Schäfter+Kirchhoff

SK7456CTO

Monochrome Line Scan Camera

7456 pixels, 4.7 µm x 4.7 µm, 40 / 20 MHz pixel frequency

Instruction Manual

08.2016

Sample Configuration

1 CCD line scan camera **SK7456CTO** mounted with

2 Mounting bracket SK5105

3 Clamping claws SK5102

4 Photo lens SK1.4/50-40 (integrated focus/aperture adjustment)

Read the manual carefully before the initial start-up. For the contents table, refer to page 3.
The right to change the described specifications is retained as the products undergo continuous cycles of improvement.

Schäfter+Kirchhoff
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

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How to Use this Instruction Manual

Please read the following sections of this Instruction Manual before unpacking, assembly or use of the Line Camera System:

- **The safety warnings on this page**
- **Introduction to the system, page 4**
- **Assembly and initial setup, page 6**

Keep this Instruction Manual in a safe place for future reference.

Safety Warnings

Electricity Warning

Assembly and initial operation of the line scan camera must be carried out under dry conditions.

Do not operate the camera if you notice any condensation or moisture in order to avoid danger of a short circuit or static discharge!

For typical use in a scanning application, please consider the following warnings:

Mechanical Warning

Ensure that the scanner axis is free to move and that no obstacles are in the way – **especially fingers!**

Do not place any body parts in the way of moving parts!

Risk of High Power Lighting

According to the application, laser or high power LED light sources might be used. These can affect your eyesight temporarily or even cause permanent damage to the eyes or skin.

Do not look directly into the light beam!

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1 Introducing the SK7456CTO Line Scan Camera

1.1 Intended Purpose and Overview

The SK line scan camera series is designed for a wide range of vision and inspection applications in both industrial and scientific environments. The SK7456CTO is compliant with CameraLink Specification Rev 1.1.

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.

CameraLink reads the camera specifications from configuration files. Prior to the iniatial start-up, the appropriate camera specific file must be created for the grabber in use.

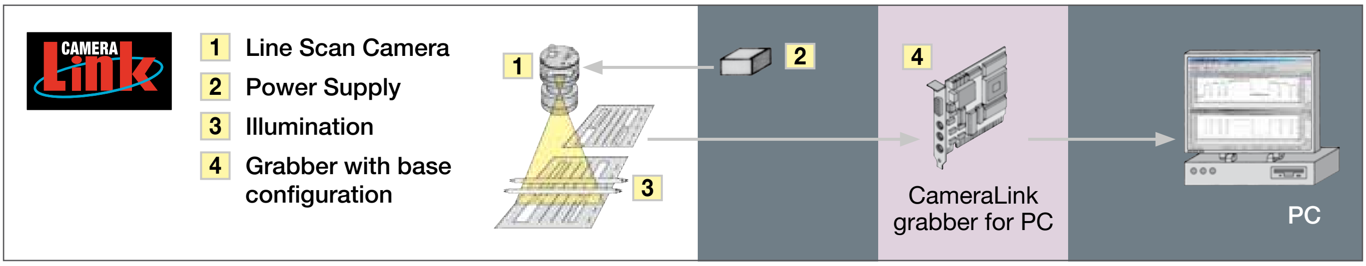
Beyond, the configuration program SkCLConfig allows the full parameterization of the camera settings, such as gain, offset and pixel frequency, via the CameraLink™ serial port interface. SkCLConfig uses the ***clser*.dll*** driver that is supplied with the CameraLink grabber board.

For the development of custom applications use the software development kits released from the grabber board producers.

Normally, functions like Shading Correction, signal modification with a look-up table (LUT) or the definition of a region of interest (ROI) are implemented in the grabber board. For special requirements these functions can be made availabel within the camera, please contact the Schäfter+Kirchhoff customer support where appropriate.

The camera is supplied precalibrated, with factory settings for gain and offset. A readjustment is normally not necessary.

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 lens 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. For further guidance see section ***4 Adjustments for Optimum Scan Results, p. 16***.



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1.2 Computer System Requirements

The SK7456CTO is compliant with CameraLink Specification Rev 1.1. It is operated in the "Base Configuration" where the signals are carried over a single connector/cable.

Power supply is provided by a separate power connector.

Along with the camera the Schäfter+Kirchhoff configuration program **SkCLConfig** is delivered. Provided a clser**.dll driver by the grabber board manufacturer is available, this program facilitates transferring the ***Set*** and ***Request*** commands for camera configuration (see page 13).

1.3 SK7456CTO Line Scan Camera - Specifications

Sensor category	CCD Monochrome Sensor
Sensor type	TCD1711DG
Pixel number	7456
Pixel size (width x height)	4.7 x 4.7 μm^2
Pixel spacing	4.7 μm
Active sensor length	35.04 mm
Anti-blooming	-
Integration control	-
Shading correction	x
Threshold detection	x
Line synchronization modes	Line Sync, Line Start, Exposure Start
Frame synchronization	x
Pixel frequency	40 / 20 MHz
Maximum line frequency	5.2 kHz
Integration time	0.19 ... 20 ms
Dynamic range	1:1000 (rms)
Spectral range	400 ... 900 nm
Video signal	monochrome 8/12 Bit digital
Interface	Camera Link
Voltage	+5V, +15V
Power consumption	2.2 W (= 5V · 320mA + 15V · 35mA)
Casing	Ø65 mm x 54 mm (Case type AC2)
Objective mount	M40x0.75
Flange focal length	19.5 mm
Weight	0.2 kg
Operating temperature	+5 ... +45°C

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2 Installation and Setup

2.1 Mechanical Installation: Mounting Options and Dimensions

Mounting Options

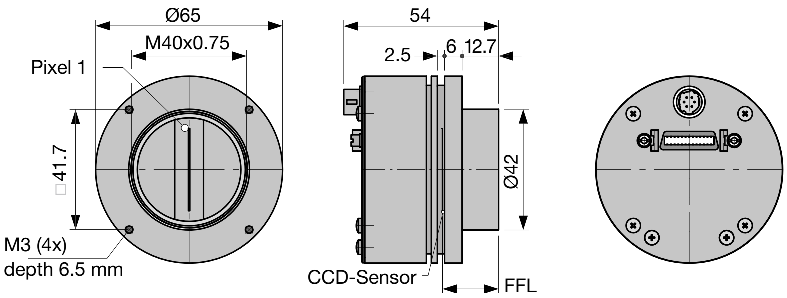
- The best fixing point of the camera is the collar for the mounting bracket SK5105 (available as an accessory).
- Four threaded holes M3 x 6.5 mm provide further options for customized brackets.
- The length and weight of the optics might be beyond the capability of the standard mounting bracket SK5105. For this purpose, a second mounting bracket type SK5105-2 to hold the tube extension ring(s) is more appropriate.

Optics Handling

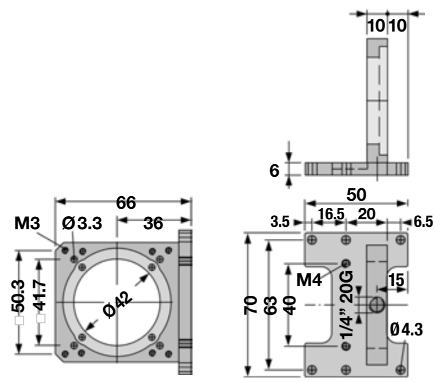
- If the camera and the optics are ordered as a kit, the components are pre-assembled and shipped as one unit. Keep the protective cap on the lens until the mechanical installation is finished.
- If you must expose the sensor or lens surface, ensure the environment is as dust-free as possible.
- Gently blow off loose particles using clean compressed air.
- The sensor and lens surfaces can be cleaned with a soft tissue moistened with water or a water-based glass cleaner.

