C5-CS Series

User Manual
for High Speed Laser 3D Sensors

Rev. 1.6
AT - Automation Technology GmbH

Automation Technology
Vision Sensors and Systems

Copyright
© 2019 Automation Technology GmbH
All rights reserved. No part of this document shall be reproduced, stored in a retrieval system, or transmitted by any means, electronic, mechanical, photocopying, recording, or otherwise without consent in writing from the owners, AT-Automation Technology GmbH.

Disclaimer
While care has been exercised in the preparation of this document to ensure that it is fully correct and comprehensive, the owners assume no responsibility for errors or omissions. Neither is any liability assumed for damages resulting from the use of the information contained herein. No license is granted under any patents or patent right of AT – Automation Technology GmbH.

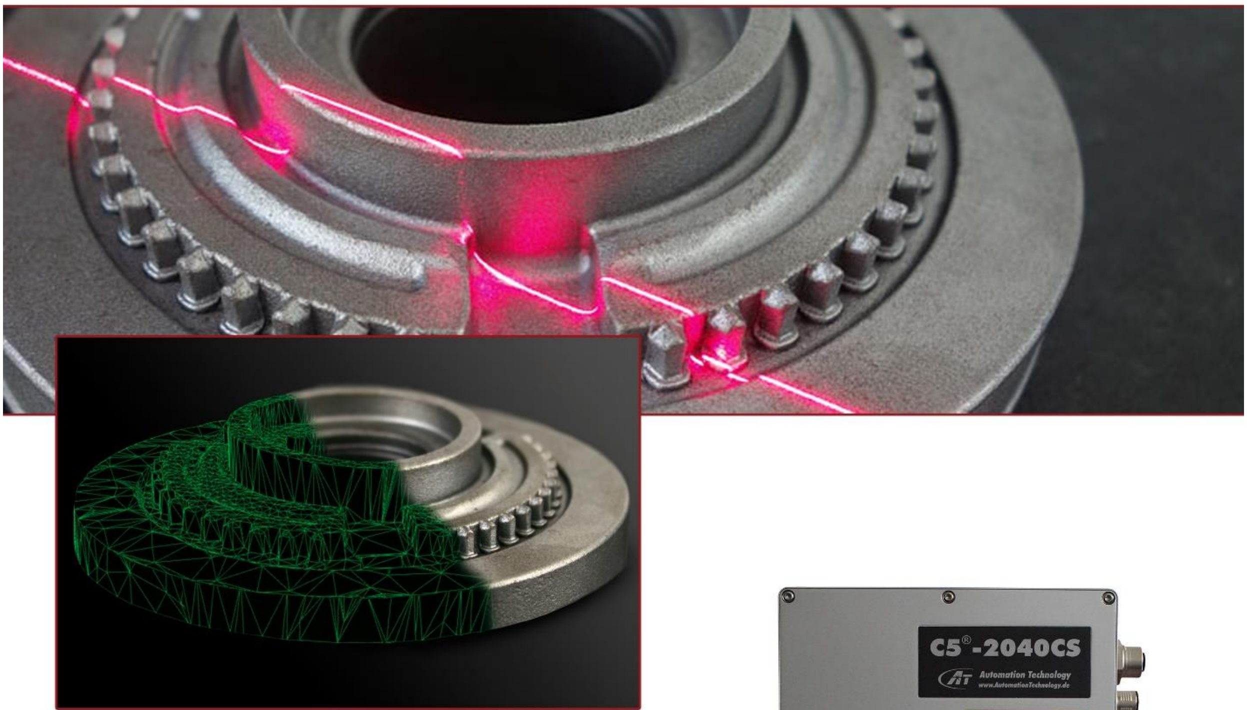
Trademarks
All nationally and internationally recognized trademarks and trade names are hereby acknowledged.
This document is subject to change without notification. All rights reserved.

Table of Contents

C5-CS Series Overview

Introduction

The C5-CS series is a revolutionary product family of intelligent high speed laser triangulation sensors. It is optimised for 3D profile measurement by means of laser triangulation technique. The 3D profile extraction is performed in the sensor by using high performance Field Programmable Gate Array processors. At the same time the 3D profile data is sent to the PC over a Gigabit Ethernet interface (GigE). This extreme data reduction boosts the measuring speed to unprecedented levels without affecting the performance of the connected image processing unit.



The C5-CS Series General Specifications

Sensor Controls	
Synchronization Modes	Free Running, Triggered, Software Triggered
Exposure Modes	Programmable, Pulse Controlled
Shutter Modes	Global Shutter
Digital Input	2 electrical isolated inputs, +5V to +24V DC VIL, logic “0” Voltage < 1.5V VIH, logic “1” Voltage > 3.5V Max. frequency: 450 kHz Min. pulse width: >2µs
Digital Output	2 electrical isolated outputs, +5 to +24V DC VOL, logic “0” Voltage < 0.5V VOH, logic “1” Voltage ≥ 3.8V IOL, logic “0” drive current max. 100 mA IOH, logic “1” drive current max. 100 mA
Encoder/Resolver Input	A+,A-, B+,B-, Z+, Z- High-Speed Triple RS-422 Receiver Max. input voltage +5V DC (TTL level) RS-422-Mode, max. frequency: 15 MHz Min. pulse width: >32ns
Laser Supply	Reverse voltage protection Supply voltage +5V to +24V DC Laser modulation
Sensor Features	
High Dynamic Range Imaging	Multiple Slope, Multi-Frame Readout
3D-Algorithms	MAX, TRSH, COG, FIR PEAK
3D-Scan Features	Automatic AOI-Tracking, Automatic AOI-Search, Multiple AOIs, AutoStart
Electrical Interface	
Power Supply	+10V to +24V DC (max. +27V DC)
Power Consumption	6W to 10W (depending on sensor model)
Operating Temperature	0°C to +50°C (non-condensing)
Output Data Interface	Gigabit Ethernet (IEEE 802.3)
Communication Protocol	GigE Vision with GenICam

Mechanical Interface		
Power Connector	17 pin, M12 connector	
Ethernet Connector	8 pin, A-coded M12 connector	
Mechanical Stress Specification		
Vibration (sinusoidal each axis)	2 g, 20 to 500Hz	IEC 60068-2-6
Vibration (random each axis)	5 g, 5 to 1000Hz	IEC 60068-2-64
Shock (each axis)	15 g	IEC 60068-2-27
Enclosure rating	IP67	IEC 600529

Laser Safety Guideline

The C5-CS series has an integrated laser (Laser = Light Amplification by the Stimulated Emission of Radiation) module, which has to incorporate additional safety features, depending on the applicable laser class.

Laser Safety Classification

The International Electrotechnical Commission (IEC) and the U.S. Center for Devices & Radiological Health (CDRH) enforce strict safety requirements for lasers and laser products.
The relevant standards, IEC 60825–1 (2001-08) and 21 CFR 1040.10/11 (CDRH), classify lasers into several categories. The regulations regarding the different classes applicable to the used laser are given here for the IEC 60825-1 standard.

Laser Categories

The classification of a laser product is based on the laser power measured according to the methods defined by the IEC standard. The classification refers to the wavelength range between 400 nm and 700 nm.
This corresponds to the maximum light power measured through a 7 mm aperture, measured in distances given in the standard. The limitations for the classification of the laser classes are then:

Class 2M:
Class II/2M lasers are visible low power lasers limited to 1 mW continuous wave or more due to the eye blink reflex for emission duration less than 0.25 seconds.
Considered eye-safe with caution, but may present a greater hazard if viewed using collecting optics. Focusing of this light into the eye could cause eye damage. Class II/2M laser products must bear warning and certification labels as shown in the figure below.

This label reprinted here is an example for an IEC classified 2M laser. For detailed specifications observe the label on your sensor.

Class 3R:

Class IIIa/3R lasers emit optical power between 1 to 5 mW. The accessible emission limit is five times higher than for Class 2 visible laser light. Radiation in this class is considered low risk, but potentially hazardous. Fewer manufacturing requirements and control measures for 3R laser users apply than for 3B lasers.

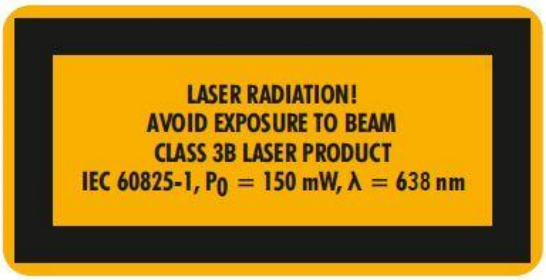
Class IIIa/3R laser products must bear warning and certification labels as shown in the figure below.

This label reprinted here is an example for an IEC classified 3R laser. For detailed specifications observe the label on your sensor.

Class 3B:

Class IIIb/3B lasers are medium power laser sources above 5mW up to 500 mW. Considered dangerous to your retina if exposed. Normally class IIIb/3B lasers will not produce a hazardous diffuse reflection. Viewing into the reflection should not exceed exposure duration more than 10 seconds

Class IIIb/3B laser products must bear warning and certification labels. In addition to the above requirements, the certification for class IIIb/3B laser systems is only given if additional safety requirements are fulfilled and a laser safety officer is named.



This label reprinted here is an example for an IEC classified 3B laser. For detailed specifications observe the label on your sensor.

Laser Responsibilities

Requirement	Class 2M	Class 3R	Class 3B
System Interlock	Not required	Not required	Required
Warning Signs	Not required	Required	Required
Emission Indicator	Not required	Not required	Required
Laser Safety Officer	Not required	Required	Required
Key Control	Not required	Not required	Required – key removal disabled laser
Eyewear Protection	Not required	Not required	Required – under special circumstances
Emission Delay	Not required	Not required	Required
Specular reflection	Not required	Avoid unintended reflections	Avoid unintended reflections
Beam Path Control	Not required	Not required	Required
Beam Attenuator	Not required	Not required	Required
Training	Not required	Required for operator and maintenance personnel	Required for operator and maintenance personnel

The C5-CS Sensor Specifications

Parameters		Sensor Specifications				
Sensor Type		CMOS				
Shutter Type		Global Shutter				
Resolution (Row x Column) in Pixel		1280x1024		1600 / 2048 x 1088	3360 x 2496	4096 x 3072
Sensor ADC Resolution		12 Bit		10 Bit		
Sensor Dynamic Range		90dB with HDR				
Max. Power Consumption		10 W		6 W	8 W	10 W
Max. Profile Rate at Max. Row Width[1]		94700 Hz		25000 Hz	10000 Hz	14500 Hz
Effective Profile Rate (Hz) at Max. Row Width	Number of Rows	Effective Frame / Profile Rate (Hz)				
		1280 Pixel	688 Pixel[2]			
	8	94700	155000	25000	10000	14500
	16	56000	95700	16000	8000	9700
	32	30840	54200	9540	5400	5800
	64	16240	29000	5240	3280	3200
	128	8340	15000	2700	1800	1700
	256	4230	7660	1400	970	900
	512	2130	3870	723	500	450
	1024	1070	1940	358	255	225
	2048	-	-	180[3]	128	113
	3072	-	-	-	-	75

[1] With reduced AOI (AoiHeight = 8)

[2] C5-1280CS-GigE models can reduce the sensor width to increase the profile rate

[3] On request

Temperature Range (Operation/Storage)

Housing temperature during operation:	0°C to +50°C (+32°F to +122°F)
Sensor chip temperature (on-board) during operation:	0°C to +65°C (+32°F to +149°F)
Humidity during operation:	20 % to 80 %, relative, non-condensing
Storage temperature:	-20°C to +80°C (-4°F to +176°F)
Storage humidity:	20 % to 80 %, relative, non-condensing

Temperature and Measurement

The 3D laser sensor will gradually become warmer during the first hour of operation. After one hour of operation, the housing temperature as well as the sensor temperature should be stabilized and no longer increase. Afterwards a reliable and stable 3D measurement is given.

General Guidelines for Heat Dissipation

- Mount the C5-CS sensor to a heat conductive material with an absolute thermal resistance of at least 6 K / W.
- Always monitor the temperature of the sensor (on-board, available over GenICam) and make sure that the temperature does not exceed 65°C.
- Keep in mind that dark current and noise performance for CMOS sensor will degrade at higher temperature.

Model Overview with Measurement Specifications

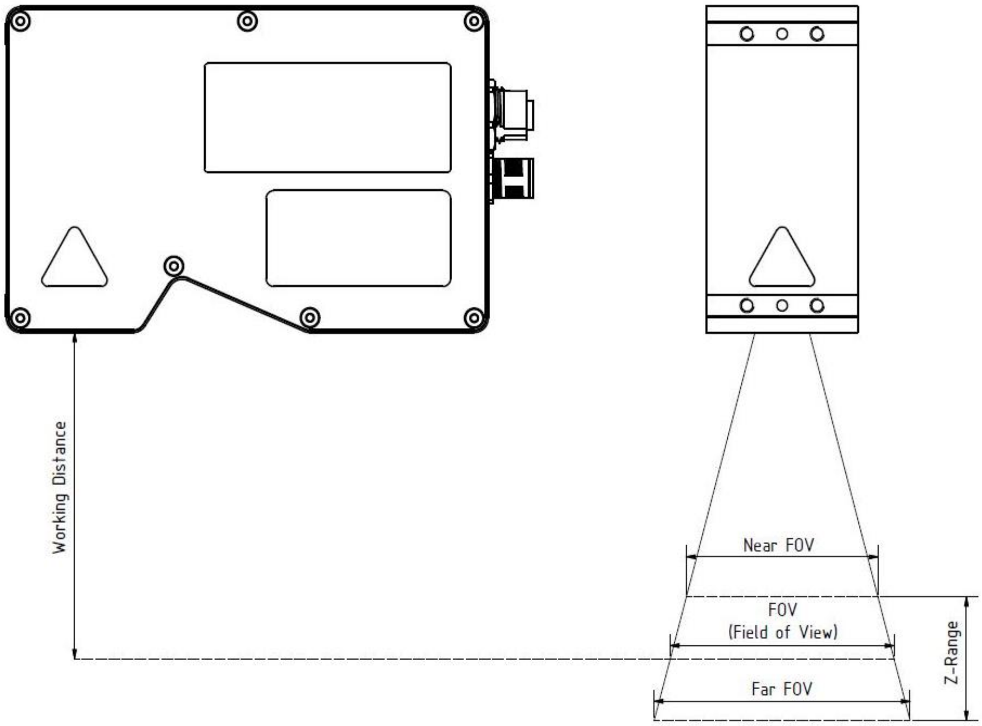
Model Name	X-FOV [mm]	Z-Range [mm]	Working Distance [mm]	Resolution X [µm]	Resolution Z [µm]	Repeat-ability [µm]	Linearity (of Z-Range) [%]	Points per Profile [pixels]	Housing Type
C5-1280CS35-7	7	5.2	31	5.5	0.2	0.2	±0.02	1280	Model 6
C5-1280CS35-12	12	8	31	10	0.2	0.1	±0.02	1280	Model 6
C5-2040CS30-12	12	6	51.5	5.5	0.2	0.2	±0.02	2048	Model 4
C5-1280CS25-20	20	20	72	16	0.5	0.2	±0.02	1280	Model 6
C5-1280CS23-29	29	40	106	23	0.8	0.4	±0.01	1280	Model 1B
C5-1600CS23-30	30	40	106	19	0.7	0.5	±0.01	1600	Model 1A
C5-2040CS23-38	38	40	106	19	0.7	0.5	±0.01	2048	Model 1A
C5-2040CS18-38-2X[1]	38	30	117	19	0.83	0.7	±0.02	2048	Model 5
C5-1280CS21-40	40	46	90	31	1.2	0.4	±0.02	1280	Model 6
C5-1280CS23-47	47	40	106	37	1.4	0.5	±0.01	1280	Model 1B
C5-1600CS23-49	49	40	106	31	1.2	0.7	±0.01	1600	Model 1A
C5-2040CS21-53	53	46	90	26	1.0	0.5	±0.02	2048	Model 6
C5-2040CS23-63	63	40	106	31	1.2	0.7	±0.01	2048	Model 1A
C5-3360CS39-67	67	15	172	20	0.5	0.4	±0.01	3360	Model 3
C5-1280CS23-75	75	40	106	59	2.3	2.0	±0.01	1280	Model 1B
C5-1280CS14-76	76	80	197	59	3.5	1.6	±0.01	1280	Model 1B

[1] Further information can be found in a separate manual

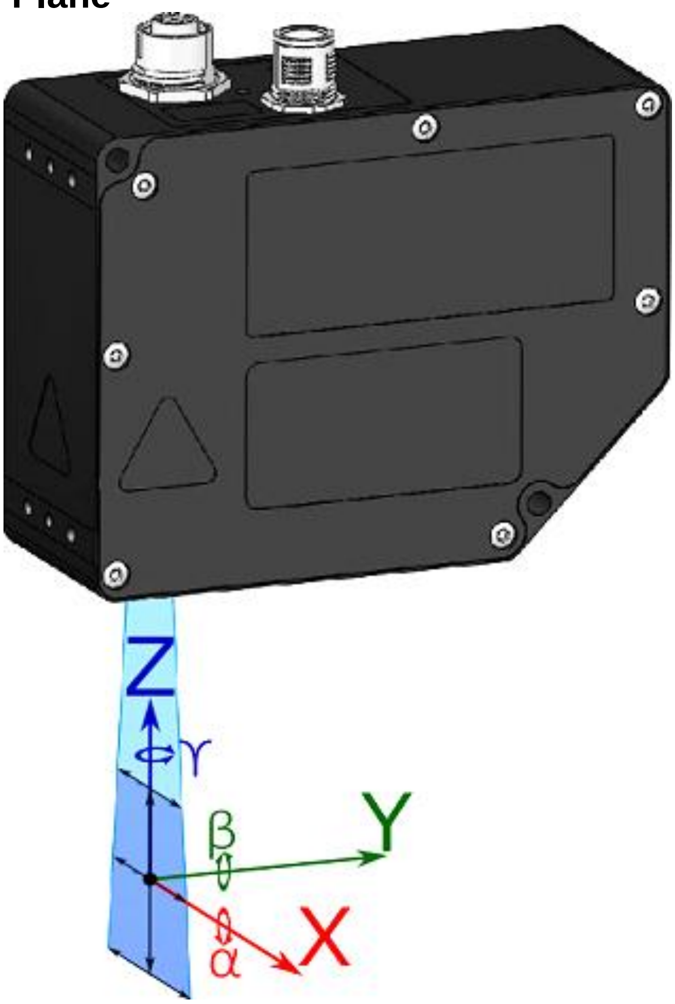
Model Name	X-FOV [mm]	Z-Range [mm]	Working Distance [mm]	Resolution X [µm]	Resolution Z [µm]	Repeat-ability [µm]	Linearity (of Z-Range) [%]	Points per Profile [pixels]	Housing Type
C5-1600CS23-78	78	40	106	49	1.9	1.0	±0.01	1600	Model 1A
C5-4090CS39-82	82	15	172	20	0.5	0.4	±0.01	4096	Model 3
C5-2040CS23-100	100	40	106	49	1.9	1.1	±0.01	2048	Model 1A
C5-2040CS14-100	100	120	197	49	3.0	2.5	±0.01	2048	Model 1B
C5-1280CS14-120	120	120	197	94	5.9	3.7	±0.01	1280	Model 1B
C5-1600CS14-125	125	120	197	78	4.9	3.7	±0.01	1600	Model 1B
C5-4090CS39-145	145	15	172	35	0.9	0.7	±0.01	4096	Model 3
C5-3360CS30-150	150	200	400	45	1.4	1.4	±0.01	3360	Model 2A
C5-2040CS14-160	160	120	197	78	4.9	6.6	±0.01	2048	Model 1B
C5-4090CS30-182	182	250	400	44	1.4	2.1	±0.01	4096	Model 2A
C5-3360CS30-236	236	300	400	70	2.2	1.2	±0.01	3360	Model 2A
C5-3360CS19-248	248	500	700	74	3.5	2.8	±0.01	3360	Model 2B
C5-1280CS30-248	248	300	400	194	6.1	3.1	±0.01	1280	Model 2A
C5-1600CS30-260	260	300	400	163	5.1	2.5	±0.01	1600	Model 2A
C5-4090CS30-288	288	300	400	70	2.2	1.2	±0.01	4096	Model 2A
C5-4090CS19-302	302	500	700	74	3.5	2.8	±0.01	4096	Model 2B
C5-2040CS30-330	330	300	400	161	5.0	2.6	±0.01	2048	Model 2A
C5-3360CS18-402	402	800	744	120	6.0	5.0	±0.01	3360	Model 2B
C5-3360CS30-406	406	300	400	121	3.8	2.2	±0.01	3360	Model 2A
C5-1280CS19-480	480	500	700	375	18	12	±0.01	1280	Model 2B

Model Name	X-FOV [mm]	Z-Range [mm]	Working Distance [mm]	Resolution X [µm]	Resolution Z [µm]	Repeat-ability [µm]	Linearity (of Z-Range) [%]	Points per Profile [pixels]	Housing Type
C5-4090CS18-490	490	800	744	120	6.0	5.0	±0.01	4096	Model 2B
C5-4090CS30-495	495	300	400	121	3.8	2.2	±0.01	4096	Model 2A
C5-1600CS19-500	500	500	700	313	15.0	10.0	±0.01	1600	Model 2B
C5-2040CS19-640	640	500	700	313	15.0	10.0	±0.01	2048	Model 2B
C5-3360CS18-691	691	800	744	206	10.4	8.0	±0.01	3360	Model 2B
C5-1600CS18-795	795	800	744	497	25.1	8.4	±0.01	1600	Model 2B
C5-4090CS18-842	842	800	744	206	10.4	8.0	±0.01	4096	Model 2B
C5-2040CS18-1015	1015	800	744	496	25.1	8.4	±0.01	2048	Model 2B
C5-2040CS15-1200	1200	800	920	586	35.0	10.5	±0.01	2048	Model 2B

Definition Working Distance and Field of View (FOV)

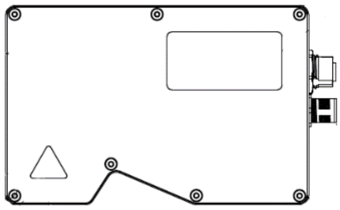
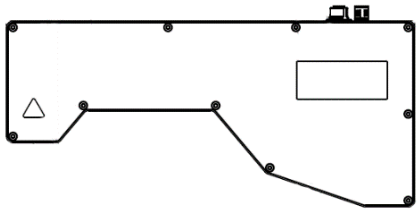
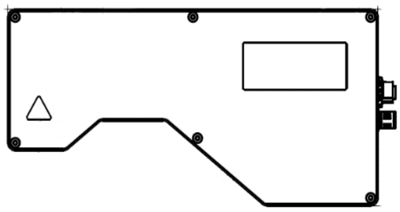
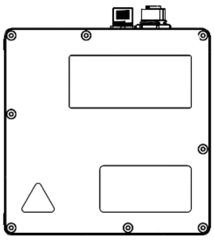
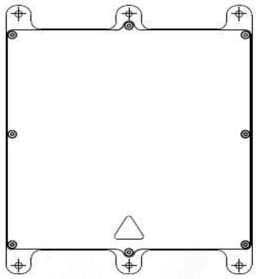
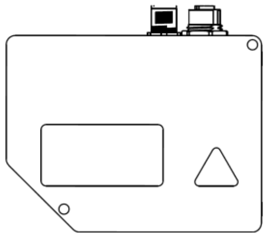


