CCD Line Scan Camera Digital b/w SK 2048 DJRI

2048 Pixels, 14 x 14 µm, 10 MHz Pixel Frequency

Camera Series DJR 2048 | 2592 | 5000 | 5150

1 **CCD Line Scan Camera SK 2048 DJRI**
mounting:
2 Camera mount SK5105
3 Clamp set SK5102
4 Photo lens with blocking bridge

Characteristics

- digital camera, 8 bit resolution
- very light-sensitive
- line frequency up to 4,8 kHz
- Integration Control
- high dynamic range
- low noise
- LVDS Interface
- Round housing Ø 65 mm

Accessories (optional)

Camera Mount SK 5105 Order Code
Wrap resistant construction for mounting the CCD Line Scan Camera.
Optional: Clamp set SK 5102 Order Code to lock the CCD Line Scan Camera in arbitrary rotation.

Mounting Console SK5105-2 for the adaption of the macro lens, extension rings ZR..., focus adapter FA22-40 and the CCD Line Scan Camera

Lenses

- high resolution Enlarging and Macro Lenses
- high speed Photo Lenses
- Lenses including blocking bridge for locking focal and aperture setting.

Adapters

Lens Adapter AOC-... for adaptation of photo lenses with bayonet mount
Focus Adapter FA22-... for adaptation of enlangement and macro lenses.

Cable set SK9019 for digital CCD Line Scan Cameras of the series XSD, DPD, DPT, DJR, DJRC etc.
36-filament shielded cable for camera control and video signals. Standard: 3m cable length, one- or two-sided Centronics connector (female).

SK9019.3 FF Order Code

FF	=Connector two-sided (female)
F	=Connector one-sided (female)
3	=3 m (standard cable length)
5	=5 m cable length
x	=cable length coustom made

PC-Interface SK 9192 D Order Code
Interface for digital CCD Line Scan Cameras
PCI-Bus, preprocessing on-board:
Shading Correction, Windowing, Thresholding
external Synchronisation (LineSync, FrameSync)

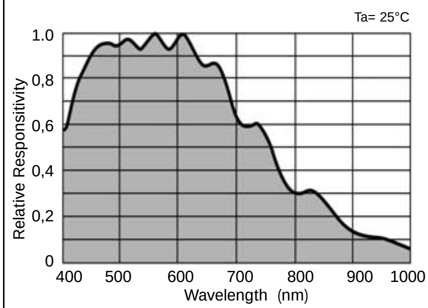
Software

SK91PCI-WIN *
SK91PCI-LX **
System software, drivers, libraries
* Windows, ** Linux

Performance Specifications

Camera Type: Order Code	SK 2048 DJRI
Sensor:	CCD linear Type ILX 751
Pixel Number:	2048
Pixel Size:	14 µm x 14 µm
Pixel Distance:	14 µm
Line Width:	14 µm
Active Length:	28,7 mm
Pixel Frequency:	max. 10 MHz
Line Frequency:	max. 4,8 kHz min. 0,05 kHz
Integration Time:	min. 5 µs max. 20 ms
Dynamic Range:	1 : 500 (rms)
Spectral Range:	400 - 900 nm

Typical Spectral Responsitivity



Input Control Signals
Master Clock
StartOfScan (SOS)

Output Signals	
Video Signal:	8 Bit digital
Interface:	LVDS

Power Supply	
Voltage:	+5 V, +12 V, -12 V
Power Consumption:	1,6 W

Connector	
Mini Centronics	36 pin-male

Cable Connector:
Series Harting Bellows
Type: 6013 036 5100

Others:	
Operating Temp.:	+ 5°C ... + 45 °
Case Dimensions:	Ø 65mm x 51mm
Weight:	0,2 kg
Lens Thread:	M 40 x 0,75

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1. Technical Specifications of the DJR Series

Camera Model	SK 2048 DJRI	SK 2592 DJR	SK 5000 DJR	SK 5150 DJR
CCD sensor	ILX 751	ILX 505	ILX 506	ILX 531 A
Number of pixels	2048	2592	5000	5150
Pixel size	14 µm x 14 µm	11 µm x 11 µm	7 µm x 7 µm	7 µm x 7 µm
Sensor width	14 µm	11 µm	7 µm	7 µm
Pixel distance	14 µm	11 µm	7 µm	7 µm
Active length	28,67 mm	28,51 mm	35 mm	36 mm
PRNU *Photo Response Non Uniformity*	3)	3)	3)	3)
Anti-Blooming	no	no	no	no
Integration Control	yes	no	no	no
CDS 1)	no	no	no	no
Pixel frequency max	10 MHz	5 MHz	10 MHz	40 MHz
Min. integration time	0,005 ms	0,53 ms	0,5 ms	0,133 ms
Max. integration time	20 ms 2)	20 ms 2)	20 ms 2)	20 ms 2)
Max. line frequency	4,8 kHz	1,88 kHz	1,98 kHz	7,53 kHz
Min. line frequency	0,05 kHz	0,05 kHz	0,05 kHz	0,05 kHz
Dynamic range	1 : 500 (rms)	1 : 500 (rms)	1 : 500 (rms)	1 : 500 (rms)
Spectral range	400 - 900 nm	400 - 900 nm	400 - 900 nm	400 - 900 nm
Video signal	8 Bit digital	8 Bit digital	8 Bit digital	8 Bit digital
Interface	LVDS	LVDS	LVDS	LVDS
Voltage supply	+5V, +12V, -12V	+5V, +12V, -12V	+5V, +12V, -12V	+5V, +15V, -15V
Power consumption	1,6W	1,6W	1,6W	3W
Lens connection	M40 x 0,75	M40 x 0,75	M40 x 0,75	M40 x 0,75
Housing (W x H x D)	Ø65mm x 51mm	Ø65mm x 51mm	Ø65mm x 51mm	Ø65mm x 51mm
Weight	0,2 kg	0,2 kg	0,2 kg	0,2 kg
Temperature range	+5°C ... +45°C	+5°C ... +45°C	+5°C ... +45°C	+5°C ... +45°C

1) CDS = Correlated Double Sampling. Noise reduction technology, increase of photosensitivity.
2) Longer exposure times are possible, but the signal-to-noise ratio will be reduced.
3) For further sensor specifications obtain the details of the sensor manufacturer. See the datasheet at the end.