Casing type AC2

AC2		
	Lens mount:	M40x0.75
	Seat for bracket:	Ø42 mm
	Flange focal length:	FFL = 19.5 mm

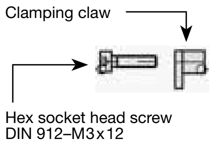


Mounting bracket SK5105



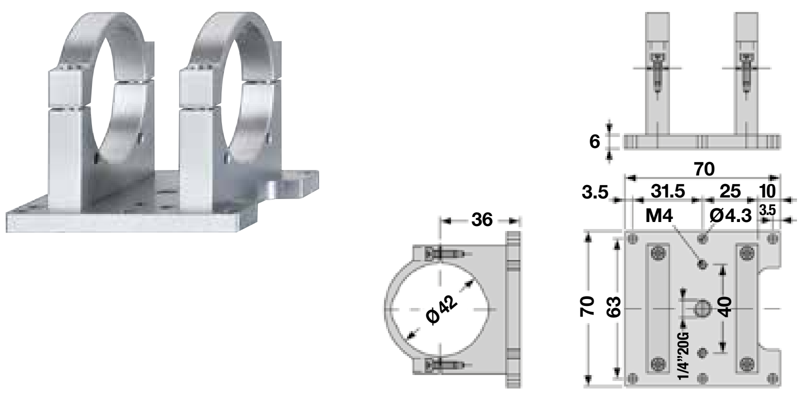
Clamping set SK5102

Set of 4 pcs. clamping claws incl. screws



Mounting system SK5105-2

for cameras with a tube extension > 52 mm



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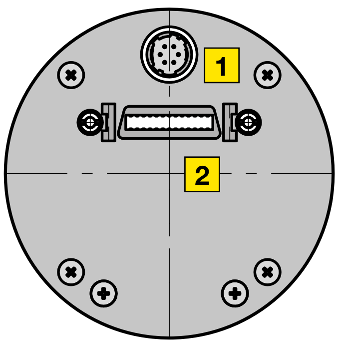
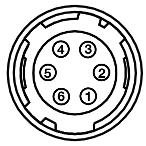
2.2 Electrical Installation: Connections and I/O Signals

- For the SK7456CTO line scan camera data transfer and camera control is provded by the Camera Link interface 2. Use a control cable SK9018.... to connect the camera with the frame grabber card in the PC. The maximum cable length is 10 m.
- The operating power has to be supplied by an external source into socket 1
- For any kind of synchronized operation the external trigger signal(s) have to be wired to the frame grabber in addition. The camera can handle two trigger signals. These must be supplied on the CC1 and CC2-pins of the Camera Link interface. For a detailed description of the interface see section *3 Interface and Camera Control, p. 8*.



1 **Power +5V, +15V**



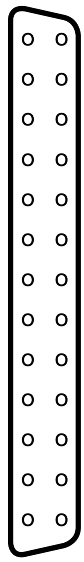
Hirose series 10A, male 6-pin

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

Total power: 2.2 W (= 5V · 320mA + 15V · 35mA)

2 **Data Connector**

Miniature Delta Ribbon, female 26-pin (MDR-26)



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

Accessories (see also *Accessories, p. 24*):

Control cable SK9018...
for line scan cameras with CameraLink interface
26-pin shielded cable, both ends with mini-ribbon connector (male 26-pin)

SK9018.xMM
MM = connector both ends male
cable length 3 / 5 m or
length according to choice, max. 10 m

Power Supply Unit PS051515
Input: 100-240 VAC, 0.8 A, 50/60 Hz, IEC 320 C14 coupler (for IEC C13 power cord)
Output: +5V DC, 2.5 A / +15 V DC, 0.5 A / -15 V DC, 0.3 A
Cable length 1 m, with Lumberg connector KV60, female 6-pin
(for power cable SK9015.x or SK9016.x)

Power Cable SK9015.xMF
Use this cable to feed external supply voltage into socket 1.
Connectors:
Hirose plug HR10A, female 6 pin (camera side)
Lumberg SV60, male 6-pin connector (for supply voltage)
Length 1.5 m (standard) or 0.2 m

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3 Interface and Camera Control

3.1 Input/Output Signals and Control System

Camera control

Signal Name	I/O	Type	Description
LINE SYNC A	I	RS644	CC1 - Synchronization input (SOS)
LINE SYNC B	I	RS644	CC2 - Start Integration period in dual synchro modus (only cameras with Integration Control)
FRAME SYNC	I	RS644	CC3 - Start acquisition of 2D area scan
	I	RS644	CC4 - not used

I = Input, O = Output, IO = Bidirectional, P = Power/Ground, NC = not connected

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 = 1 (low).
DVAL is always set to the value = 1 (high).

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

Bit allocation 12-bit data: D[0-11], Serial command: F12

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

Bit allocation 8-bit data: D[0-7], Serial command: F8

The bit allocation conforms to the CameraLink Standard basic configuration.

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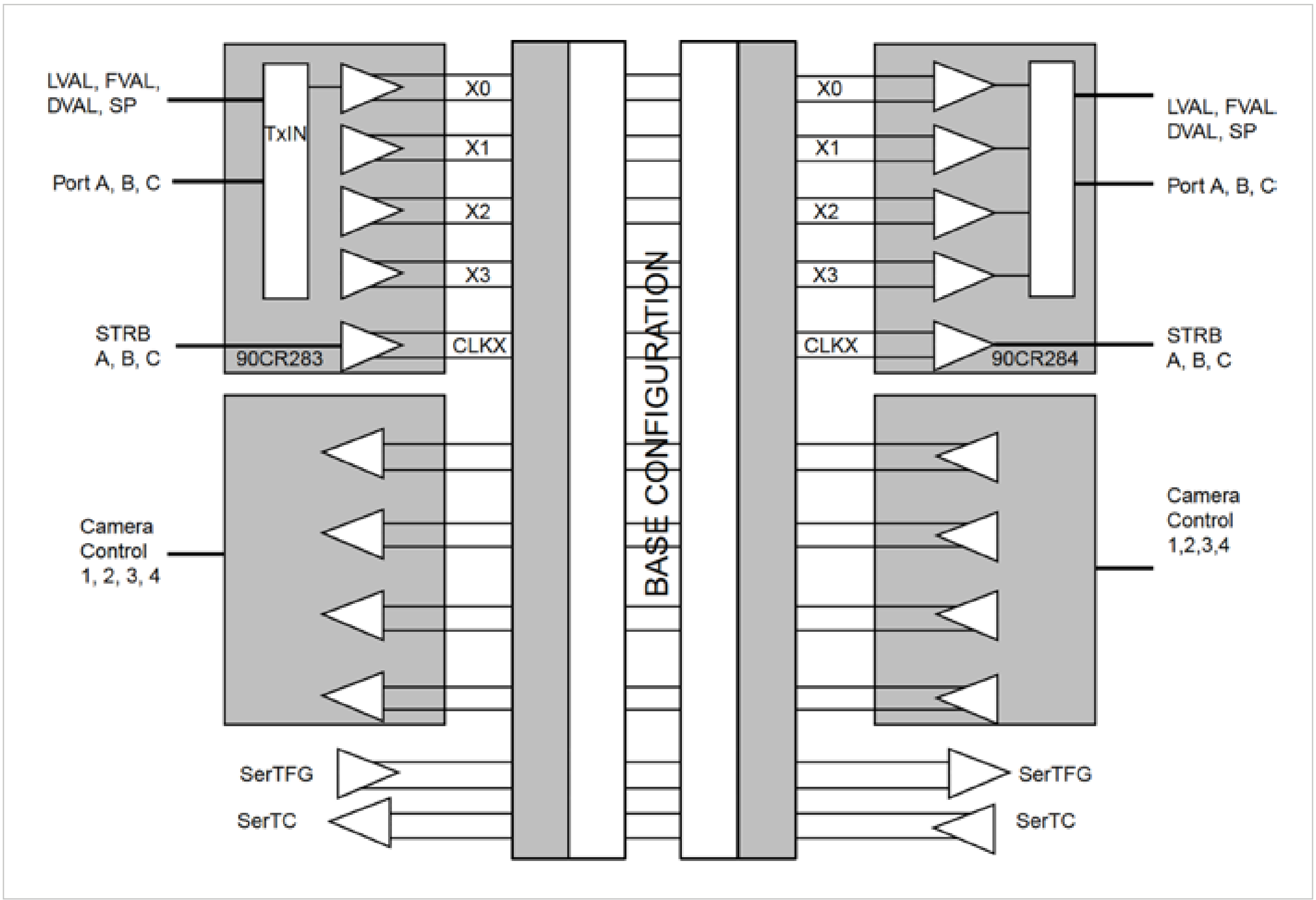
Serial communication

