CCD Line Scan Camera Digital b/w SK 4096 DPD

4096 Pixels, 10 x 10 µm, 40 MHz Pixel Frequency

Camera Family DPD | 512 | 1024 | 2048 | **4096**

1 **CCD Line Scan Camera SK 4096 DPD** mounting:
2 Camera mount SK5105
3 Clamp set SK5102
4 Photo lens with blocking bridge

Characteristics

- digital camera, 8 bit resolution
- high line frequency up to 9.46 kHz
- anti-blooming
- integration control
- low noise
- high dynamic range
- optical fill factor 100%
- 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:	**SK 4096 DPD**
Order Code	

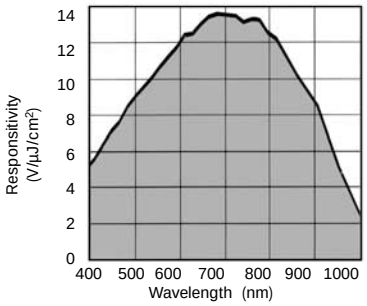
Physical Characteristics

Sensor:	CCD linear
	Type IL-P1-4096
Pixel Number:	4096
Pixel Size:	10 µm x 10 µm
Pixel Distance:	10 µm
Line Width:	10 µm
Active Length:	40.96 mm

Operating Ranges

Pixel Frequency:	maximum 40 MHz
Line Frequency:	maximum 9.46 kHz
	minimum 0.05 kHz
Integration Time:	minimum 10 µs
	maximum 20 ms
Dynamic Range:	1 : 2500 (rms)
Spectral Range:	400 - 1000 nm

Typical Spectral Responsivity



Input Control Signals

Master Clock
StartOfScan (SOS)

Output Signals

Video Signal:	8 Bit digital
Interface:	LVDS

Power Supply

Voltage:	+5 V, +15 V, -15 V
Power Consumption:	3 W

Connector

Mini Centronics 36 pin-male

Opposite connector:
Series Harting Bellows
Typ: 6013 036 5100

Others:

Operating Temp.:	+ 5°C ... + 45 °
Size:	Ø 65mm x 51mm
Weight:	0.2 kg
Lens Thread:	M 40 x 0.75

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1. Technical Specifications of the DPD Series

Type of Camera	**SK 512 DPD**	**SK 1024 DPD**	**SK 2048 DPD**	**SK 4096 DPD**
CCD Sensor	IL-P1-512	IL-P1-1024	IL-P1-2048	IL-P1-4096
Number of pixels	512	1024	2048	4096
Pixel Size	10 µm x 10 µm	10 µm x 10 µm	10 µm x 10 µm	10 µm x 10 µm
Pixel distance	10 µm	10 µm	10 µm	10 µm
Line distance	10 µm	10 µm	10 µm	10 µm
Active length	5.12 mm	10.24 mm	20.48 mm	40.96 mm
PRNU *Photo Response Non Uniformity*	3)	3)	3)	3)
Anti-Blooming	yes	yes	yes	yes
Integration Control	yes	yes	yes	yes
CDS 1)	no	no	no	no
Max. pixel frequency	40 MHz	40 MHz	40 MHz	40 MHz
Min. integration time	10 µs	10 µs	10 µs	10 µs
Max integration time	20 ms 2)	20 ms 2)	20 ms 2)	20 ms 2)
Max. line frequency	69.4 kHz	36.76 kHz	18.94 kHz	9.46 kHz
Min. line frequency	0.05 kHz	0.5 kHz	0.05 kHz	0.05 kHz
Dynamic range Spectral	1 : 2500 (rms)	1 : 2500 (rms)	1 : 2500 (rms)	1 : 2500 (rms)
range	400 - 1000 nm	400 - 1000 nm	400 - 1000 nm	400 - 1000 nm
	100%	100%	100%	100%
Video signal				
Interface	8 Bit digital	8 Bit digital	8 Bit digital	8 Bit digital
	LVDS	LVDS	LVDS	LVDS
Voltage supply				
Power consumption	+5V, +15V, -15V	+5V, +15V, -15V	+5V, +15V, -15V	+5V, +15V, -15V
	3 W	3W	3W	3W
Lens connection				
Housing	C-Mount	C-Mount	M40 x 0,75	M40 x 0,75
Weight	Ø65mm x 50mm	Ø65mm x 50mm	Ø65mm x 50mm	Ø65mm x 50mm
	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 Camera