Definition Coordinate Plane



Mechanical Drawings

Housing Type

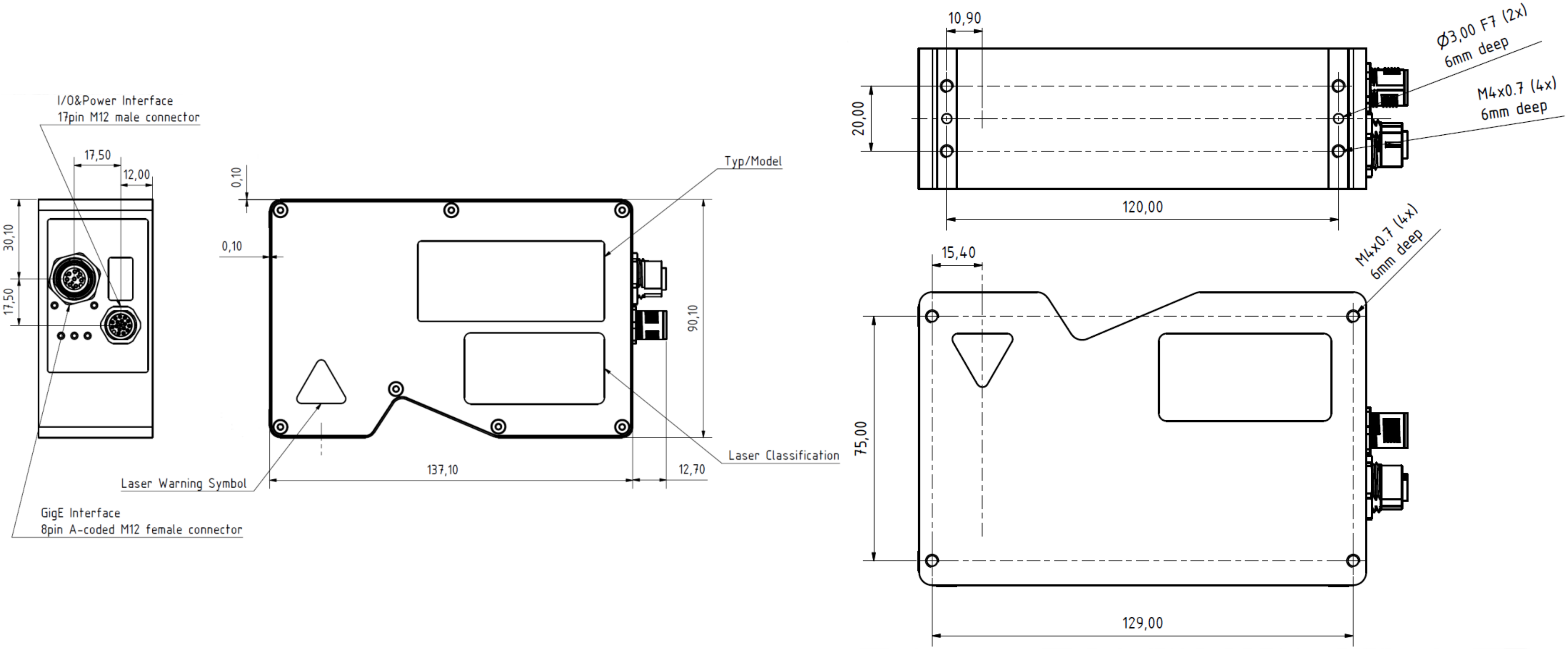
Model 1	Model 2	Model 3
		
Model 4	Model 5	Model 6
		

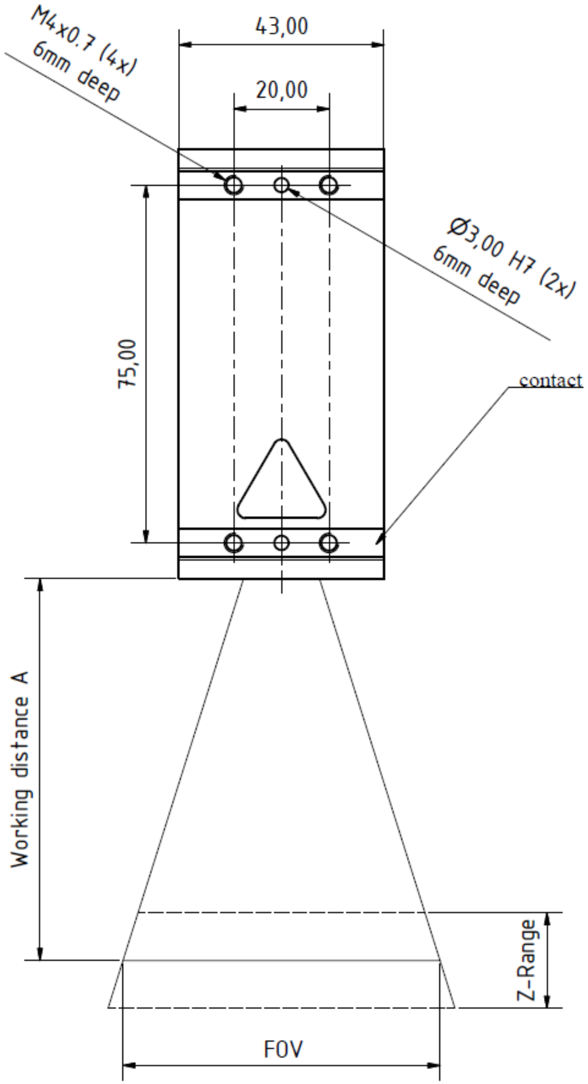
Dimensions

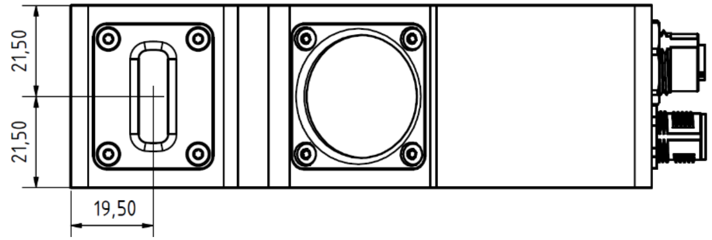
Model 1

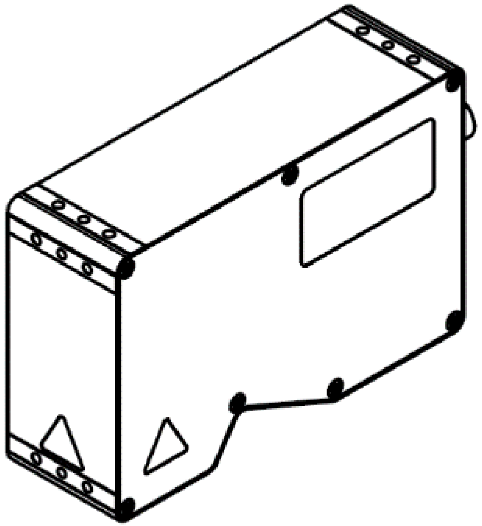
<u>Version A</u>

All dimensions in mm





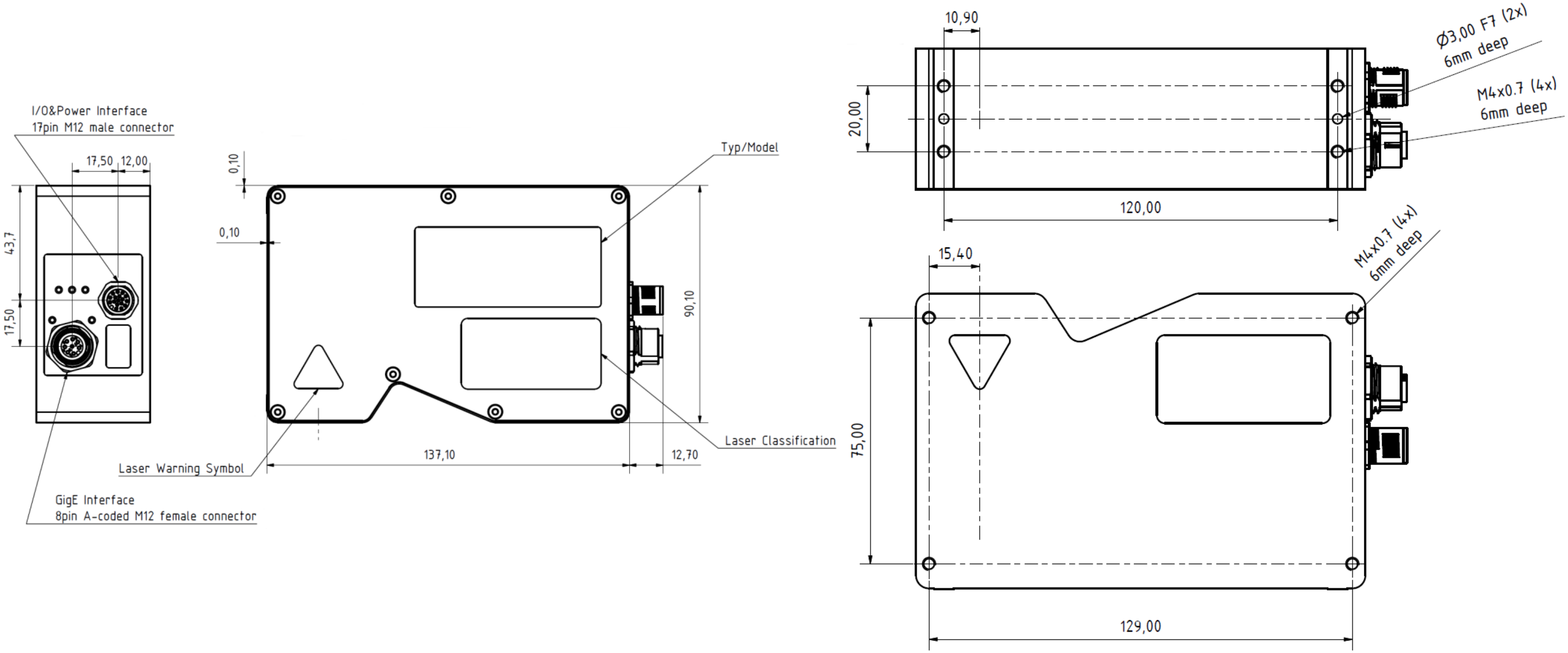


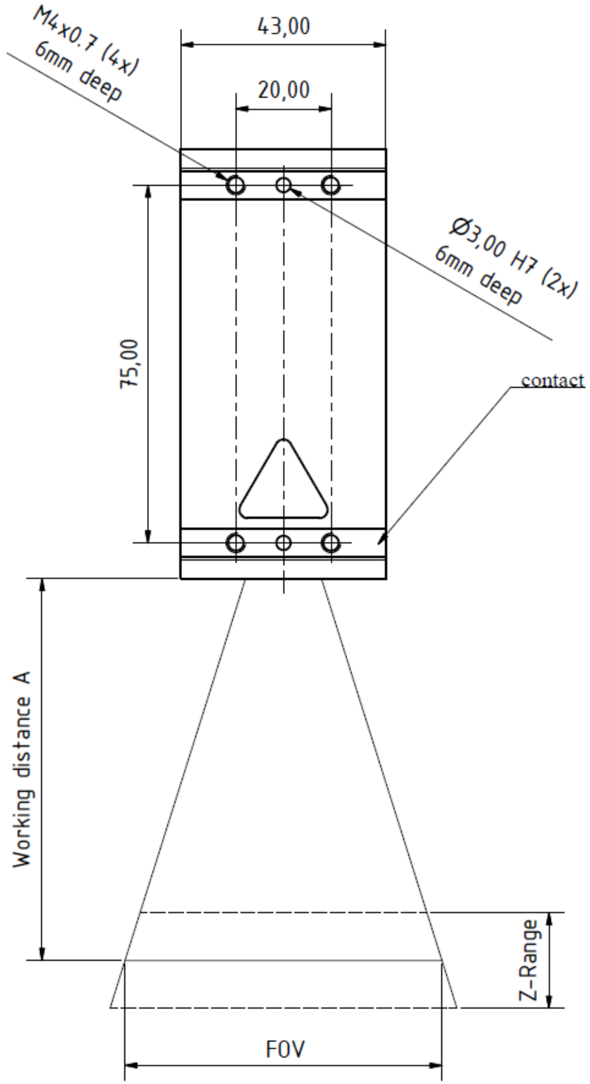


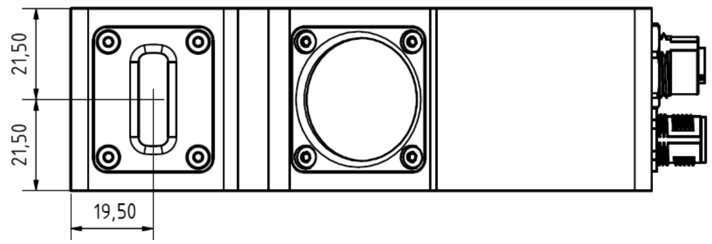
All dimensions in mm

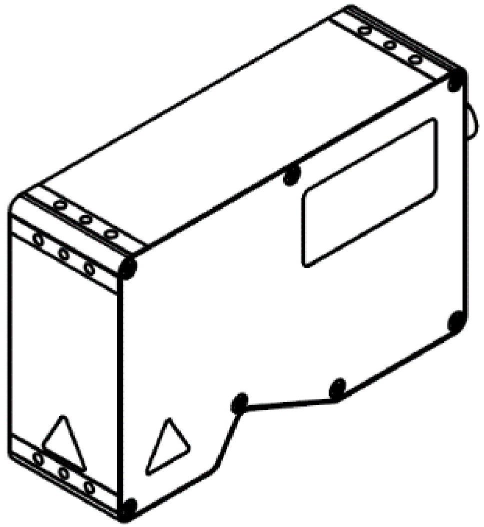
Version B

All dimensions in mm



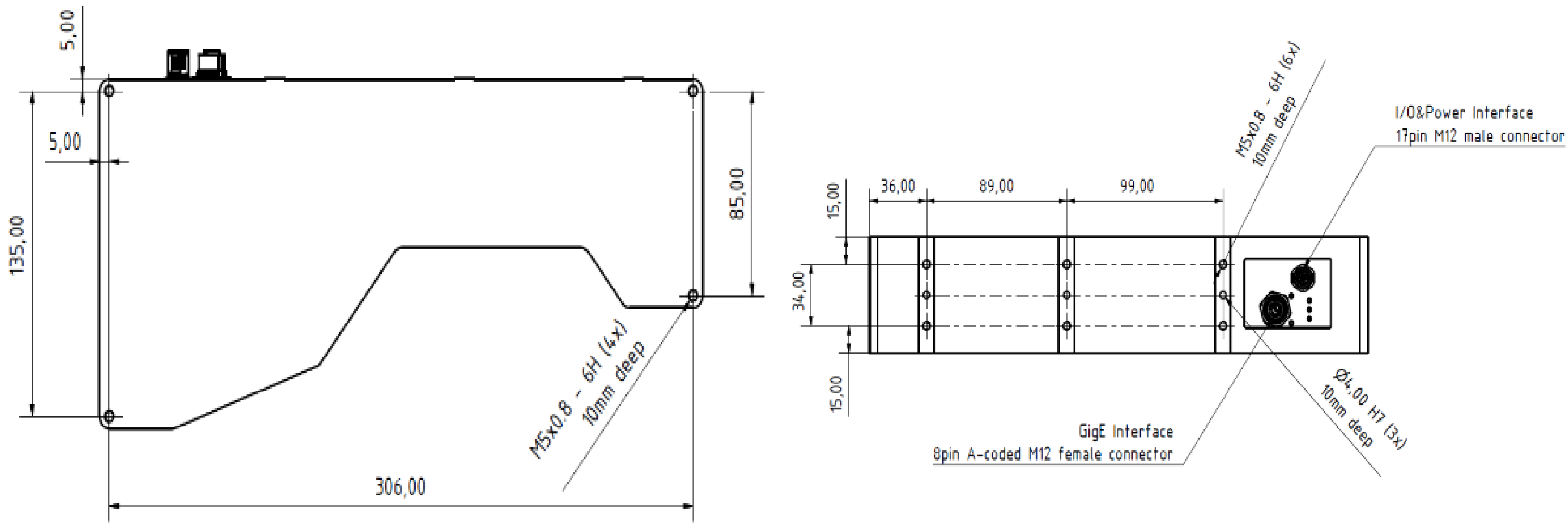

43,00
20,00
M4x0,7 (4x)
6mm deep
Ø3,00 H7 (2x)
6mm deep
75,00
contact
Working distance A
Z-Range
FOV