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



Block Diagram of Camera Link Base Configuration

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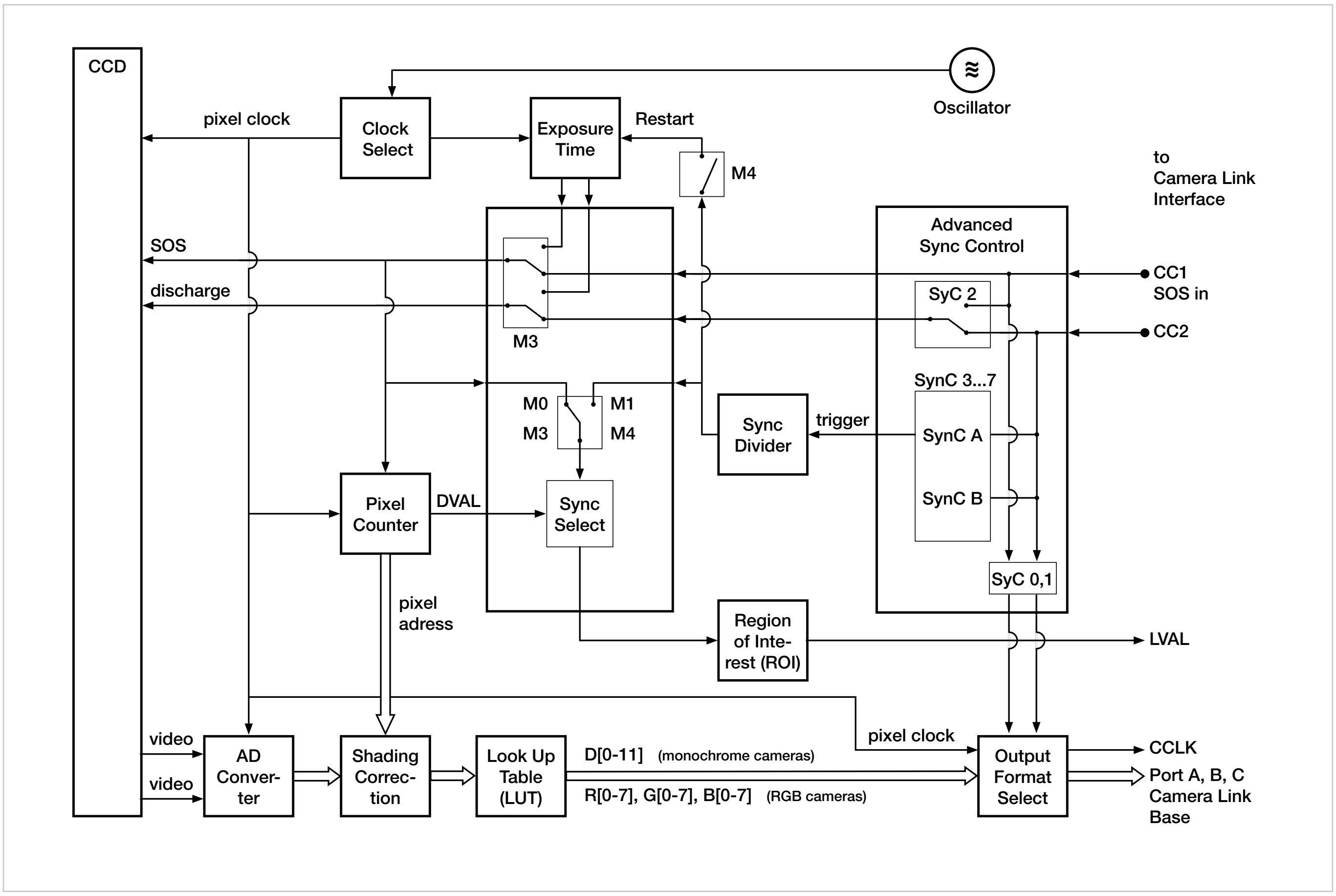

Logical Diagram of the Camera Control System

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3.2 Control Signals and Timing Diagram

The control signals needed to run the CCD line scan camera are "Clock" (CCLK) and "Start Of Scan" (SOS). The clock signal is generated internally by a programmable oscillator.

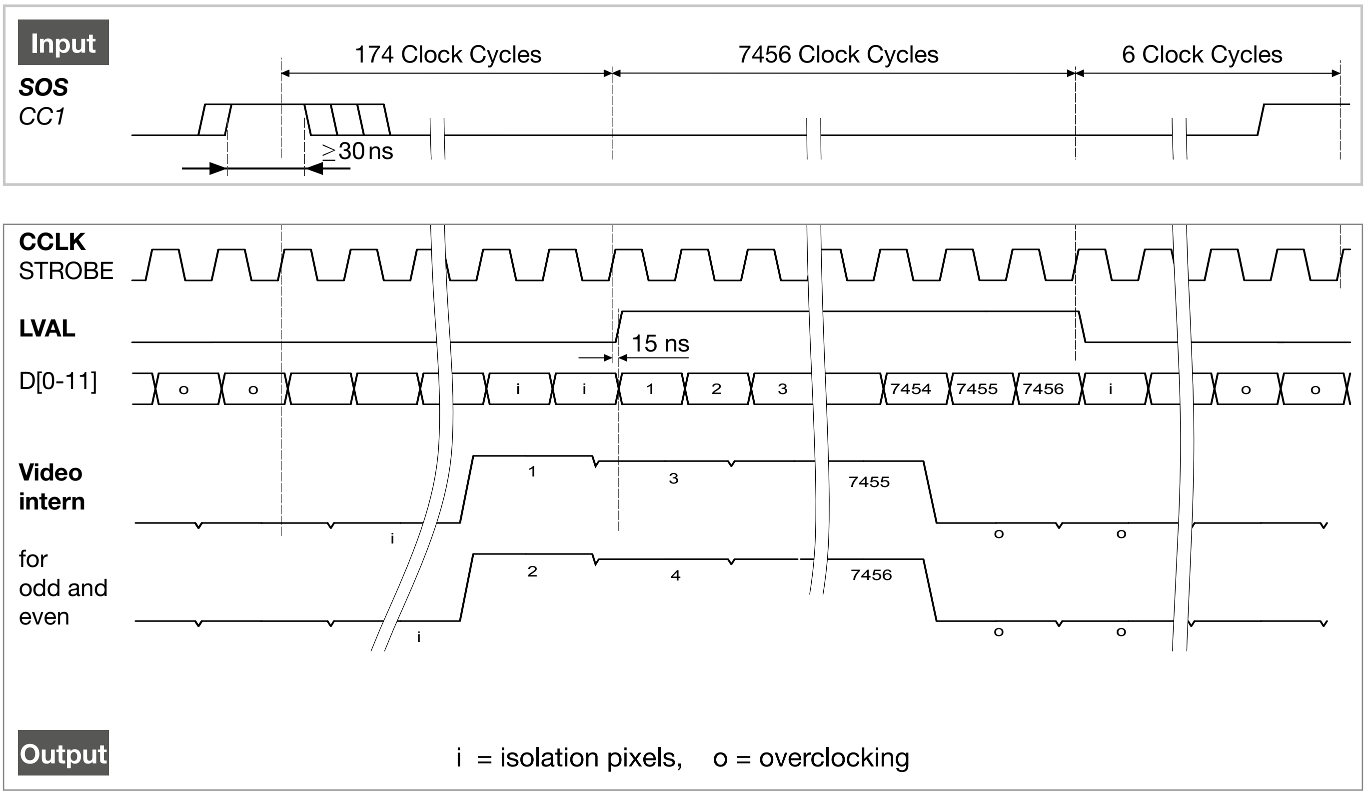
The SOS can be initiated internally by adjusting the Exposure Time or externally by the grabber board. For internal control, the camera must be set in the **'Free Run' mode** by using command **'M0'**. When the SOS signal is generated by the grabber board then the camera must be set to the **'external Trigger CC1' mode** using **'M3'**.

