HOMMEL _WERKE

Operating Instructions

COLORLINE-1728

Colinear CCD Color Line Scan Camera

Version E-00 / 21/11/02

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1 General

Mechanical and Electronic Interfaces

The Color Line Scan Camera COLORLINE-1728 for industrial image processing is a robust and simple construction in a stable stainless-steel case.
The cameras are fitted with a NIKON bayonet lens mount for small format lenses.
The camera's electronic interfaces are equipped with differential transmitter and receiver chips of the LVDS EIA-644 generation. They are most highly compatible with standardized RS422 interfaces.

2 Available Accessories

50.06.05 Connection cable COLORLINE-1728 to frame grabber
Type i2S Land of Vision – Horizon 4LC
Combined interface and data cable in HF radiation-proof design,
(power lines integrated)
100 Ohm wave impedance, cable length 5m
(other lengths available on request)

50.09.05 Connection cable COLORLINE-1728 to frame grabber
Model: ELTEC - p3i_DIG
Combined interface and data cable in HF radiation-proof design,
(power lines integrated)
100 Ohm wave impedance, cable length 5m
(other lengths available on request)

50.04.05 Connection cable COLORLINE-1728 to frame grabber
Model: MIKROTRON - Inspecta-4D
Combined interface and data cable in HF radiation-proof design,
(power lines integrated)
100 Ohm wave impedance, cable length 5m
(other lengths available on request)

50.02.10 CAM – Power Assembly set
Printed circuit board for slot assembly. For easy connection of the
PC power supply (12V) to the CAM interface cable.

50.02.05 Power supply connection cable in HF radiation-proof design,
Cable length 5m (other lengths available on request),
Already fitted to the camera, other end free.

50.03.05 Incremental encoder connection cable in HF radiation-proof design,
Cable length 5m (other lengths available on request),
Already fitted to the camera, other end free.

50.05.05 Frame start connection cable in HF radiation-proof design,
Cable length 5m (other lengths available on request),
Already fitted to the camera, other end free.

3 Description

The cameras in the COLORLINE series are compact, robust industrial line scan cameras with a powerful range of features. Even at the maximum data rate, the ambient temperature of the camera can equate to 45°C. This enables use in very hot production environments.
The heart of the camera is the CCD color line sensor, which impresses through its extreme sensitivity, linearity and color-stability. With this sensor chip, the color pixels are not arranged in 3 adjacently staggered sensor lines, but in a row, which results in a pixel series of R(ed), G(reen) and B(lue) in the following order RGBRGBR..... .
For industrial applications, this single-line arrangement often demonstrates advantages compared to three-line technology. In these applications, the object to be scanned is seldom moved with a constant velocity. Color line scan cameras with three sensor lines (RGB) arranged side by side require an external synchronization logic to overlap the three color lines. In case of varying velocities, this problem can only be solved with big expenditure or not at all (sorting objects in free-fall). The color line scan camera COLORLINE does not have this important disadvantage, since its pixels are arranged sequentially in one single line.
The camera electronics automatically correct the temperature-specific drift of the offset level (black level) independent of the integration time and data rate. Additional computer-based offset correction is not required therefore.
One particular highlight that is worth mentioning is that process trigger signals, for instance, from an incremental encoder for the line start, or from an initiator for the frame start, can be connected directly to the COLORLINE-1728. The encoder is supplied with a corresponding supply of electricity direct from the camera. Therefore, cabling for the system is kept at a minimum, because, as a rule, all components are available on the production line.
The camera merely needs a single supply 12V power unit since the current required for operation is generated in the camera via corresponding DC-DC converters. Some frame grabbers supply +12V DC current from the computer on their interface plugs. This allows the electricity for the camera to be supplied via the data and interface cable. If the grabber does not provide electricity, the 4-pin power plug on the rear of the camera can be used.

4 Camera Electronics

The camera outputs the three color channels serially to the interface plug as 8 Bit data words. The color channels are multiplexed internally in the camera. If valid data is displayed to the frame grabber using the LineValid Signal (LVAL), the first data word belongs to the red color channel. This is followed by the green channel, and the third data word follows in the form of the blue channel. This sequence (R_G_B_R_G_B_R) now repeats itself until all pixels (3 x 1728 = 5184) are read out.
By setting the gain in the red and green color channel color adjustment can easily be carried out. Both of these channels are also equipped with an offset controller which should also be reset after altering the gain (black adjustment). This allows the camera to be optimally adjusted to various lighting and object conditions.

5 Application Examples

The color line scan camera COLORLINE-1728 is a multi-purpose device.