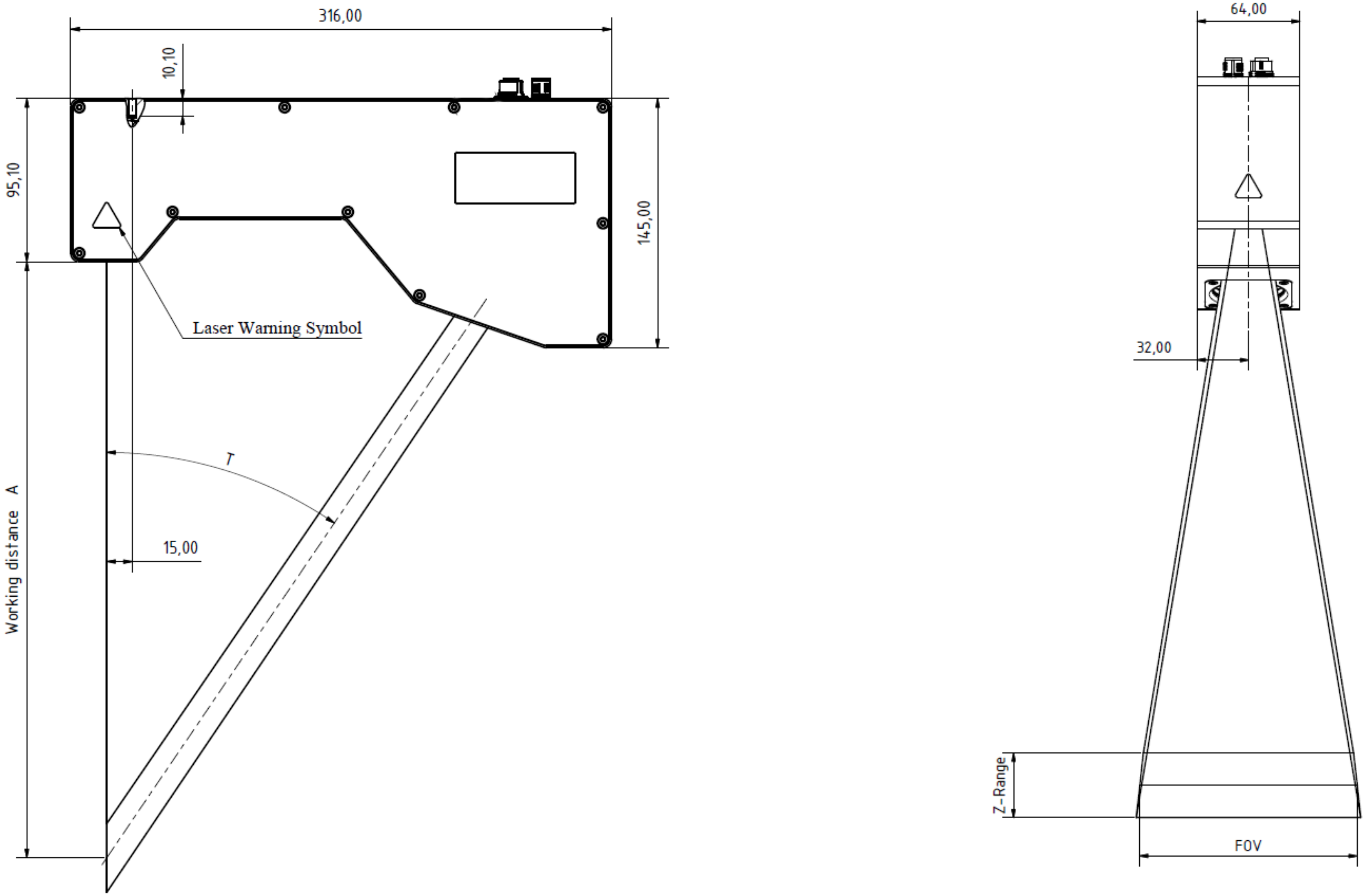

21,50
21,50
19,50



Model 2

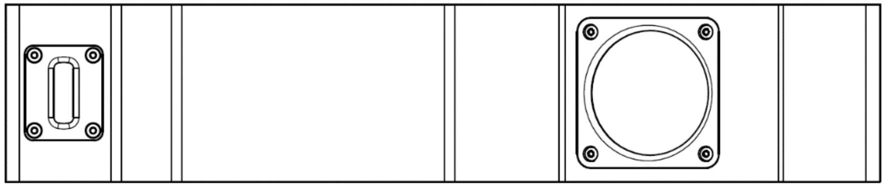
All dimensions in mm



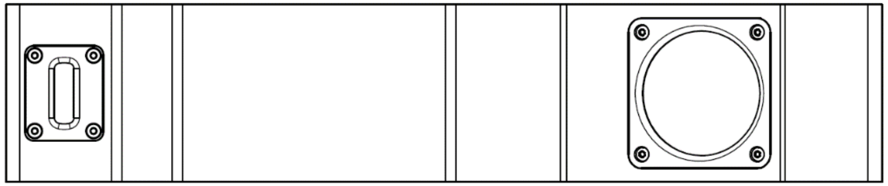


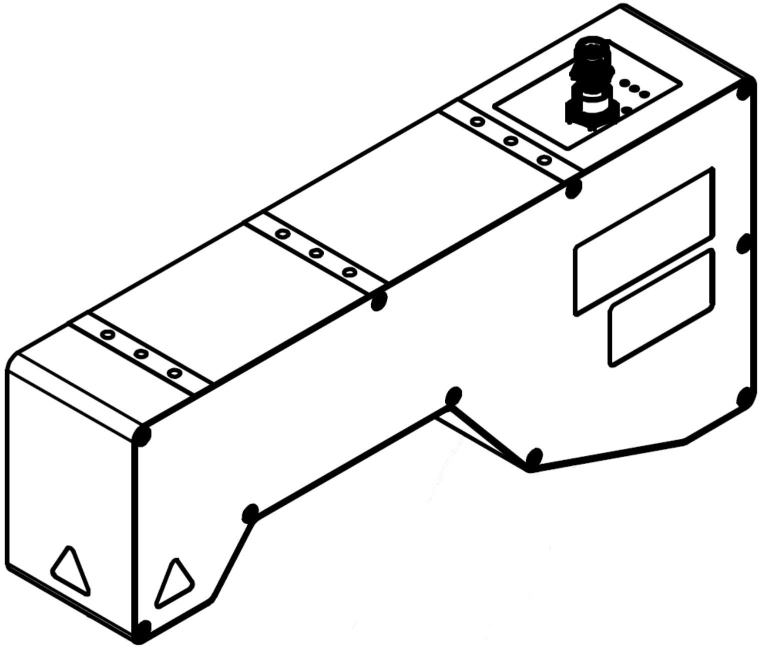
All dimensions in mm

Version A



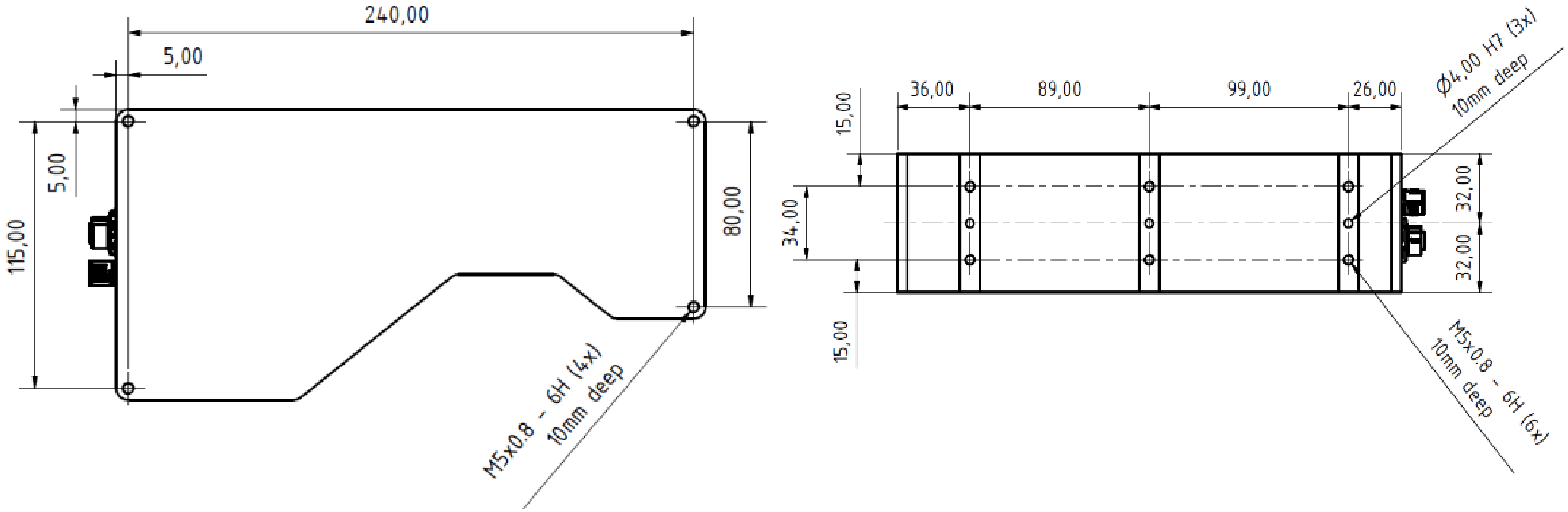
Version B

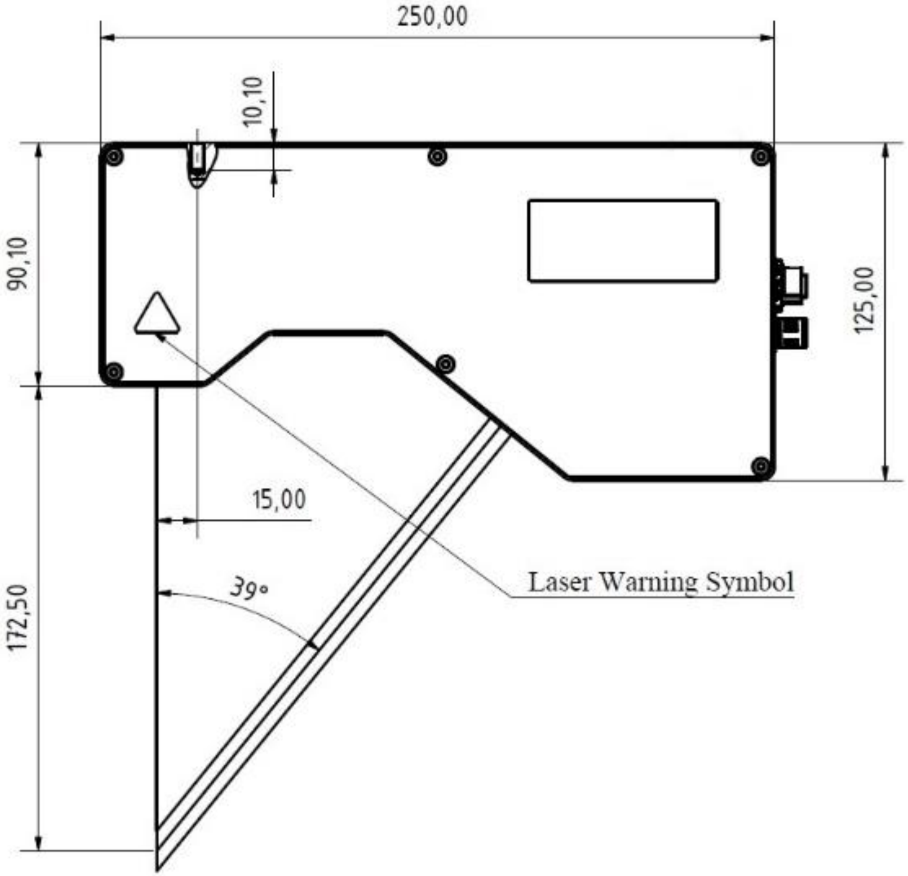


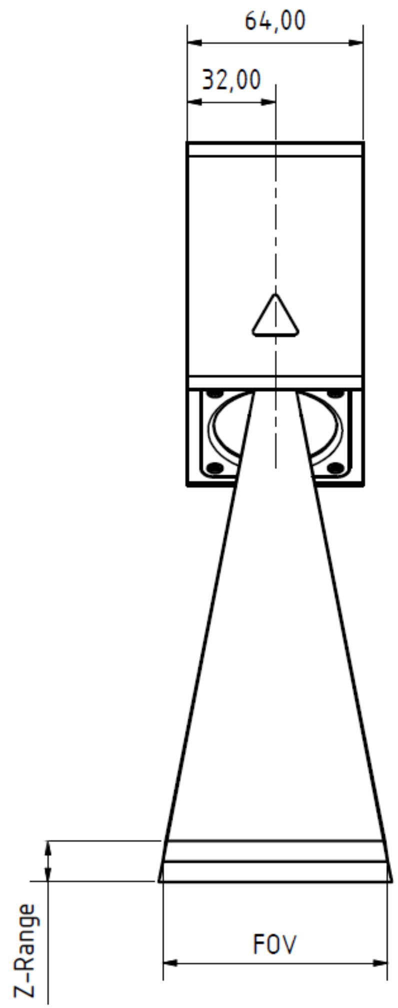


Model 3

All dimensions in mm



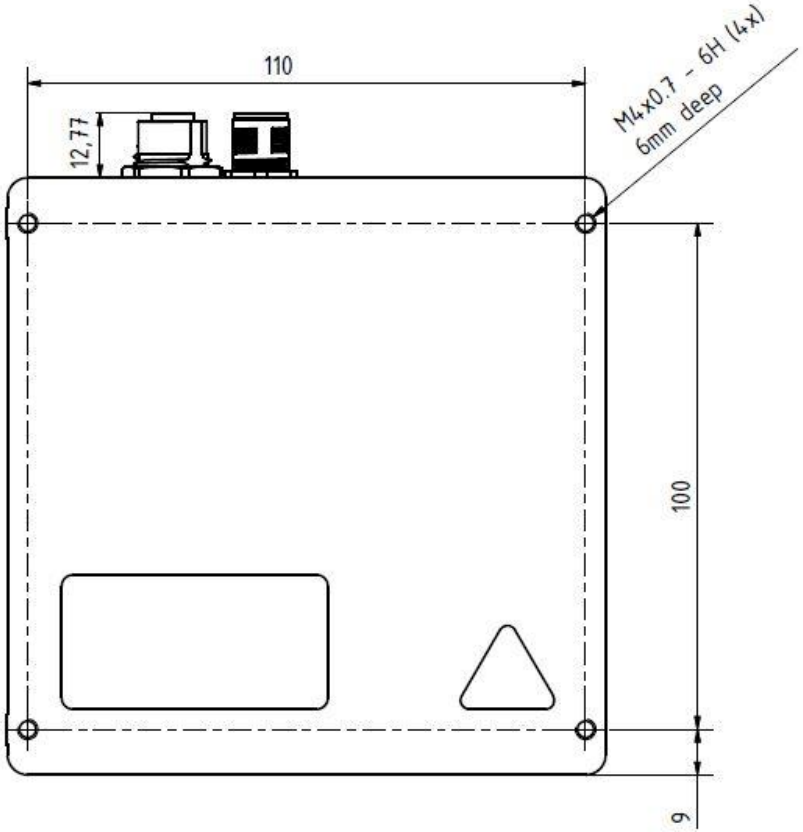


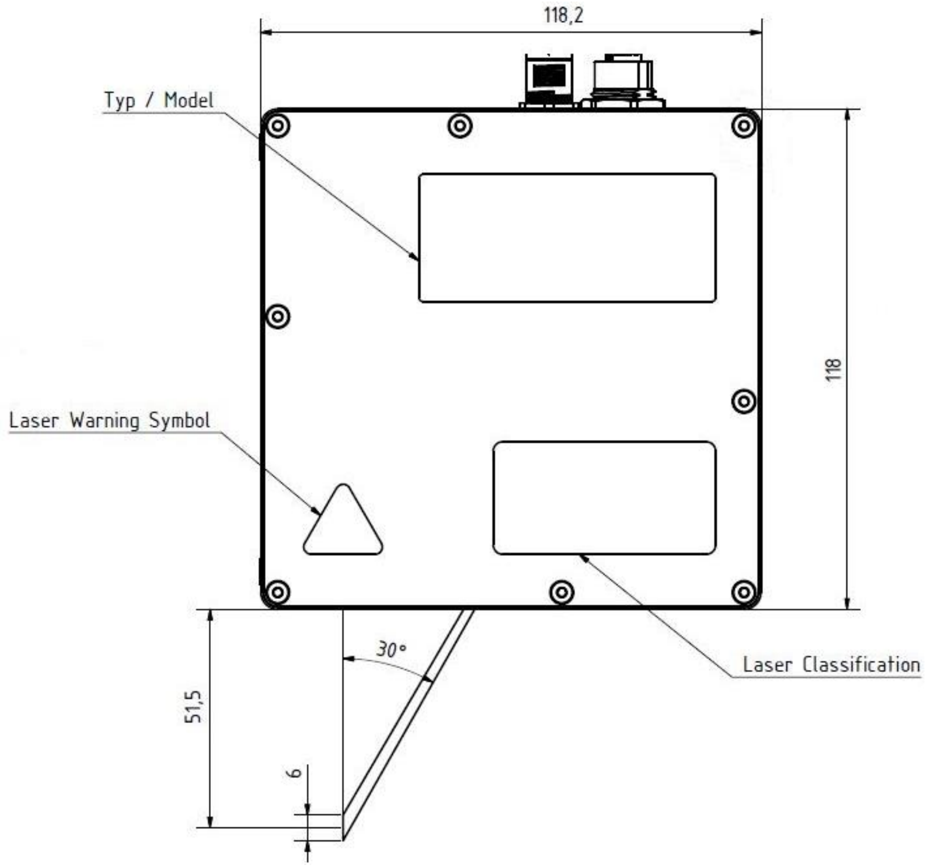


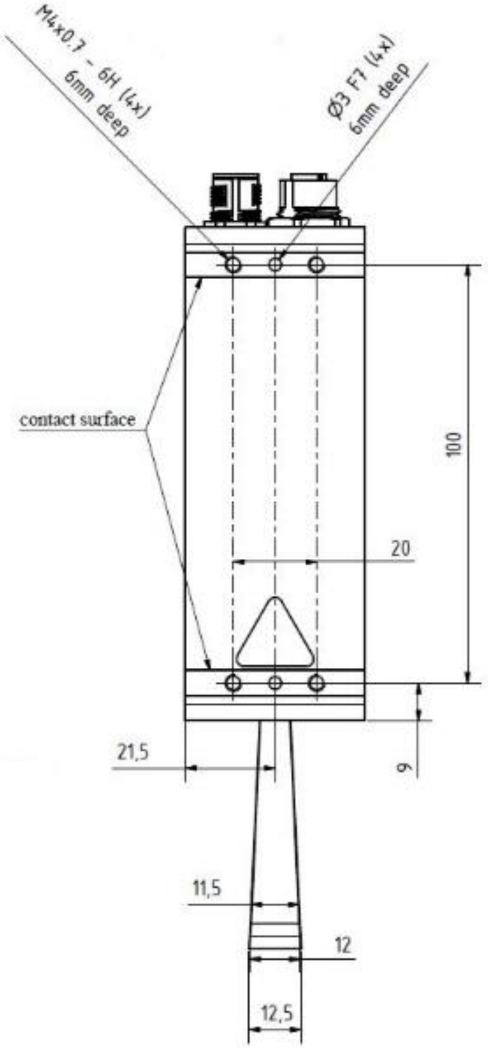
All dimensions in mm

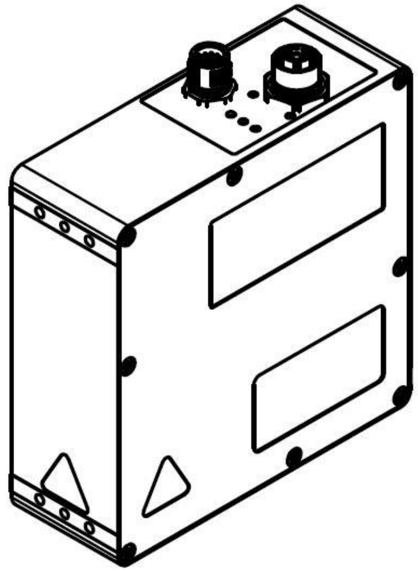
Model 4

All dimensions in mm





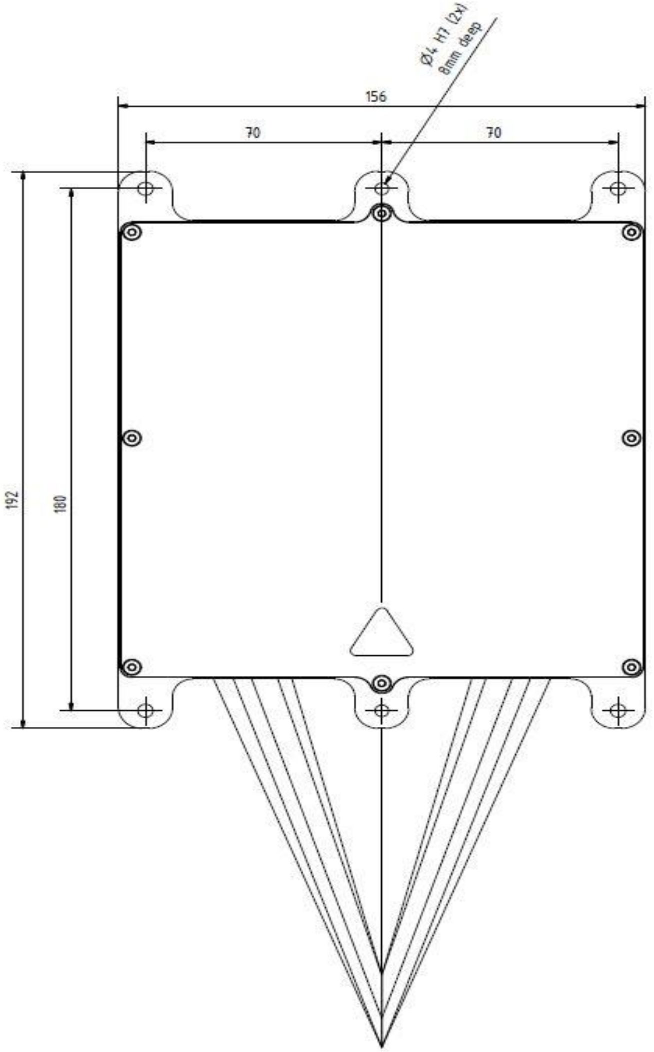


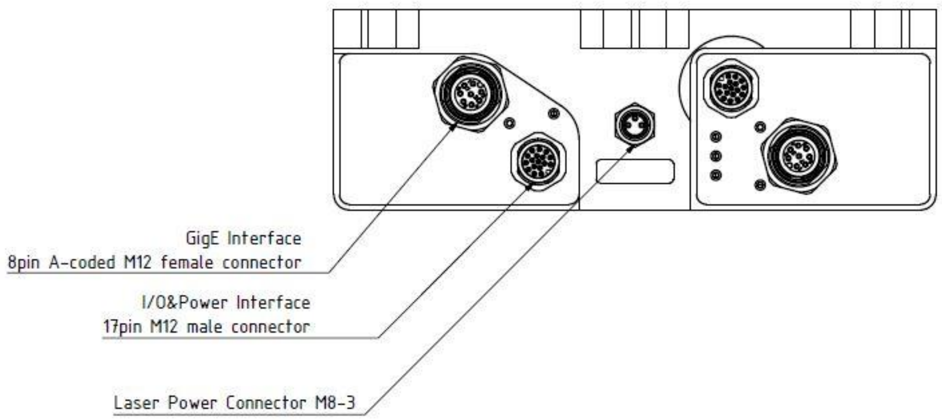


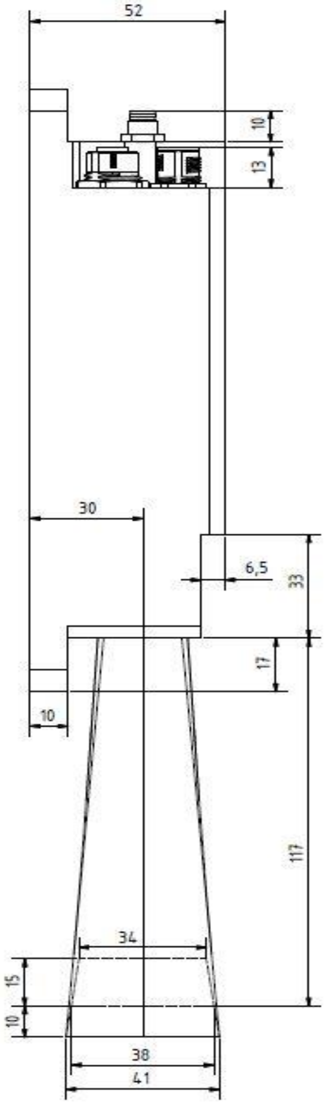
All dimensions in mm

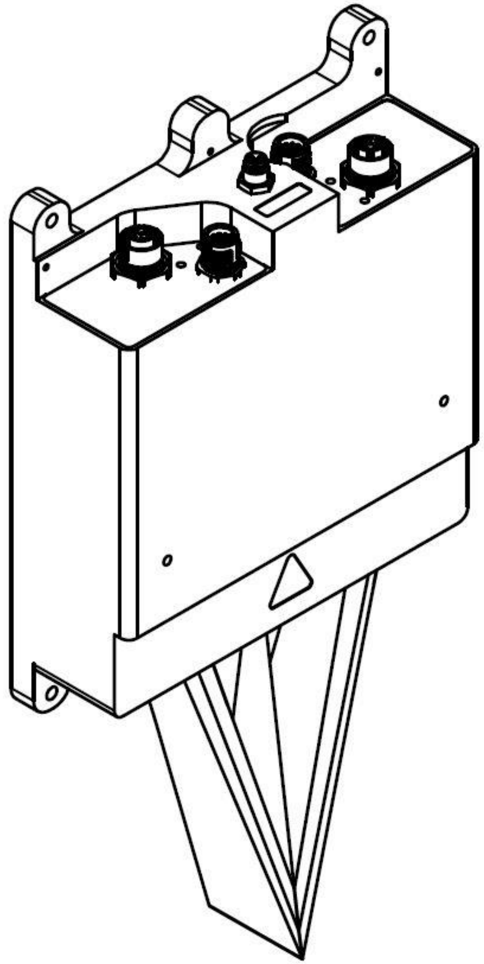
Model 5

All dimensions in mm





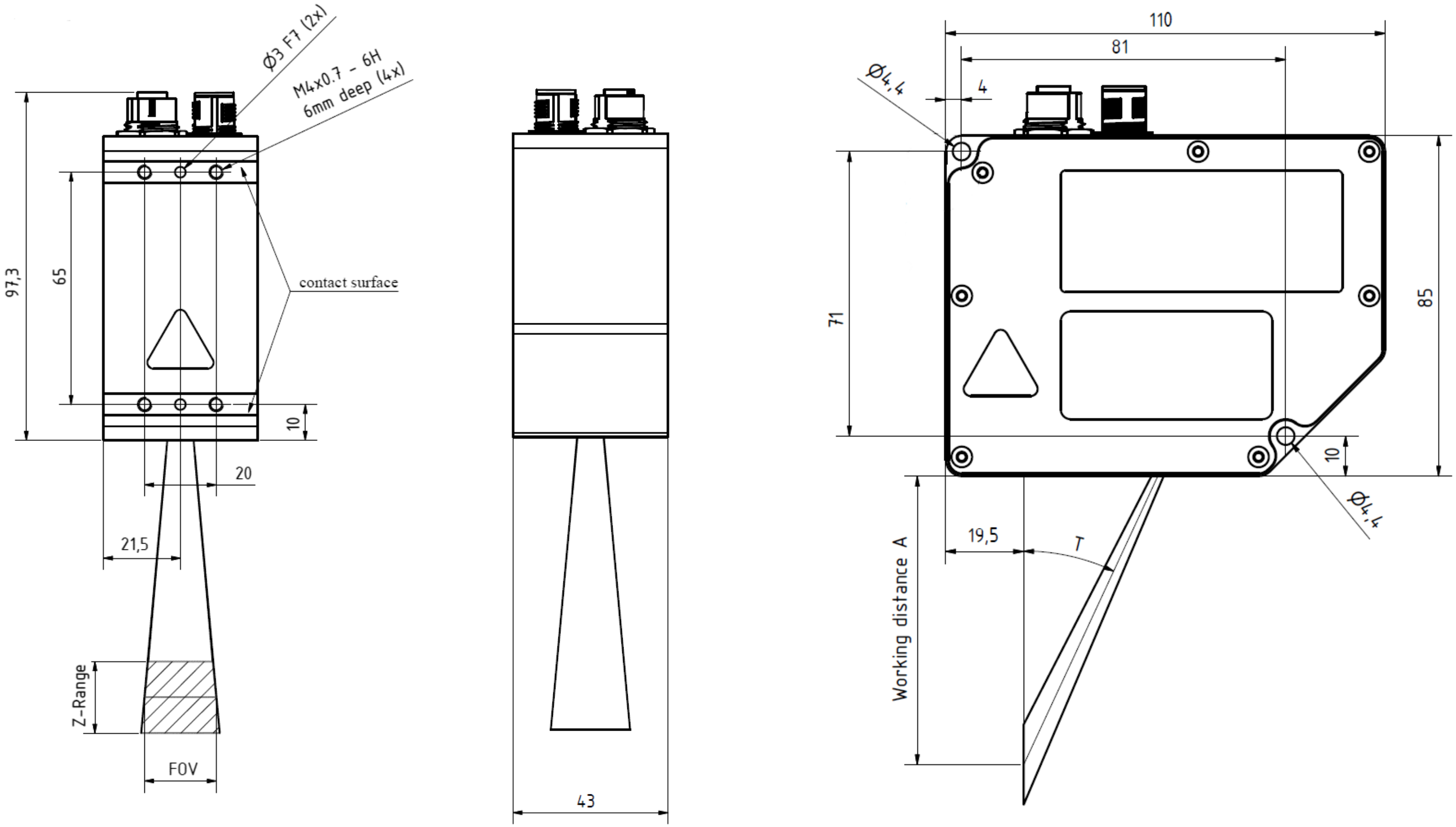


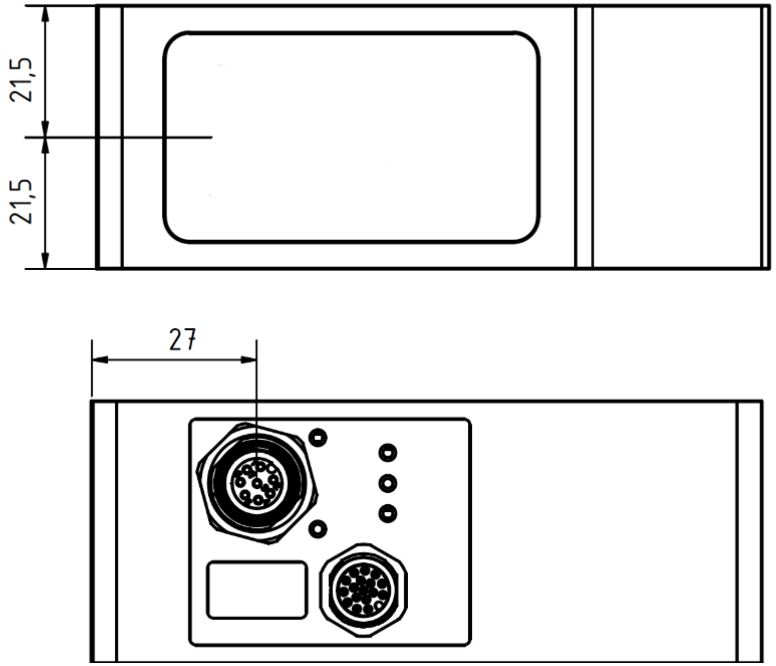


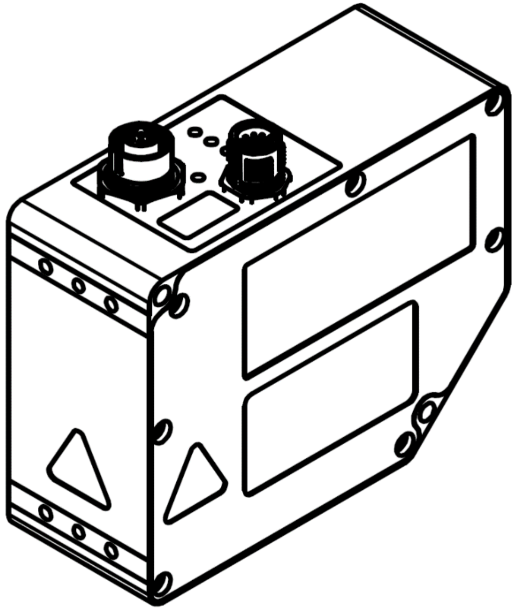
All dimensions in mm

Model 6

All dimensions in mm







All dimensions in mm

Compact Sensor Options

Laser

Part Number #	Description
202 204 105	C5 Compact Sensor Red Laser Option, 660 nm, Class 2M
202 204 110	C5 Compact Sensor Red Laser Option, 660nm, 130 mW, Class 3B
202 204 100	C5 Compact Sensor Blue Laser Option, 405 nm, 25 mW, Class 3R
202 204 106	C5 Compact Sensor Blue Laser Option, 405 nm, Class 2M
202 204 107	C5 Compact Sensor Blue Laser Option, 405nm, 160 mW, Class 3B thin line
202 204 108	C5 Compact Sensor Blue Laser Option, 405nm, 160 mW, Class 3B

Band-Pass Filter

202 204 200	C5 Compact Sensor Narrow Band-Pass Filter Option, 660 nm ± 20 nm

Laser MTBF (Mean Time Between Failures)

The laser MTBF describes the expected time between failures of a laser during operation. The described MTBF values are for an environment temperature of 25°C. Higher temperatures will reduce the laser life time.