The frequency of the 'SOS' signal determines the number of lines that are read per second (= line frequency). On each rising edge of this signal, the accumulated charges within the sensor are transferred to the analog transport registers in parallel with the sensor line information.

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 SK7456CTO camera requires 7636 clock pulses for a line scan to be read out completely. This corresponds to the number of pixels per line plus several extra cycles prior and past the charge acquisition.

Accordingly, the line frequency is limited to 1/7636 part of the clock freqeuncy. Lower line frequency values can be used without restriction. The minimum SOS pulse length is 30 ns.



Line Scan Camera SK7456CTO Manual (08.2016) • SK7456CTO_CameraControl(3d)_CamLink_CtrlSignals-Timing.indd (08.2016)

3.3 Camera Control with SKCLConfig Tool

The software requires that the clser***.dll supplied with the CameraLink grabber board is installed.

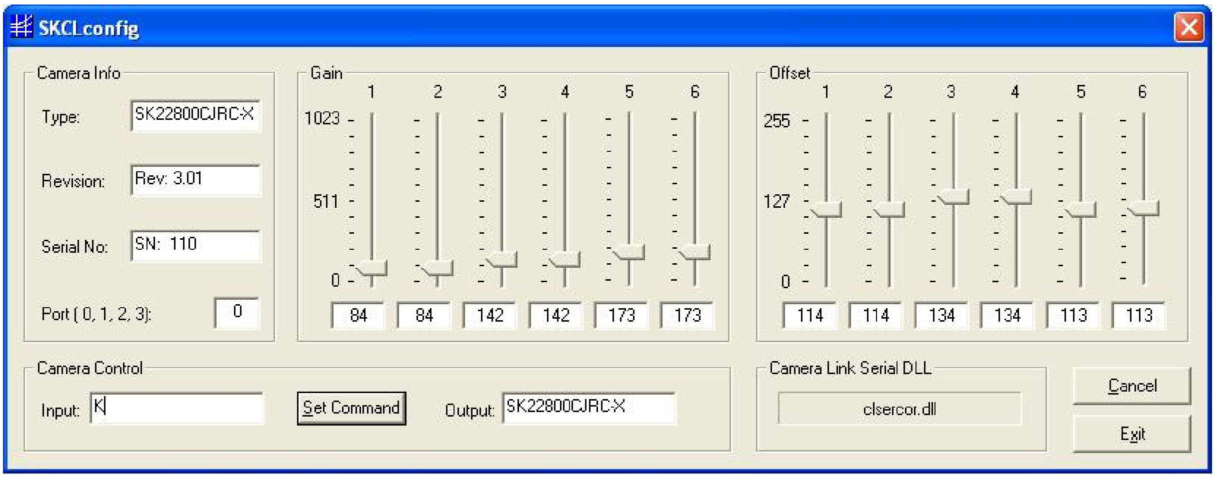
The most important camera functions can be set using serial commands, by using either the software from the grabber manufacturer or by using the configuration program SkCLConfig tool from Schäfter+Kirchhoff.

SkCLConfig provides the direct adjustment of line scan camera parameters, such as gain, offset, and pixel frequency, via the serial channel of the CameraLink interface.

Similarly, current parameters, as well as specific product information, can be read from the camera using the request commands. All set and request commands are listed in the tables below.

The parameter settings are stored in the non-volatile flash memory of the camera and are available after a rapid start-up, even after a complete shut down or loss of power.

On startup, the camera declares information about type, revision and serial number. If the camera type field is empty then switch off the camera, check the connections and restart.



Dialog for Gain and Offset Adjustment and Camera Control Command Input

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Set Commands

Set Operation	Description
G*oooo*<CR>	Gain 1 setting 0-24 dB
B*oooo*<CR>	Gain 2 setting 0-24 dB
O*ppp*<CR>	Offset 1 setting
P*ppp*<CR>	Offset 2 setting
F8<CR>	output format: 8 bit output data
F10<CR>	output format: 10 bit output data
F12<CR>	output format: 12 bit output data
F16<CR>	output format: 2 x 8 bit output data (double Tab)
C20<CR>	camera clock: 20 MHz data rate
C40<CR>	camera clock: 40 MHz data rate
T0<CR>	Test pattern off / SCM off
T1<CR>	Test pattern on (turns off with power off)
T2<CR>	Shading Correction on
T3<CR>	auto program Shading Corr. / SCM on
T4<CR>	copy Flash Memory 1 to SCM
T5<CR>	save SCM to Flash Memory 1
T6<CR>	Video out = SCM data
M0<CR>	free run with selected line rate
M2<CR>	free run with maximum line rate
M3<CR>	extern SOS CC1-input and Integration control CC1 or CC2-input
A*xxxx*<CR>	SCM address (*xxxx* = 0-7455)
D*xxxx*<CR>	SCM data (*xxxx* = 0-4095) and increment SCM address
W*yyyyy*<CR>	line clock frequency (*yyyyy* = 50-6535 Hz)
X*yyyyy*<CR>	exposure time (*yyyyy* = 153-20000) (µs)
SNES<CR>	enable NES (no EEPROM save)
SCOG<CR>	enable COG (coupling of gain1-gain2)
RNES<CR>	disable NES (no EEPROM save)
RCOG<CR>	disable COG (coupling of gain1-gain2)
RESET<CR>	reset Memory to manufacturer default

Acknowledgement for all set commands:
0 = OK, 1 = not OK

Request Commands

Request	Return	Description
K<CR>	*SK7456CTO*	returns SK type number
R<CR>	*Rev2.50*	returns revision number
S<CR>	*SNr00163*	returns serial number
I1<CR>	VCC: *yyyyy*	returns VCC (1=10mV)
I2<CR>	VDD: *yyyyy*	returns VDD (1=10mV)
I3<CR>	moo: *yyyyy*	returns mode of operation
I4<CR>	CLo: *yyyyy*	returns camera clock low frequency (MHz)
I5<CR>	CHi: *yyyyy*	returns camera clock high frequency (MHz)
I6<CR>	Ga1: *yyyyy*	returns gain 1
I7<CR>	Ga2: *yyyyy*	returns gain 2
I8<CR>	Of1: *yyyyy*	returns offset 1
I9<CR>	Of2: *yyyyy*	returns offset 2
I19<CR>	Tab: *yyyyy*	returns video channels
I20<CR>	CLK: *yyyyy*	returns selected clock frequency (MHz)
I21<CR>	ODF: *yyyyy*	returns selected output data format
I22<CR>	TRM: *yyyyy*	returns selected trigger mode
I23<CR>	SCO: *yyyyy*	returns shading correction on/off
I24<CR>	Exp: *yyyyy*	returns exposure time (µs)
I25<CR>	miX: *yyyyy*	returns minimum exposure time (µs)
I26<CR>	LCK: *yyyyy*	returns line frequency (Hz)
I27<CR>	maZ: *yyyyy*	returns maximum line frequency (Hz)
I32CR>	Tmp: *yyyyy*	returns Video Board Temperature (1=1°C)