- Surface testing
- Color classification
- Process control
- Document scanning
- Checking labels and markings
- OCR
- Photographic reproduction

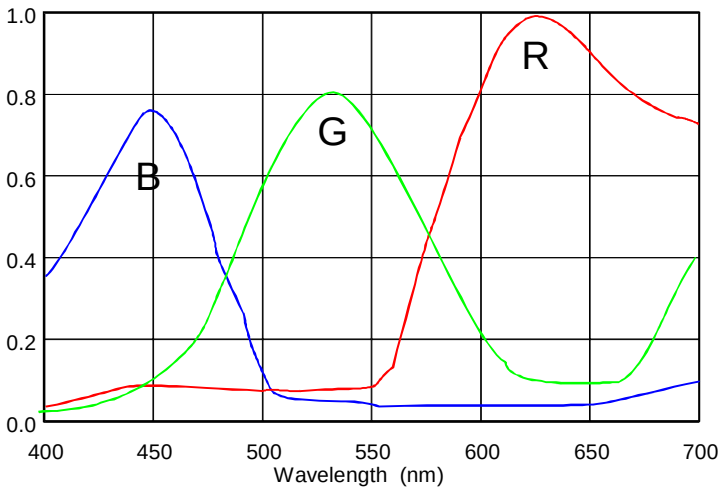
6 Adjustment and Calibration

Adjustment

The camera is adjusted and calibrated in the factory. The sensor chip is adjusted concentrically to the optical axis.
The mechanical reference surfaces are the external mounting and application planes with the fixing threads. This allows for reproducible mounting of the camera.

7 Sensor Sensitivity

The sensitivity of the sensor is given in Diagram 1 up to a wavelength of 700 nm.



7.1 Diagram 1: Sensor sensitivity

8 Description of the Camera's Control Inputs

8.1 Pseudo shutter

Since the sensor chip has an electronic shutter, the COLORLINE-1728 is equipped with a pseudo shutter. This means that despite a fluctuating line start frequency, a constant integration time is achieved. This is, of course, only possible at the expense of the maximum line frequency. If the pseudo shutter is activated, the maximum potential scan rate is reduced by 50 per cent. For applications where the maximum scan frequency is required , the pseudo shutter can be deactivated, and the integration time lasts from the line start signal to the next line start signal.

The consequence of this is that this additional pseudo shutter feature heavily influences the camera's basic method of functioning. Please make sure that the integration timer code switch is set to the correct operating mode.

Pseudo shutter on	code switch integration timer not to pos. "0"
The pseudo shutter off	code switch integration timer to pos. "0"

8.2 EXSYNC (External Line Start)

The required operating mode is defined on the "EXSYNC" input on the interface. If the Exsync input is not periodically pulsed, and no incremental encoder is connected, the camera switches over to free-processing mode after a watchdog time of 420 ms. This means that the line start is performed independently by the camera according to the integration codes switch setting.
By applying a dynamic start signal (Exsync) the line start is started by the signal's negative edge. The low state of the EXSYNC signal that now follows represents the integration time (exposure time). If the Exsync signal returns to high after the integration time has culminated, the read out phase begins from the positive Exsync edge according to 84 x PVAL. The Line Valid Signal (LVAL) goes to high, and 5184 pixels can now be latched to the interface with the Pixel Valid Signal (PVAL) serially beginning with R - G - B as respective 8 bit deep color value information.
Default setting: If the EXSYNC input on the interface is not connected, and no incremental encoder is connected, the camera automatically switches to free-processing mode.

8.3 Mode

The camera can be operated with two master clock frequencies. Either the master clock signal (MCLK) on the interface is supplied by a frame grabber, or the camera electronics run with the "internal" master clock oscillator (24 MHz). In this operating mode, the camera produces a serial RGB pixel clock frequency (PCLK) of 9 MHz. The interrelationship between master clock and pixel clock is described in the following formula.

$$PCLK = \frac{MCLK * 3}{8} \qquad PCLK = \frac{24\ Mhz * 3}{8} = 9\ Mhz$$

If the master clock is supplied by the frame grabber, please ensure that the frequency of the required pixel clock is appropriately set to the grabber according to the formula given below. If, for instance, 6 MHz pixel clock is wanted, the grabber must supply 16 MHz (maximum: 24 MHz).

$$MCLK = \frac{PCLK * 8}{3} \qquad MCLK = \frac{6\ Mhz * 8}{3} = 16\ MHZ$$

The selection of the required master clock is defined on the MODE input on the interface.

Low ⇒ external master clock active	frame grabber supplies MCLK
High⇒ internal master clock active	camera generates 9 MHz PVAL

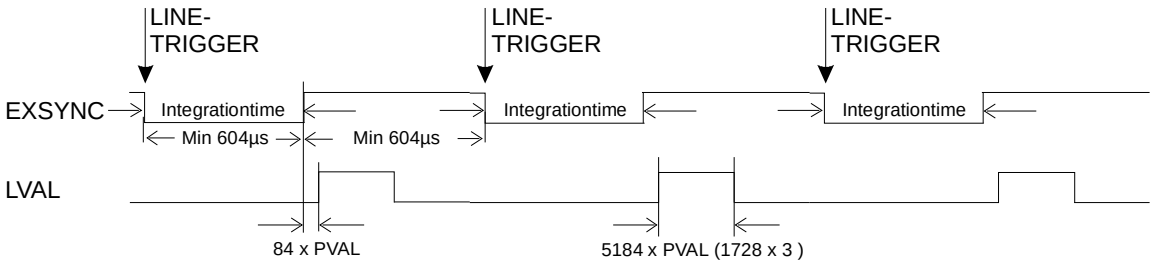
Default setting: If the MODE input on the interface is not connected, the camera automatically selects the camera-internal clock.