Part Number #	Description	MTBF @25°C (h)
Default	C5 Compact Sensor Red Laser, 660nm, 20 mW, Class 3R	20000
202 204 105	C5 Compact Sensor Red Laser Option, 660nm, Class 2M	160000
202 204 110	C5 Compact Sensor Red Laser Option, 660 nm 130 mW Class 3R or 3B	75000
202 204 100	C5 Compact Sensor Blue Laser Option, 405nm, 25 mW, Class 3R	25000
202 204 104	C5 Compact Sensor Blue Laser Option, 450 nm 75 mW Class 3B	15000
202 204 106	C5 Compact Sensor Blue Laser Option, 405 nm, Class 2M	50000
202 204 107	C5 Compact Sensor Blue Laser Option, 405nm, 160 mW, Class 3B thin line	10000
202 204 108	C5 Compact Sensor Blue Laser Option, 405nm, 160 mW, Class 3B	10000
202 202 066	C5-2040CS18-38-2X, Blue Laser, 450nm, 10mW, 2M	10000

Subpixel Limitations

The range values of the 3D sensors are limited to 16bit which result to possible values between 0 and 65535. Setting the subpixel value to 6 correspond to a factor of 2^6 = 64. If the laser line appears at a sensor row higher than #1023 (with 6 subpixel) will result in a bit overflow. For example: laser line at row #1500 -> 1500 x 2^6 = 96000.

Therefore it can be necessary to use a lower subpixel value to avoid a bit overflow. The table below shows the maximum subpixel value in compare to the used number of rows and the laser line appearance on the sensor ship without bit overflow. The subpixel value in the factory configuration is always set to fit the complete Z-Range on the sensor chip without overflows.

Subpixel / Rows	0	1	2	3	4	5	6
1023	✓	✓	✓	✓	✓	✓	✓
2047	✓	✓	✓	✓	✓	✓	✗
3072	✓	✓	✓	✓	✓	✗	✗

Nevertheless it is still possible to use a higher subpixel value even when the laser line appears on a sensor row >#1023. In that case make sure that the defined AOI is smaller or even 1023/2047 rows and that the flag AbsOffsetPos (Camera Control -> Mode and Algorithm Control -> AbsOffsetPos) is set to false. Then the offset position with respect to the start row of the AOI is returned and thus the laser line can appear on sensor rows >#1023.

With the release of the new C5-1280CS models some new features were implemented based on the SFNC 2.3 standard as well as some AT specific features.

One new feature is the Mono8 mode in 3D line mode to reduce the amount of acquired data to be able to increase the maximum profile frequency. This reduction leads to a specific set up which is described in the table below.

Subpixel / Rows	0	1	2	3	4	5	6
3	✓	✓	✓	✓	✓	✓	✓
7	✓	✓	✓	✓	✓	✓	✗
15	✓	✓	✓	✓	✓	✗	✗
31	✓	✓	✓	✓	✗	✗	✗
63	✓	✓	✓	✗	✗	✗	✗
127	✓	✓	✗	✗	✗	✗	✗
255	✓	✗	✗	✗	✗	✗	✗

Using number of rows with a higher subpixel accuracy then stated in the table above can result in a bit overflow. That happen easy, when the pixel values go over the 8 Bit (2^8 - 1 = 255) range.

More details regarding the operation of the C5-1280CS sensor can be found in a separate application note.

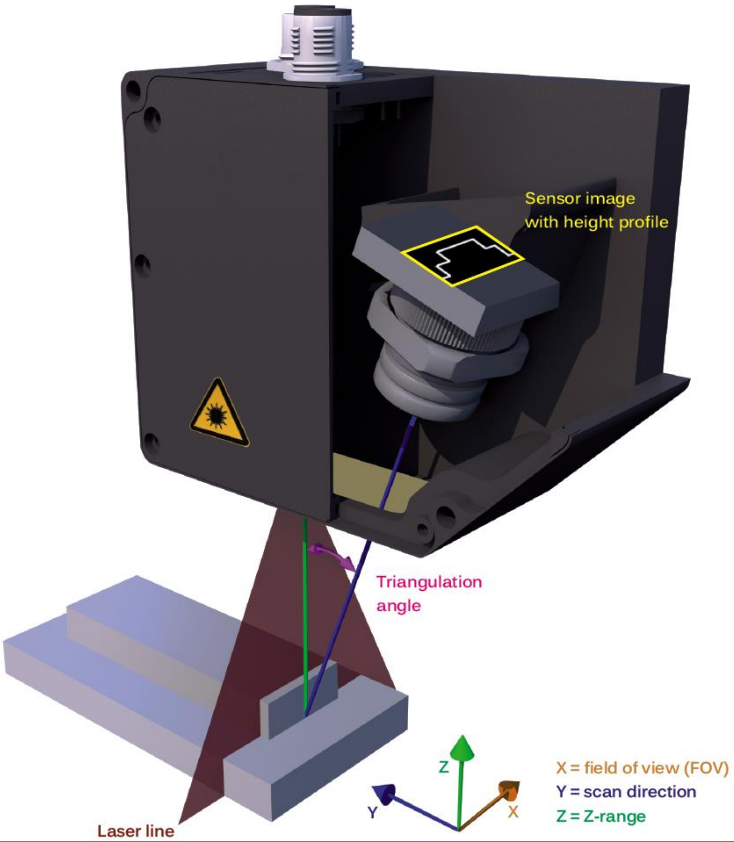
C5-CS Series Operational Reference

Measuring Principle

The C5-CS sensor acquires height profiles and height images based on the laser triangulation principle. According to this method a laser line is projected on the object from one direction. The imager sensor views the object from another angle defining the triangulation geometry. The resulting sensor image is evaluated by the embedded processor and converted into a single height profile. By scanning the laser line over the object a complete height image can be acquired.
The figure below demonstrate the typical triangulation geometry. The following notation is used in the approximation of height resolution:
ΔX= resolution along the laser line (lateral),
ΔY= resolution perpendicular to the laser line (longitudinal in the direction of motion),
ΔZ= height resolution.

Measurement Geometry

The laser line is projected perpendicular to the object surface, while the camera views the object under the triangulation angle α. The height resolution can be approximated:
$\Delta Z \approx \Delta X / \sin(\alpha)$



The C5-CS Sensor Algorithms

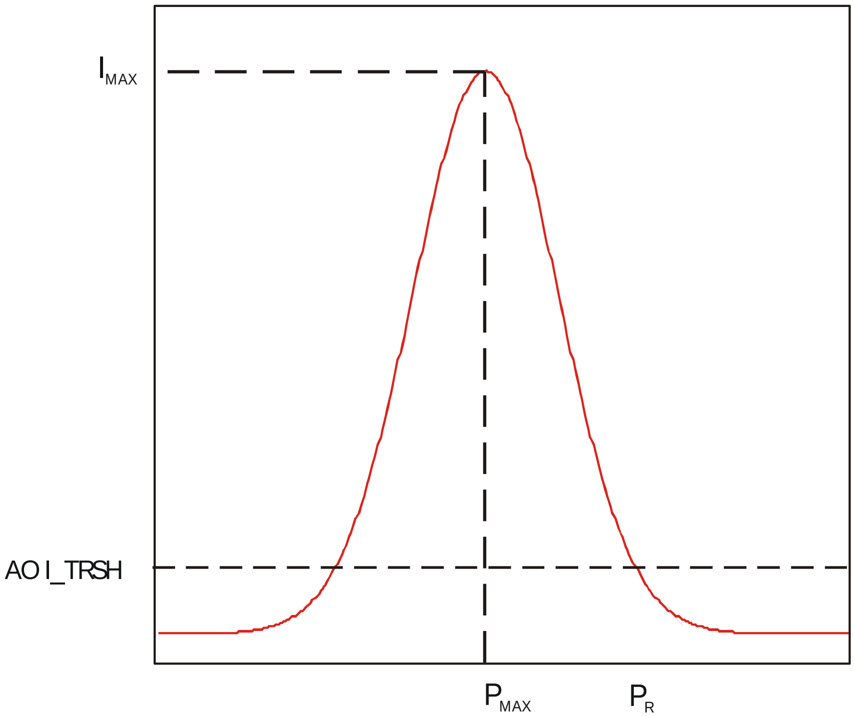
The C5-CS laser sensor can be operated both in a variety of 3D profile modes and in image mode. The current operation mode can be chosen by setting the parameter Camera Controls→ ModeAndAlgorithmControls→CameraMode.
The frame rate can be increased in all camera modes by reducing the AOI size. In the image mode the frame rate is limited by the output rate of the camera interface (GigE). However, due to reduced data size in profile mode the frame rate is limited only by the sensor output rate. As a matter of principle the processing speed is independent of the chosen profile mode and is determined by the AOI size.
In all profile modes only intensity values higher than the AOI intensity threshold AOI_TRSH are processed in order to suppress weak signal noise. In case that no position value can be found, e.g. no intensity value is higher than threshold, the position value 0 is returned.

The Image Mode (IMG)

In the image mode the C5-CS-GigE camera is operated similar to a standard CMOS camera. In this mode grey scale data of 8 or 10 bit resolution are acquired over the camera interface. Furthermore, the sensor can be divided into multiple regions, whose data can be summarised in one output frame.

The Maximum Intensity Profile Mode (MAX)

In this mode the position of the maximum intensity of laser beam profile is calculated. The result includes the position value of the maximum (P_{MAX}) as well as the maximum intensity value (I_{MAX}).

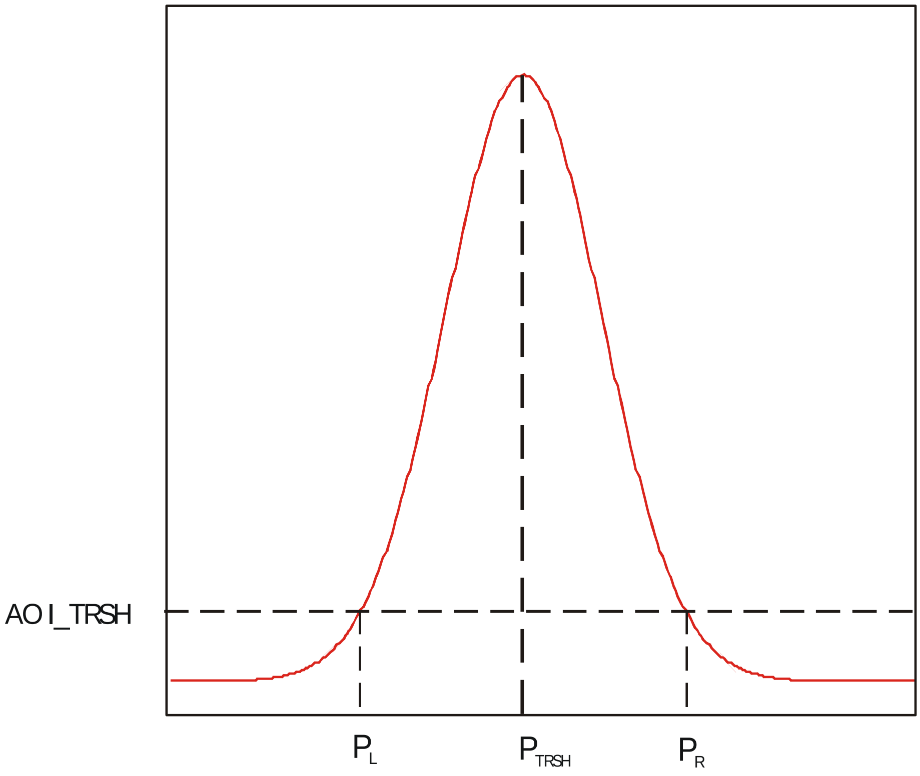


The calculation of position value is performed with simple pixel accuracy, i.e. the evaluation of 1088 rows delivers a position range from 0 to 1087 pixels (11 bit). If there is more than one local maximum (e.g. when the intensity is saturated), the position of the first detected maximum is output. In order to avoid intensity saturation, it is recommended to activate the Multiple Slope Mode of the camera.

The detection of the maximum intensity position can be improved by enabling the smoothing mode of the FIR filter of the camera.

The Threshold Mode (TRSH)

In this mode the position of left (P_L) and right (P_R) edge of the laser beam profile are detected for a given threshold value of intensity AOI_TRSH.



The position value of the laser line is approximated: $P_{TRSH} = (P_L+P_R) / 2$. In order to simplify the digital representation the division over 2 is not performed and thus an integer representation with one subpixel is realised. The evaluation of 1088 rows delivers a position range from 0 to 1087 pixels (11 bit).

In threshold mode the camera can output either the left and right threshold position separately or the subpixel position (P_L+P_R) and the line width (P_R-P_L). Moreover, the maximum intensity value can be optionally output.

The precision of the position calculation can be improved by enabling the smoothing mode of the FIR filter of the camera.

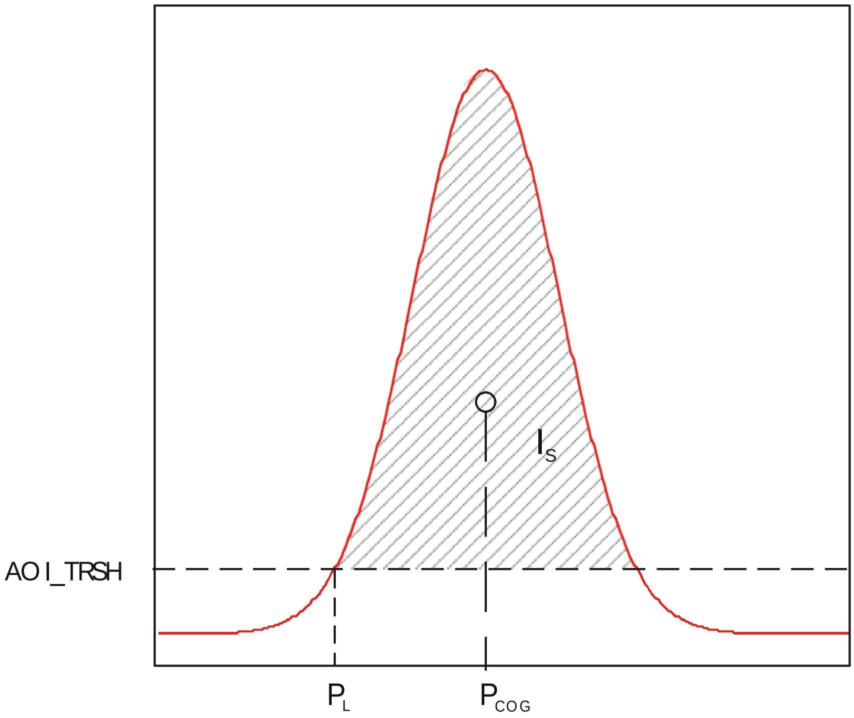
The Center Of Gravity Mode (COG)

In this mode the center of gravity of laser beam profile is calculated. For this purpose the following parameters are computed:

Position value of the left edge of laser beam profile for a given intensity threshold value P_L ,

Sum of intensity value $I_s = \sum I_p$,

Sum of first order moment $M_s = \sum I_p * P$.



The position value of laser line (center of gravity of beam profile) is then obtained from:

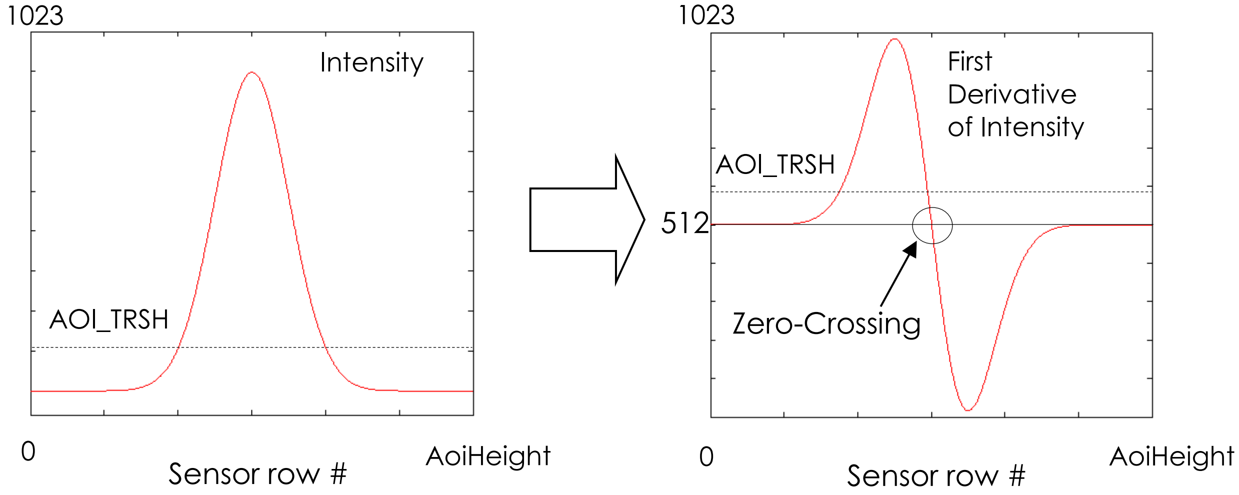
$P_{COG} = P_L + M_s / I_s$.

In addition the laser line width can be delivered over the Data Output Channel DC1. The average intensity of the illumination profile can be calculated by normalising the sum of intensity value I_s with the line width.

The precision of the COG calculation (up to 6 subpixel) can be improved by enabling the smoothing mode of the FIR filter of the camera.

The FIR Peak Mode (FIR PEAK)

In this mode the first derivative of the intensity Gauss curve of laser beam profile is calculated.



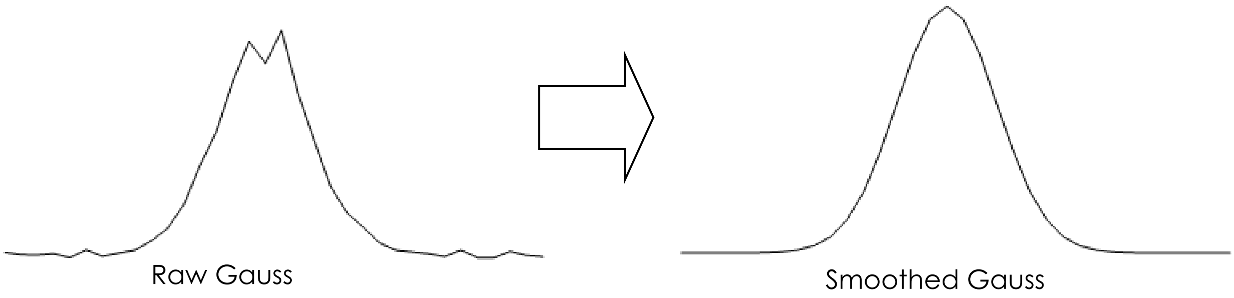
The position of zero-crossing of first derivative is detected and output with subpixel accuracy (up to 6 subpixel). In this case the threshold AOI_TRSH is used to detect the first rising edge of the derived intensity signal. Valid values of AOI_TRSH range from 513 to 1023 (Mono16).

More details regarding the operation of the FIR Peak mode can be found in a separate application note.

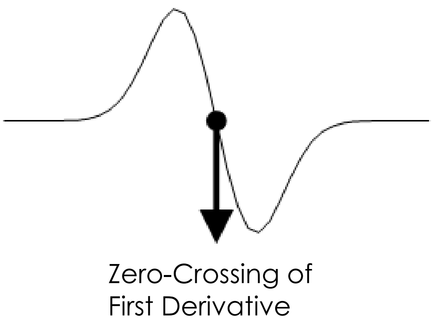
The FIR Filter Function

The FIR filter is a signal processing function aiming to increase the precision of laser line detection in the sensor image. It consists of a digital Finite Impulse Response filter (FIR) and can be operated in a smoothing or differentiating mode.

<u>FIR in smoothing mode (in combination with MAX, TRSH and COG algorithms):</u>



<u>FIR in derivative mode (FIR PEAK):</u>



Pre-defined templates with 5, 7 or 9 coefficients let the FIR filter to be customised to the Gauss size and shape of the application.

More details regarding the operation of the FIR filter function can be found in a separate application note.

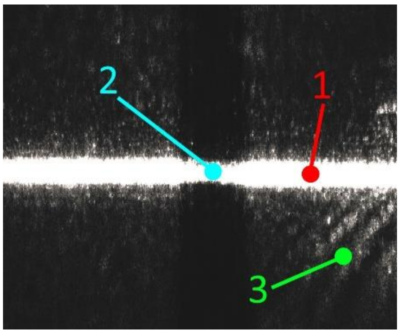
The High Dynamic Range 3D Feature (HDR-3D) of C5-CS-GigE

One of the most powerful features of the C5-CS series is the HDR-3D (High Dynamic Range) functionality, which allows scanning materials and surfaces with inhomogeneous reflection properties. Using HDR-3D the dynamic range of image intensity is extended up to 90dB, thus avoiding intensity saturation.
The HDR-3D comprises two independent sensor functions.

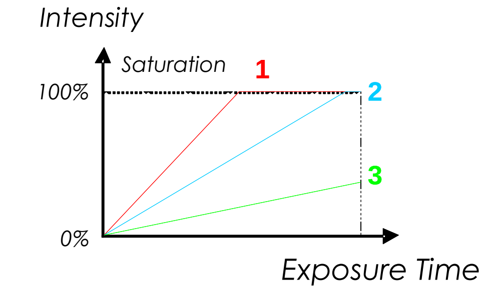
Multiple Slope Function

The aim of the Multiple Slope function is to avoid the saturation of pixels during sensor chip exposure. This high optical dynamic range is achieved by using a piecewise linear response. The intensity of illuminated pixels, which reach a certain level, is clipped, while darker pixels remain untouched. The clipping level can be adjusted 2 times within one exposure time to achieve a maximum of 3 slopes in the response curve. The points of the curve, where the slope changes, are called “knee points”. The latter are defined through the setting of clipping levels for the intensity (thresholds) and time points within the exposure time.
These parameters can be adjusted using the GenICam registers Multi Slope Exposure Limit and Multi Slope Saturation Threshold of the Acquisition Control (XML grid visibility must be set to “Expert”). A knee point time is defined as percentage of the overall exposure time. A clipping level is defined as percentage of the maximum sensor intensity (saturation).

