

CCD Line Scan Camera digital b/w SK 2048 DPD

2048 Pixels, 10 x 10 µm, 40 MHz Pixel Frequency

Camera Family DPD 512 1024 2048 4096

- 1 CCD line scan camera SK 2048 DPD mounted on
- 2 Camera mount SK5105
- 3 Clamp set SK5102
- 4 Photo lens



Charakteristics

- digital camera 8 Bit
- high dynamics
- high line frequency up to 18.9 kHz
- anti blooming
- integration control
- very low noise
- light sensitive
- round housing Ø 65 mm

Accessoires (optional)



Camera mount SK 5105 (Order Code)
Wrap resistant construction for the mounting of the CCD line scan camera. Optional: Clamp set SK 5102 (Order code) to lock the CCD line scan camera in arbitrary rotation.



Mounting console SK 5105-2
for adaptation of macro lens, extension ring ZR..., focus adapter FA22-C and the CCD- line scan camera

Lenses



- high resolution **Enlarging lenses and macro lenses**
- high speed **photo lenses**
- lenses with additional **blocking bridge** for locking of focus and aperture setting.

Adapter



- Lens adapter AOC-...**
for adapting photo lenses onto the CCD line scan camera
- Focus adapter FA22-...**
für adapting Enlarging lenses and macro lenses.



Connecting cable SK9019 for Digital CCD Line Scan Cameras of Camera Series XSD, DPD, DPT, DJR, DJRC etc.

36-pin shielded cable for camera and video signals. Standard: 3m cable length, one- or double-sided with Centronics connectors (female, 36-pin).

SK9019.3 FF Order Code

- FF = Connector double-sided (female)
- F = Connector one-sided (female)
- 3 = 3 m (standard cable length)
- 5 = 5 m cable length
- x = Cable length custom made



PC-Interface SK 9192 D Order Code
Interface für digitale CCD-Zeilenkameras
PCI-Bus, preprocessing on-board:
shading correction, windowing, thresholding
external synchronisation (LineSync, FrameSync)

Software



SK91PCI-WIN *
SK91PCI-LX **
System Software,
Drivers, DLLs,
* Windows, ** Linux

Performance Specifications

Camera Type: SK 2048 DPD

Order Code

Physical Characteristics

Sensor: CCD linear
Type IL-P1-2048

Pixel Number: 2048

Pixel Size: 10 µm x 10 µm

Pixel Distance: 10 µm

Line Width: 10 µm

Active Length: 20.48 mm

Operating Ranges

Pixel Frequency: maximum 40 MHz

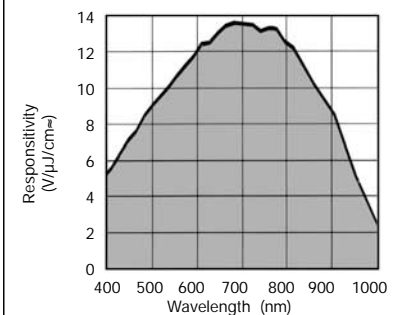
Line Frequency: maximum 18.9 kHz

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

Content

Content	Page	Page
Characteristics, Performance, optional Accessories	1	5
1. Technical Specifications of the DPD Camera Series	2	6
2. Handling Details of the Line Scan Camera	2	7
3. Connecting and Control Signals	3	7
Pin-out and Voltage supply	3	8
4. Exposure and Integration Control	4	9
5. Generating an Image – Scan a Surface	4	10
6. Timing Diagram		5
7. Anti Blooming		6
8. Gain / Offset Settings		7
9. References, Warranty and EC-Declaration of Conformity		7
10. Dimension Diagrams		8
11. Sensor Data		9
12. Performance specifications		10