9 Possible Line Scan Camera Operating Modes

The camera can be operated in five different modes.
The individuals modes are described in the following along with their time diagrams.

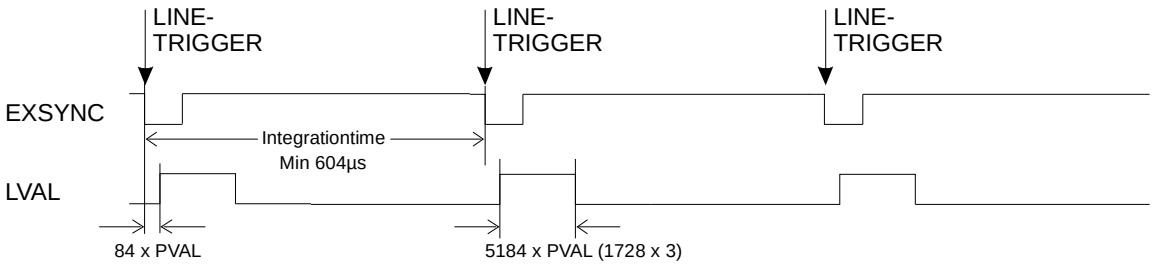
9.1 EXSYNC - Mode 1 - Frame grabber controls camera and code switch integration timer not to pos. "0"

The line start is triggered by the frame grabber with falling edge of the Exsync signal. The programmable low state of the signal is the integration time. The rising edge of the Exsync signal triggers a read out phase. After a camera-internal delay of 84 x PVAL, the LINE VALID signal goes to High and remains there for 5184 PVAL (3 x 1728 - R G B)
Maximum line frequency: 827 Hz
Please make sure that both the Exsync signal high state and the low state last at least 604µs.



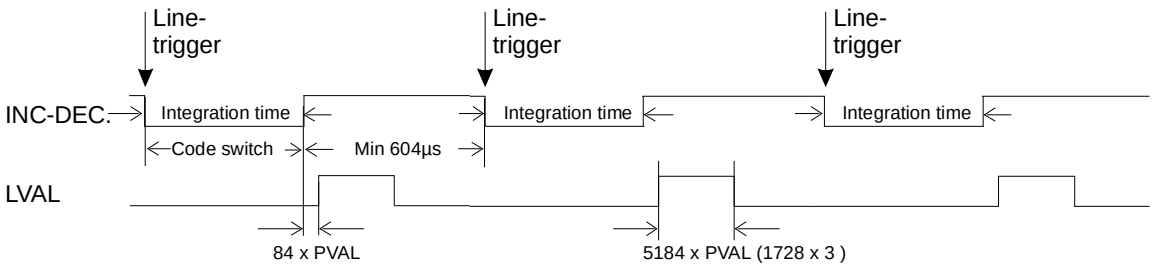
9.2 EXSYNC - Mode 2 - Frame grabber controls camera and code switch integration timer to pos. "0"

The line start is triggered by the frame grabber with the falling edge of the Exsync signal. The integration time is the time until the next falling edge of the Exsync signals.
Maximum line frequency: 1.65 kHz
Please make sure that the Exsync signal's falling edges have a minimum pitch of 604µs to ensure reliable operation.



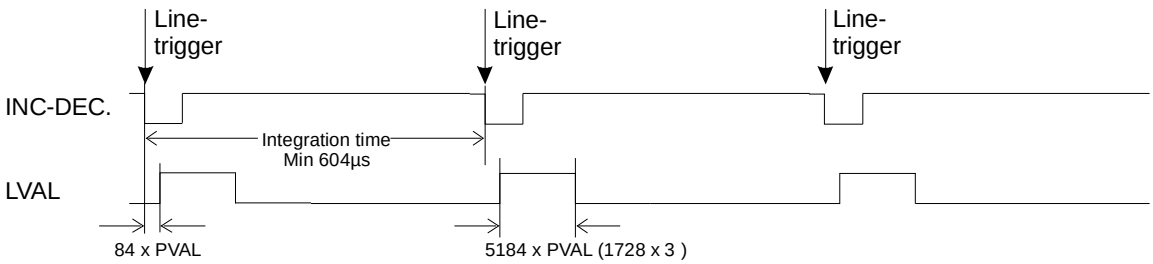
9.3 Incremental encoder controls camera - Mode 1

A rotary input type encoder is connected directly to the camera
and code switch integration timer not to pos. "0"
The line start is triggered by the rotary input type encoder with the falling edge. The integration time is generated by the camera-internal integration timer depending on the code switch setting. A read out phase is initiated after the integration time has culminated. After a camera-internal delay of 84 x PVAL, the LINE VALID signal goes to High and remains there for 5184 PVAL (3 x 1728 - R G B)
Maximum line frequency: 827 Hz
Please make sure that the incremental encoder trigger impulses maintain a minimum pitch of "set integration time + 604µs" to ensure reliable operation.