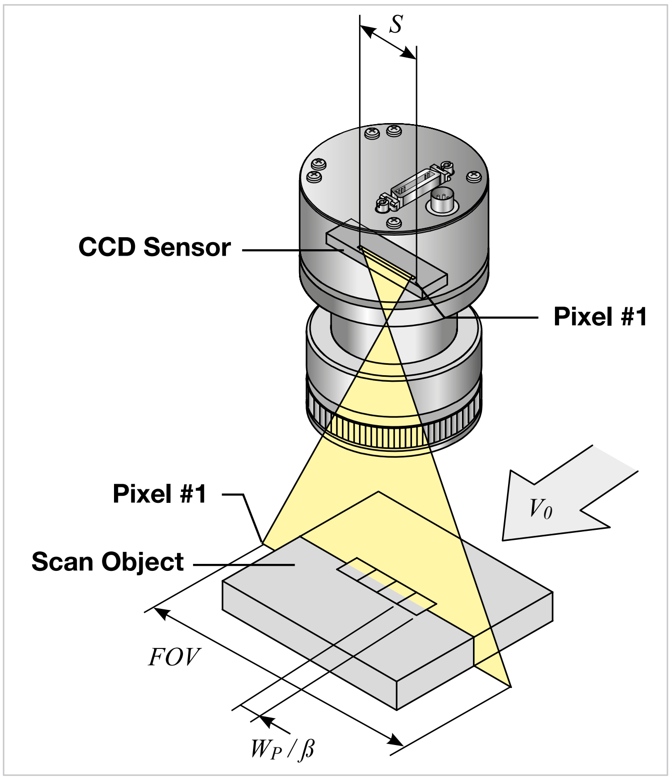
SCM: Shading Correction Memory
SOS: Start of Scan

Range of values:
oooo = 0 ... 1023
ppp = 0 ... 255
xxxx = 4 digits integer value as ASCII
yyyyy = 5 digits integer value as ASCII

Line Scan Camera SK7456CTO Manual (08.2016) • SK7456CTO_CameraControl(4)_ByCommands.indd (08.2016)

3.4 Synchronization of the Imaging Procedure and the Object Scan Velocity

- A two-dimensional image is generated by moving either the object or the camera. The direction of the translation movement must be orthogonal to the sensor axis of the CCD line scan camera.
- To obtain a proportional image with the correct aspect ratio, a **line-synchronous transport** with the laterally correct pixel assignment is required. The line frequency and the constant object velocity have to be coordinated.
- In cases of a variable object velocity or particularly high accuracy requirements then an **external synchronization** is necessary. The various **synchronization modes** are described below.



The optimum object scan velocity is calculated from:

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

If the velocity of the object carrier is not adjustable then the line frequency of the camera must be adjusted to provide an image with the correct aspect ratio, where:

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

V_O	=	object scan velocity
W_P	=	pixel width
f_L	=	line frequency
S	=	sensor length
FOV	=	field of view
β	=	magnification
	=	S / FOV

Example 1:

Calculating the object scan velocity for a given field of view and line frequency:

Pixel width	= 4.7 µm
Line frequency	= 5.2 kHz
S	= 35.04 mm
FOV	= 60 mm

$$V_O = \frac{4.7\,\mu\text{m} \cdot 5.2\text{ kHz}}{(35.04\text{ mm} / 60\text{ mm})} = 42\text{ mm/s}$$

Example 2:

Calculating the line frequency for a given field of view and object scan velocity:

Pixel width	= 4.7 µm
Object scan velocity	= 40 mm/s
S	= 35.04 mm
FOV	= 60 mm

$$f_L = \frac{40\text{ mm/s} \cdot (35.04\text{ mm} / 60\text{ mm})}{4.7\,\mu\text{m}} = 5\text{ kHz}$$

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4 Adjustments for Optimum Scan Results

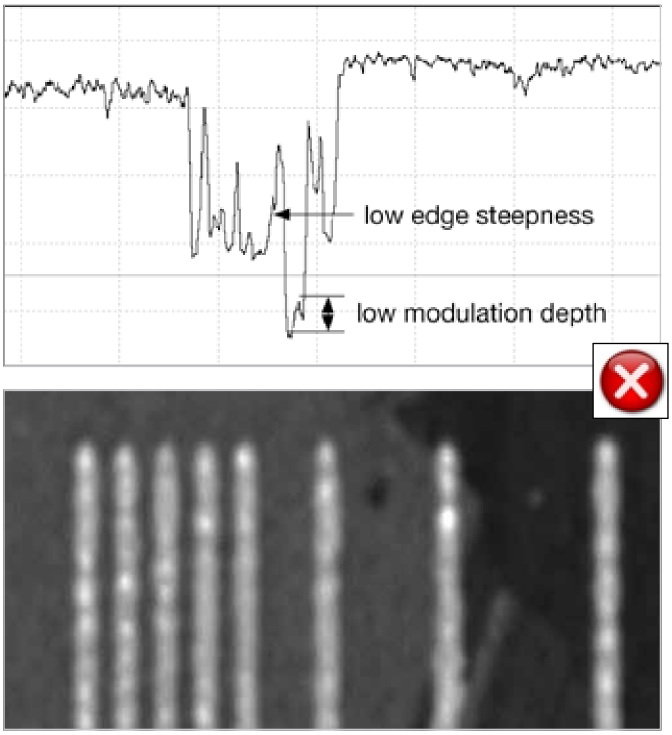
Prior to a scan, the following adjustments and parameter settings should be considered for optimum scan signals:

- Lens focussing
- Sensor alignment
- Gain/Offset
- Shading correction
- Integration time
- Synchronization of the sensor exposure and the object surface velocity, trigger mode options.

4.1 Lens Focussing

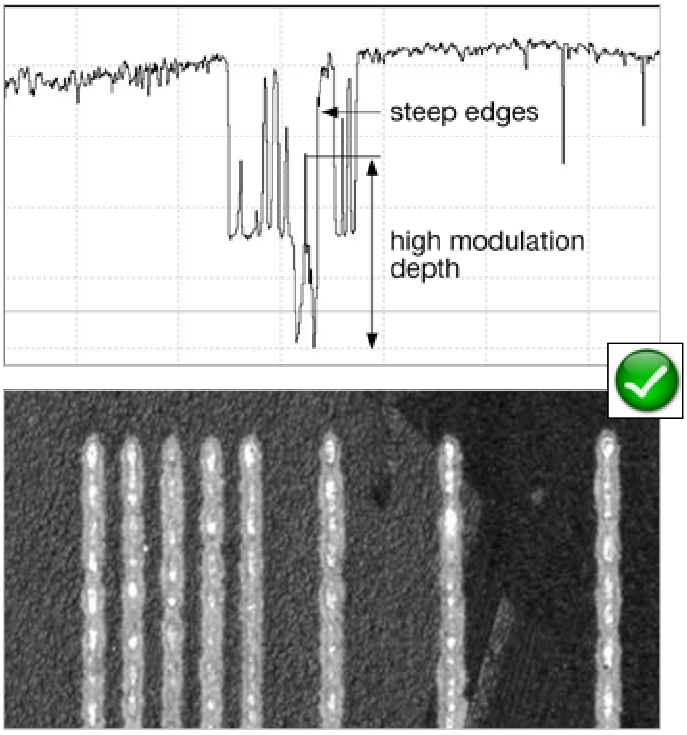
A real time line signal facilitates the effective focussing of the line scan camera system, even for two-dimensional measurement tasks. For determining the correct focus, the edge steepness at dark-bright transitions and the modulation of the line scan signal are the most important factors.

- Adjust the focus using a fully opened aperture to restrict the depth of field and to amplify the effects of focus adjustments.
- The signal amplitude may require trimming when using a fully opened aperture and this can achieved most readily by shortening the integration time.