2. Handling details of the line scan cameras

Attention:
Before the line scan camera is atached to or detached from the power supply make sure the power supply is switched off.
Otherwise, a permanent damage of the line scan camera device is risked.

To prevent damage due to heat accumulation and keep the temperature of the camera below 45°C, a sufficient air circulation around the camera housing has to be ensured.

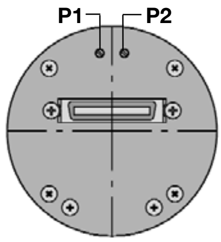
To start operation the required voltages, the Master-Clock- and StartOfScan-Signals using a 36-pin Centronics Miniature Connector have to be applied to the camera.

The camera is shiped aligned and set to default settings in gain and offset. Extensive modifications of the gain/offset-parameter can lead to a decrease in signal quality.
A successful application of the line scan camera is based upon a careful adjustment of the whole optical system. Attention should be paid to the arrangement of the illumination, the aperture setting, the focussing range of the lens, as well as the orientation of the sensor axis to the scanning direction.

Recommendation:
Using the **SK9192D** PC-Interface and the **SkLineScan®** software by **Schäfter+Kirchhoff** the camera is ready for operation immediately. The oscilloscopical display of the line scan camera signal including the zoom-function and the online parameter setting of the camera is a valuable tool while arranging the optical system setup. The hardware preprocessing on the Interface board (Shading Correction, Windowing, Thresholding) enables recording and evaluation with maximum line frequency. Furthermore, the comfortable methods of the class libraries for C++ support the development of user software.

3. Connection and Control Signals

Back Side of Camera



J1 = Mini Centronics 36pin-male, P1 = Offset adj., P2 = Gain adj.

Voltage Supply

+ 5 V	± 5%	ca. 120 mA
+12 V to +15 V	± 5%	ca. 50 mA
-12 V to -15 V	± 5%	ca. 20 mA

Pin out

Miniature Centronics 36 pin Connector (male)

	Signal	Pin		Pin	Signal	
	GND	18	O O	36	GND	
(+5V)	VCC	17	O O	35	VCC	(+5V)
	GND	16	O O	34	D7 - out	
(+5V)	VCC	15	O O	33	D7 + out	
	CCLK - out	14	O O	32	D6 - out	
	CCLK + out	13	O O	31	D6 + out	
	LVAL - out	12	O O	30	D5 - out	
	LVAL + out	11	O O	29	D5 + out	
	SOS - in	10	O O	28	D4 - out	
	SOS + in	9	O O	27	D4 + out	
	MCLK - in	8	O O	26	D3 - out	
	MCLK + in	7	O O	25	D3 + out	
	GND	6	O O	24	D2 - out	
(-12V bis -15V)	VEE	5	O O	23	D2 + out	
(+12V bis +15V)	VDD	4	O O	22	D1 - out	
(+12V bis +15V)	VDD	3	O O	21	D1 + out	
	GND	2	O O	20	DO - out	
	Analog Video A out (for test only)	1	O O	19	DO + out	

Digital Control Inputs

Input Control Signals:

The Low Voltage Differential input Signals (LVDS) are converted into TTL conform signals inside of the CCD camera.

The camera uses only the control signals "Clock" (MCLK) and "Start Of Scan" (SOS) for operation. The camera electronic responds to the rising signal edges that should be 'sharp' and free from noise.

The frequency of the "Start of Scan" signal determines the total count of line scans per second. On the rising edge of this signal all the accumulated charges inside the pixels will be tranferred to the analog shift register of the sensor. The shift register (transport register) will be read out with the 'Clock' signal.

The 'Clock' signal frequency gives the read-out rate for single pixel informations of the linear sensor. This is just the rate of the video output signal of the camera. Every rising edge of 'Clock' transfers the next following pixel's charges to the video output amplifier.

The 'Clock' and the 'SOS' signals need not to be syncronized. The 'Clock' frequency should be set to a sufficient large number to ensure enough 'Clock' pulses to read out the line sensor completely between two successive 'SOS' signals. The SK 2048 DJRI-Camera needs 2048+51 'Clock' signals to read out a line scan completely. Generally, transferring a larger number of 'Clock' pulses as needed is unproblematic and usual.

MCLK: Master-Clock in: determines the pixel transport frequency, maximum 10 MHz. Low voltage differential input.

SOS: Start of Scan: 50 ns minimum pulslength. Differential input.

The frequency of the 'SOS' signal determines the line frequency readout of the camera.

The charges of the sensor are accumulated while the 'SOS' signal is low. This way the length of the 'low' period can be used to effectively control the actual integration time at a fixed or rapidly changing line frequency.

The rising edge of the 'SOS' signal initiates the readout operation and the charges are transferred into the onchip analog shift register.