Single Slope Mode (Default Mode)

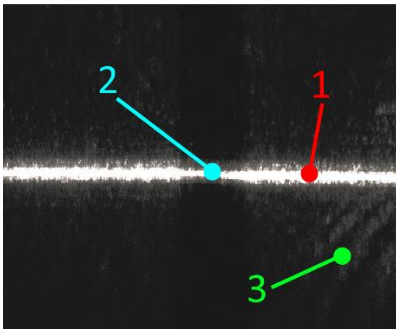


Weld Seam

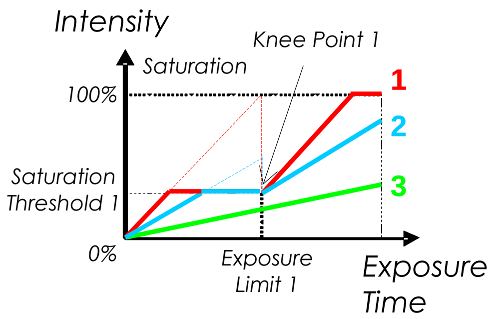


Property	Value
Root	
Device Control	
Image Format Control	
Acquisition Control	
Acquisition Start	Execute!
Acquisition Stop	Execute!
Acquisition Mode	Continuous
Acquisition Abort	Execute!
Acquisition Frame Count	1
Acquisition Frame Rate	25 Hz
Acquisition Line Rate	-
Acquisition Status Selector	Acquisition Trigger Wait
Acquisition Status	false
Acquisition Maximum Numbe	3
Multi Slope Mode	Off
Multi Slope Knee Point Count	0
Multi Slope Knee Point Selector	1
Multi Slope Exposure Limit	60 %
Multi Slope Saturation Threshold	49.2063 %
Exposure Mode	Timed
Exposure Time	1000

Dual Slope Mode (1 Knee Point)

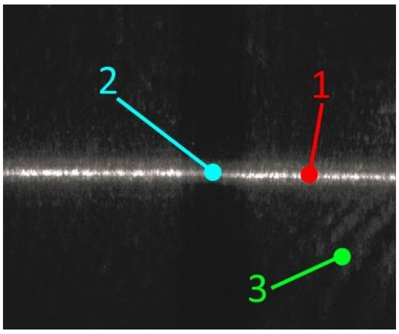


Weld Seam

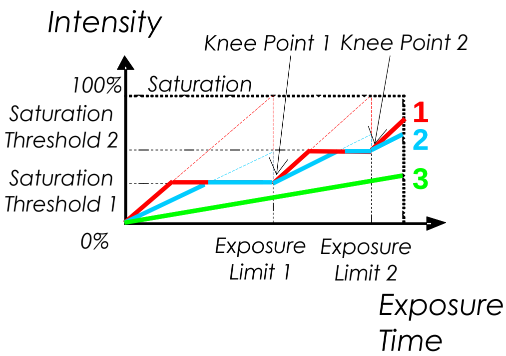


Property	Value
Root	
Device Control	
Image Format Control	
Acquisition Control	
Acquisition Start	Execute!
Acquisition Stop	Execute!
Acquisition Mode	Continuous
Acquisition Abort	Execute!
Acquisition Frame Count	1
Acquisition Frame Rate	25 Hz
Acquisition Line Rate	-
Acquisition Status Selector	Acquisition Trigger Wait
Acquisition Status	false
Acquisition Maximum Numbe...	3
Multi Slope Mode	Manual
Multi Slope Knee Point Count	1
Multi Slope Knee Point Selector	1
Multi Slope Exposure Limit	50 %
Multi Slope Saturation Threshold	34.9206 %
Exposure Mode	Timed
Exposure Time	1000

Triple Slope Mode (2 Knee Points)



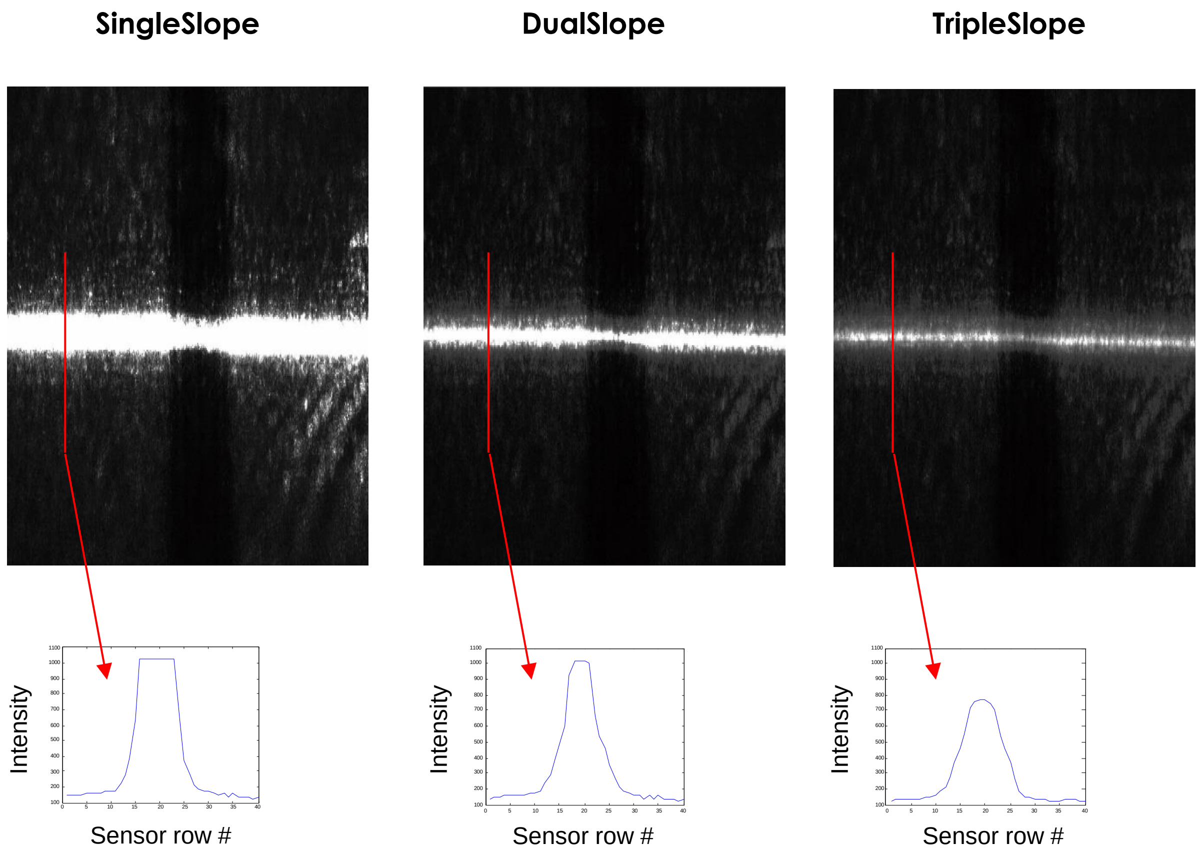
Weld Seam



Property	Value
Root	
Device Control	
Image Format Control	
Acquisition Control	
Acquisition Start	Execute!
Acquisition Stop	Execute!
Acquisition Mode	Continuous
Acquisition Abort	Execute!
Acquisition Frame Count	1
Acquisition Frame Rate	25 Hz
Acquisition Line Rate	-
Acquisition Status Selector	Acquisition Trigger Wait
Acquisition Status	false
Acquisition Maximum Numbe...	3
Multi Slope Mode	Manual
Multi Slope Knee Point Count	2
Multi Slope Knee Point Selector	2
Multi Slope Exposure Limit	85 %
Multi Slope Saturation Threshold	66.6667 %
Exposure Mode	Timed
Exposure Time	1000

Comparison of Slope Modes

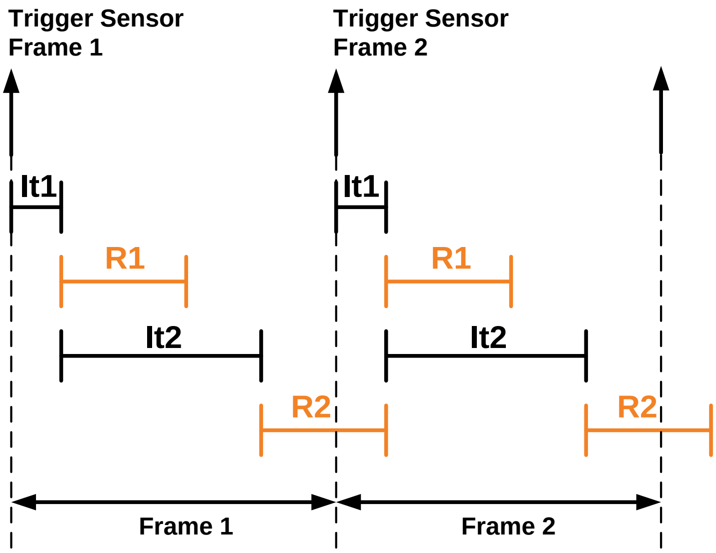
Application of MultipleSlope function on the image of a laser line projected on a surface with non-homogeneous reflectivity (weld seam).

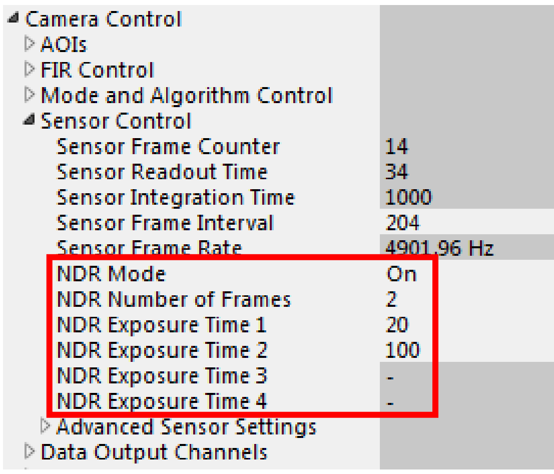


More details regarding the operation of the MultipleSlope function can be found in a separate application note.

Multi-Frame Readout Mode (NDR)

With the Non-Destructive Readout (NDR) mode it is possible to readout up to 4 images at different exposure times. It allows the combination of profile data from different integration levels and it ensures accurate profile data even for difficult surfaces with strong changes in reflectance.
The following timing diagram shows the function of NDR with 2 frames, when subsequent sensor images are acquired. The exposure times for NDR frame 1 and 2 are depicted with It1 and It2 respectively. Please note that the readout of the second frame R2 cannot begin unless the first frame R1 has been readout. The same applies also between two subsequent sensor images, i.e. the first NDR frame of sensor image 2 cannot be readout unless the last NDR frame of sensor image 1 has been readout.





It1 : Exposure Time 1
It2 : Exposure Time 2
R1 : Readout Frame It1
R2 : Readout Frame It2

The Data Output Format of C5-CS-GigE

The image and 3D data output is performed by selecting the data channel DC0-DC2 (node Camera Controls→DataOutput). Depending on the algorithm the data can be acquired by enabling the corresponding output Data Channel (DC). Every DC is saved in a new image row. The bit depth of output data depends on the selected algorithm. In 3D mode the camera outputs data with 16 bit. In Image mode the camera can output 8 or 10 bit data. When in 8 bit Image mode, the DC0 delivers the 8 most significant bits of the 10 bit intensity data.

The Data Channel Assignment DC0, DC1 and DC2

Camera Mode	FIR	FIRMode	DC0	DC1	DC2
Image	False	-	Sensor intensity	Not used	Not used
	True	Derivative	First derivative of sensor intensity	Not used	Not used
	True	Smoothing	Smoothed sensor intensity	Not used	Not used
MaximumIntensity	False	-	Maximum intensity of Gauss	Position of rising edge of Gauss (PosL)	Position of maximum intensity of Gauss (PosM)
	True	Smoothing	Maximum intensity of Gauss detected in smoothed sensor image	Position of rising edge of Gauss (PosL) detected in smoothed sensor image	Position of maximum intensity of Gauss (PosM) detected in smoothed sensor image
Threshold	False	-	Maximum intensity of Gauss	- Position of rising edge of Gauss (PosL) or - Gauss width (PosR-PosL)	- Position of falling edge of Gauss (PosR) or - Position of Gauss with 1/2 pixel resolution (PosL+PosR)

Camera Mode	FIR	FIRMode	DC0	DC1	DC2
	True	Smoothing	Maximum intensity of Gauss detected in smoothed sensor image	- Position of rising edge of Gauss (PosL) or - Gauss width (PosR-PosL) detected in smoothed sensor image	- Position of falling edge of Gauss (PosR) or - Position of Gauss with 1/2 pixel resolution (PosL+PosR) detected in smoothed sensor image
CenterOfGravity	False	-	Sum of intensity values of Gauss I_s	- Position of rising edge of Gauss (PosL) or - Gauss width (PosR-PosL)	Position of center of gravity of Gauss with $1/(2^N)$ pixel resolution, where N=number of subpixel bits (0-6)
	True	Smoothing	Sum of intensity values of Gauss I_s in smoothed sensor image	- Position of rising edge of Gauss line (PosL) or - Gauss width (PosR-PosL)	Position of center of gravity of Gauss in smoothed sensor image with $1/(2^N)$ pixel resolution, where N=number of subpixel bits (0-6)
FIRPeak	True	Derivative	Zero-crossing slope (Absolute value)	- Index of next sensor row to the left of zero-crossing or - maximum value of intensity first derivative	Position of Gauss peak with $1/(2^N)$ pixel resolution, where N=number of subpixel bits (0-6)

The Output Frame Structure

Depending on configuration, the C5-CS-GigE writes data to the output frame according to following scheme:

1) NDR mode disabled (NDRMode="Off")

```
for(profile_idx=1; profile_idx <=ProfilesPerFrame; profile_idx ++)
{
     for(AOI_idx=1; AOI_idx<=NumAOIs; AOI_idx++)
     {
          if(EnableDC0==true)
               write_data_of_DC0(AOI_idx);
          if(EnableDC1==true)
               write_data_of_DC1(AOI_idx);
          if(EnableDC2==true)
               write_data_of_DC2(AOI_idx);
     }
}
```

2) NDR mode enabled (NDRMode="On")

```
for (profile_idx=1; profile_idx <=ProfilesPerFrame/2; profile_idx ++)
{
     for(AOI_idx=1; AOI_idx<=NumAOIs; AOI_idx++)
     {
          for(NDR_idx=1: NDR_idx <= NumberOfNDRFrames; NDR_idx ++)
          {
               if(EnableDC0==true)
                    write_data_of_DC0(AOI_idx,NDR_idx);
               if(EnableDC1==true)
                    write_data_of_DC1(AOI_idx,NDR_idx);
               if(EnableDC2==true)
                    write_data_of_DC2(AOI_idx,NDR_idx);
          }
     }
}
```

Index Definition

Index #	Range	Description
Profile_idx	1-17475	Index of Profile
AOI_idx	1-8	Index of sensor AOI
NDR_idx	1-4	Index of NDR frame

Examples of Output Frame Structure

1) Configuration with single AOI, single DC, disabled NDR mode and output of 6 profiles resulting to a frame height of 6 rows:

```
ProfilesPerFrame      = 6
NumAOIs               = 1
EnableDC0             = false
EnableDC1             = false
EnableDC2             = true
NDRMode               = ”Off”
```

Row #	Description	Profile #
1	Data of DC2 readout from AOI1	1
2	Data of DC2 readout from AOI1	2
3	Data of DC2 readout from AOI1	3
4	Data of DC2 readout from AOI1	4
5	Data of DC2 readout from AOI1	5
6	Data of DC2 readout from AOI1	6

2) Configuration with two AOIs, two DCs, disabled NDR mode and output of 5 profiles resulting to frame height of 20 rows:

```
ProfilesPerFrame      = 5
NumAOIs               = 2
EnableDC0             = true
EnableDC1             = false
EnableDC2             = true
NDRMode               = ”Off”
```

Row #	Description	Profile #
1	Data of DC0 readout from AOI1	1
2	Data of DC2 readout from AOI1	
3	Data of DC0 readout from AOI2	
4	Data of DC2 readout from AOI2	
5	Data of DC0 readout from AOI1	2
6	Data of DC2 readout from AOI1	
7	Data of DC0 readout from AOI2	
8	Data of DC2 readout from AOI2	
9	Data of DC0 readout from AOI1	3
10	Data of DC2 readout from AOI1	
11	Data of DC0 readout from AOI2	
12	Data of DC2 readout from AOI2	
13	Data of DC0 readout from AOI1	4
14	Data of DC2 readout from AOI1	
15	Data of DC0 readout from AOI2	
16	Data of DC2 readout from AOI2	
17	Data of DC0 readout from AOI1	5
18	Data of DC2 readout from AOI1	
19	Data of DC0 readout from AOI2	
20	Data of DC2 readout from AOI2	

3) Configuration with single AOI, single DC, NDR mode with two NDR frames and output of 3 profiles resulting to a frame height of 6 rows:

```
ProfilesPerFrame      = 3
NumAOIs               = 1
EnableDC0             = false
EnableDC1             = false
EnableDC2             = true
NDRMode               = ”On”
NumberOfNDRFrames     = 2
```

Row #	Description	Profile #
1	Data of DC2 extracted from NDR1, readout from AOI1	1
2	Data of DC2 extracted from NDR2, readout from AOI1	
3	Data of DC2 extracted from NDR1, readout from AOI1	2
4	Data of DC2 extracted from NDR2, readout from AOI1	
5	Data of DC2 extracted from NDR1, readout from AOI1	3
6	Data of DC2 extracted from NDR2, readout from AOI1	

Advanced AOI Functions

The C5-CS-GigE features an area CMOS sensor, whose frame rate depends on the number of pixels to readout. By defining a sensor Area of Interest (AOI) the frame rate and hence the profile speed will be significantly increased due to the smaller number of pixels to readout.
In some cases the AOI position may not be constant and it should follow the image of laser line on the camera sensor. The C5-CS-GigE features functions for performing an automatic AOI positioning (AOI-Search) as well as line tracking (AOI-Tracking).

AOI-Search

The AOI-Search mode can be used in 2D mode as well as in 3D mode and has the benefit to adjust the AOI at the start of the acquisition to the optimal position of the laser line. In that case the laser line is automatically centered to the AOI.
The user must only define the minimum required AOI-Height (number of required sensor rows) for the expected laser line and afterwards the camera will adjust the vertical AOI-Offset (AoiOffsetY) value to the best position.

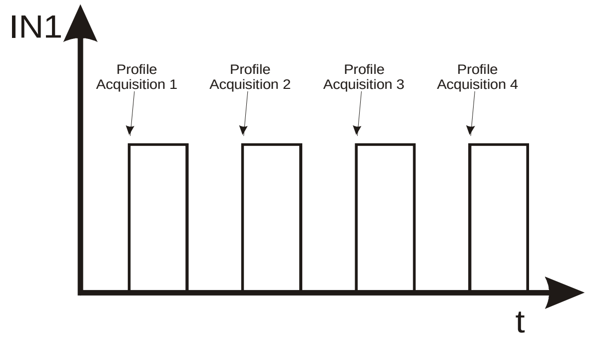
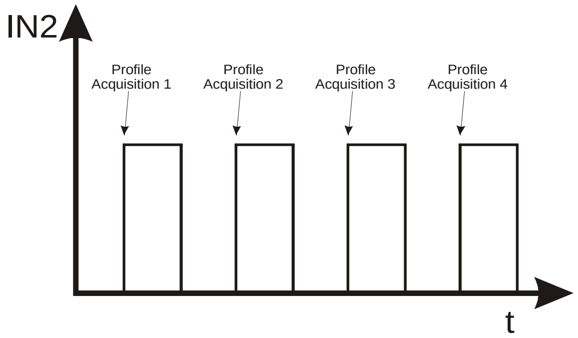
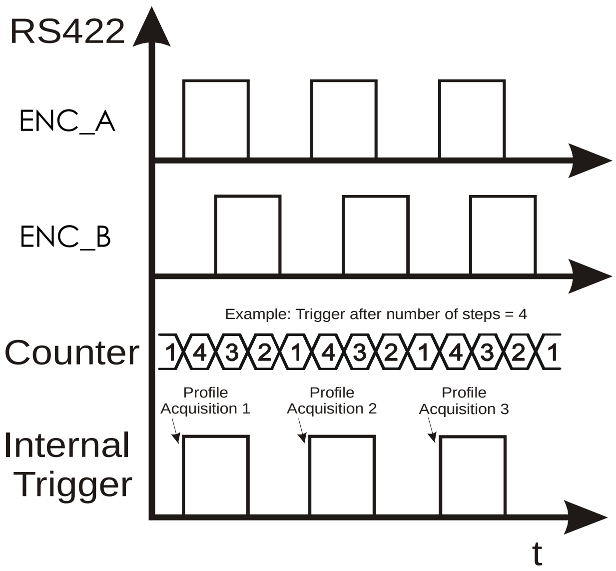
AOI-Tracking

The automatic AOI-Tracking is the dynamic version of the static AOI-Search mode. While the AOI-Search is only working at the beginning of each 3D acquisition, the AOI-Tracking mode is working continuously during 3D image acquisition.
Thus 3D profile acquisition with AOI-Tracking is able to cover the complete image/sensor size although the defined AOI size could be much smaller. This is very useful in case of applications involving continuous profile measurements with variable distances to the surface.

A detailed description of these functions can be found in a separate application note.

C5-CS-GigE Triggering

Description of Profile Trigger Modes

No.	Profile Trigger Mode (PTM)
0	**Free-run (PTM0)**
1	**Camera input 1 (PTM1)** 
2	**Camera input 2 (PTM2)** 
3	**Encoder/Resolver Interface (PTM3)** 

Trigger Control – RS422 Resolver

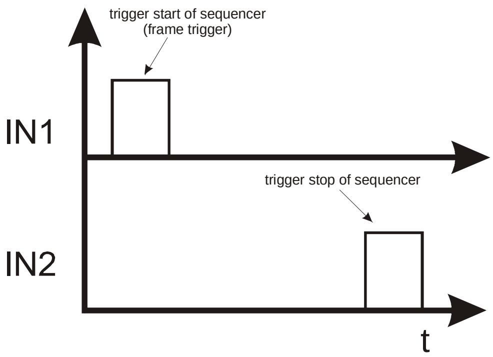
The *TriggerCoord* node always counts all the raw trigger signals arriving at the camera
-> rising AND falling edge!
The *TriggerDivider* is used internally by the camera. The camera doesn't change its behavior if the *TriggerDivider* is set to another value. A *TriggerDivider* of 10 for example will use every tenth incoming trigger for one profile measurement.

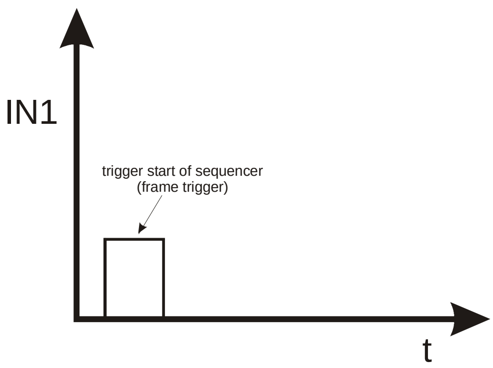
If single-ended encoder signals are required it is set over *TriggerSingleChannelMode*. Triggering over Channel A or B or over Input1 and Input2 is then possible.
If other encoder signals than RS422 are needed, use the Inputs of the camera instead of the encoder inputs and set *UseAlternateResolverInputs* to true.

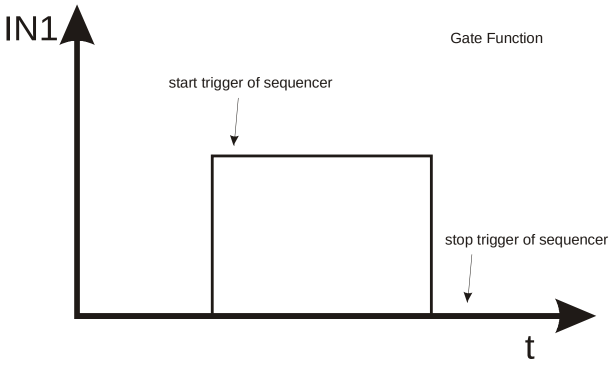
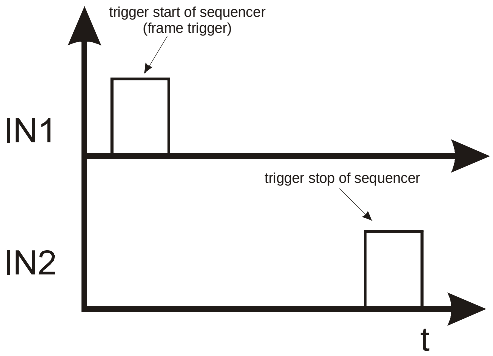
Name	Interface	Access	Visibility	Description
TriggerDivider *(*)*	IInteger	RW	Beginner	Trigger divider Min: 1 Max: 65535 Increment: 1
TriggerCoord	IInteger	RO	Beginner	Trigger coordinate
TriggerDirectionMode	IBoolean	RW	Beginner	Count resolver pulses in both directions
TriggerReverseDirection	IBoolean	RW	Beginner	Reverse the resolver count direction
TriggerSingleChannelMode *(*)*	IEnumeration	RW	Guru	Enable resolver in single channel mode (1): Disabled (Value= 0) (2): EnableIn1 (Value= 1) (3): EnableIn2 (Value= 2)
TriggerDividerLoadAtStart *(*)*	IBoolean	RW	Beginner	Load trigger divider upon start trigger
LoadTriggerDivider *(*)*	ICommand	WO*	Beginner	Load trigger divider
ClearTriggerCoord	ICommand	WO*	Beginner	Reset trigger coordinate

ResetTriggerCoordZeroPos	IEnumeration	RW	Beginner	Reset the Trigger Coordinate/Counter at Zero Position (Index, Z-Channel) (1): Off (Value= 0) (2): On (Value= 1)
TriggerCoordinateCountAlways	IBoolean	RW	Guru	TRUE: Count trigger coordinate always, FALSE: Count trigger coordinate during image acquisition only
UseAlternateResolverInputs (*)	IBoolean	RW	Guru	Use IN1/IN2 instead of A/B as inputs
UseAlternateResolverInputsInverted (*)	IBoolean	RW	Guru	Use inverted IN1/IN2

Description of Modes for Triggering of Sequencer/Frame and Profile Acquisition

<table>
<tr><th>No.</th><th>Sequencer/Frame Trigger Mode</th><th>Profile Trigger Mode (PTM)</th></tr>
<tr><td rowspan="3">0</td><td rowspan="3">Free-run</td><td>PTM0 (free-run)</td></tr>
<tr><td>PTM1 (IN1)</td></tr>
<tr><td>PTM2 (IN2)</td></tr>
<tr><td rowspan="2">1</td><td rowspan="2">Start/stop over camera input 1/2
<u>Continuous</u> frame acquisition is started with the rising edge of camera input 1 (IN1) and stopped with rising edge of camera input 2 (IN2).