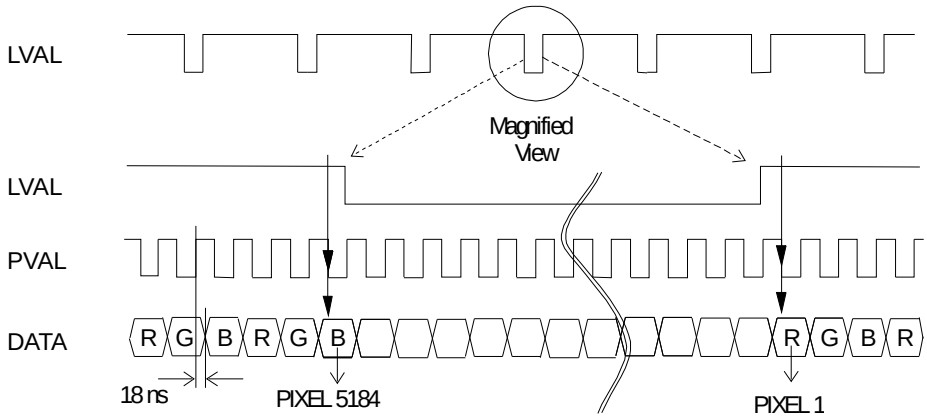
9.4 Incremental encoder controls camera - Mode 2

A rotary input type encoder is connected directly to the camera
and code switch integration timer to pos. "0"
The line start is triggered by the rotary input type encoder with the falling edge. The integration time is the time until the next falling edge of the rotary input type encoder. The Integration time integration time is generated by the camera-internal integration timer depending on the code switch setting. A read out phase is initiated after the integration time has culminated. After a camera-internal delay of 84 x PVAL, the LINE VALID signal goes to High and remains there for 5184 PVAL (3 x 1728 - R G B)
Maximum line frequency: 1.65 kHz
Please make sure that the rotary input type encoder falling edges have a minimum pitch of 605µs to ensure reliable operation.



9.5 Free-processing operation

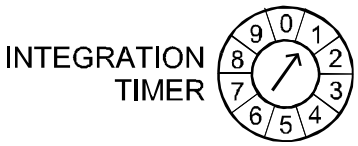
The line scan camera automatically switches into free-processing operation when no edges are detected on the EXSYNC input for a period of 420 ms and no incremental encoder is connected. It is irrelevant whether the grabber allows the EXSYNC output to remain at static low or high.
Another possibility is to leave EXSYNC open as a camera input. The camera then switches to free-processing operation on its own. It then generates scan rates which are independent of the integrations timer's BCD-code switch setting. The integration times in free-processing operation can be referenced from the table in Chapter 9.6. The valid pixel data is displayed with the Line Valid Signal (LVAL) high state. The pixel data transfer takes place with the Pixel Valid Signal (PVAL). With a delay of 18 ns to the positive edge, the data exchange takes place on the interface. The data can be adopted reliably with the negative edge.

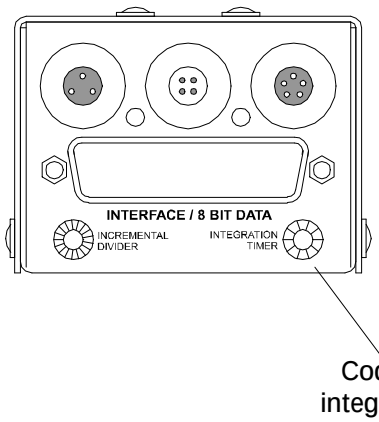


9.6 Integration time table for free-processing operation

If the COLORLINE-1728 is not controlled via the EXSYNC input and no incremental encoder is connected, the camera switches to free-processing operation.
The integration time in this operational mode then needs to be set using the "integration timer" code switch. If, for instance, the code switch arrow position is set to "0", the camera generates its maximum line frequency of 1.65 5 kHz.
In this operational mode, the pixel clock (PCLK) is always 9 MHz. As a result of this, the read out phase Line Valid High State (LVAL) is always 576 µs and the Low State the remaining time specific to the integration times listed in the table.

Arrow position	Integration time	Line frequency
0	604µs	1.65 kHz
1	733µs	1.36 kHz
2	917µs	1.09 kHz
3	1.14ms	877 Hz
4	1.43ms	700 Hz
5	1.79ms	558 Hz
6	2.24ms	446 Hz
7	2.79ms	358 Hz
8	3.49ms	286 Hz
9	4.36ms	229 Hz