Output Signals:

'Clock' and 'Start of Scan' signals are echoed at the camera output to monitor system timings. These signals, like the input 'Clock' and 'Start of Scan' signals, are 'Low Voltage Differential signals' (LVDS).

CCLK: Camera-Clock out / Low Voltage Differential driver.

LVAL: Line Valid / Differential driver. A 'High'-level shows the availability of valid pixel data at the AD-converter output. The signal 'LVAL' contains a 'CLT' pulse at the beginning of the line, necessary to synchronize **Schäfter+Kirchhoff** - Interface boards.

D0-D7: 8 bit digital video output (8 x Low Voltage Differential driver LVDS) D0=LSB, D7=MSB

4. Exposure and Integration Control

Exposure:

The light sensitive elements of the sensor store the charge which are generated by the incident light during the exposure cycle. This accumulated charge is then converted into voltage. These values are a measure for the incident light intensity on each pixel.

The process of integration starts with the falling edge of the ‘StartOfScan’ (SOS)-signal. While the SOS-signal is ‘Low’, charge is accumulated. With the rising edge of the SOS-signal the exposure is concluded. The SOS-signal level stays a short time on ‘High’, before the next falling edge triggers the next exposure cycle.

Exposure time:

The exposure time of a single line scan t_B is the time interval of adjacent positive edges of the ‘StartOfScan’ (SOS)-signal. The time period of this interval (pixel clock) is determined by the minimum number of necessary pulses to read the accumulated charge into the shift register of the line scan sensor.

The sum of the pixel clock pulses results from the number of pixels **N** plus sensor dependent passive pixel clock pulses N_P. The camera SK2048DJRI needs 51 pixel clock pulses. The read out frequency is determined by the pixel frequency (MCLK). The exposure time t_B of a camera calculates:

$$t_B = \frac{(N + N_P)}{f_P}$$

The line frequency is given by:

$$f_L = 1/t_B$$

- **Exposure time:** Time interval between successive ”SOS“ signals.
- **Integration time:** Duration of the actual charge accumulation during the exposure time.
- **Integration Control:** for CCD line scan cameras it is possible to program shorter integration times within the actual exposure time (Shutter operation).

Integration Control (SK 2048 DJRI - Camera):

In the default setting of the camera the SOS signal between two exposure cycles shows ‘High’ only at very few pixel clock pulses. The Integration time and the exposure time are virtually of the same length.

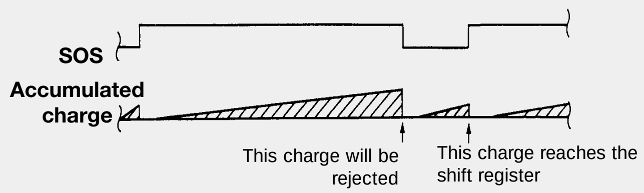
The Integration Control function allows the extention of the ‘High’-level condition in the SOS signal about a specified number of pixel clock pulses. The start of the accumulation of charge during an exposure cycle is thus delayed.

The integration time t_A is shortened to the difference of during one exposure period necessary pixel clock pulses ($N + N_P$) and the specified number of clock pulses for the extension of the ‘High’-level condition in the SOS signal (**SOSL**).

The line scan frequency is not influenced by the Integration Control function.

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

Mode of operation of the Integration Control function



Example:	SK 2048 DJRI, SK 9192D 10 MHz pixel frequency	**IntegrationCtrl:**	SOSL= 256;
	t_B = (2048 + 64) / 10 MHz		t_A = ((2048 + 64) - 256) / 10 MHz
	t_B = 0,21 ms		t_A = 0,18 ms
	f_L = 10 MHz / (2048 + 64)		t_B = 0,21 ms,
	f_L = 4,75 kHz		f_L = 4,75 kHz

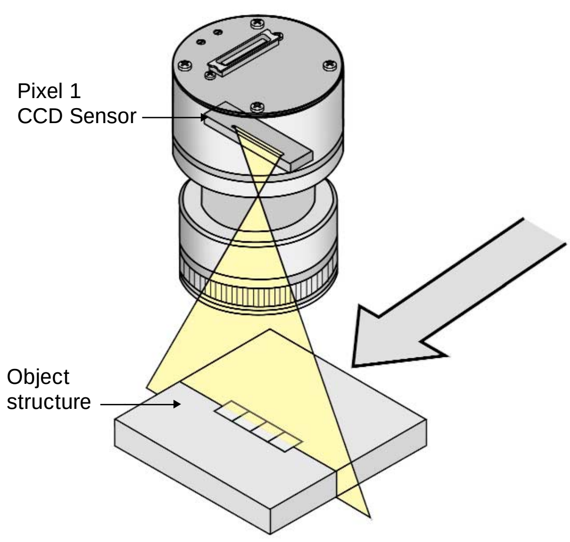
5. Generating an Image – Scan a Surface

A two-dimensional image is generated by moving the object or the camera. The direction of the movement needs to be orthogonal to the sensor axis of the CCD line scan camera.