SK_2048_DPD_E

1. Technical Specifications of the DPD Camera Series

Camera Model	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
Sensor width	10 µm	10 µm	10 µm	10 µm
Pixel distance	10 µm	10 µm	10 µm	10 µm
Active length	5.12 mm	10.24 mm	20.48 mm	40.96 mm
PRNU <i>Photo Response Non Uniformity</i>	3)	3)	3)	3)
Anti-Blooming	yes	yes	yes	yes
Integration Control	yes	yes	yes	yes
CDS ¹⁾	no	no	no	no
Pixel frequency max	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	0.05 kHz	0.05 kHz	0.05 kHz
Dynamic range	1 : 2500 (rms)	1 : 2500 (rms)	1 : 2500 (rms)	1 : 2500 (rms)
Spectral range	400 - 1000 nm	400 - 1000 nm	400 - 1000 nm	400 - 1000 nm
optical filling factor	100%	100%	100%	100%
Video signal	8 Bit digital	8 Bit digital	8 Bit digital	8 Bit digital
Interface	LVDS	LVDS	LVDS	LVDS
Voltage supply	+5V, +15V, -15V	+5V, +15V, -15V	+5V, +15V, -15V	+5V, +15V, -15V
Power consumption	3 W	3W	3W	3W
Lens connection	C-Mount	C-Mount	M40 x 0,75	M40 x 0,75
Housing (W x H x D)	Ø65mm x 50mm	Ø65mm x 50mm	Ø65mm x 50mm	Ø65mm x 50mm
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 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, 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 camera has to be connected to the necessary voltages, the MasterClock- and StartOf-Scan-Signals using a 36-pin Centronics Miniature Connector.

The camera is shipped 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.

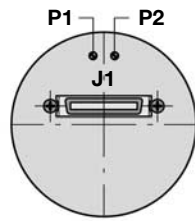
Recommendation:

Using the **SK9192D** PC-Interface and the **SkLineScan®** software by **Schäfter+Kirchhoff** the camera is ready for operation immediately. The oscilloscopic 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 = Gain even, P2 = Gain odd

Voltage Supply

+ 5 V \pm 5% ca. 170 mA (10 MHz Clock)

ca. 280 mA (40 MHz Clock)

- 12 V to -15 V \pm 5% ca. 30 mA

+15 V \pm 5% ca. 80 mA

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 transferred 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 synchronized. 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 DPD-Camera needs 2048 + 64 'Clock' signals to read out a line scan completely. Generally, transferring a larger number 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

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/-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	D0 - out	
Analog Video A out (Test purpose only)		1	O O	19	D0 + out	

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 SK 2048 DPD needs min. 2048+64 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:

$$f_L = 1 / t_B$$

<p>Example: SK 2048 DPD, SK 9192D 40 MHz pixel frequency $t_B = (2048 + 64) / 40 \text{ MHz}$ $t_B = 52.8 \mu\text{s}$ $f_L = 40 \text{ MHz} / (2048 + 64)$ $f_L = 18.94 \text{ kHz}$</p>	<p>Integration Ctrl: SOSL= 256; $t_A = ((2048+64) - 256) / 40 \text{ MHz}$ $t_A = 46.4 \mu\text{s}$ $t_B = 52.8 \mu\text{s},$ $f_L = 18.94 \text{ kHz}$</p>
---	--

- **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:

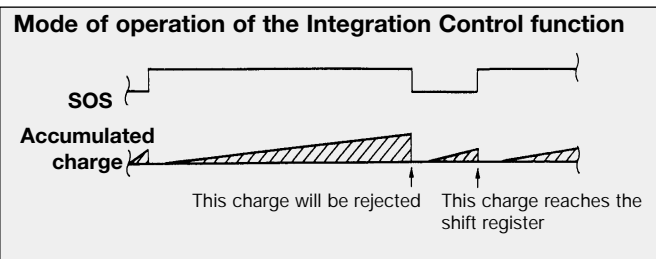
In the default setting of the camera the SOS signal between two exposure cycles shows 'High' only at very few pixel clock pulses. The Integration time and the exposure time are virtually of the same length.

The Integration Control function allows the extension 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.