Incremental encoder directly connected to the camera

The COLORLINE-1728 is designed so that an incremental encoder can be connected directly to the camera. The encoder has a +5V current supplied directly from the camera via a 500mA fuse. The fuse is located in the camera on the mainboard.
When the encoder plug in plugged into the 5-pin socket the camera logic switches to the internal integration timer. Please make sure that pin 4 (Set_Ink) in the 5-pin socket in the connection plug is bridged to pin 5 (0VD). The switch over only takes place when pin 4 is connected to 0VD. The control signal EXSYNC with which the grabber normally controls the camera is put out of action in this operational mode.
The symmetrical (RS 422) incremental encoder signals are terminated by the camera with 100 Ohm resistance values, and integrated symmetrically with RS 422 receivers across a settable prescaler in the camera controller.
If, for instance, the "INCREMENTAL DIVIDER" code switch arrow is set to "0", each incremental encoder edge activates an integration and read out phase. In arrow position "5", only every 6th negative edge effects a line start. This means that the scan density on the test piece can be directly influenced in the camera through the integrated prescaler.
The integration time required is set using the "integration timer" code switch. If, for instance, the "INCREMENTAL DIVIDER" code switch arrow is set to "1", the integration time is 733µs.
In pseudo shutter mode (code switch for integration time set to "not zero", please make sure that the incremental encoder trigger impulses have a minimum pitch of

"set integration time + 604 µs"

to ensure safe operation.

If the pseudo shutter mode is deactivated (code switch for integration time set to "zero"), please make sure that the incremental encoder trigger impulses have a minimum pitch of

604µs

to ensure reliable operation.
If retriggering takes place earlier, timing is no longer coordinated, and a malfunction occurs when transferring the data to the framegrabber.

10 Code Switch Tables

10.1 The incremental encoder prescaler

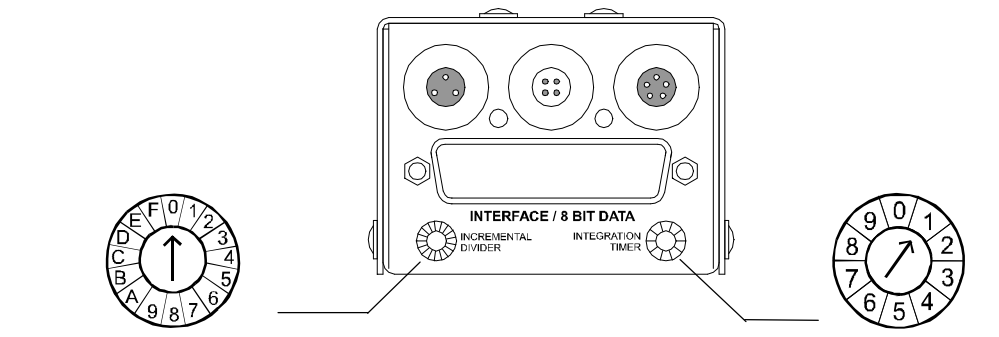
Code switch table for the incremental encoder prescaler

Arrow position	Scaler factor	Arrow position	Scaler factor
0	1	8	9
1	2	9	10
2	3	A	11
3	4	B	12
4	5	C	13
5	6	D	14
6	7	E	15
7	8	F	16

10.2 Integration timer

Code switch table for the integration timer

Arrow position	Integration time	Arrow position	Integration time
0	604µs	5	1.79ms
1	733µs	6	2.24ms
2	917µs	7	2.79ms
3	1.14ms	8	3.49ms
4	1.43ms	9	4.36ms



Code switch incremental encoder prescaler

Code switch integration time

11 Incremental Encoder Connection Cable

The following is an example for the connection of an Heidenhain incremental encoder to the
COLORLINE-1728.
The 12-pin Heidenhain round plug is soldered to the cable already fitted to the camera with the Opti-Sens purchase order no. 50.03.05 according to the following
connection diagram.

NB: In addition, in the Heidenhain plug a bridge from pin 2 (white) to pin 12 and from pin 11 (gray) to pin 10 (blue) needs to be soldered.

COLORLINE-1728					INCREMENTAL ENCODER
PIN	Color	Signal		Color	PIN
1	White	+5VD		White	2 plus bridge to 12
2	Brown	- UA 1		Brown	6
3	Black	+ UA 1		Black	5
4	Blue	Set_Ink		Blue	10
5	Grey	0VD		Grey	11 plus bridge to 10
Casing	Shield			Shield	Casing

12 Frame start Initiator Connected Directly to the Camera

The COLORLINE-1728 allows you to directly connect various initiators to the camera. Thus, for example, an induction hood proximity switch of the type NPN or PNP can be directly connected via pre-assembled industrial cables of varying lengths.
The encoder has a +12V current supplied directly from the camera via a 350mA fuse. The fuse is located in the camera on the mainboard.
From an electrical point of view, the initiator does not initiate any triggering in the camera electronics. The unsymmetrical initiator signal is merely converted into a symmetrical RS 644 LVDS signal and applied to the interface data plug. This simplifies the system cabling since the frame start signal is also transmitted along the same cable as the data and control signals.

13 Gain Control and Gamma Features

Via two control bits, three different gains and a gamma correction can be programmed on the COLORLINE-1728. The control bits are TTL-compatible inputs on the camera interface plug.
As a rule, frame grabbers are equipped with programmable
I/O channels on their camera interfaces which can be used for the simple control of the camera gain.
The bit constellations can be sourced from the following truth table.