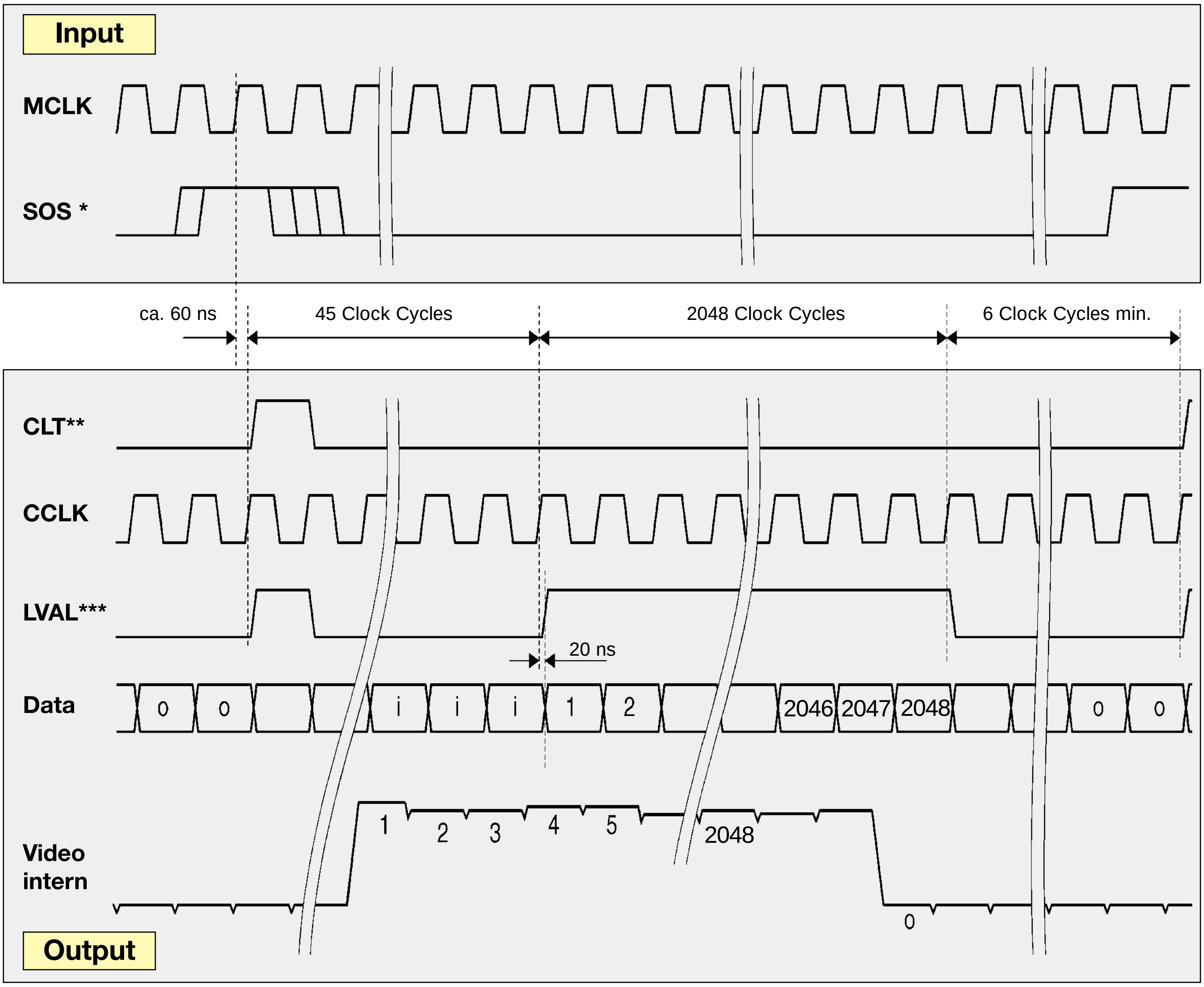
To optain a propotional image with correct aspect ratios a line synchronous transport and a laterally correct pixel assignment is required.

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

V_O	=	Object rate
W_P	=	Pixel width
β	=	Magnification
t_B	=	Exposure time



6. Timing Diagram



* The rising edge of 'SOS' should not occur within a range of 5 bis 30 ns before leading edge of 'MCLK'. (Integration Control Timing see below)

** CLT = Camera Line Transfer (internal line scan camera Signal)

*** The signal 'LVAL' contains a 'CLT' pulse at the line beginning, which is required for the synchronisation of the **Schäfter+Kirchhoff** Interface boards.

If requested, the CCD line scan camera is available without 'CLT' pulse at the line beginning of the 'LVAL'. Order Code: SK 2048 DJRI-3

The pixels determining the black level value are the 3rd to the 20th before pixel no. 1.

N = Sensor pixels

i = Isolation pixels

o = Overclocking

7. Blooming

Blooming

Extended illumination of saturated pixels, which are not able to accumulate further charge due to long exposure, leads to charge overflow into adjacent pixels. This effect is called **blooming**. Blooming causes a corruption of the geometrical allocation of image and object in the line signal.

CCD line scan cameras with **anti-blooming** sensors direct the abundant charge to a ”drain gate”. Charge overflow into adjacent, less illuminated pixels is prevented. Depending on pixel frequency and spectral range, overexposure up to factor of 30 can thus be handled.

The CCD line scan cameras of the DJR-series do not contain anti-blooming sensors. Nevertheless, they are prevented from overexposure due to a special design. DJR-cameras can be densed to a factor of 3.8, without blooming the sensor.

Figure 1 shows the line scan signal of a SK2048DJRI-camera with increased illumination in the center. For a better visualisation of the blooming effect the saturation voltage of the sensor V_{SAT} was reduced to roughly 90% of the maximum ADC-voltage. Thus, even with overexposure the maximum of 255 of the 8-bit digitized signal intensity will not be reached. In the central section the sensor is on the verge of saturation.

The marked region from figure 1 is zoomed in figure 2. Here, the integration time $\mathbf{t_A}$ amounts to 0.634 ms.