When “stop” occurs, the frame is not transmitted immediately over the GigE interface but the sensor continues to acquire profile data, until the predefined frame height is reached.</td><td>PTM0 (free-run)</td></tr>
<tr><td>PTM3 (RS422)</td></tr>
<tr><td rowspan="3">2</td><td rowspan="3">Trigger one frame over camera input 1
<u>Single</u> frame acquisition is triggered over the rising edge of camera input 1 (IN1).

</td><td>PTM0 (free-run)</td></tr>
<tr><td>PTM2 (IN2)</td></tr>
<tr><td>PTM3 (RS422)</td></tr>
</table>

<table>
<tr><th>No.</th><th>Sequencer/Frame Trigger Mode</th><th>Profile Trigger Mode (PTM)</th></tr>
<tr><td rowspan="3">3</td><td rowspan="3">Gate over camera input 1
Continuous frame acquisition is performed as long as the camera input 1 is on high state.

</td><td>PTM0 (free-run)</td></tr>
<tr><td>PTM2 (IN2)</td></tr>
<tr><td>PTM3 (RS422)</td></tr>
<tr><td rowspan="2">4</td><td rowspan="2">Start/stop with instant transmission over camera input 1/2
<u>Continuous</u> frame acquisition is started with rising edge of camera input 1 (IN1) and stopped with rising edge of camera input 2 (IN2).


When "stop" occurs, the frame is transmitted immediately over the GigE interface. Using the Chunk Data mode of C5-CS sensor, it is possible to determine how many rows of the frame contain valid data (see ChunkImageInfo for details).</td><td>PTM0 (free-run)</td></tr>
<tr><td>PTM3 (RS422)</td></tr>
<tr><td rowspan="4">5</td><td rowspan="4">AutoStart (no external signal is required)</td><td>PTM0 (free-run)</td></tr>
<tr><td>PTM1(IN1)</td></tr>
<tr><td>PTM2 (IN2)</td></tr>
<tr><td>PTM3 (RS422)</td></tr>
</table>

Remarks:

The above table (except AutoStart) applies also to acquisition in image mode. In this case the sensor delivers a gray scale sensor image for every profile trigger.

A detailed description of the AutoStart function can be found in a separate application note.

The Chunk Data Mode of C5-CS-GigE

General Description

The C5-CS-GigE features a Chunk Data mode for providing additional information to the acquired image data. The implementation of XML nodes is performed according to SFNC 1.4:

- Category ChunkDataControl
- ChunkModeActive
- ChunkModeSelector (OneChunkPerFrame, OneChunkPerProfile)

The ChunkData generated by the camera have the following format:

- ChunkImage
- 1…N x ChunkAcqInfo
- ChunkImageInfo

Depending on camera mode (image or 3D) the ChunkData block („ChunkAcqInfo") can be sent as follows:

- In image mode, the camera can send only one ChunkAcqInfo block per image frame.
- In 3D mode, the camera can send one ChunkAcqInfo block either per 3D frame ("OneChunkPerFrame") or per 3D profile ("OneChunkPerProfile").

The „ChunkImageInfo" is the last ChunkData sent by the camera and contains following data:

- Number of valid rows in ChunkImage
- Number of valid ChunkAcqInfo blocks
- Flags identifying the current frame as „Start" or „Stop" and the buffer status in AutoStart mode

The ChunkAcqInfo block consists of totally 32 bytes containing following data

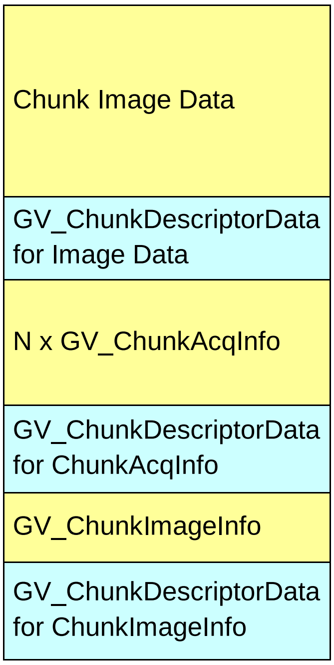
- 64 bit timestamp
- 32 bit frame counter
- 32 bit trigger coordinate
- 8 bit Trigger status
- 32 bit I/O Status
- 72 bit AOI information

The data of timestamp, frame counter, trigger coordinate, trigger status and I/O status are assigned at the start of every image integration.
When ChunkMode is disabled, the camera uses the "regular" GEV image protocol, in which the optional transfer of frames with variable height and payload is supported.

Furthermore, when ChunkMode is enabled, the camera sends the full payload, even if the ChunkImage or ChunkAcqInfo blocks contain partially valid data. The number of valid ChunkImage rows and ChunkAcqInfo blocks can be read from ChunkImageInfo.

For example, when in Start/Stop mode with instant frame transmission, the camera stops the frame acquisition as soon as the stop trigger occurs and transfers the complete contents of internal image buffer. Using the ChunkImageInfo data block, it is possible to detect how many image rows and ChunkAcqInfo blocks are valid in the payload buffer. The tag of ChunkData has big endian byte order. The data of ChunkData has little endian byte order. An endian converter for ChunkData is not supported.

Payload Layout in Chunk Data Mode



XML Descriptors and Id's

ChunkImageInfo

<Port Name="FrameInfoPort">
<ChunkID>*11119999*</ChunkID>
</Port>

ChunkAcqInfo

<Port Name="CameraChunkPort">
<ChunkID>*66669999*</ChunkID>
</Port>

ChunkImage

<Port Name="ImageInfoPort">
<ChunkID>*A5A5A5A5*</ChunkID>
</Port>

Chunk Data Structure

```
#pragma pack(push)
#pragma pack(1)

#define CHUNKACQINFO_TRIGGERSTATUS_BIT_TRIGGER_OVERRUN 0x01
#define CHUNKACQINFO_TRIGGERSTATUS_BIT_RESOLVER_CNT_UP 0x02
#define CHUNKACQINFO_TRIGGERSTATUS_BIT_IN0             0x10
#define CHUNKACQINFO_TRIGGERSTATUS_BIT_IN1             0x20
#define CHUNKACQINFO_TRIGGERSTATUS_BIT_OUT0            0x40
#define CHUNKACQINFO_TRIGGERSTATUS_BIT_OUT1            0x80

typedef struct _GV_ChunkAcqInfo
{
  unsigned int   timeStamp64L;    // 0..3
  unsigned int   timeStamp64H;    // 4..7
  unsigned int   frameCnt;        // 8..11
  signed int     triggerCoord;    // 12..15
  unsigned char  triggerStatus;   // 16
  unsigned short DAC;             // 17..18
  unsigned short ADC;             // 19..20
  unsigned char  INT_idx;         // 21
  unsigned char  AOI_idx;         // 22
  unsigned short AOI_ys;          // 23..24
  unsigned short AOI_dy;          // 25..26
  unsigned short AOI_xs;          // 27..28
  unsigned short AOI_trsh;        // 29..30
  unsigned char  AOI_alg;         // 31
} GV_ChunkAcqInfo;

#define CHUNKIMAGEINFO_FLAG_BIT_START_FRAME            0x01
#define CHUNKIMAGEINFO_FLAG_BIT_STOP_FRAME             0x02
#define CHUNKIMAGEINFO_FLAG_BIT_BUFFER_OVERRUN         0x04

typedef struct _GV_ChunkImageInfo
{
  unsigned int mSizeYReal;
  unsigned int numChunkAcqInfo;
  unsigned int flag;
} GV_ChunkImageInfo;

typedef struct _GV_ChunkDescriptor
{
  unsigned int descriptor;
  unsigned int length;
} GV_ChunkDescriptorData;

#pragma pack(pop)
```

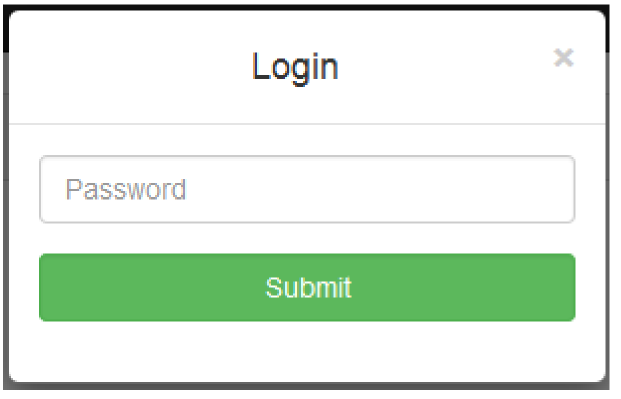
The GigE-Vision Events

The C5-CS-GigE supports a number of events that can be monitored by a software application by means of a callback function. Events provide real time notification on various stages of the acquisition sequence and data transfer.

Event Name	Event ID , (Hex)	Description
AcquisitionStart	36882 , (9012)	Frame Acquisition is started
AcquisitionEnd	36883 , (9013)	Frame Acquisition is terminated
TransferStart	36884 , (9014)	Frame transfer is started from the camera
TransferEnd	36885 , (9015)	Frame transfer is terminated
AoiTrackingOn	36886 , (9016)	The AOI tracking process is started and the laser line image is valid for AOI alignment
AoiTrackingOff	36887 , (9017)	The AOI tracking process is stopped and the AOI position is not updated anymore
AoiSearchFailed	36888 , (9018)	AOI-Search failed to detect the laser line
AutoStarted	36889 , (9019)	Frame Acquisition is initiated through AutoStart

The Web Interface

The service web interface gives access to basic device and runtime information aside from the common GenICam interface. It can be accessed with an ordinary web browser, by typing the cameras IP address into the browsers URL field, e.g.: http://169.254.64.2. A login window appears, as the following figure shows. The static password "**admin**" gives access to the camera service web interface.



Connect via web browser by using the set IP e.g. "http://169.254.64.2/".
The static password for login is "admin".

In the header bar is the manufacture info, the model name and the serial number.

The "Device Info" panel displays model specific information.

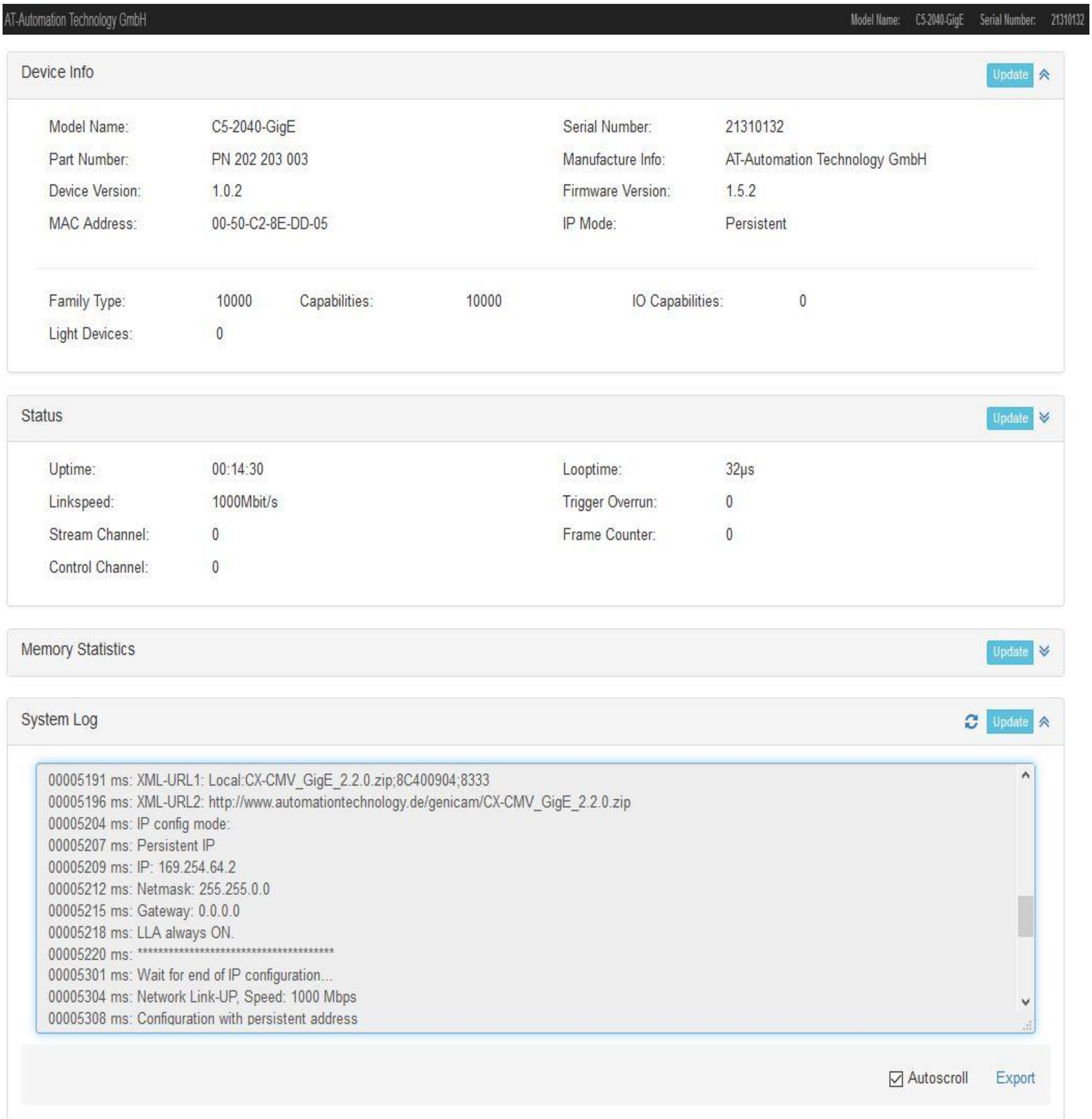
The "Status" panel shows runtime status information.

The "Memory Statistics" have an overview of used memory for each component displaying current usage, memory size, maximum usage and error.

The "System Log" shows the complete serial log of the device.

Every panel has an *Update Button* in the panel header. Each button updates the data for the specific panel. Collapsing and opening the panel by clicking the *Arrow* on the right hand side.

At the "System Log" panel is an additional button which start an update process and will fetches every two seconds the log data. The state of auto update process is shown by *Spinning Button* (ON) or not spinning (OFF). The *Autoscroll* flag enable an automatically scroll down to the latest log entry. Over the button *Export* the complete log and JSON data of each panel data, wrapped in a single text file will exported.

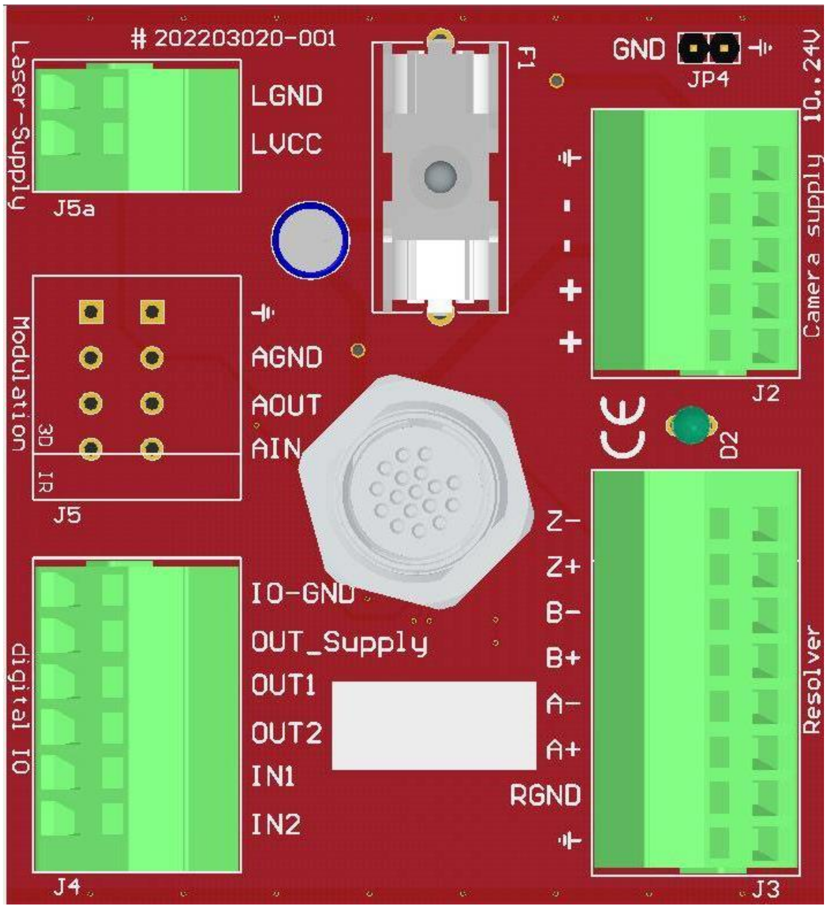

AT-Automation Technology GmbH
Model Name: C5-2040-GigE Serial Number: 21310132
Device Info
Update
Model Name: C5-2040-GigE
Serial Number: 21310132
Part Number: PN 202 203 003
Manufacture Info: AT-Automation Technology GmbH
Device Version: 1.0.2
Firmware Version: 1.5.2
MAC Address: 00-50-C2-8E-DD-05
IP Mode: Persistent
Family Type: 10000
Capabilities: 10000
IO Capabilities: 0
Light Devices: 0
Status
Update
Uptime: 00:14:30
Looptime: 32µs
Linkspeed: 1000Mbit/s
Trigger Overrun: 0
Stream Channel: 0
Frame Counter: 0
Control Channel: 0
Memory Statistics
Update
System Log
Update
00005191 ms: XML-URL1: Local:CX-CMV_GigE_2.2.0.zip;8C400904;8333
00005196 ms: XML-URL2: http://www.automationtechnology.de/genicam/CX-CMV_GigE_2.2.0.zip
00005204 ms: IP config mode:
00005207 ms: Persistent IP
00005209 ms: IP: 169.254.64.2
00005212 ms: Netmask: 255.255.0.0
00005215 ms: Gateway: 0.0.0.0
00005218 ms: LLA always ON.
00005220 ms: **
00005301 ms: Wait for end of IP configuration...
00005304 ms: Network Link-UP, Speed: 1000 Mbps
00005308 ms: Configuration with persistent address
Autoscroll
Export

The External CS-IO-Panel (Breakout Board)

The CS-IO-Panel (#202 201 402) provides a user friendly way to connect the power, I/O and laser supply of the C5-CS sensor. The camera power supply includes a reverse voltage protection and features a 2A (two ampere) micro-fuse.

Fuse Specification	
Current	2A
Dimension	5 x 20mm
Characteristic	T
Operating Temperature	-50°C to +125°C

Mechanical Drawings

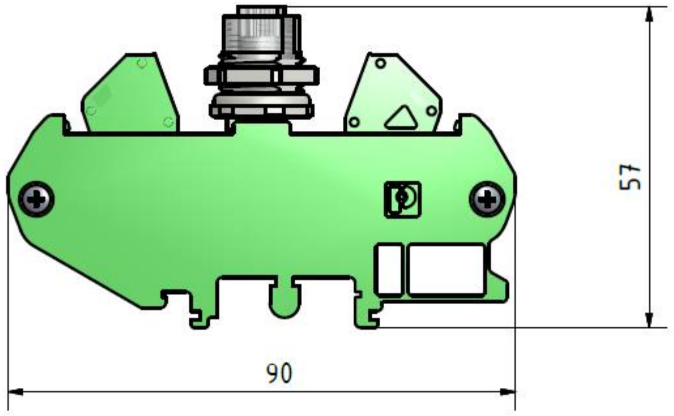


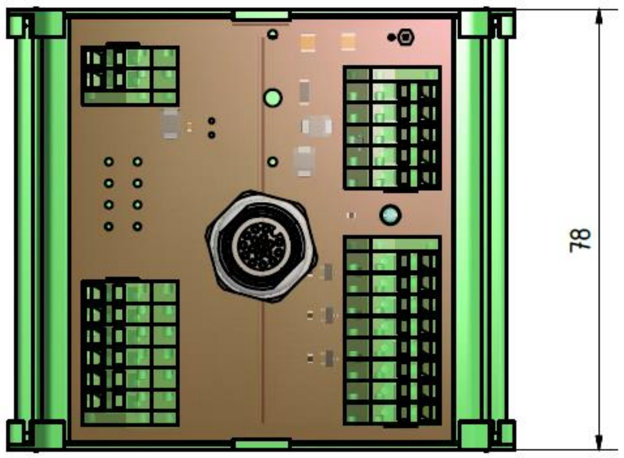
Don´t connect C5 cameras to the CS-IO-Panel. Wrong wiring can cause damage to the camera.