Attention:
Before the Line Scan Camera is attached to or detached from the power supply, make sure the power supply is switched off.
Otherwise, the Line Scan Camera can be permanently damaged.

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

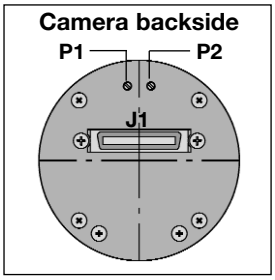
To start operation the required voltages, the Master-Clock- and StartOfScan-Signals using a 36-pin Centronics Miniature Connector have to be applied to the camera.

The camera is shiped aligned and with 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. Connecting and Control Signals



J1 = Mini Centronics 36pin-male, P1 = Gain even, P2 = Gain odd

Voltage Supply

+ 5 V ± 5%	ca. 180 mA	(10 MHz Clock)
	ca. 320 mA	(40 MHz Clock)
-12V bis -15V ± 5%	ca. 30 mA	
+15 V ± 5%	ca. 80 mA	

Pin Assignment

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/-15V)	VEE	5	O O	23	D2	+ out	
(+15V)	VDD	4	O O	22	D1	- out	
(+15V)	VDD	3	O O	21	D1	+ out	
	GND	2	O O	20	DO	- out	
Analog Video A out (Test purpose 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 the CCD camera.

The camera uses only the control signals "Clock" (MCLK) and "Start Of Scan" (SOS) for operation. The camera electronics respond 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 the SOS-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 exactly 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 do not need 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 4096 DPD camera needs 4096 + 128 ‘Clock’ signals to read out a line scan completely. In general, transferring a larger amount of ‘Clock’ pulses as needed is unproblematic.

MCLK: Master-Clock in: determines the pixel transport frequency, maximum 40 MHz. Low voltage differential input.

SOS: Start of Scan: 30 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 SK4096 DPD need 73 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:

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.

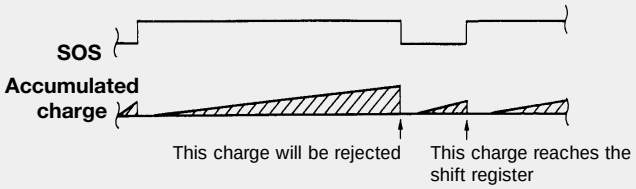
The Integration Control function allows the extention of the 'High'-level condition in the SOS signal about a specified number of pixel clock pulses. The start of the accumulation of charge during an exposure cycle is thus delayed.

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 4096 DPD, SK 9192D
40 MHz pixel frequency
t_B = (4096 + 128) / 40 MHz
t_B = 105.6 µs
f_L = 40 MHz / (4096 + 128)
f_L = 9,47 kHz

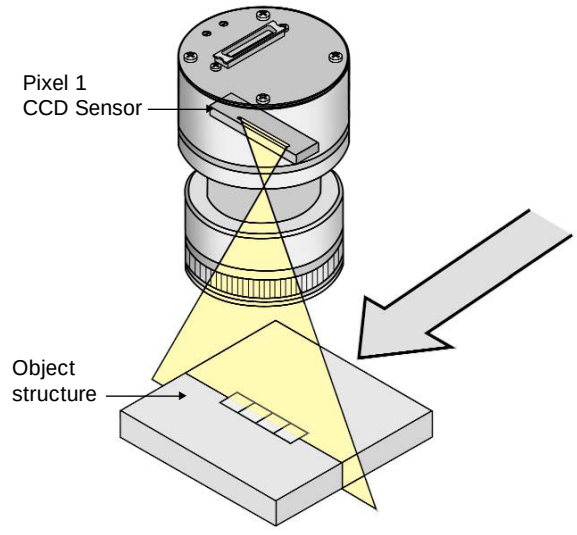
IntegrationCtrl: SOSL= 256;
t_A = ((4096+128) - 256) / 40 MHz
t_A = 99.2 µs
t_B = 105.6 µs,
f_L = 9,47 kHz