Out-of-focus:

- Low edge steepness
- Signal peaks are blurred
- High-frequency gray values with low modulation



Optimum focus:

- Dark-bright transitions with steep edges
- Large modulation in the signal peaks
- High-frequency gray value variations

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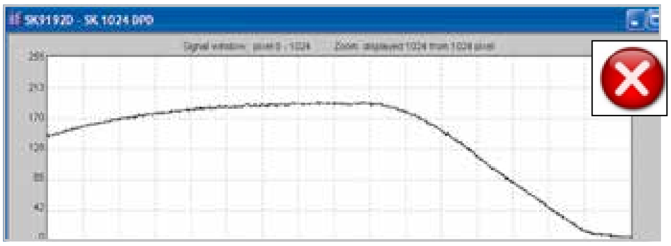
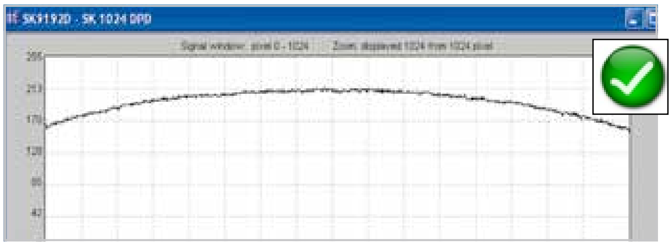
4.2 Sensor Alignment

If you are operating with a linear illumination source, check the alignment of the illumination source and the sensor prior to performing a shading correction, as rotating the line sensor results in asymmetric vignetting.



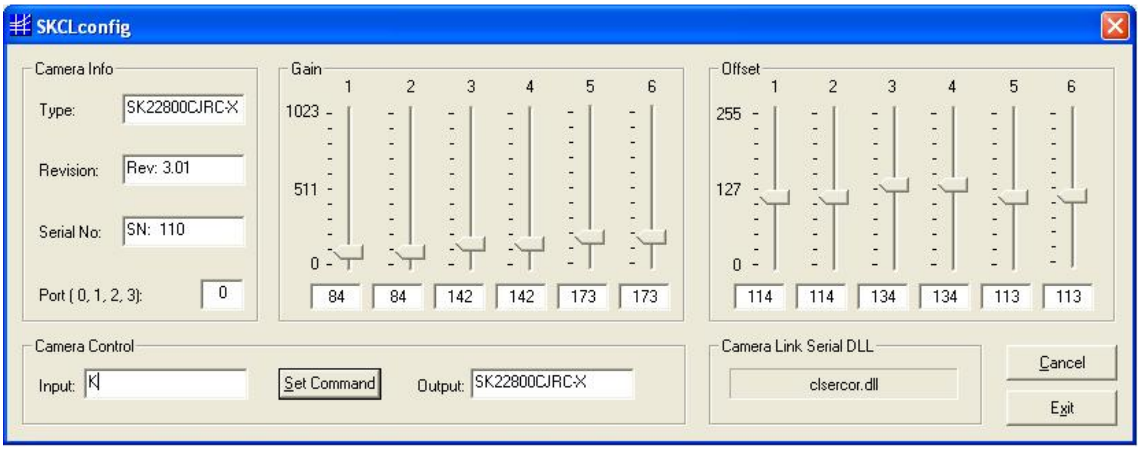
Sensor and optics rotated in apposition



Sensor and optics aligned

4.3 Gain/Offset Adjustment

Cameras are shipped prealigned with gain/offset factory settings. Open the "Gain/Offset Control" dialog to re-adjust or customize these settings.



Gain/Offset Control dialog

The gain/offset dialog contains up to 6 sliders for altering gain and offset. The number of active sliders depends on the individual number of adjustable gain/offset channels of the camera. When "Coupled Gain Channels" is ticked, all channels are adjusted synchronously with one slider.

Enter commands for advanced software functions in the 'Camera Control' field (see page 13).

Adjustment principle

1. Offset

To adjust the zero baseline of the video signal, totally block the incident light and enter "00" (volts) for channel 1.

For a two- or multi-channel sensor, minimize any differences between the channels by adjusting the other Offset sliders.

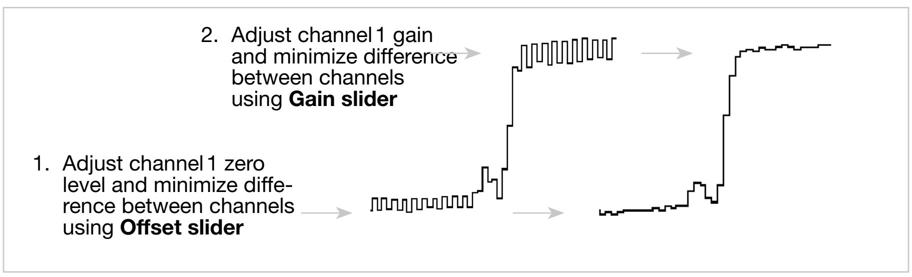
A slight signal noise should be visible in the zero baseline.

2. Gain

Illuminate the sensor with a slight overexposure in order to identify the maximum clipping. Use the Gain slider "1" to adjust the maximum output voltage.

For a two- or multi-channel sensor, minimize any differences between the channels by adjusting the other Gain sliders.

For the full 8-bit resolution of the camera, the maximum output voltage is set to 255 and for 12-bit is set to 4095.



Offset and gain adjustment for more than one gain/offset channel

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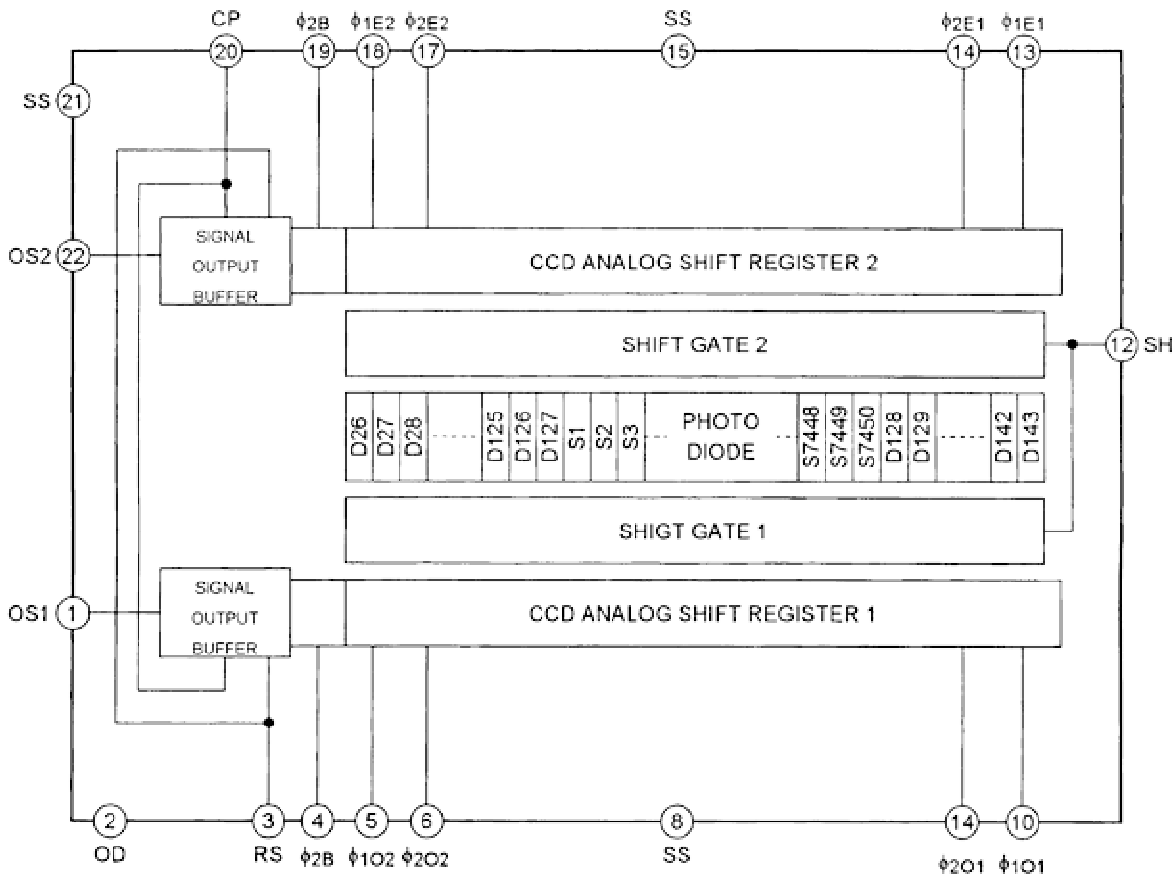
5 Sensor Information