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



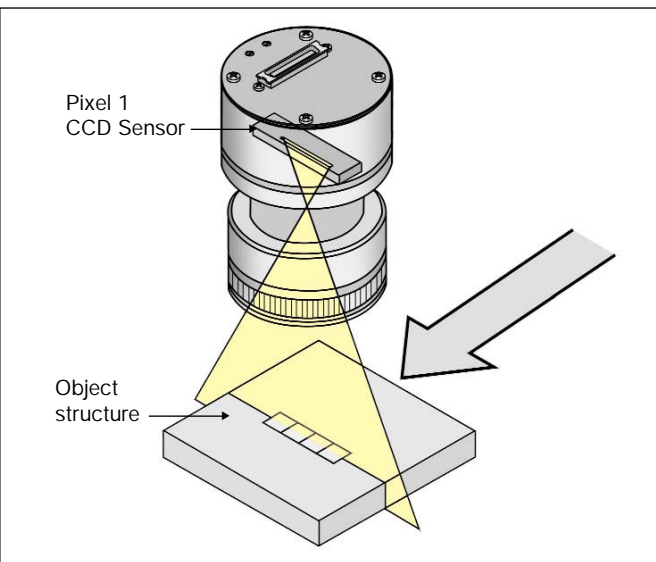
5. Generating an Image – Scan a Surface

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.

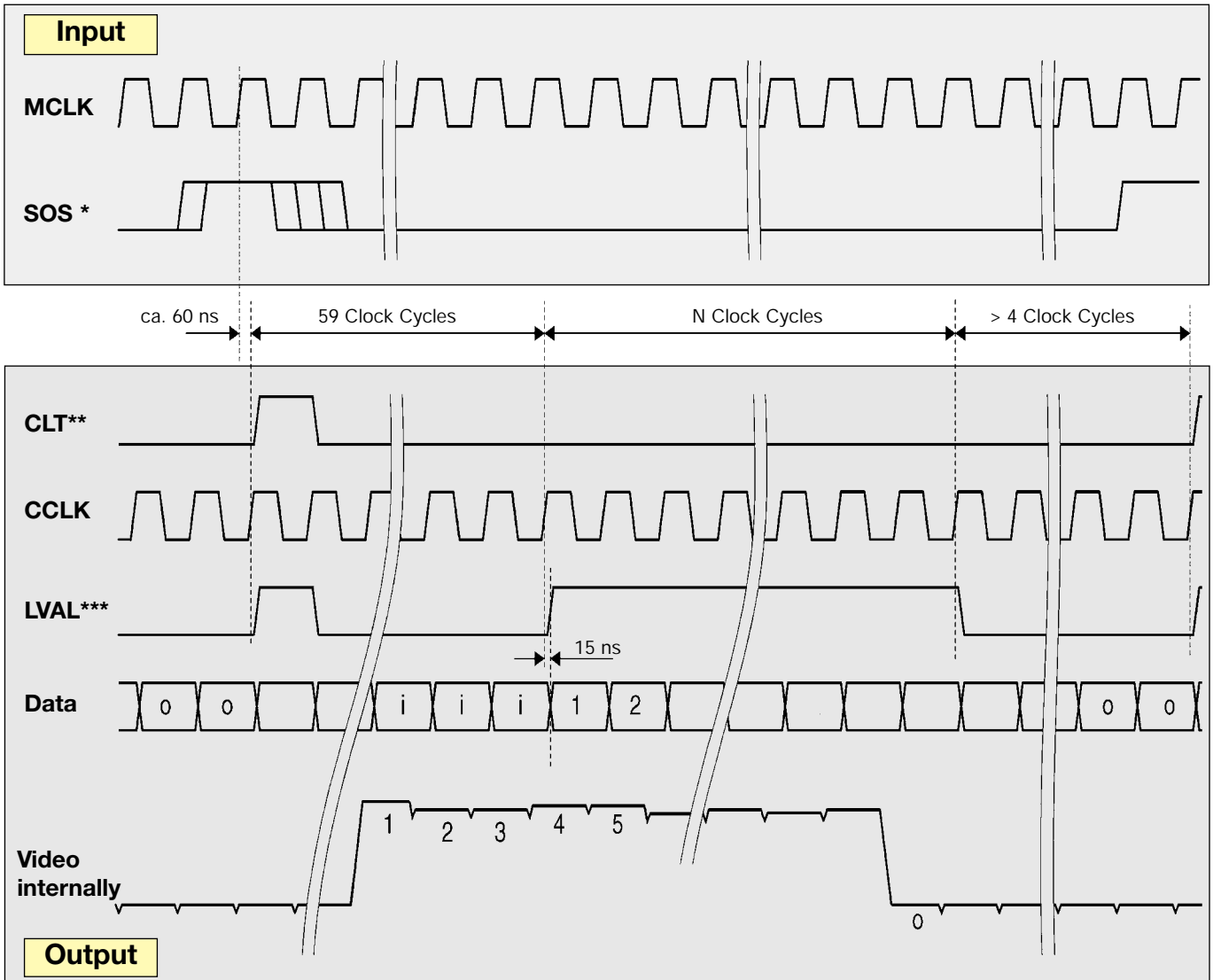
To obtain a proportional image with correct aspect ratios a line synchronous transport and a laterally correct pixel assignment is required.