5. Generating an Image – Scan a Surface

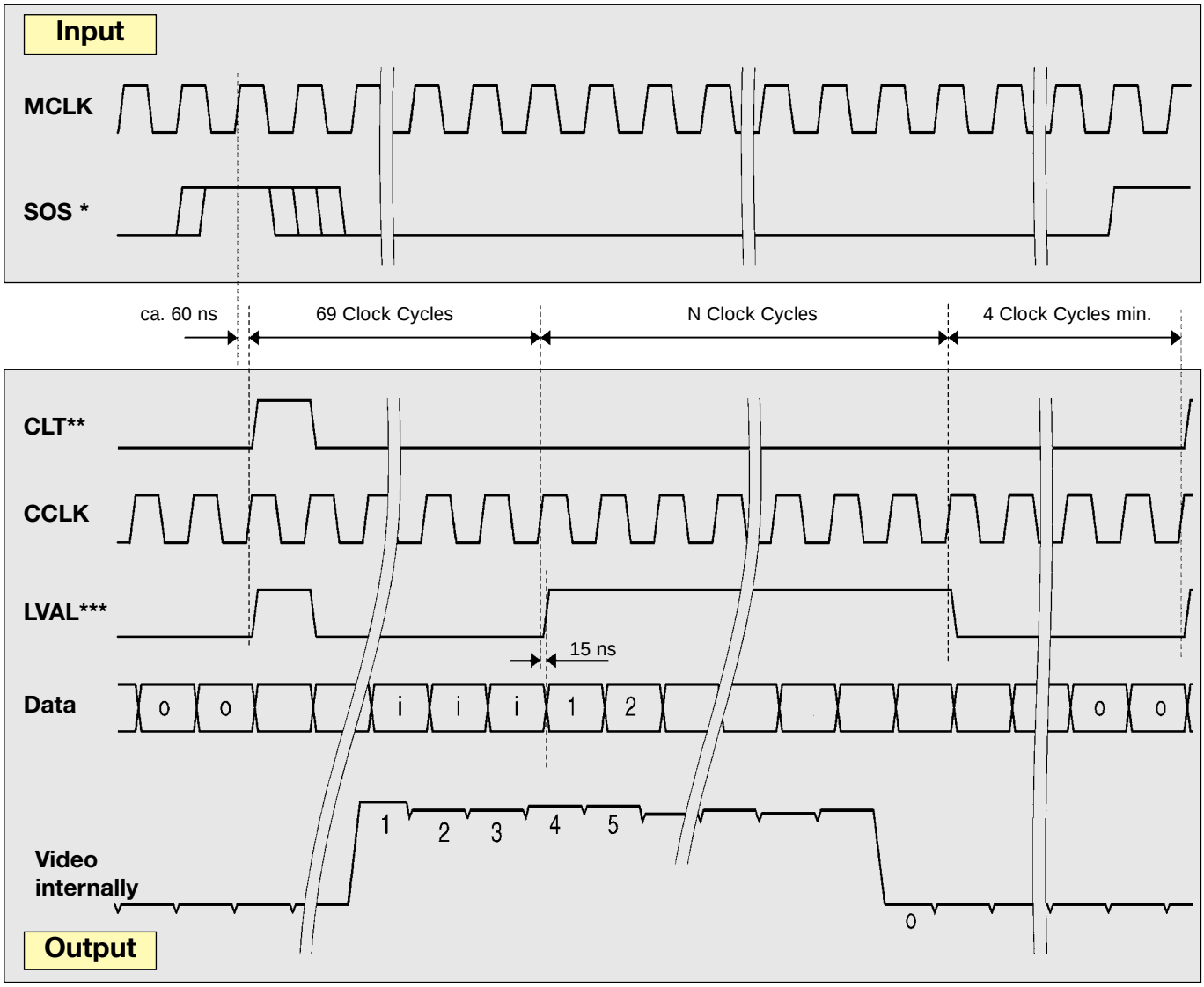
A two-dimensional image is generated by moving the object or the camera. The direction of the movement needs to be orthogonal to the sensor axis of the CCD line scan camera.
To optain a propotional image with correct aspect ratios a line synchronous transport and a laterally correct pixel assignment 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 3 to 25 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 4096 DPD-3