Manufacturer: TOSHIBA Corporation
Type: TCD1711DG
Data source: TOSHIBA CCD Linear Image Sensor CCD (Charge Coupled Device) TCD1711DG, 2004-01-30

Features

- Number of Image Sensing Elements: 7450 elements
- Image Sensing Element Size: 4.7 µm by 4.7 µm on 4.7 µm center
- Photo Sensing Region: High sensitive and low voltage dark signal pn photodiode
- Clock: 2-phase (5 V)
- Package: 22-pin CERDIP package

Circuit Diagram and Pin Names



φ1E, O	Clock (Phase 1)
φ2E, O	Clock (Phase 2)
φ2B	Final Stage Clock (Phase 2)
SH	Shift Gate
RS	Reset Gate
CP	Clamp Gate
OS1	Signal Output 1
OS2	Signal Output 2
OD	Power
SS	Ground
NC	Non Connection

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Optical/Electrical Characteristics

(Ta = 25°C, V_{OD} = 10 V, V_ϕ = V_{SH} = V_{RS} = V_{CP} = 5 V (パルス), f_ϕ = 1 MHz,
t_{INT} (INTEGRATION TIME) = 10 ms, LIGHT SOURCE = DAYLIGHT FLUORESCENT LAMP,
LOAD RESISTANCE-100kΩ)

CHARACTERISTIC	SYMBOL	MIN	TYP	MAX	UNIT	NOTE
Sensitivity	R	12	15	18	V/lx·s	
Photo Response Non Uniformity	PRNU	—	4	10	%	(Note2)
	PRNU (3)	—	6	12	mV	(Note8)
Saturation Output Voltage	V_{SAT}	1.5	1.8	—	V	(Note3)
Saturation Exposure	SE	0.08	0.12	—	lx·s	(Note4)
Dark Signal Voltage	V_{DRK}	—	1.0	3	mV	(Note5)
Dark Signal Non Uniformity	DSNU	—	4.0	10	mV	(Note5)
DC Power Dissipation	P_D	—	250	375	mW	
Total Transfer Efficiency	TTE	92	98	—	%	
Output Impedance	Z_O	—	0.2	1	kΩ	
Dynamic Range	DR	—	1800	—		(Note6)
DC Signal Output Voltage	V_{OS1}	3.0	4.5	6.0	V	(Note7)
	V_{OS2}	3.0	4.5	6.0		
DC Differential Error Voltage	$\lvert V_{OS1} - V_{OS2} \rvert$	—	—	300	mV	
Random Noise	$N_{D\sigma}$	—	1.0	—	mV	(Note9)

Note 2: Measured at 50% of SE (Typ.)

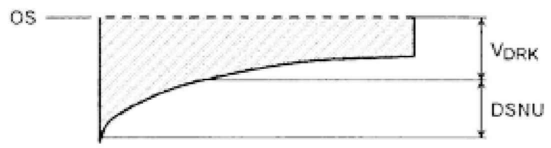
Definition of PRNU : PRNU = $\frac{\Delta\chi}{\bar{\chi}} \times 100(\%)$

Where $\bar{\chi}$ is average of total signal outputs and $\Delta\chi$ is maximum deviation from $\bar{\chi}$ under uniform illumination. (Channel 1)
In the case of 3725 elements (Channel 2), the condition is the same as above too.

Note 3: V_{SAT} is defined as minimum saturation output voltage of all effective pixels.

Note 4: Definition of SE : SE = $\frac{V_{SAT}}{R}$ (lx·s)

Note 5: V_{DRK} is defined as average dark signal voltage of all effective pixels.
DSNU is defined as different voltage between VDRK and VMDK when VMDK is maximum dark signal voltage.



Note 6: Definition of DR : DR = $\frac{V_{SAT}}{V_{DRK}}$

V_{DRK} is proportional to t_{INT} (Integration Time).
So the shorter t_{INT} condition makes wider DR values.

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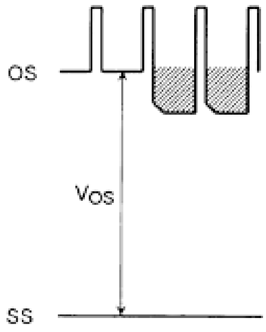
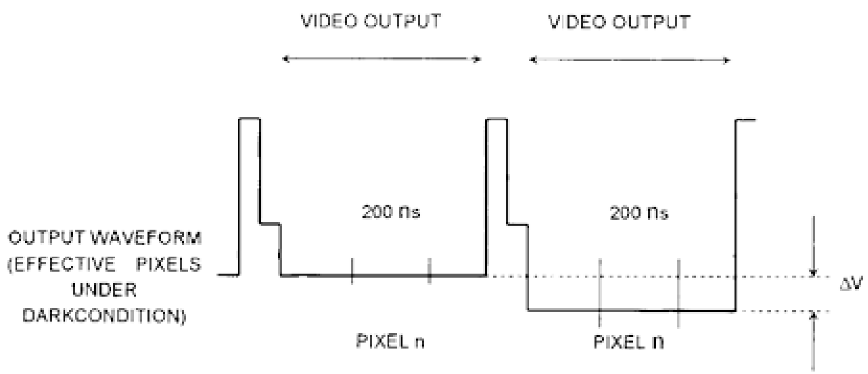
Note 7: DC signal output voltage and DC compensation output voltage are defined as follows:



Note 8: PRNU (3) is defined as maximum voltage with next pixel, where measured 5% of SE (Typ.)

Note 9: Random noise is defined as the standard deviation (sigma) of the output level difference between two djacent effective pixels under no illumination (i.e. dark condition) calculated by the following procedure.



1) Two adjacent pixels (pixel n and n + 1) in one reading are fixed as measurement points.
2) Each of the output levels at video output periods averaged over 200 nanosecond period to get Vn and Vn + 1.
3) Vn + 1 is subtracted from Vn to get ΔV.

   $\Delta V = Vn - Vn + 1$
4) The standard deviation of ΔV is calculated after procedure 2) and 3) are repeated 30 times (30 readings).

$$\overline{\Delta V} = \frac{1}{30}\sum_{i=1}^{30}|\Delta Vi| \qquad \sigma = \sqrt{\frac{1}{30}\sum_{i=1}^{30}\left(|\Delta Vi| - \overline{\Delta V}\right)^2}$$

5) Procedure 2), 3) and 4) are repeated 10 times to get 10 sigma values.

$$\overline{\sigma} = \frac{1}{10}\sum_{j=1}^{10}\sigma j$$

6) $\overline{\sigma}$ value calculated using the above procedure is observed $\sqrt{2}$ times larger than that measured relative to the ground level. So we specify the random noise as follows.

$$\text{Random noise} = \frac{1}{\sqrt{2}}\overline{\sigma}$$

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Glossary

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.