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

- 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 2048 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

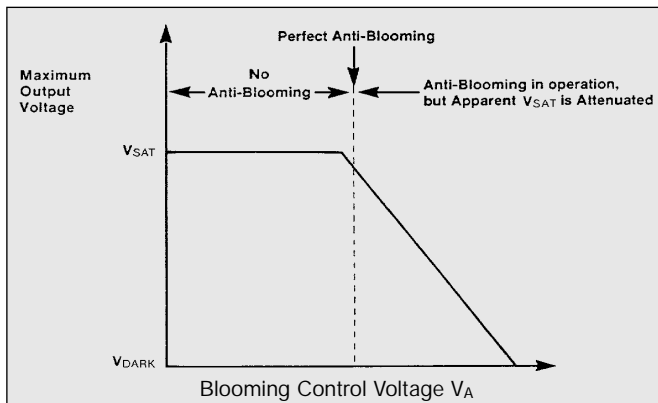
Extended illumination of saturated pixels, which are not able to accumulate further charge due to long exposure, leads to charge overflow into adjacent pixels. This effect is called **blooming**. Blooming causes a corruption of the geometrical allocation of image and object in the line signal.

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 do contain anti-blooming sensors, i.e. they are prevented from overexposure due to a special design. The Blooming Drain Gate has a limited capacity, though.

The less pixels are overexposed, the better is the anti blooming effect of the drain gate. For single pixels a charge excess of up to a factor of 50 above saturation can be drained. With increasing quantities of oversaturated pixels the charge drainage decreases.

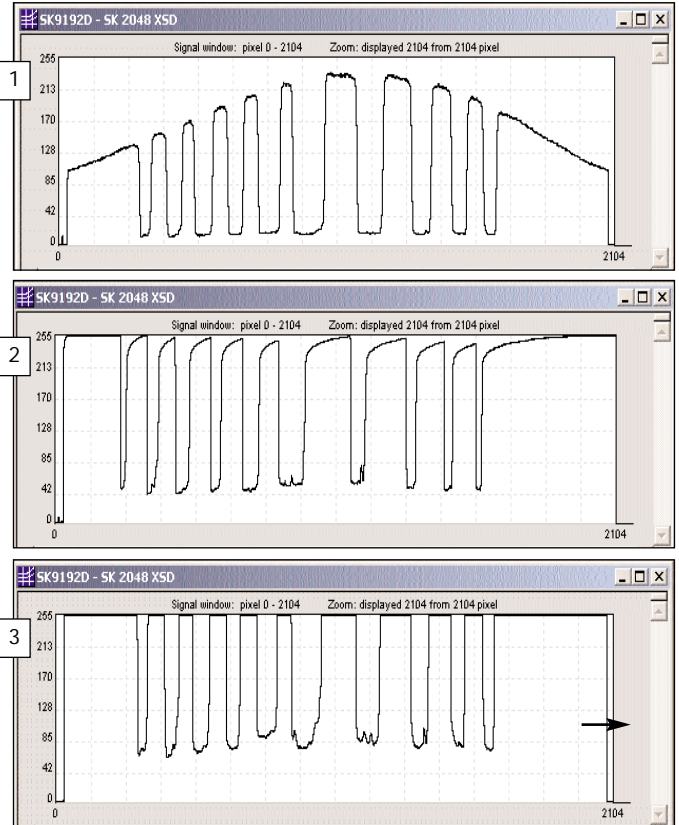
The electronics of the DPD camera series support the blooming control possibilities of the sensor. The saturation load is regulated by the blooming control voltage V_A . The higher the voltage V_A the lower the level of anti blooming effect initiation. A high voltage V_A increases the saturation protection, but it limits the output voltage of the video signal and reduces the dynamic range of the camera. Tuning the voltage V_A to a level too small, the anti blooming effect is switched off completely. The maximum output voltage of the sensor reaches the saturation level V_{SAT} .