Function	BIT 0 (PIN 21)	BIT 1 (PIN 32)
GAMMA	0	0
GAIN = 1	1	0
GAIN = 2	0	1
GAIN = 4	1	1

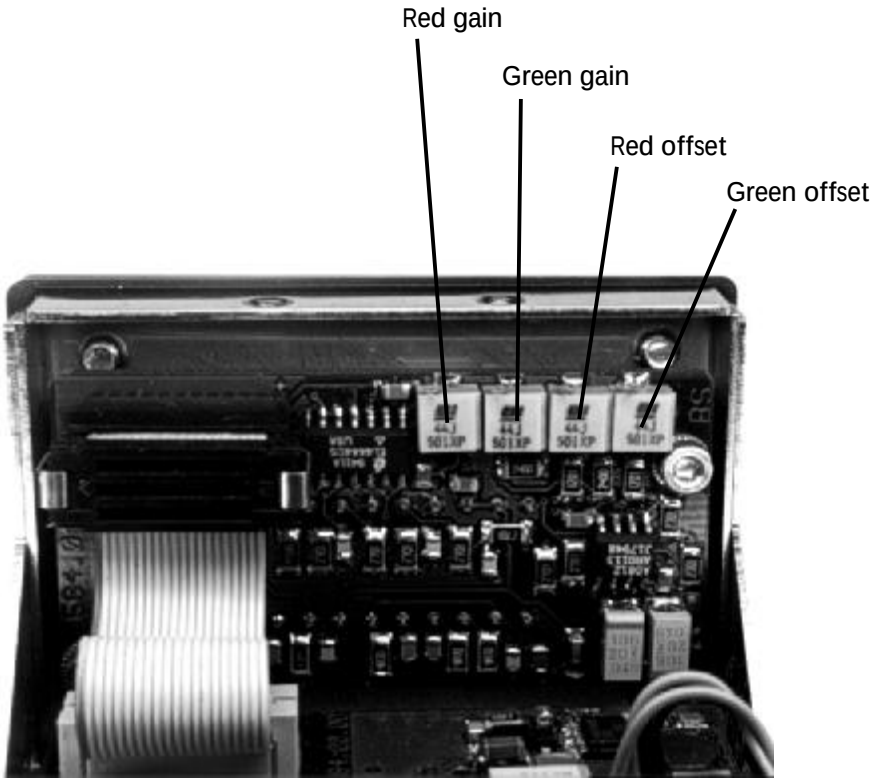
Gain truth table

Default setting: If the gain control inputs on the interface are not connected, the camera selects Gain = 1!

Attention: The internal camera factory settings for color adjustment (white adjustment) is performed at gain = 1 and at maximum pixel clock velocity (MCLK internal = 24 MHz). If a different gain than 1 is used, the darkness level of the red and green color channel needs to be reset using the appropriate offset controllers. This also applies if a lower MCLK is fed in externally from the frame grabber.
Refer to chapter 14.1

14 Color Adjustment for the COLORLINE-1728

White adjustment is carried out for each camera in the factory.
For particular applications however, it is necessary to run the camera using calibrations which deviate from those set in the factory. For this purpose, the COLORLINE-1728 allows you to calibrate the red and the green color channel in the gain and offset to the blue channel or corresponding to the application.
It is to be observed here that with a recalibration of the gain in the offset red and green channel (black adjustment) the corresponding channel also needs to be reset.
The camera has to be dimmed to carry out black adjustment. Using the appropriate potentiometer, the channel is now set to + 1 to +2 digits above zero. Since there is a slight influence of the gain and offset controller in relation to one another, it is necessary to repeat gain and offset calibration alternately.



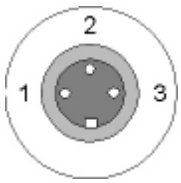
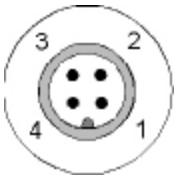
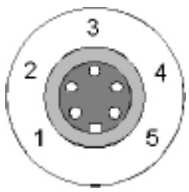
14.1 Adjustment procedure

(using the red color channel as an example)

1.) Using the red gain controller, set the desired level for the red channel.
2.) Dim the camera and adjust the level of darkness by +1 to +2 digits using the red offset controller.
3.) Apply the scene to be calibrated to the camera once more and check the previously set level and, if necessary, reset using the red gain controller.
4.) Dim the camera again and check the level of darkness using the red offset controller and, if necessary, adjust by +1 to +2 digits.
After one or two repetitions, the new calibration for the red color channel is finished.