In figure 3 the integration time was increased to $\mathbf{t_A}$ 2.419 ms. Only from this point on the sensor starts to bloom. The signal edge is displaced slightly to the right, caused by excessive charge congesting the adjacent pixels.

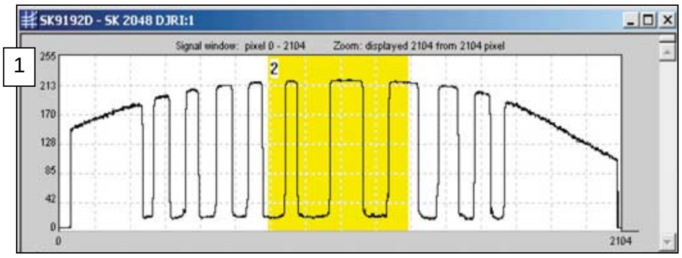
Even longer integration times result in an intolerable deformations of the signal structures. In figure 4 the integration time was set to $\mathbf{t_A}$ 3.38 ms, corresponding in an overexposure of a factor of 5.3.

Figure 5 shows a phenomenon at extreme overexposure of CCD line scan cameras. The large charge excess of the preceding scan leads in the shown sample to an overload of the pixels at the beginning of the line. In this area the pixels determining the dark level are located. These pixels are used as a reference for the offset control. The large dark level intensity induces a reduction of the total signal intensity. Under these conditions more light generates a smaller signal intensity at the camera output.

In case of a very small output signal at operation start up of the CCD line scan camera, an extreme overexposure can be the reason.

Consider:

CCD line scan cameras including anti-blooming sensors can be densed to a factor of 50 before showing any effect of blooming.

1


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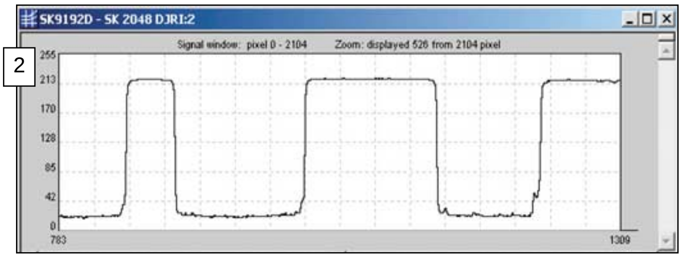

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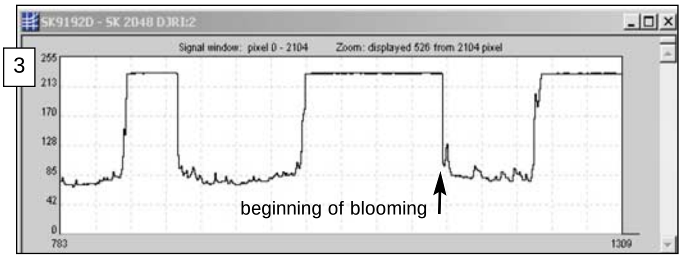

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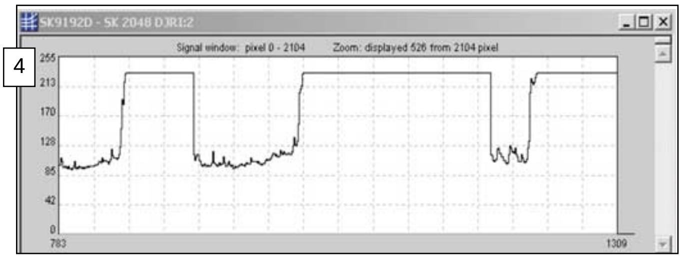

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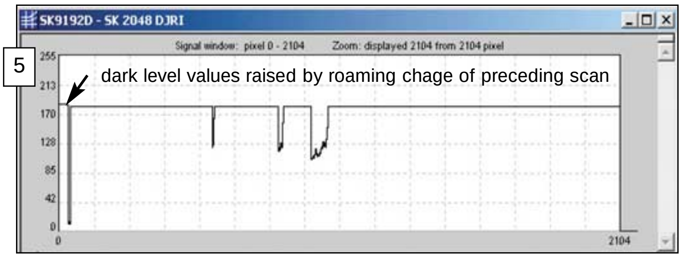


Oscilloscopic display of line scan signals (barcode illuminated with incident light), SK 2048 DJRI

1. CCD line scan signal with increased illumination in the center and sharp rising signal edges.
2. Zoomed detail from the center of the CCD line scan signal in 1, integration time $\mathbf{t_A}$ = 0.634 ms
3. Extended integration time $\mathbf{t_A}$ = 2.419 ms. The signal edge is displaced slightly to the right. At an overexposure of a factor of 3.8 the sensor starts to bloom.
4. Overexposure caused by an increased integration time results in signal deformations for sensors without anti-blooming technology.
5. Charge by extreme overexposure penetrate the following scan and cause an overload of the black level pixel values. The offset control unit of the camera is disturbed and the CCD line scan camera supplies a reduced signal.

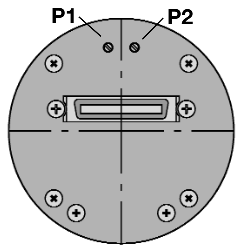
8. Gain / Offset - Settings

The camera is shiped with optimum Gain / Offset calibration. If a recalibration becomes necessary please follow the instructions given below:

1. Shade the line scan sensor and balance the video signal to zero voltage („00“ digital) using the P1 (offset) trimmer.
2. Illuminate the sensor to a slight overexposure to identify the maximum clipping. Use the P2 (gain) trimmer to adjuste the maximum output voltage.