The pixels determining the black level value are the 4th to the 7th before pixel no. 1.

N = Sensor pixels

i = Isolation pixels

o = Overclocking

7. Anti Blooming

Blooming

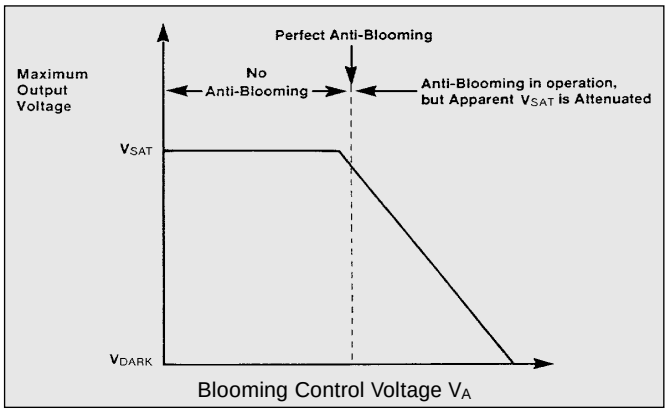
Extended illumination of saturated pixels, which are not able to accumulate further charge due to long exposure, leads to charge overflow into adjacent pixels. This effect is called blooming. Blooming causes a corruption of the geometrical allocation of image and object in the line signal.

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 50 can thus be handled.

The CCD line scan cameras of the DPD series have an anti-bloooming sensor and are thus protected against overexposure. However, the blooming drain gate capacity is limited. In principle:

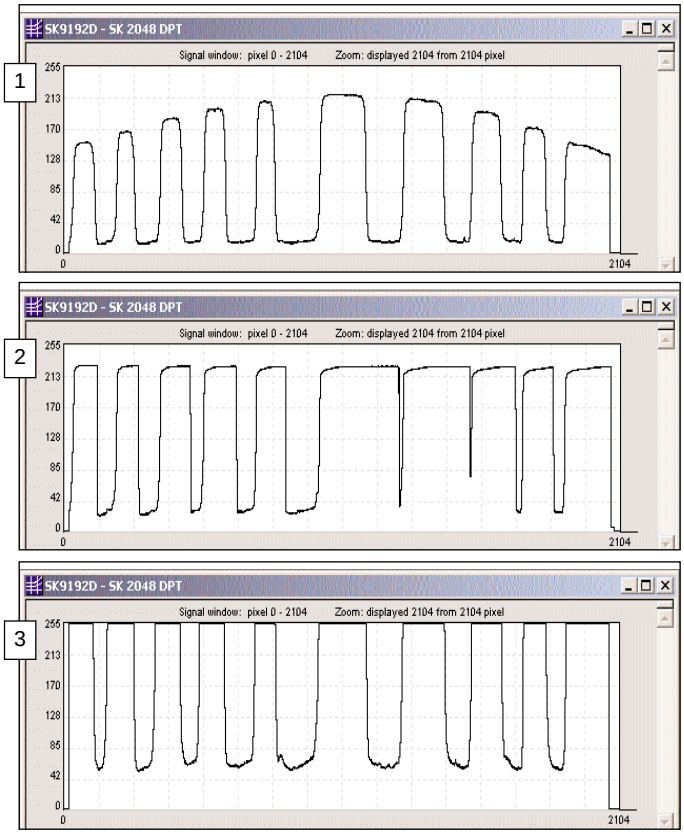
The smaler the number of overexposured pixels the better is the anti-blooming effect of the drain gate. For single pixels a charge overflow up to a factor of 50 beyond the saturation charge can be drained. With a higer number of overexposed pixels the ‘drainable’ charge overflow decreases.