15 Pin Assignment Plans

15.1 Frame start - power - and incremental ports

Port for frame start initiator			Port for operating voltage			Port for incremental encoder		
								
Pin	Signal	IN/OUT	Pin	Signal	IN/OUT	Pin	Signal	IN/OUT
1	0V	O	1	+12V	i	1	+5V	O
2	Encoder signal	I	2	+12V	I	2	-Ua1	I
3	+12V	O	3	0V	I	3	+Ua1	I
			4	0V	I	4	Set_Ink	I
						5	0V	O

15.2 Interface HD 44: female - signals listed in pairs

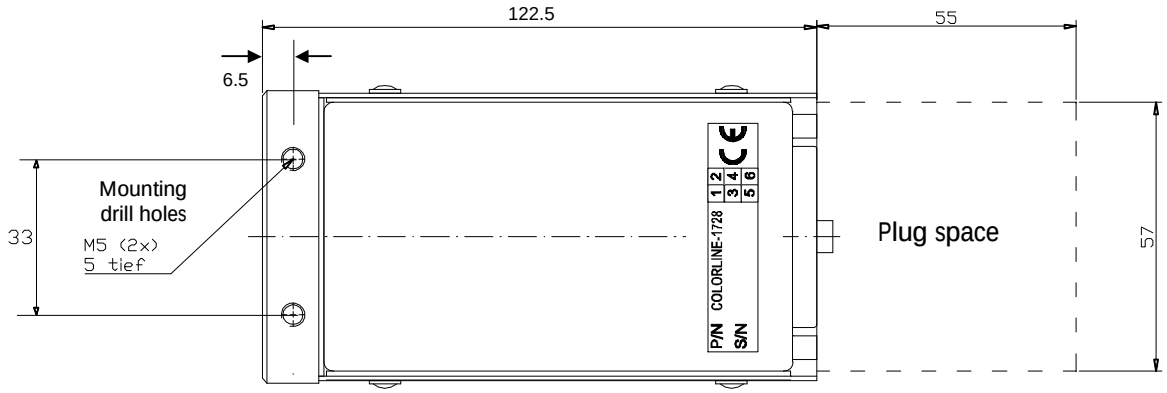
Pin	Signal	Pin	Signal
40	+ D0	20	OVD
39	- D0	36	+ Frame trigger
12	+ D1	35	- Frame trigger
11	- D1	34	- MCLK
27	+ D2	33	+ MCLK
26	- D2	4	+ MCLK mode: INT/EXT
42	+ D3	3	- MCLK mode: INT/EXT
41	- D3	19	+ EXSYNC
14	+ D4	18	- EXSYNC
13	- D4	2	+ Future use input
29	+ D5	1	- Future use input
28	- D5	21	Bit gain-0 TTL
44	+ D6	32	Bit gain-1 TTL
43	- D6	17	NC
15	+ D7	16	NC
30	- D7	37	NC
10	+ Lval	38	NC
9	- Lval	31	NC
25	+ Pval	8	+12V IN POWER
24	- Pval	23	+12V IN POWER
6	OVD	7	0V IN POWER
5	OVD	22	0V IN POWER

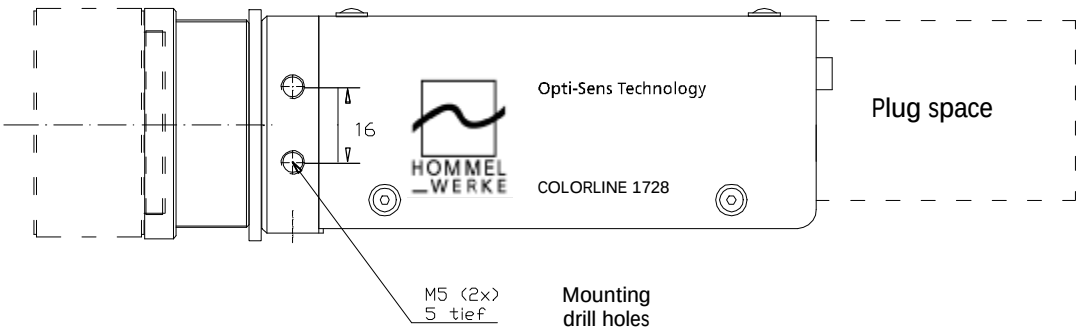
15.3 Interface HD 44: female - signals listed according to ascending pin no.