Exposure period

is the illumination cycle of a line scan sensor. It is the → ***integration time*** plus the additional time to complete the read-out of the accumulated charges and the output procedure. While the charges from a finished line scan are being read out, the next line scan is being exposed. The exposure period is a function of the pixel number and the → ***pixel frequency***. The minimum exposure period of a particular line scan camera determines the maximum → ***line frequency*** that is declared in the specifications.

Integration control

Cameras with integration control are capable of curtailing the → ***integration*** time within an → ***exposure period***. This performs an action equivalent to a shutter mechanism.

Integration time

The light-sensitive elements of the photoelectric sensor accumulate the charge that is generated by the incident light. The duration of this charge accumulation is called the integration time. Longer integration times increase the intensity of the line scan signal, assuming constant illumination conditions. The complete read-out of accumulated charges and output procedure determines the minimum → ***exposure period***.

Line frequency, line scan frequency

is the reciprocal value of the → ***exposure period***. The maximum line frequency is a key criterion for line scan sensors as this is the limiting factor for the scan velocity.

Optical resolution

Two elements of a line scan camera determine the optical resolution of the system: first, the pixel configuration of the line sensor and, secondly, the optical resolution of the lens. The worst value is the determining value. In a phased set-up, both are within the same range.

The optical resolution of the line sensor is primarily determined by the number of pixels and secondarily by their size and spacing, the inter-pixel distance. Currently available line scan cameras have up to 12000 pixels, ranging from 4 to 14 µm in size and spacing, for sensors up to 56 mm in length and line scan frequencies up to 83 kHz.

During a scanning run, the effective resolution perpendicular to the sensor orientation is determined by the velocity of the scan and by the → ***line frequency***

Pixel frequency

The pixel frequency for an individual sensor is the rate of charge transfer from pixel to pixel and its ultimate conversion into a signal.

Region of Interest

A freely programmable window (region of interest, ROI) can be applied to the line sensor so that only the pixel information within the ROI can reach the memory.

By only illuminating these ranges, data volume and data processing is accelerated for both line and area scan acquisitions.

Constraint: the ROI memory allocation must be divisible by 8.

Shading correction

→ ***Shading Correction***, section 3.2

SoI (Start of Integration)

In addition to → ***SoS***, cameras with → ***Integration Control*** function generate an internal SoI-signal that initiates the integration period.

SoS (Start of Scan)

is an internally generated trigger signal for sequential control of the camera, The signal is induced either by an internal counter or by an external line synchronization signal, depending on the selected line synchronization mode.

→ ***Synchronization***

→ ***Advanced Synchronization Control***, section 4.2

Synchronization

To obtain a proportional image with the correct aspect ratio, a line synchronous transport with the laterally correct pixel assignment is required. The → ***Line frequency*** and constant object velocity have to be compatible with each other.

For more accurate requirements or with a variable object velocity, external synchronization is necessary.

→ ***Synchronization of the Imaging Procedure and the Object Scan Velocity***, section 3.2

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CE-Conformity

The product complies with the following standards and directives:

2014/30/EU

EMC Directive

DIN EN 61326-1:2013

Electrical equipment for measurement, control and laboratory use – EMC requirements

Part 1: General requirements

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.

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We reserve the right to improve or change specifications so that the system description and depictions in the Instruction Manual may differ in detail from the system actually supplied. The Instruction Manual is not covered by an update service.

Date of document publication: 18.08.2016

Schäfter+Kirchhoff GmbH
Kieler Straße 212
22525 Hamburg
Germany

Tel.: +49 40 853997-0
Fax: +49 40 853997-10
Email: info@SuKHamburg.de
Internet: www.SuKHamburg.com

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Features

- **Extended Trigger Functions**
  Direction of movement or slippage can be detected by using two external synchronization signals.
- **Shading Correction Memory (SCM) and Look-Up Table (LUT) options**
  The calibration data in the SCM automatically adjusts the line signal data directly in the camera after each exposure.
  The LUT is a separate memory block that can also be used for postprocessing the line signal data, such as applying a Gamma function.
- **Window-Function**
  The line signal data to be transferred can be restricted to a defined section of the line sensor.
- The **Gains or Offsets** for all four AD-converter channels can be **adjusted simultaneously**, simplifying handling.
- **Integrated Temperature Sensor**

Accessories

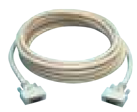
Power supply unit PS051515

Input: 100-240 VAC, 0.8 A, 50/60 Hz
IEC 60320 C14 coupler (for IEC C13 power cord)
Output: +5 VDC, 2.5 A / +15 VDC, 0.5 A / -15 VDC, 0.3 A
Cable length: 1 m, with Lumberg connector KV60, female 6-pin

PS051515 — Order Code

Power cord IEC 60320 C13, 1.5 m, 10 A, 250 VAC

PC150DE — Order Code
DE = Europe / US = USA, Canada, Japan / UK = United Kingdom



Control cable SK9018...

26-pin shielded cable, both ends with mini-ribbon connector (male 26-pin)

SK9018.x-MM — Order Code
MM = connector both ends male
cable length 3 / 5 m or
length according to choice, max. 10 m

Power cable SK9015.x

for GigE Vision^{TM}, CameraLink and externally supplied USB 3 line scan cameras.

Shielded cable with Hirose plug HR10A, female 6-pin (camera side), and Lumberg SV60, male 6-pin connector (power supply unit side).

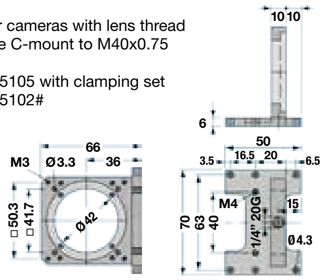
SK9015.x — Order Code
cable length 0.2 / 1.5 m

M1 Mounting Bracket SK5105

Order Code
SK5105

For cameras with lens thread size C-mount to M40x0.75

SK5105 with clamping set SK5102#



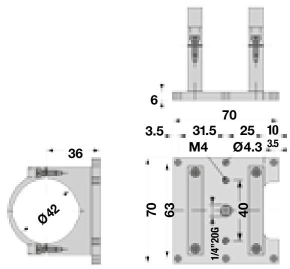
MC1 Clamping Set SK5102

Order Code
SK5102
(set of 4 pcs.)

M3 Mounting System SK5105-2

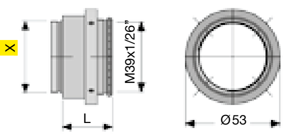
Order Code
SK5105-2

For camera configurations with tube length > 55 mm using extension rings **ZR**



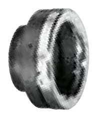
FA1 Focus adapter FA22...

FA22-x — Order Code
42 = M42 x 1
40 = M40 x 0.75
39 = M39 x 1/26"
32 = M32 x 0.75
C = C-Mount
length L: 22 ... 32 mm



A3 Lens Adapter F-Mount

for line scan cameras with case type **Axx** or **BGx**.



AOC-F-... — Order Code

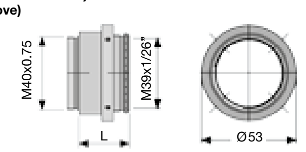
Attachment thread:
45 = M45x0.75
40 = M40x0.75
32 = M32x0.75
C = C-Mount 1"-32-TP

FA2 Focus adapter L-Mount (M39x1/26" Leica)

any rotation angle adjustable (V-groove)
attachement thread M40x0.75, male

FA22R-40 — Order Code
length L: 28 ... 38 mm

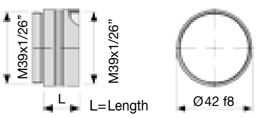
FA22RL-40 — Order Code
length L: 35 ... 45 mm



ZR Extension rings L-Mount (M39x1/26" Leica)

attachment threads M39x1/26" male/female

ZR 10 — Order Code
10 = Length 10 mm
15 = Length 15 mm
20 = Length 20 mm
50 = Length 50 mm



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