Clamp Configuration

Clamp No.	Signal Name	Description
J2/1	SHIELD	Sensor shield
J2/2	GND_EXT (-)	Sensor supply ground
J2/3	GND_EXT (-)	Sensor supply ground
J2/4	VCC_EXT (+)	Sensor supply voltage (+10 to +24V DC)
J2/5	VCC_EXT (+)	Sensor supply voltage (+10 to +24V DC)
J3/1	Z-	Differential encoder/resolver index track Z-
J3/2	Z+	Differential encoder/resolver index track Z+
J3/3	B-	Differential encoder/resolver track B-
J3/4	B+	Differential encoder/resolver track B+
J3/5	A-	Differential encoder/resolver track A-
J3/6	A+	Differential encoder/resolver track A+
J3/7	RGND	Encoder/Resolver ground
J3/8	SHIELD	Encoder/Resolver shield
J4/1	IO-GND	Reference ground for digital inputs (IN1, 2) and outputs (OUT1, 2)
J4/2	OUT_Supply	Power supply voltage of sensor isolated outputs (+5 to +24V DC)
J4/3	OUT1	Isolated output #1 (reference voltage OUT_Supply)
J4/4	OUT2	Isolated output #2 (reference voltage OUT_Supply)
J4/5	IN1	Isolated input #1 (+5 to +24V)
J4/6	IN2	Isolated input #2 (+5 to +24V)
J5a/1	LGND	Laser supply ground
J5a/2	LVCC	Laser supply voltage (+5 to +24V)

Mechanical Dimension

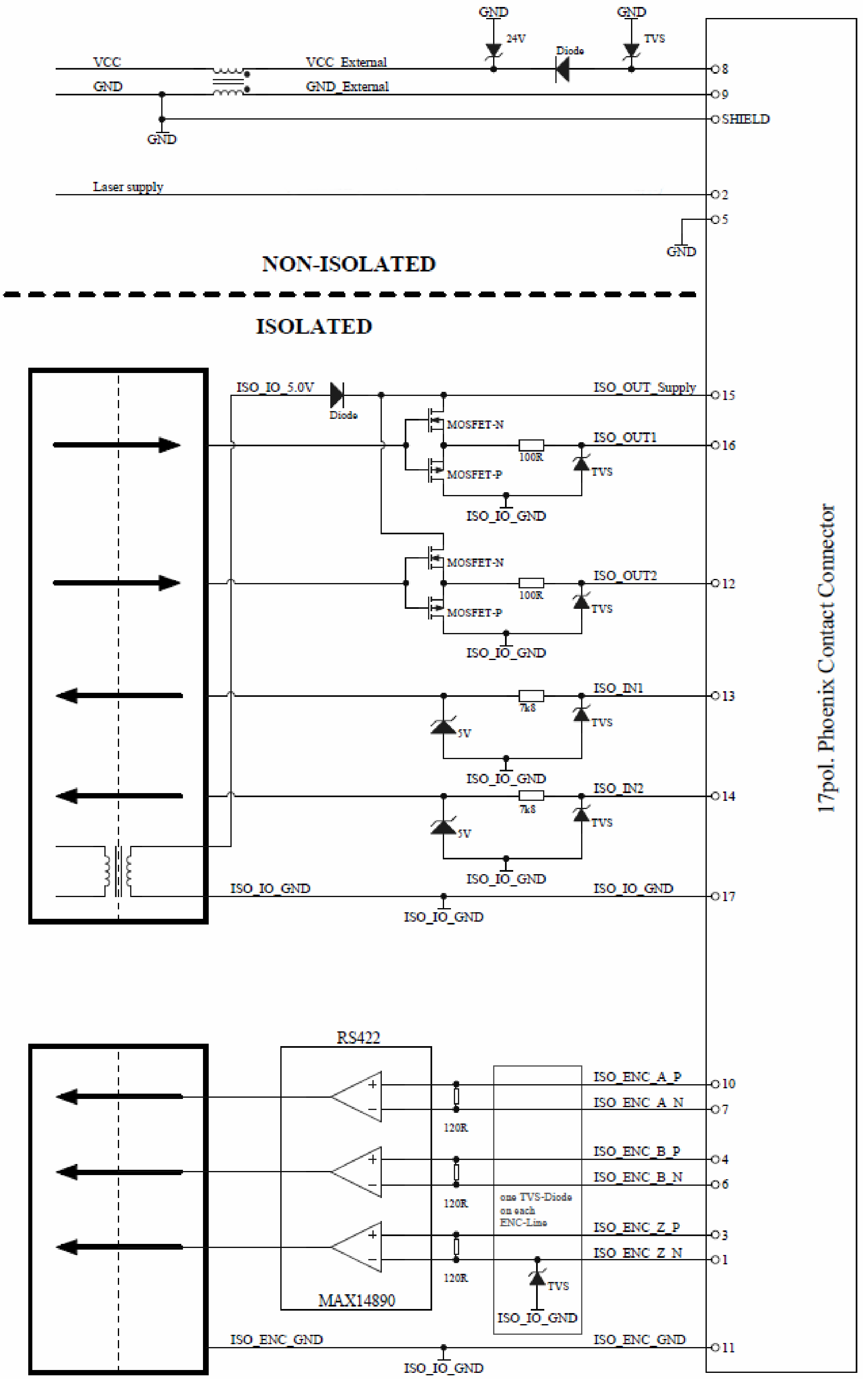




All dimensions in mm
Mount for DIN rail assembly

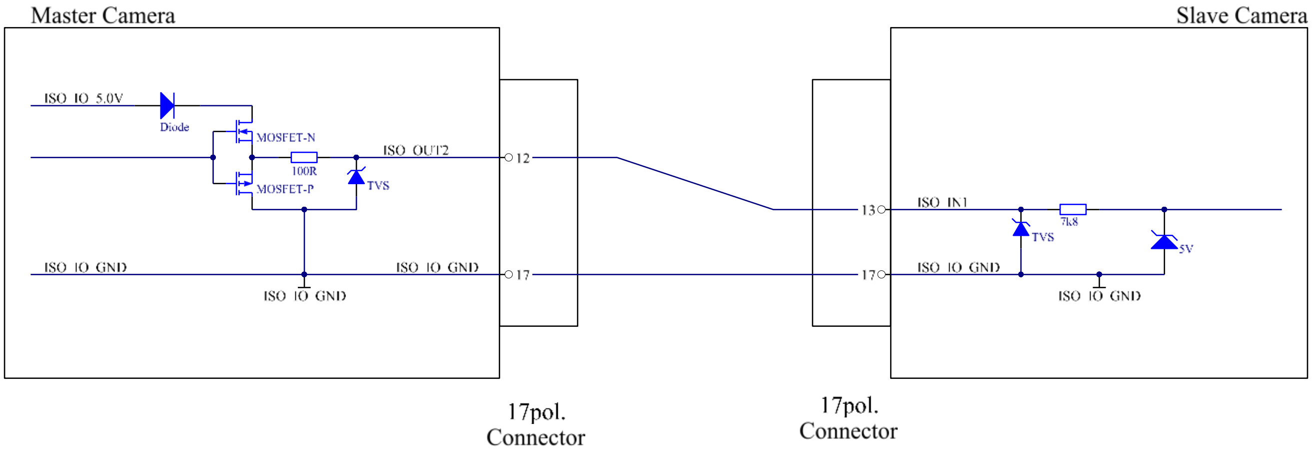
The C5-CS Series I/O Schematics

I/O and Encoder with Differential TTL-Mode for RS422

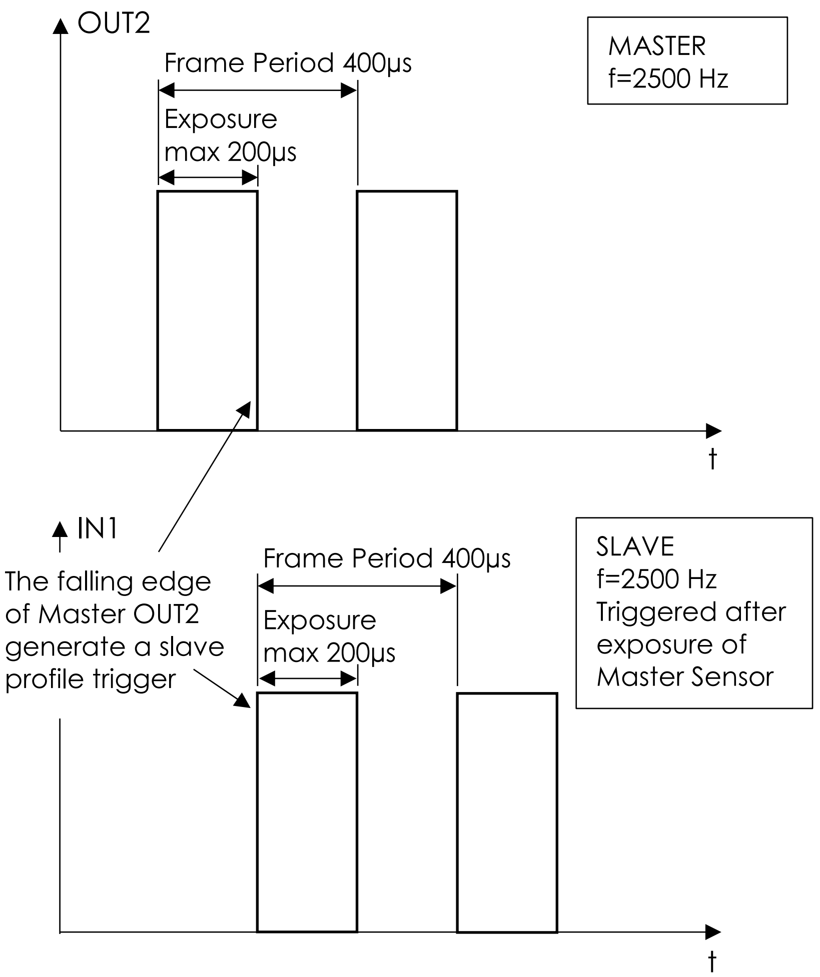


Master/Slave Connection

This schematic shows the required wiring to operate two C5-CS sensors in a Master/Slave mode. For this purpose the OUT2 of the master sensor is exemplary connected to the trigger input IN1 of the slave sensor. The Master/Slave mode can be realized with both inputs (IN1/IN2) and outputs (OUT1/OUT2).



Example configuration for Master/Slave Connection



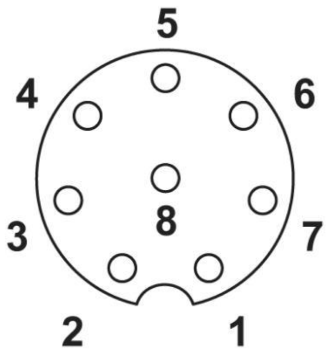
Use Registers:

Master:
Output2 = Out2_IntegrationActive
Output2Invert = true

Slave:
ProfileTriggerMode = CameraInput1

C5-CS-GigE Interface

The GigE Interface

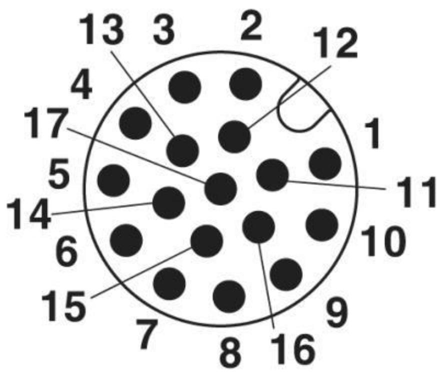


M12 GigE Female Connector Pin Assignment

Pin No.	GigE Signal Name
1	BI_DC-
2	BI_DD+
3	BI_DD-
4	BI_DA-
5	BI_DB+
6	BI_DA+
7	BI_DC+
8	BI_DB-
Shield	Shield

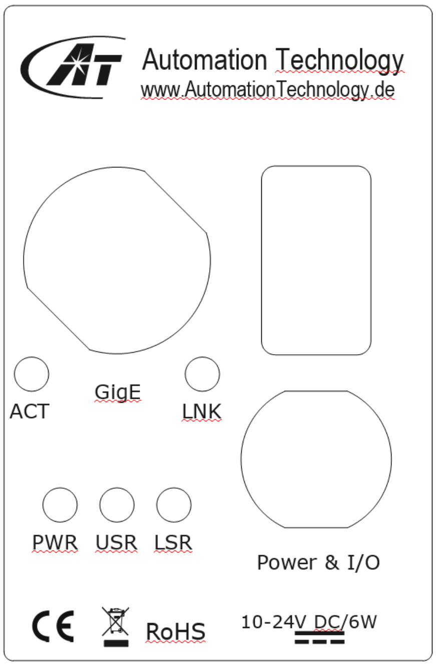
The I/O & Power Interface

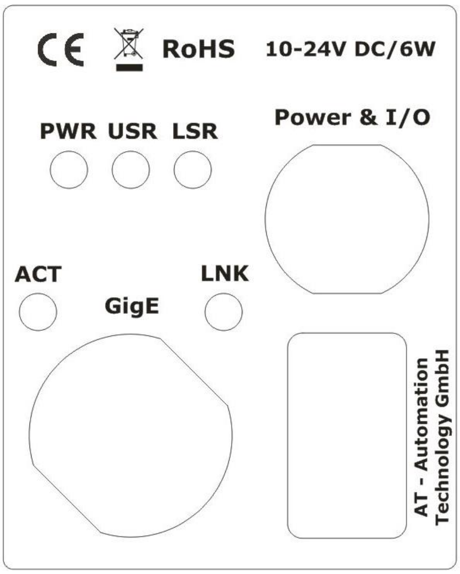
M12 I/O Male Connector Pin Assignment



Pin No.	Signal Name	Description
1	ENC_Z-	Encoder/Resolver index track Z-
2	LASER_Supply	Laser supply voltage (+5 to +24V DC)
3	ENC_Z+	Encoder/Resolver index track Z+
4	ENC_B+	Encoder/Resolver Track B+
5	GND_EXT	Laser/Sensor supply GND Pin1
6	ENC_B-	Encoder/Resolver Track B -
7	ENC_A-	Encoder/Resolver Track A -
8	VCC_EXT	Sensor supply voltage (+10 to +24V DC)
9	GND_EXT2	Laser/Sensor supply GND Pin2
10	ENC_A+	Encoder/Resolver Track A+
11	ENC_GND	Encoder/Resolver ground
12	OUT2	Electrically isolated digital output 2
13	IN1	Electrically isolated digital input 1 (+5 to +24V DC)
14	IN2	Electrically isolated digital input 2 (+5 to +24V DC)
15	OUT_Supply	Reference supply for digital isolated outputs (+5 to +24V DC)
16	OUT1	Electrically isolated digital output 1
17	IO_GND	Reference ground for digital inputs (IN1, 2) and outputs (OUT1, 2)
Shield	SHIELD	Is connected to sensor case

Description of LEDs





LED	Description
1 (PWR)	Green On= Power On and camera start up completed Off = Power Off or camera start up failed
2 (USR)	<u>After Power On:</u> Off = no network cable connected Green On = network connected <u>After Network connected:</u> Green On = CCP status connected Off = CCP status disconnected Red On= no network found, no network cable connected
3 (LSR)	Red On = Laser is On Off = Laser is Off
4 (ACT)	Green blink = Indication of network activity
5 (LNK)	Green On = Linkspeed 1 Gbit Amber On = Linkspeed 100 Mbit Off = Linkspeed 10 Mbit or wait for end of autonegotiation

The C5-CS Cables

Cables for Power, I/O and Laser Control

Part Number #	Description
202 202 300	M12 17 pin cable for power, I/O and laser control, custom length and connector configuration (straight/angled), shielded, high flex
202 202 301	M12 17 pin cable for power, I/O and laser control, straight M12 female connector (IP67) to straight M12 male connector (IP67), shielded, length 0.5m, high flex
202 202 302	M12 17 pin cable for power, I/O and laser control, straight M12 female connector (IP67) to straight M12 male connector (IP67), shielded, length 3m, high flex
202 202 303	M12 17 pin cable for power, I/O and laser control, straight M12 female connector (IP67) to straight M12 male connector (IP67), shielded, length 5m, high flex
202 202 304	M12 17 pin cable for power, I/O and laser control, straight M12 female connector (IP67) to straight M12 male connector (IP67), shielded, length 10m, high flex

Pigtail cables:

202 202 311	M12 17 pin pigtail cable for power, I/O and laser control, straight M12 female connector (IP67) on camera plug, shielded, length 3m, high flex
202 202 312	M12 17 pin pigtail cable for power, I/O and laser control, straight M12 female connector (IP67) on camera plug, shielded, length 5m, high flex
202 202 313	M12 17 pin pigtail cable for power, I/O and laser control, straight M12 female connector (IP67) on camera plug, shielded, length 10m, high flex

Angled adapter cables:

202 201 501	M12 17 pin angled adapter cable for power, I/O and laser control, 90° angled M12 female connector (IP64) on camera plug to straight M12 male (IP64), angled connector configuration "DOWN", length 0.2m, standard
202 201 511	M12 17 pin angled adapter cable for power, I/O and laser control, 90° angled M12 female connector (IP64) on camera plug to straight M12 male (IP64), angled connector configuration "UP", length 0.2m, standard

Wire Assignment of M12 17 pin Pigtail Cable

Pin/Wire No.	Wire Colour	Signal Name	Description
1	Brown	ENC_Z-	Encoder/Resolver index track Z-
2	Blue	LASER_Supply	Laser supply voltage (+5 to +24V DC)
3	White	ENC_Z+	Encoder/Resolver index track Z+
4	Green	ENC_B+	Encoder/Resolver Track B+
5	Pink	GND_EXT	Laser/Sensor supply GND Pin1
6	Yellow	ENC_B-	Encoder/Resolver Track B-
7	Black	ENC_A-	Encoder/Resolver Track A-
8	Gray	VCC_EXT	Sensor supply voltage (+10 to +24V DC)
9	Red	GND_EXT2	Laser/Sensor supply GND Pin2
10	Violette	ENC_A+	Encoder/Resolver Track A+
11	Gray/Pink	ENC_GND	Encoder/Resolver ground
12	Red/Blue	OUT2	Opto-isolated digital output 2
13	White/Green	IN1	Opto-isolated digital input 1 (+5 to +24V DC)
14	Orange/Green	IN2	Opto-isolated digital input 2 (+5 to +24V DC)
15	White/Yellow	OUT_Supply	Reference supply for digital output signals (+5 to +24V DC)
16	Yellow/ Orange	OUT1	Opto-isolated digital output 1
17	White/Gray	IO_GND	Reference ground for digital inputs (IN1, 2) and outputs (OUT1, 2)

Cables for GigE Interface

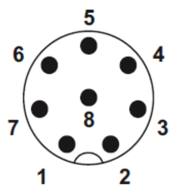
Part Number #	Description
202 201 200	M12 GigE cable with custom length and connector configuration (straight/angled)
202 201 201	M12 GigE cable, straight M12 male connector (IP67) on camera plug to RJ45 (IP20), length 0.5m, standard
202 201 202	M12 GigE cable, straight M12 male connector (IP67) on camera plug to RJ45 (IP20), length 3m, standard
202 201 203	M12 GigE cable, straight M12 male connector (IP67) on camera plug to RJ45 (IP20), length 5m, standard
202 201 204	M12 GigE cable, straight M12 male connector (IP67) on camera plug to RJ45 (IP20), length 10m, standard
202 201 205	M12 GigE cable, straight M12 male connector (IP67) on camera plug to RJ45 (IP20), length 15m, standard
202 201 206	M12 GigE cable, straight M12 male connector (IP67) on camera plug to RJ45 (IP20), length 30m, standard

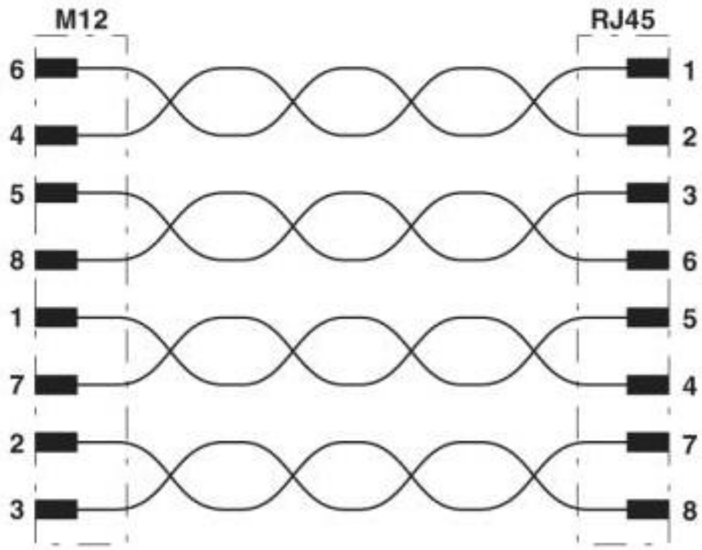
Angled adapter cables:

202 201 502	M12 GigE angled adapter cable for GigE, 90° angled M12 male connector (IP64) on camera plug to straight M12 female (IP64), angled connector configuration “DOWN”, length 0.2m, standard
202 201 512	M12 GigE angled adapter cable for GigE, 90° angled M12 male connector (IP64) on camera plug to straight M12 female (IP64), angled connector configuration “UP”, length 0.2m, standard

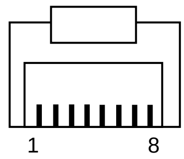
M12

Male Plug





RJ45
Male Plug



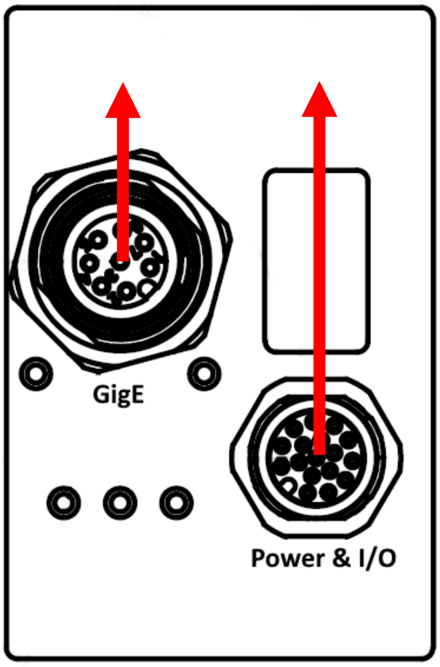
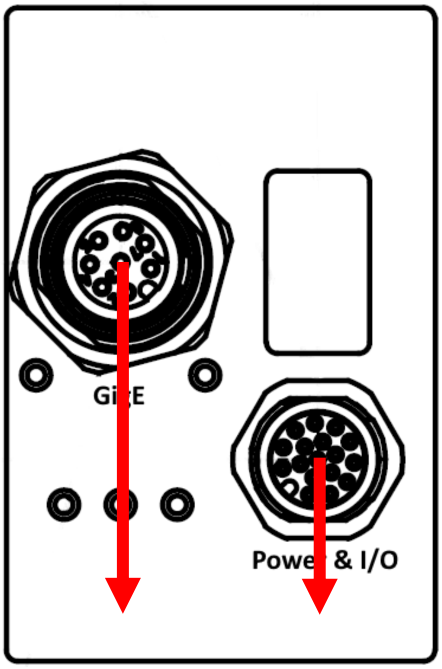
GigE Signal Name	Pin No. M12	Pin No. RJ45
BI_DC-	1	5
BI_DD+	2	7
BI_DD-	3	8
BI_DA-	4	2
BI_DB+	5	3
BI_DA+	6	1
BI_DC+	7	4
BI_DB-	8	6
Shield	Shield	Shield

Orientation of Angled Adapter Cable

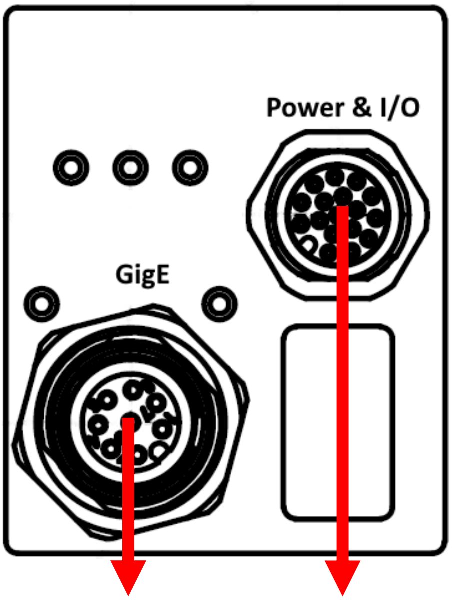
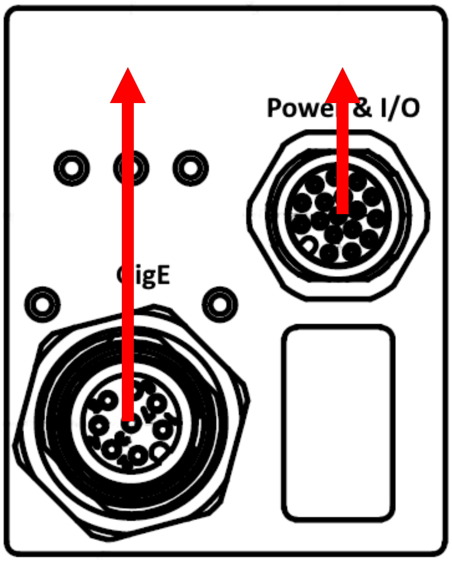
Depending on the used sensor the orientation of the angled adapter cables differs. The option “UP” or “DOWN” will change the outlet direction of the angled cables.

Part Number #	Description
202 201 501	Power & I/O “DOWN”
202 201 502	GigE “DOWN”
202 201 511	Power & I/O “UP”
202 201 512	GigE “UP”

For the sensor models Model 1A, Model 2A/2B and Model 3 the adapter cables have following orientation.

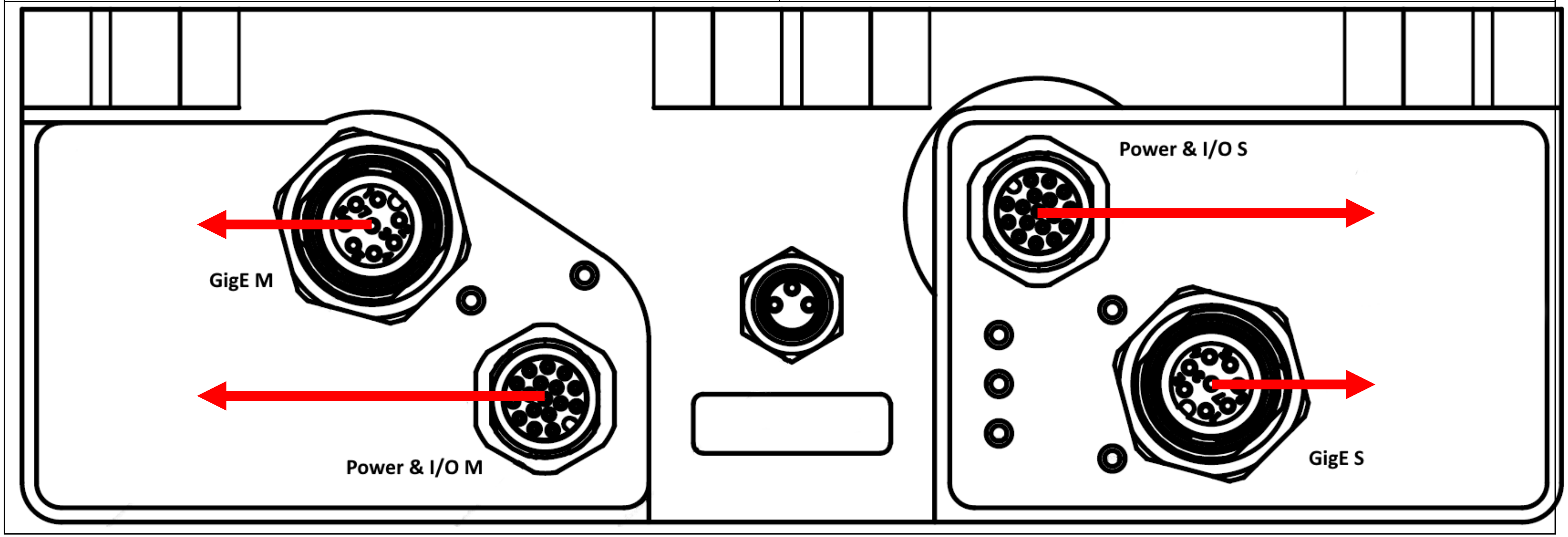
DOWN	UP
	

For the sensor models Model 1B, Model 4 and Model 6 the adapter cables have following orientation.