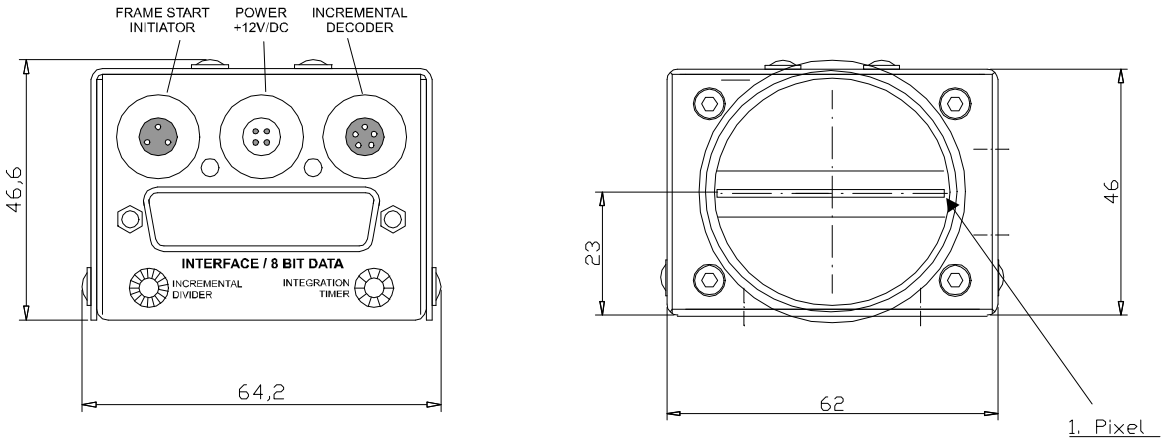
Pin		Signal	Pin		Signal
1	-	Future use input	23		+12V IN POWER
2	+	Future use input	24	-	Pval
3	-	MCLK mode: int/ext	25	+	Pval
4	+	MCLK mode: int/ext	26	-	D2
5		OVD	27	+	D2
6		OVD	28	-	D5
7		0V IN POWER	29	+	D5
8		+12V IN POWER	30	-	D7
9	-	Lval	31		NC
10	+	Lval	32		Bit Gain-1 TTL
11	-	D1	33	+	MCLK
12	+	D1	34	-	MCLK
13	-	D4	35	-	Frame trigger
14	+	D4	36	+	Frame trigger
15	+	D7	37		NC
16		NC	38		NC
17		NC	39	-	D0
18	-	EXSYNC	40	+	D0
19	+	EXSYNC	41	-	D3
20		OVD	42	+	D3
21		Bit gain-0 TTL	43	-	D6
22		0V IN POWER	44	+	D6

16 Camera Dimensions and Assembly

When mounting the camera, please make sure that is it insulated. This means that the camera casing should not be connected to the machine bed electrically. Grounding for the camera takes place over the connection cable from the grabber (PC) to the camera. This prevents interference caused by ground loops which may significantly impair signal quality.







17 Technical Data

Sensor		Timing	
Pixel geometry	7µm x 21µm	Pixel frequency	9 Mhz.
Number of pixels	5184 (3 x 1728)	Line frequency: free run	1.65 KHz max.
active length of the sensor line	36.288 mm	External start frequency	1.60 KHz max.
Sensitivity	R 3.7V/(lx*s)	G 5.7V/(lx*s)	B 2.27V/(lx*s)

Electronics		
Inputs HD SUB 44	Selection MCLK INT/EXT Static low equivalent to Static high equivalent to	RS 644 LVDS master clock grabber active master clock camera active
	Master clock external (MCLK)	RS 644 LVDS
	External line start (EXSYNC) including shutter function Falling edge triggers the Low state corresponds to	RS 644 LVDS line start integration time
	Gain control	2 TTL control bits
Optional	Shutter (integration control) High Low	RS 644 LVDS integration time pixel reset
Inputs Initiator socket: 3-pin	Frame start PNP or NPN initiators 10V-30V DC models	low ~ 0.5V - high ~ +12V
Incremental socket: 5-pin	Line start over incremental encoder +5V supplied to encoder	RS 644 or RS 422
Power socket: 4-pin	Operating voltage	+12V-DC ± 10% ~ 350mA
Outputs HD SUB 44	PIXEL VALID (PVAL)	RS 644 LVDS
	LINE VALID (LVAL)	RS 644 LVDS
	R-G-B serial VIDEO DATA 8 BIT	RS 644 LVDS
	FRAME START	RS 644 LVDS
Power consumption	including supply power for incremental encoder and initiator	4.2 W
Operating temperature		0° C - 45° C
Max. humidity	non-condensing	90%
Camera weight without lens		430 gr.
Lens	Lens mount	NIKON bayonet

Subject to change without notice 7/2002

18 Maintenance

The glass surfaces of the lenses and the sensor line may not be touched and may not come into contact with other objects.

A dusty glass surface is best cleaned with dry compressed air. If dust should stick because of static electrical charges, we recommend to use ionized air.

A smeared glass surface is cleaned with a wad soaked with ethyl alcohol.

Caution: Do not scratch glass surfaces!

If the camera is not used, it should be kept protected against dust and dirt.

If higher temperature differences arise due to room change, camera and accessories should be pre-heated or pre-cooled, respectively, to prevent dew condensation on the glass surfaces.

19 Guarantee and Warranty Conditions

- The camera may exclusively be screwed by means of the adaptation threads.
- The cables may be connected or disconnected only in switched off state.
- The cables must not be bent.

20 EC Declaration of Conformity

Document No./Month.Year 041/CE COLORLINE-1728 /07.2002

Manufacturer
Address

Opti-Sens Technology

August-Borsig-Str. 13
D-78467 Konstanz

Product name: CCD Color Line Scan Camera

The product referred to complies with the provisions of the following European directives:

r	RL73/23/EEC	Low Voltage Directives
r	RL89/336/EEC	EMC

Affixing the CE label	07 / 2002
Issuer	see Manufacturer
City, Date	Konstanz, 23.07.2002

Legally binding signature

r This statement does not provide any guarantee of properties.
r The safety instructions supplied with the product information are to be observed.