   The maximum output voltage is set to approx. 2.5 volts („FF“ digital) per default.

Camera backside



To adjust the gain-setting of the pixel the camera does not need to be opened. The trimmers are accessible from the outside.

9. References and Warranty

Although this manual has been reviewed carefully for technical accuracy, errors are possible. The reader is kindly asked to contact us, if errors are suspected.

The indicated circuits, descriptions and tables are not warranted to be free from rights of third parties.

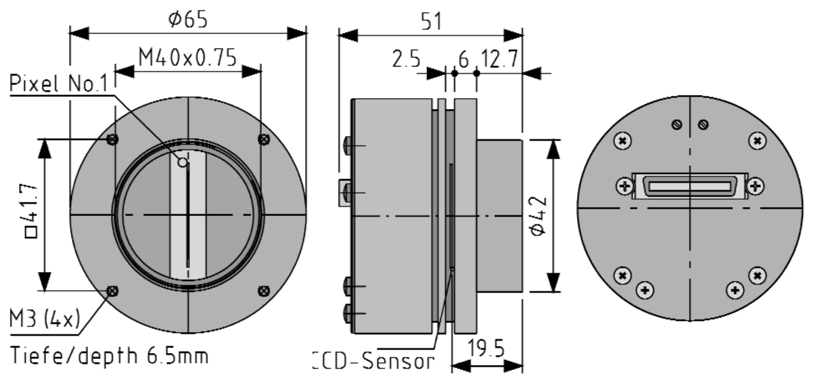
With the statements in the technical descriptions only assembly groups are specified. Characteristics as well as the suitability for a particular purpose is not guaranteed.

The warranty period for the CCD line scan camera is 24 months. The warranty ends with inappropriate actions.

EC-Declaration of Conformity

CE

This product meets the requirement of the EC directive 89/336/E.E.G. The requirements of DIN EN 61326 are fullfilled.

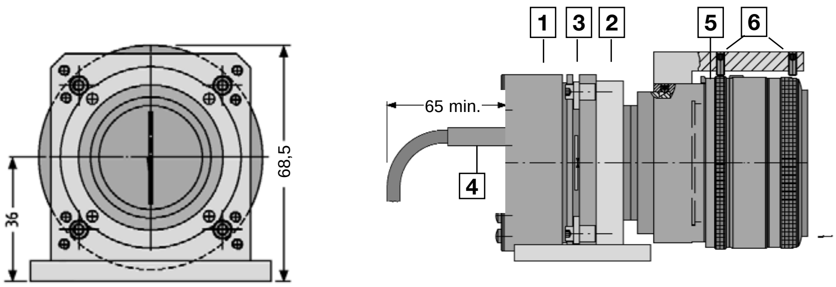


CCD line scan camera digital

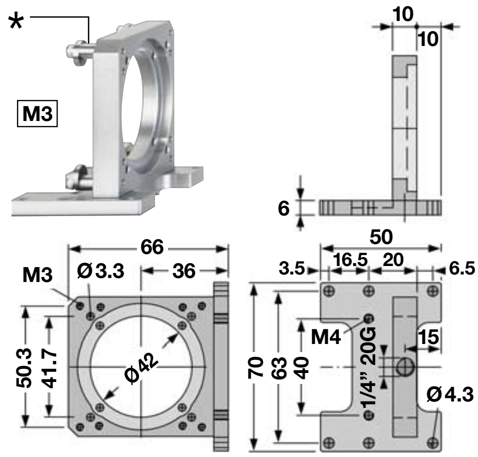
Lens thread: M40 x 0.75
distance to sensor: 19.5 mm
Connector: Centronics miniature 36 pin-male

Type of Cameras:

DJR series from 2048 to 5150 pixels and SK 10680 DJR



1 **CCD line scan cam. digital**
Lens thread M40 x 0.75
mounted on:
2 Camera mount SK 5105
3 Clamp set SK 5102
4 **Cable set** SK 9019.3.FF
5 **Lens**
6 **Blocking bridge**
(aperture and focus)

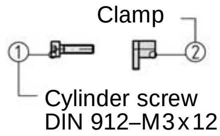


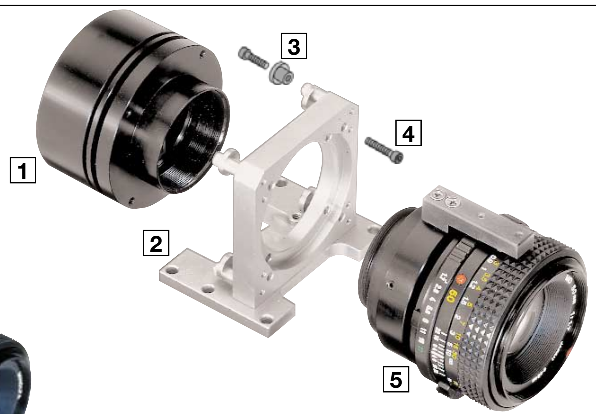
Camera mount SK 5105

for digital and analog cameras
Order Code: SK 5105
Wrap resistant construction for mounting a CCD Line Scan Camera

* Clamp set SK 5102

(4 units)
to lock the CCD Line Scan Camera in arbitrary rotation.