The blooming control voltage V_A is by default prepared to a level where the output voltage of the camera reaches approx. 90% of the saturation voltage V_{SAT} at maximum. Thus, an optimum anti blooming effect is ensured. **The voltage V_A should only be altered in exceptional cases.**

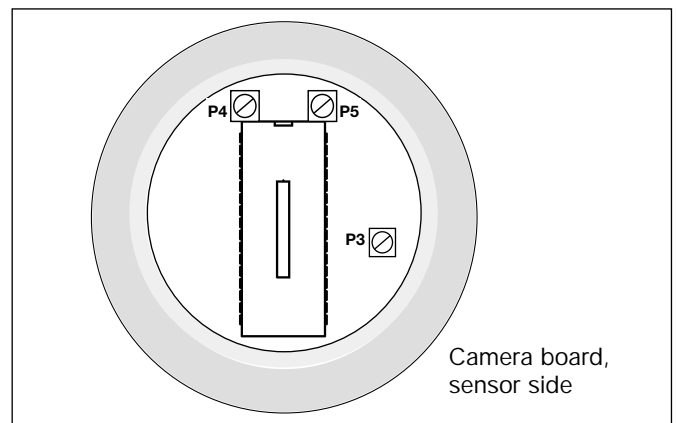
The anti blooming control voltage V_A is adjusted with the trimmer P3. Turning the trimmer P3 to the left, the voltage V_A rises. Turning it to the right the voltage V_A decreases. Turning it to the right bedstop, the anti blooming is switched off.

The trimmer P3 is accessed from the front of the



Oscilloscopic signal display of the CCD line scan signal (barcode with incident light), SK 2048 XSD

- 1 Line scan signal with central enhanced illumination and sharp rising signal edges. Integration time $t_A = 0,158$ ms
- 2 Over exposure due to longer integration time ($t_A = 0,533$ ms). The blooming effect is raised in the sensor by misadjusting the blooming control voltage (low V_A). The structures of the signal are 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 technique is active. Also, with even longer integration time ($t_A = 0,806$ ms) the signal edge positions from Fig. 1 are preserved.



camera with the lens taken off.

To prevent misadjustment of the line scan camera, the effect of the P3 adjustment should be performed and tracked with sufficient illumination observing an oscilloscopic display of the line scan signal on the PC monitor.

8. Gain / Offset - Settings

The line sensor of the DPD camera provides two shift registers. The video signal is split into two channels, one operates the even, the other on the odd pixel numbers. With this camera the setting of the gain is thus always a matter of multiple steps:

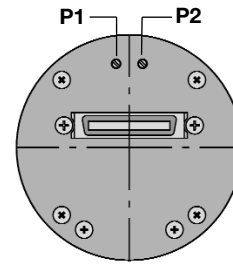
1. Employing the aperture wide open and apply sufficient illumination, adjust the odd pixel numbers using the trimmer P1 to the maximum output voltage reasonable.
2. Use trimmer P2 to adjust the even pixel numbers to the intensity of the odd pixels as good as possible.