The electronics of the DPD camera series support the blooming control features of the sensor. The saturation charge is adjustable with the blooming control voltage V_A. The higher the Voltage V_A , the sooner the anti blooming effect is enforced. On one hand a higher voltage V_A increases the suppression of over exposure, on the other hand it reduces the output voltage of the video signal and concurrently the dynamic range of the camera. If the setting of V_A is too small, the anti blooming effect is switched off. The maximum output voltage of the sensor reaches the saturation voltage V_{SAT}.



The default setting (delivery condition) of the blooming control voltage V_A allows the output voltage of the camera to reach 90% of the saturation voltage V_{SAT} . With this setting an optimum anti blooming effect is ensured. **The voltage V_A should be changed only in exceptional cases.**

The blooming control voltage V_A is altered using the trimmer P3. The voltage V_A is increased by turning the trimmer to the left. Turning it to the right the voltage V_A is decreased. Turning the trimmer all the way to the right bedstop the anti blooming is switched off.

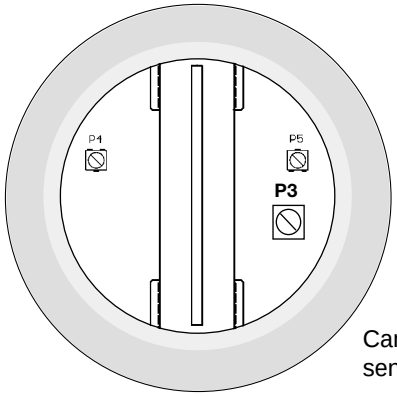


Oszilloscopic signal display of CCD-line scan signals (barcode in reflected light), SK 2048 DPT

1 CCD-line scan signal with central enhanced illumination and sharp signal edges. Integration time t_A= 0,634 ms

2 Overexposure due to longer integration time (t_A= 1,21 ms). The blooming effect is activated by altering the blooming control voltage (small V_A). The signal structure is distorted.

3 The blooming control voltage limits the output signal of the sensor to approx. 90% of the saturation voltage V_{SAT}. The anti blooming capacity is active. Also, with even longer integration times (t_A= 1,555 ms) the positions of the edges from picture 1 are maintained.



Camera board, sensor (front) side

The trimmer P3 is accessible from the front side of the camera, once the camera lens is detached.

To avoid misalignment of the line scan camera the effect of the P3-adjustment should be controlled by viewing the oscilloscopic display of the line scan signal on a PC-monitor. Ensure sufficient illumination.

8. Gain / Offset - Settings

The CCD line scan camera SK4096DPD containes two shift registers. The video signal is split into two chanels, one provides the eaven, the other on the odd pixel numbers. With this camera the setting of the gain is thus always a matter of multiple steps:

1. Employing the aperture wide open and apply sufficient illumination, adjust the odd pixel numbers using the trimmer P1 to the maximum output voltage reasonable.

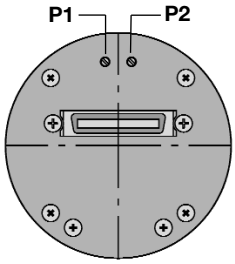
2. Use trimmer P2 to adjust the eaven pixel numbers to the intensity of the odd pixels as good as possible.