5 **Lens, e. g.:** Photo lens MD by Minolta
Lens thread: M40 x 0.75
1:1.7, f' = 50 mm, sensor length max. 35 mm

1 **CCD line scan cam. digital**
Lens thread M40 x 0.75
mounted on:
2 Camera mount SK 5105
3 Clamp set SK 5102
for locking the CCD Line Scan Camera in arbitrary rotation

optional
4 Locking using 4 units cylinder screws DIN 912 - M3x16

Further video, enlargement and macro lenses: see brochure CCD Line Scan Cameras 2002E p. K9

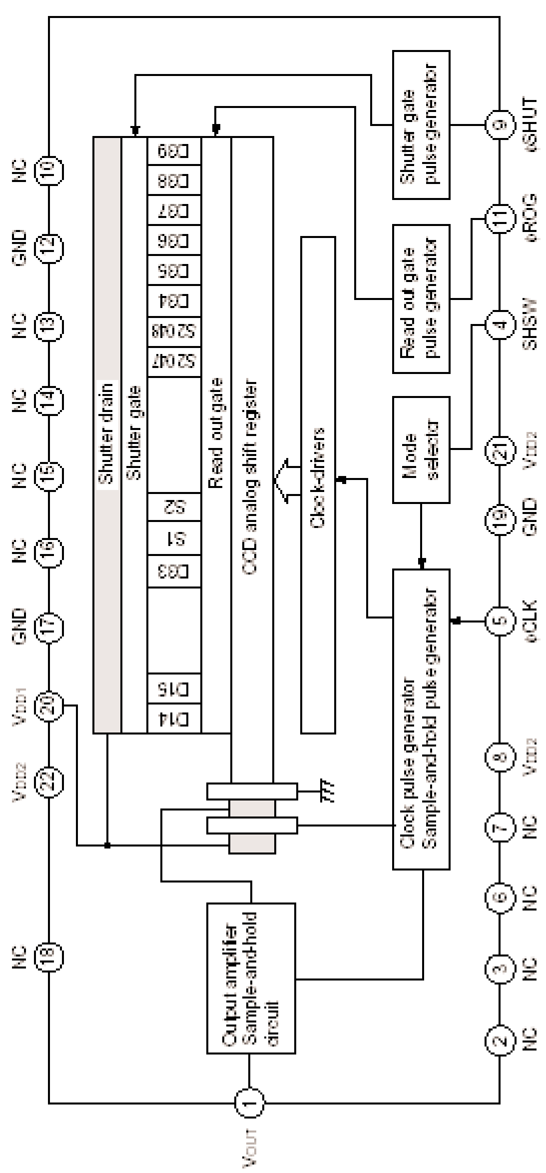
11. Sensor Data

Manufacturer: SONY®

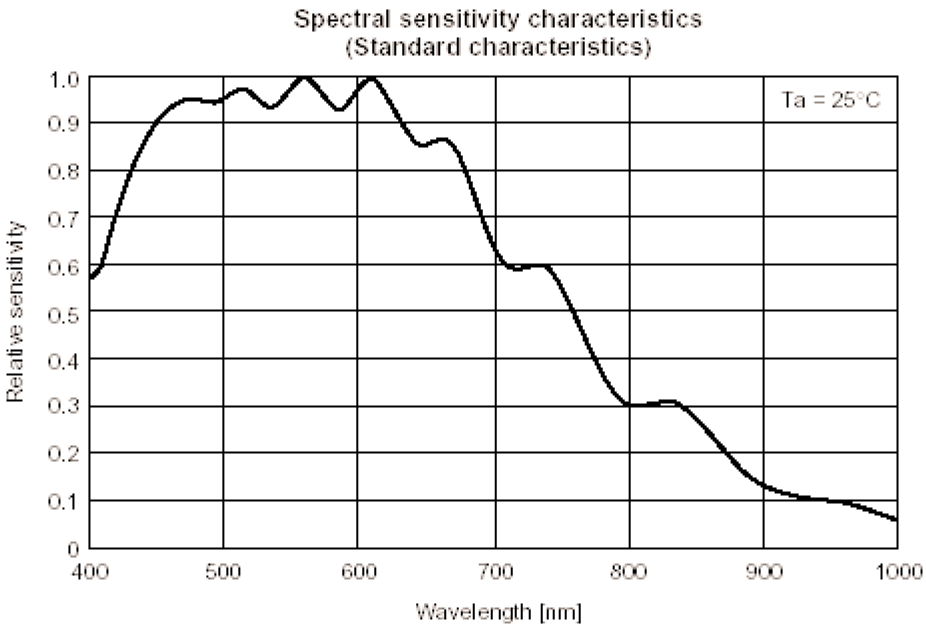
Type: ILX 751

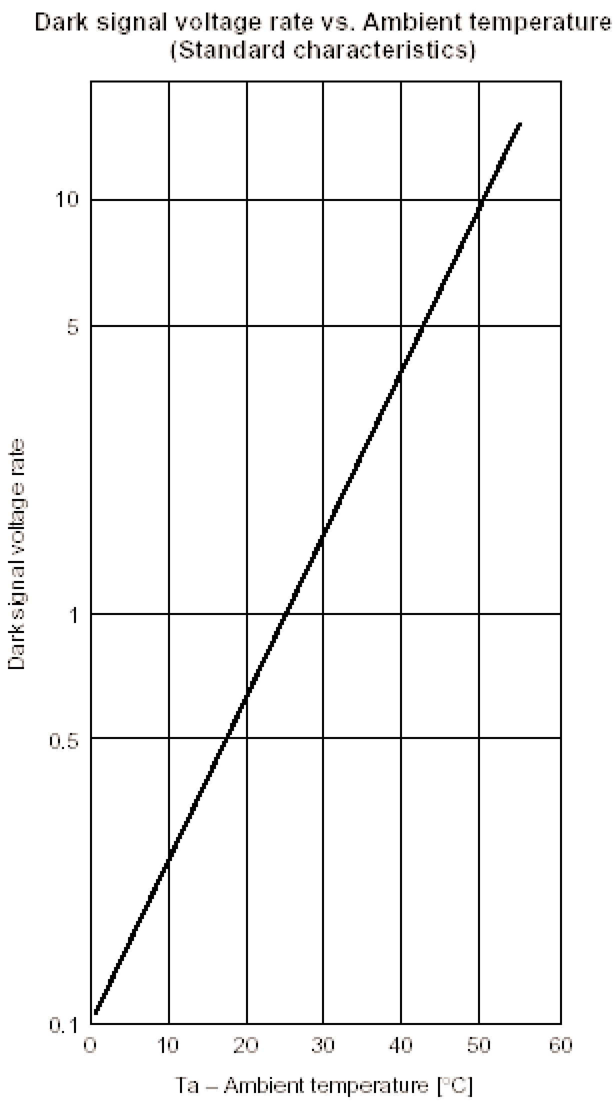
Data Source: SONY® - CCD Linear Sensor - DataSheet

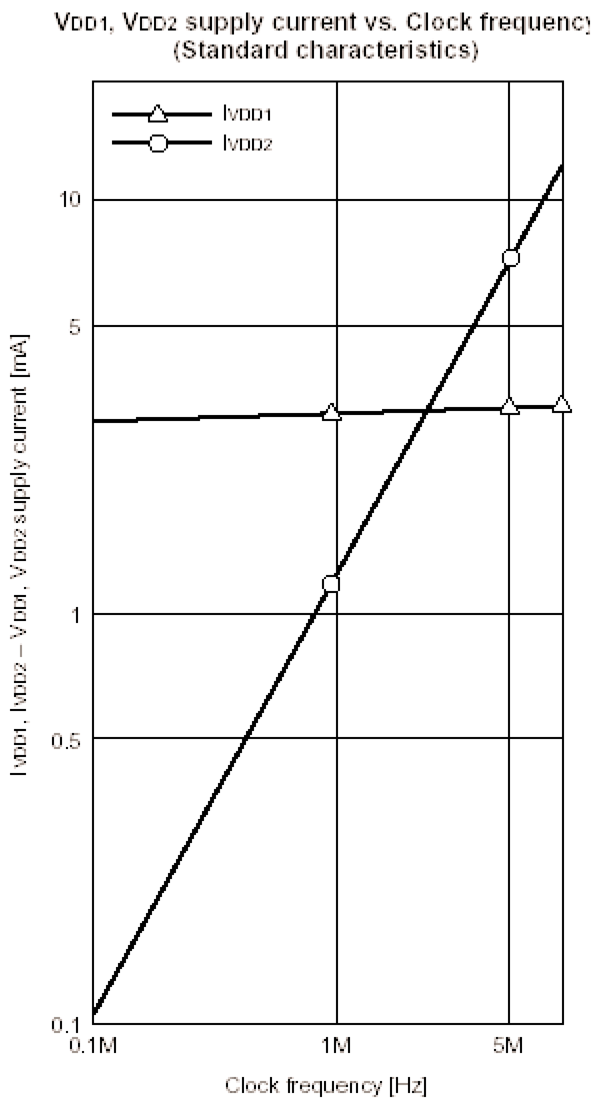
Block Diagram



Example of Representative Characteristics







Electrooptical Characteristics

(Ta = 25°C, V_{DD1} = 9V, V_{DD2} = 5V, Clock frequency = 1MHz, Light source = 3200K, IR cut filter: CM-500S (t = 1.0mm))

Item	Symbol	Min.	Typ.	Max.	Unit	Remarks
Secsitivity	R	30	40	50	V/(lx · s)	Note 1
Sensitivity nonuniformity	PRNU	—	2.0	8.0	%	Note 2
Saturation output voltage	V_{SAT}	1.5	1.8	—	V	—