Changing the pixel frequency significantly can require a repetition of this balancing procedure.

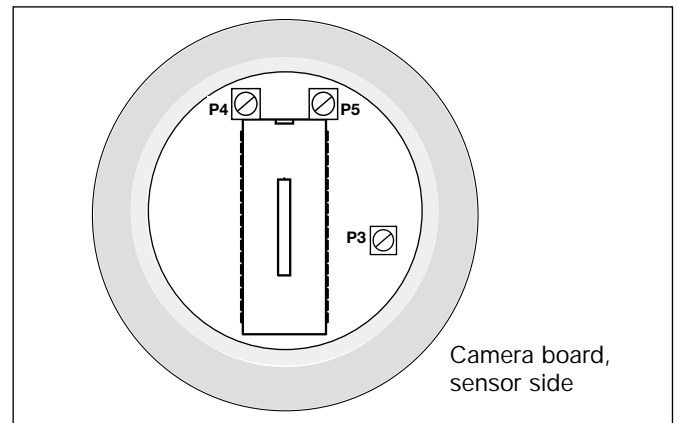
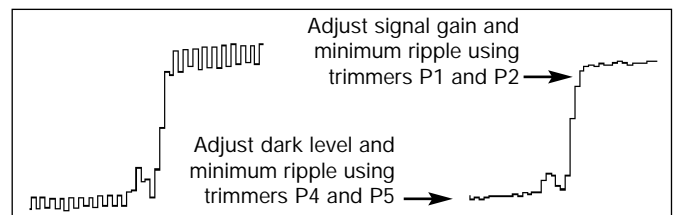
The maximum output voltage is set at 40 MHz pixel frequency to approx. 2.5 Volts ('FF' Digital) per default.

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 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



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

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.