By changing the pixel frequency significantly it can become necessary to repeat this balancing procedure

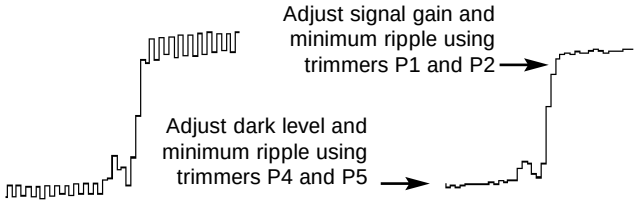
The default setting of the maximum output voltage signal is set at 40 MHz pixel frequency to approx. 2.5 V ('FF' Digital).

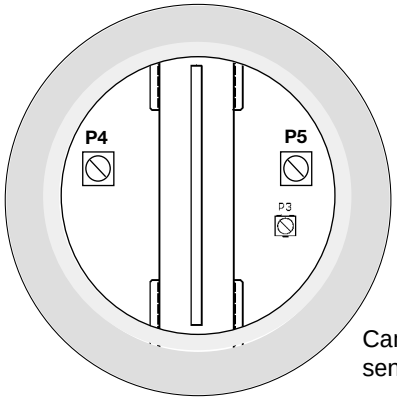
If necessary, the even and the odd dark level signals can be adjusted aswell. Shade off all light incident on the line scan camera and adjust the levels of the pixels using the trimmers P4 and P5 situated on the frontside of the board to 0 Volts.

Camera backside



To adjust the gain-setting of the even and odd pixel numbers the camera does not need to be opened. The trimmers for balancing are accessible from the camera backside.





Camera board,
sensor side

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.

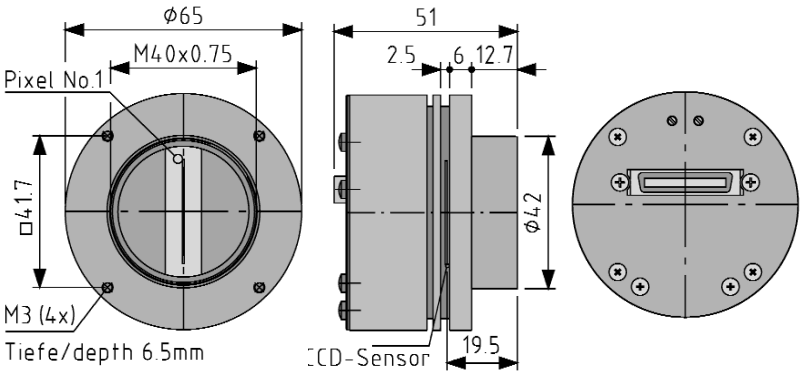
The warranty period for the CCD line scan camera is 24 months. The warranty ends with inappropriate actions.

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.

10. Dimension Diagrams

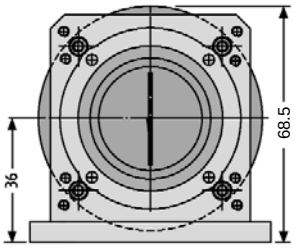


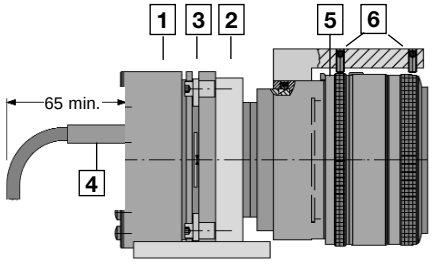
CCD line scan camera digital

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

Type of Cameras:

