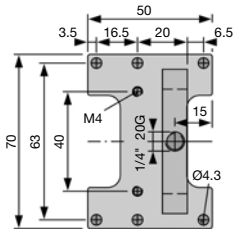
Camera type:
C series from 512 to 6288 pixels

1 **CCD line scan camera, digital**
Lens thread (AC3) M45x0.75
mounted on:
2 Clamp set SK5102
3 Camera mount SK5105
4 Lens
5 Locking bridge (aperture and focus)









Mounting bracket SK5105
for digital and analog cameras
Order Code: SK5105
Warp resistant construction for mounting a CCD Line Scan Camera

Clamp set SK5102
(set of 4)
to lock the CCD Line Scan Camera at an arbitrary rotation

9. Warranty

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

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

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

The warranty period for the CCD line scan camera when used for the purpose for which it was intended is 24 months.

The warranty is immediately void on inappropriate modification, use or damage.

EC Declaration of Conformity

CE This product satisfies the requirements of the EC directive 89/336/EEG as well as DIN EN 61326.

10. Accessories

Mounting bracket
SK5105 Order Code
Warp-resistant construction for mounting the line scan camera

Clamp set
SK5102 Order Code
to lock the line scan camera in desired position
(set of 4)

Mounting Console
SK5105-2 Order Code
for indirect mounting of the line scan camera via the extension tube, suitable for extension tube larger than 50 mm, for example with macro lens.

Control cable SK9018...
26-pin shielded cable, both ends with mini-D ribbon connector, male/male **MM**

SK9018.5-MM Order Code
3 = 3 m cable length
5 = 5 m (standard)
x = length of choice (maximum = 100 m)

Power supply cable SK9015...
Shielded cable with Lumberg SV60 male 6-pin and Hirose HR10A female 6-pin connectors, **MF**

SK9015.1.5-MF Order Code
1.5 = 1.5 m standard
3 = 3 m
x = length of choice

Power Supply:
PS051515 Order Code
Input: 100–240 V AC, 50/60 Hz, 0.8 A
3-pin input connection (IEC 320)
Output: 5 V DC/2.5 A
15 V DC/0.5 A, -15 V DC/0.3 A
output connector: Lumberg KV60
female 6-pin, length 1 m

Software:
SK91CL-WIN * Order Code

SkCLConfig control program for line scan cameras with a CameraLink™ interface (all grabber boards).
SkLineScan operating program with oscilloscope display and scan function.

Operating system: * Windows XP/2000

Lenses:
- high resolution **enlarging and macro lenses**
- high speed **photo lenses**
- lenses with additional **blocking bridge** for locking of focus and aperture setting

Adapter:
Lens adapter AOC-...
- for fitting photo lenses onto the CCD line scan camera

Focus adapter FA22-...
- for fitting enlarging or macro lenses

Schäfter + Kirchhoff GmbH
Kieler Str. 212, 22525 Hamburg, Germany • Tel: +49 40 85 39 97-0 • Fax: +49 40 85 39 97-79 • info@SuKHamburg.de • www.SuKHamburg.de