Clamp

Cylinder screw
 DIN 912-M3x12

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

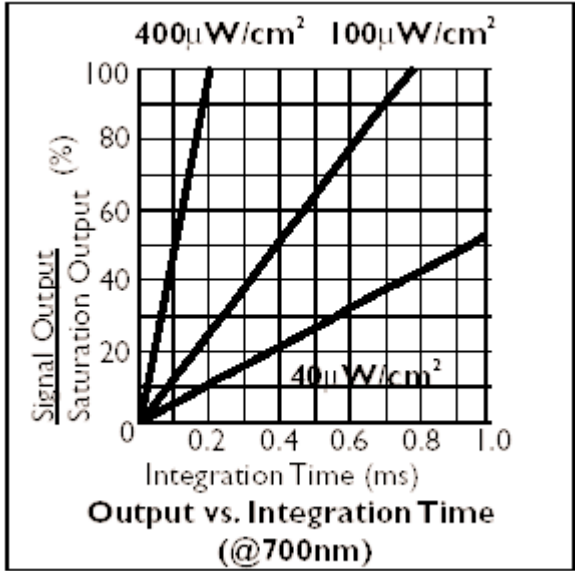
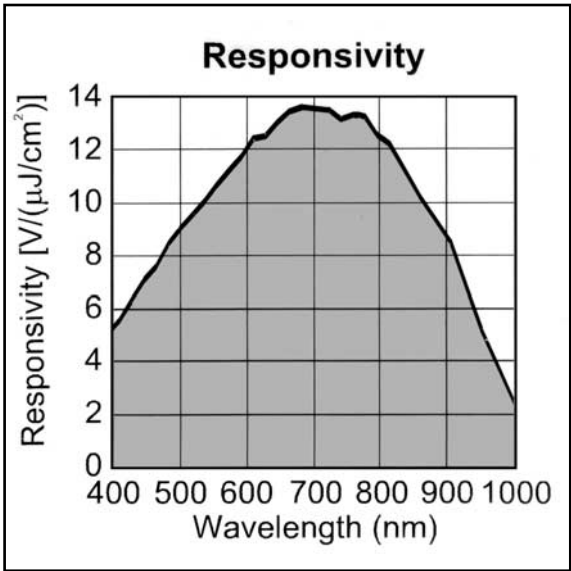
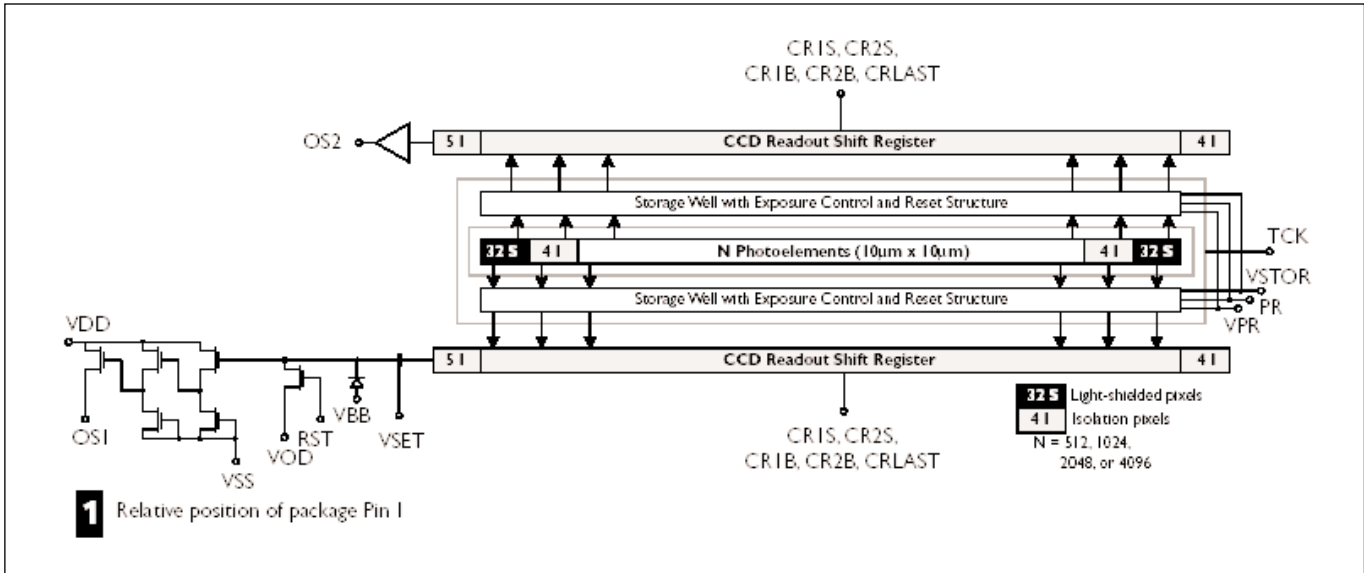
4 Locking the clamp set
 using 4 pcs. cylinder screws
 DIN 912 - M3x16

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

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

11. Sensor Data

Produced by: DALSA®
 Type: IL-P1-512, IL-P1-1024, IL-P1-2048
 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/($\mu\text{J}/\text{cm}^2$)	11.0	12.0	13.5
Dynamic Range		2250:1	3200:1	3900:1
Charge Conversion Efficiency (CCE)	$\mu\text{V}/\text{e}^-$	4.7	5.0	5.3
Noise Equivalent Exposure (NEE)	pJ/cm^2	21	23	28
Saturation Equivalent Exposure (SEE)	nJ/cm^2	52	75	
Full Well Capacity	ke^-	132	180	
Fixed Pattern Noise (FPN) ^{1,2}	pk-pk		0.5	1.0
	PR exposure control disabled		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 = 84 μs	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 $f_{\text{LINE}} = 10\text{kHz}$.

Test Conditions:

- Operating temperature = 35°C.
- $f_{\text{RST}} = \text{data rate per output} = 25\text{MHz}$.
- $I_{\text{LOAD}} = 8\text{mA}$.
- $C_{\text{LOAD}} = 10\text{pF}$.
- 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.