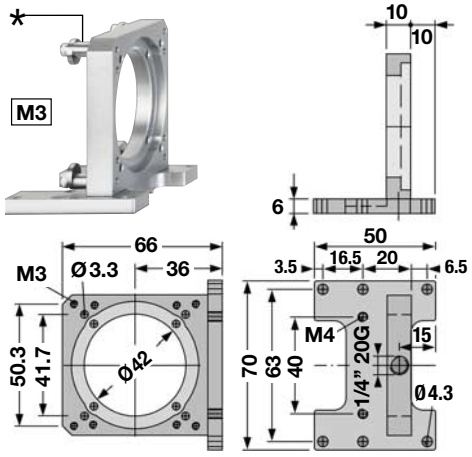
SK 2048 DPD
SK 4096 DPD





1 CCD line scan camera 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)

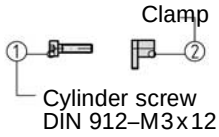


Camera mount SK 5105

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. 41 mm

1 CCD line scan camera 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 the clamp set using 4 pcs. cylinder screws DIN 912 - M3x16

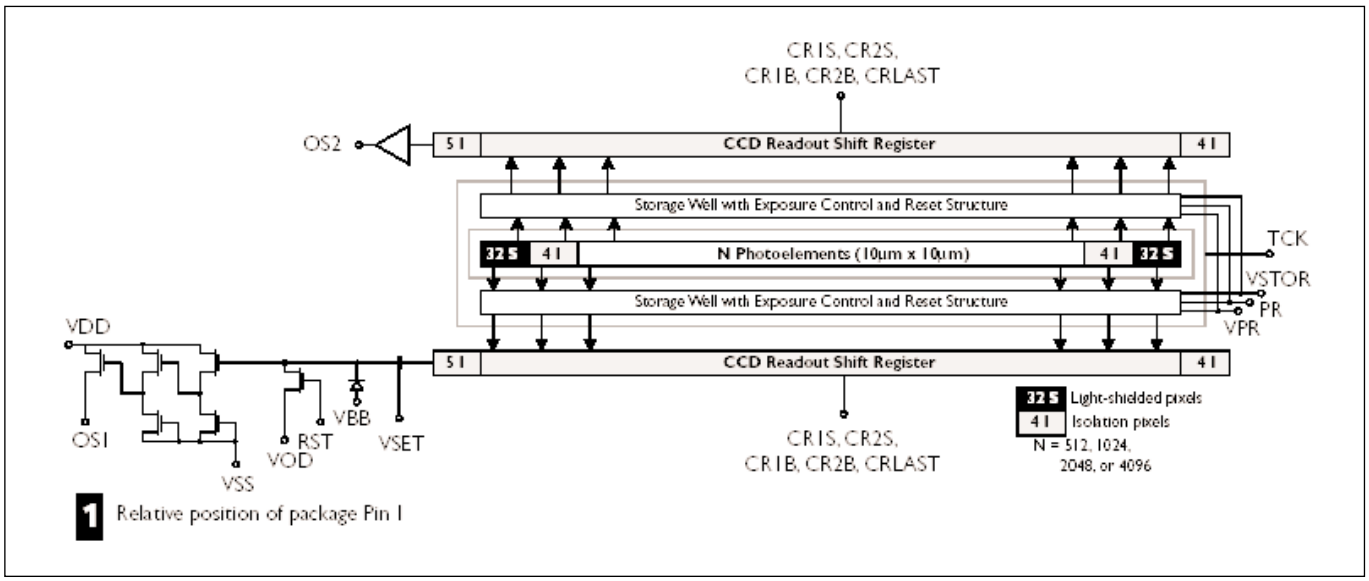
Further video, enlargement and macro lenses: see brochure CCD Line Scan Cameras 2002E p. K9