Dark voltage average	V_{DRK}	—	0.3	2.0	mV	Note 3
Dark signal nonuniformity	DSNU	—	0.5	3.0	mV	Note 3
Image lag	IL	—	0.02	—	%	Note 4
Dynamic range	DR	—	6000	—	—	Note 5
Saturation exposure	SE	—	0.045	—	lx · s	Note 6
9V supply current	I_{VDD1}	—	4.0	8.0	mA	—
5V supply current	I_{VDD2}	—	1.8	5.0	mA	—
Total transfer efficiency	TTE	92.0	97.0	—	%	—
Output impedance	Zo	—	600	—	Ω	—
Offset level	Vos	—	4.0	—	V	Note 7
Shutter lag	SHUT	0	1.0	5.0	%	Note 8

Notes)

1. For the sensitivity test light is applied with a uniform intensity of illumination.
2. PRNU is defined as indicated below. Ray incidence conditions are the same as for Note 1.

$$PRNU = \frac{(V_{MAX} - V_{MIN})/2}{V_{AVE}} \times 100\ [\%]$$

The maximum output is set to V_{MAX}, the minimum output to V_{MIN} and the average output to V_{AVE}.

3. Integration time is 10ms.
4. V_{OUT} = 500mV
5. $DR = \frac{V_{SAT}}{V_{DRK}}$

When optical accumulated time is shorter, the dynamic range gets wider because dark voltage is in proportion to optical accumulated time.

6. $SE = \frac{V_{SAT}}{R}$
7. Vos is defined as indicated below.