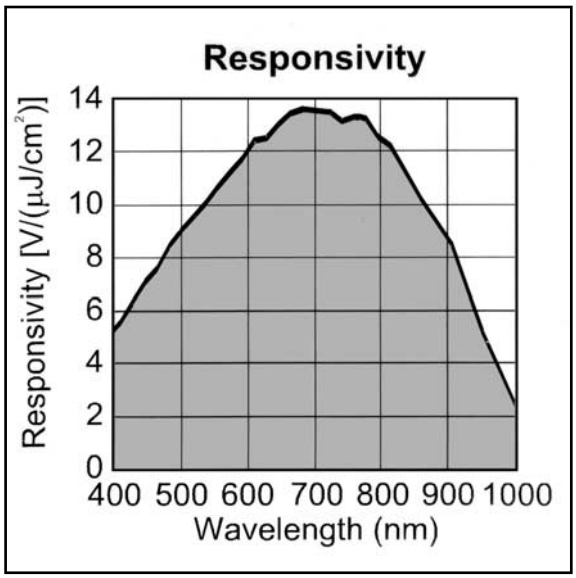
11. Sensor Data

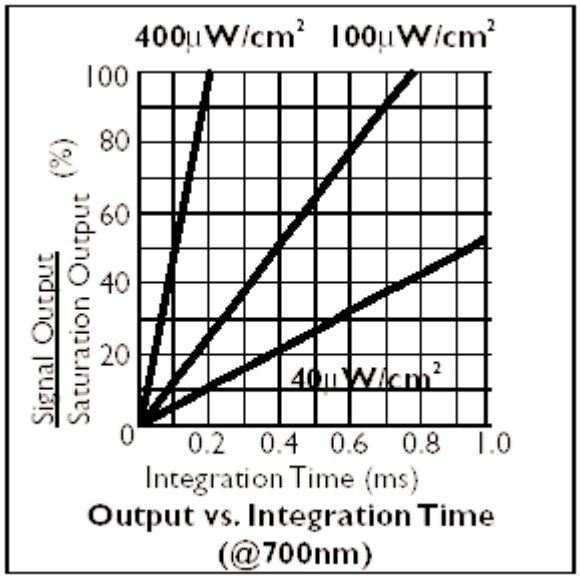
Produced by: DALSA®

Types: IL-P1-4096 E

Data source: DALSA® Line Scan Sensors ,DALSA IL-P1 - Data Sheet







12. Performance specifications

Specification		Unit	Min.	Typ.	Max.
Saturation Output Voltage (VSAT)		mV	700	900	1100
rms Noise		mV		0.28	0.31
Wavelength of Peak Responsivity		nm		700	
Peak Responsivity		V/(μJ/cm^2)	12.6	13.8	15.5
Dynamic Range			2250:1	3200:1	3900:1
Charge Conversion Efficiency (CCE)		μV/e	5.4	5.7	6.1
Noise Equivalent Exposure (NEE)		pJ/cm^2	18	20	25
Saturation Equivalent Exposure (SEE)		nJ/cm^2	45	65	
Full Well Capacity		ke	115	158	
Fixed Pattern Noise (FPN) [1,2]	PR exposure control disabled	mV		0.5	1.0
	PR exposure control enabled	mV		2.0	5.0
Photoresponse Non-Uniformity (PRNU) [3,4]		% OS			
PR exposure control disabled	8 pixel local neighborhood			2.2	6.0
	Global			3.5	8.5
PR exposure control enabled	8 pixel local neighborhood			2.5	6.5
	Global			3.8	8.8
Charge Transfer Efficiency (CTE) (readout register)			0.99999	0.999999	
First Field Lag [5]		mV		11.5	
Dark Signal, Integration time = 84μs		mV		0.15	0.5

Notes:

1. Maximum peak-to-peak variation of all outputs.
2. Due to its general purpose design, DALSA's camera and sensor evaluation hardware provides an output that cannot be used to directly measure low FPN.
3. The peak-to-peak variation is measured at ~50% SEE.
4. With output gain mismatch correction.
5. Lag is measured at VSAT with f_{LINE} = 10kHz.

Test Conditions:

- Operating temperature = 35°C.
- f_{RST} = data rate per output = 25MHz.
- I_{LOAD} = 8mA.
- C_{LOAD} = 10pF
- Tungsten halogen light source, black body color temperature 3200K, filtered with 750nm IR cutoff filter.
- See Sensor Measurement Definitions (doc# 03-36-00149) for specification definitions.