DOWN	**UP**
	

For Model 5 the orientation of the angled adapter cables is as following. Only #202 201 501and #202 201 502 are recommended.

DOWN	DOWN



The C5-CS Series GenICam Features

A complete list of all GenICam features for all types of compact sensor models (C5-1280CS, C5-1600CS/C5-2040CS, C5-3360CS and C5-4090CS) can be found in separate notes.

Device Control

Description of the camera and its sensor

Image Format Control

Features controlling the size and type of the transmitted image

Acquisition Control

Feature relating to actual frame acquisition

Camera Control

Features relating to camera control

AOIs

Features relating to area of interest

FIR Control

Features relating to FIR

Mode and Algorithm Control

Features relating to camera mode and algorithm

AoiTracking

Features relating to AOI-Tracking mode

AoiSearch

Features relating to the AOI-Search mode

ColumnEvaluationMask

Features relating to the Column Evaluation Mask. It is a global mask and valid for all functions (AOI-Tracking, AOI-Search, AutoStart)

Sensor Control

Features relating to sensor control

Advanced Sensor Settings

Features relating to advanced sensor settings

Data Output Channels

Features relating to data output

Commands

Commands for camera

Light Control

Features relating to Light Control

Camera IO

Features relating to camera input and output

Trigger Control

Features relating to trigger controls

RS422 Resolver

Features relating to RS422 resolver

AutoStart

Features relating to AutoStart

Transport Layer Control

Features related to GigE Vision specification

GigE Vision

Features related to GigE Vision specification

User Set Control

Features related to the User Set Control to save and load the user device settings

Chunk Data Control

Features relating to chunk data control

Event Control

Features required to control the generation of event notifications sent to host application

File Access Control

Category that contains the file access control features

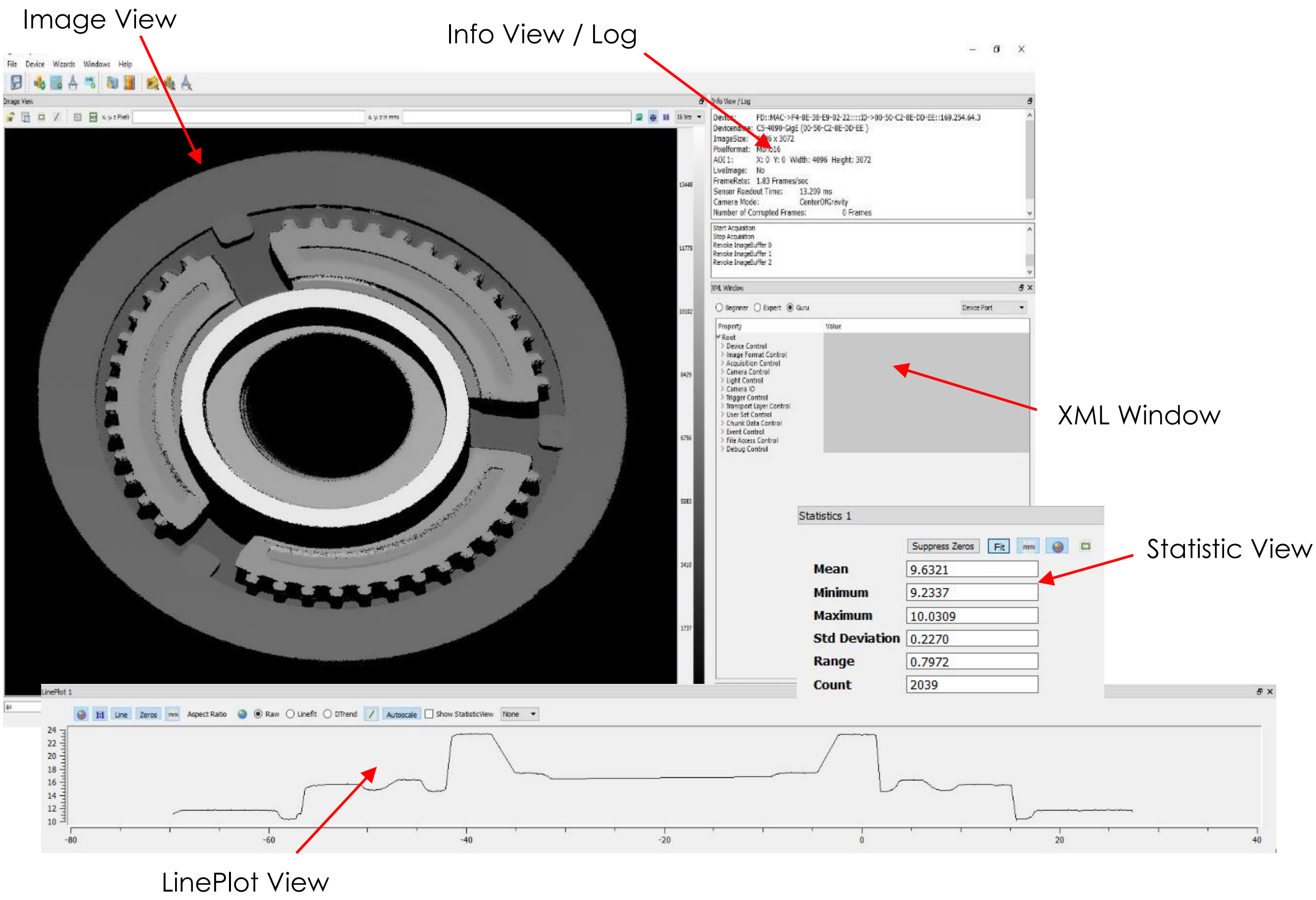
cxExplorer Overview

The cxExplorer

Configuration of a C5-CS sensor can be easily done with the cxExplorer, which is a graphical user interface provided by AT - Automation Technology. With the help of the cxExplorer a sensor can be simply adjusted to the required settings. Furthermore, the cxExplorer gives the opportunity to display various information like the 2D image, 3D height image and many more.

This chapter gives some general information about the layout of the cxExplorer such as an overview of how to set parameters and features.

More details regarding the operation of the cxExplorer can be found in a separate application note.



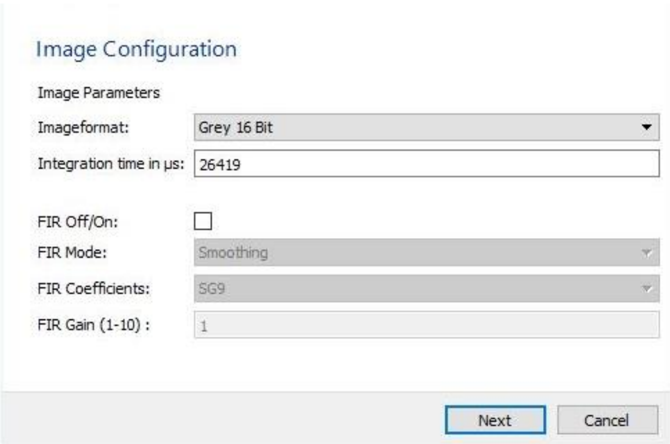
cxExplorer Features

As mentioned in the previous chapter **The C5-CS Sensor Algorithms** every C5-CS sensor is able to run in 2D image mode or in 3D mode.

The configuration of the required mode can be easily done with the cxExplorer via the *Image Wizard, 3D Wizard* or over the *XML Window*.

Image Wizard

The Image Wizard is an easy way to set the camera to the 2D greyscale image mode. Select the image format, set the integration time and enable or disable the FIR filter.



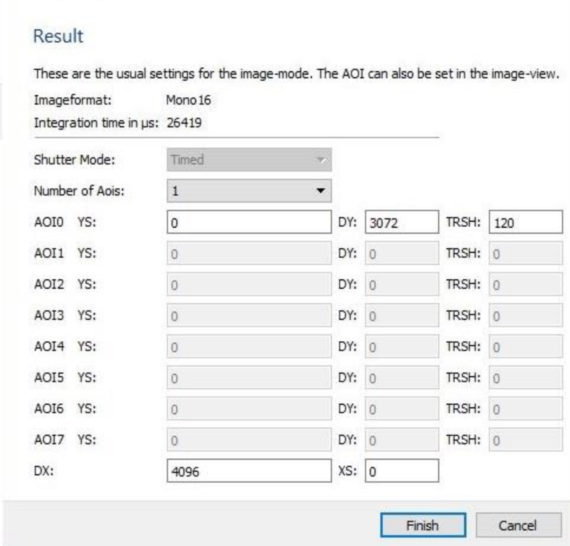
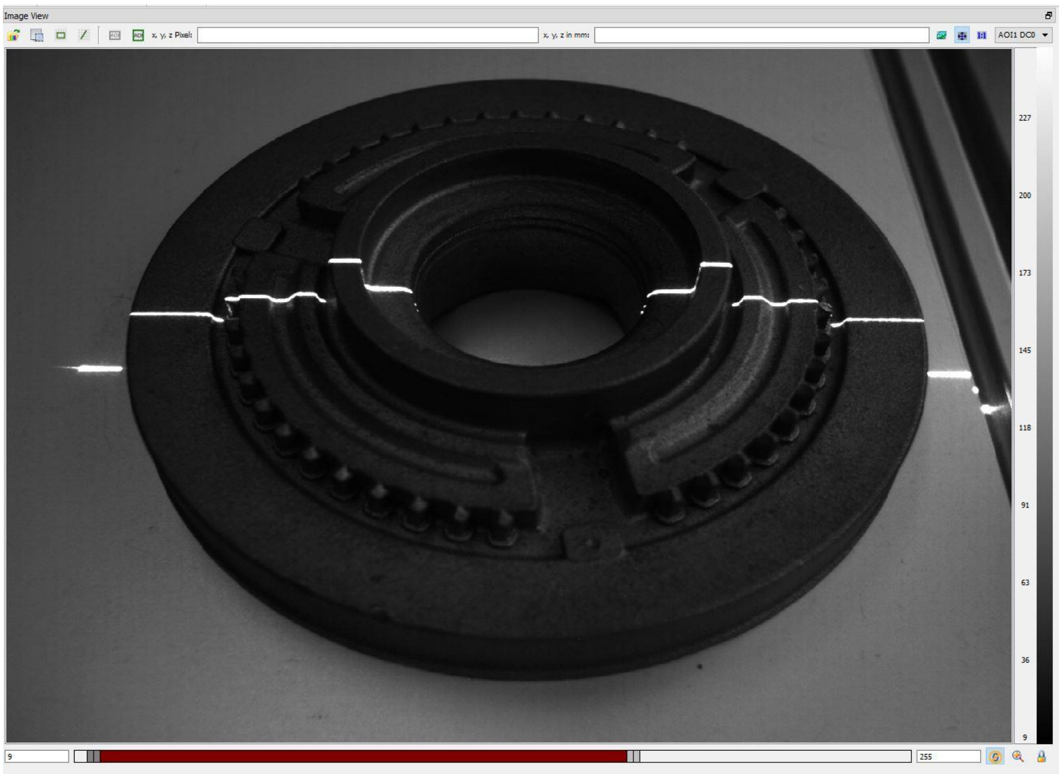


Image Mode

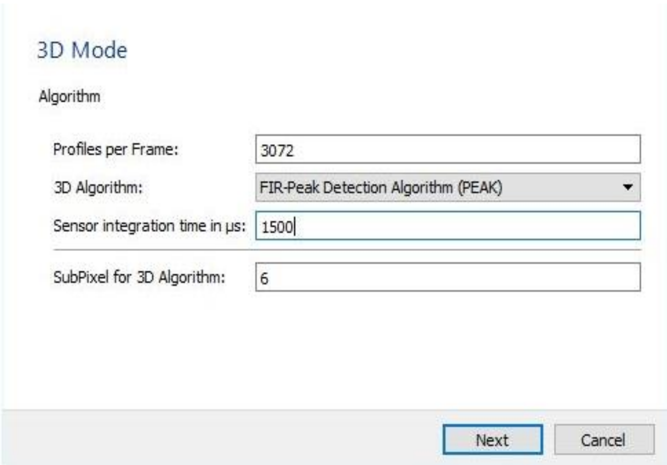
The image mode enables the output of the 2D CMOS sensor images of the camera. That can be helpful i.e. to set and optimize the laser power, the Area Of Interest (AOI) or the exposure time.

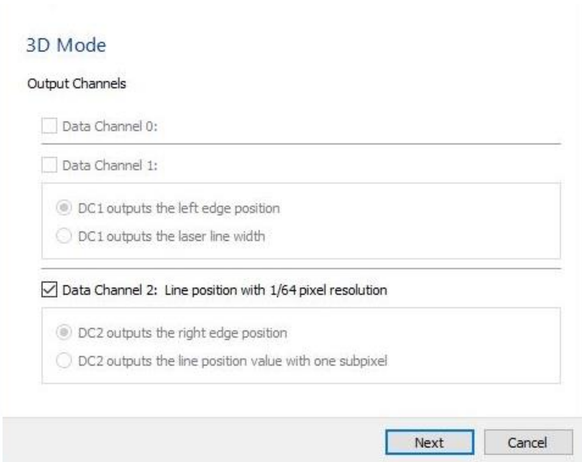


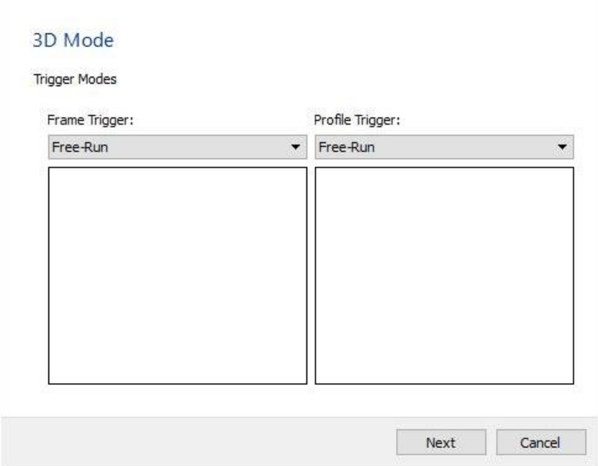
(2D greyscale image)

3D Wizard

With the 3D Wizard the camera mode can be easily switched to 3D mode. Set the number of profiles per frame, choose the 3D algorithm, set the integration time and select the number of subpixel. Enable the required Output Channels and select the trigger mode to finish the wizard.

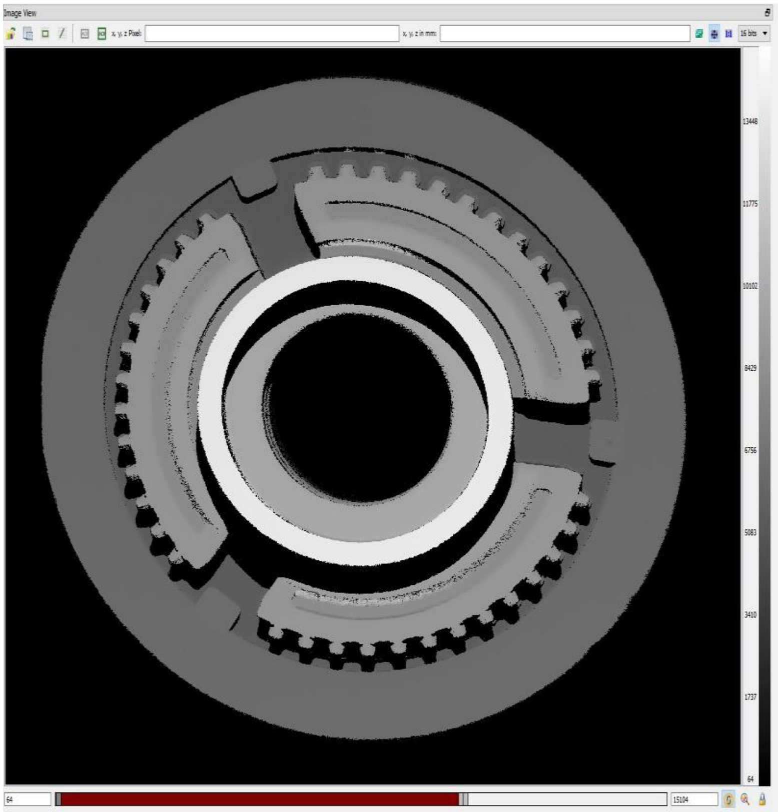






3D Mode

In the 3D mode a greyscale height image can be acquired and displayed in the Image View using one of the four different algorithms. Furthermore, the intensity image can be also displayed.

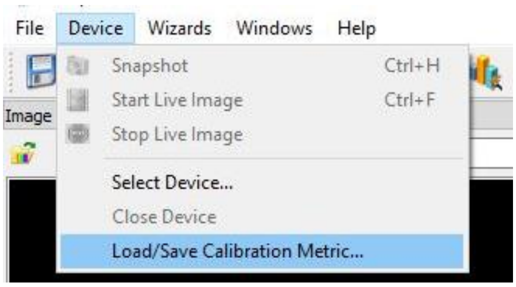


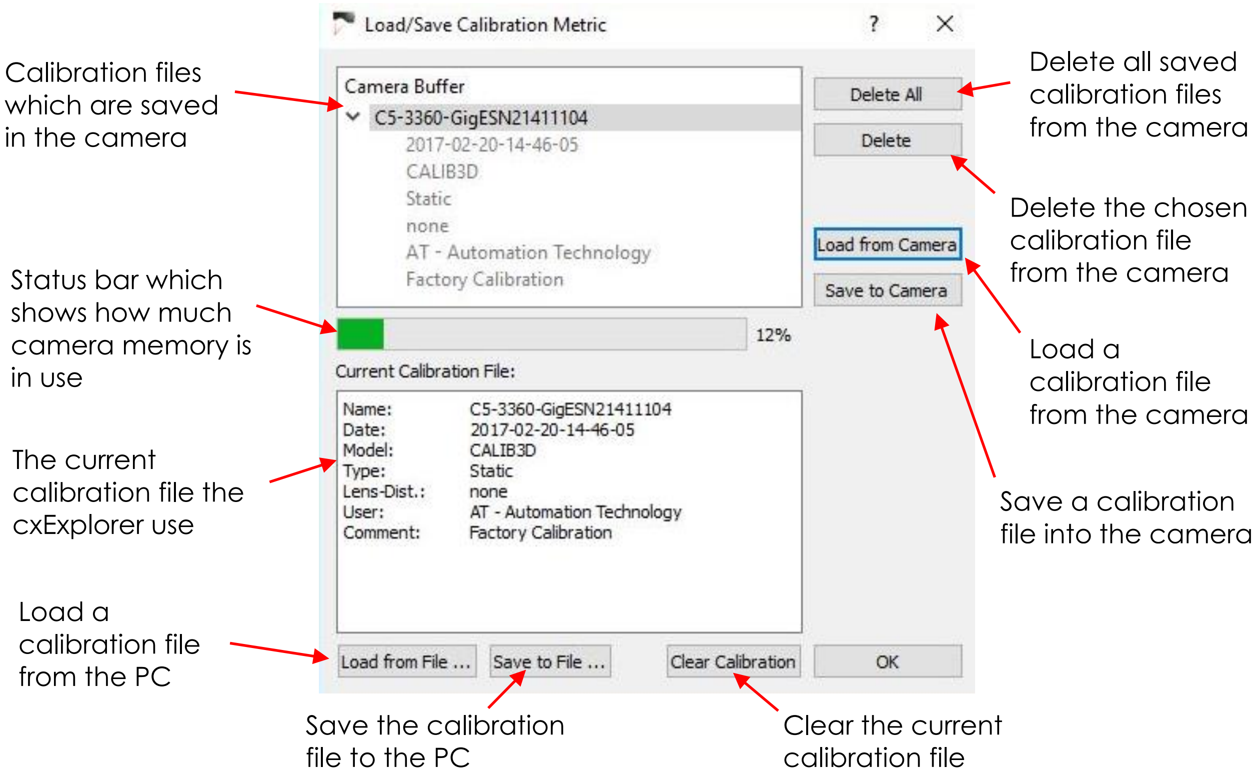
(3D greyscale height image)

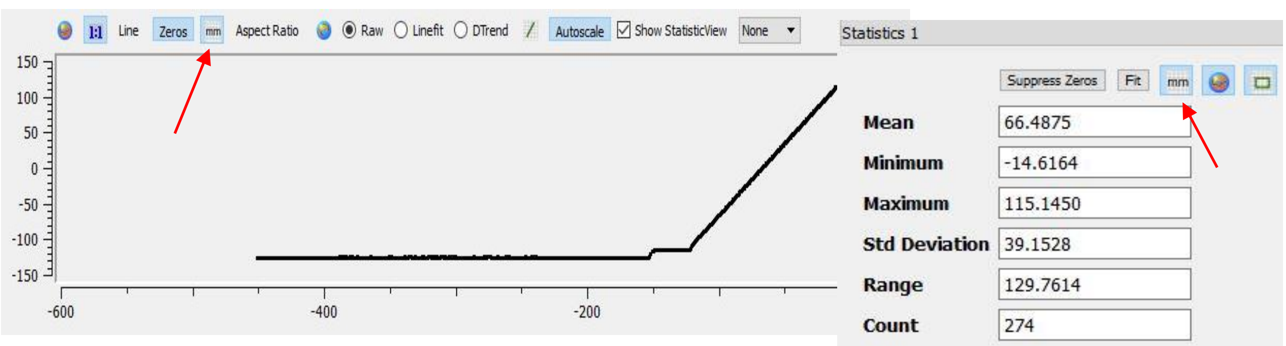
A detailed description of the operation of the cxExplorer can be found in a separate note.

Calibrate the Sensor Data

The data the C5 compact sensor acquires are always non-calibrated. By factory every C5-CS sensor has a stored calibration file to translate pixel values into metrical values. Load and save calibration files in the cxExplorer over *Device -> Load / Save Calibration Metric*.







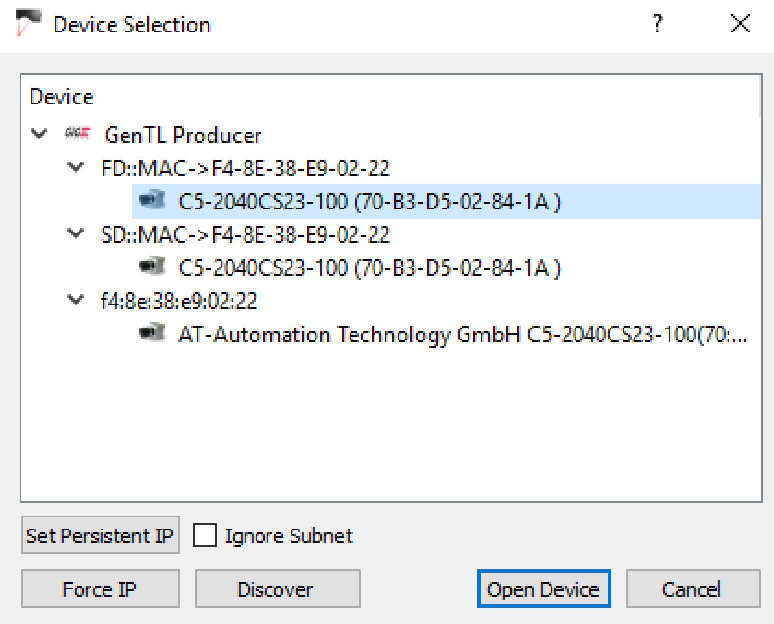
Change in the LinePlot View or in the Statistics View the pixel values into millimeter by enable the mm button.

Quickstart a C5-CS Sensor

This chapter explains the handling to set up a C5-CS sensor and the computer to acquire the first images.

Set the computer to the recommended settings in the following.

1. **Turn off** all possible software which can block sent packages from the sensor to the PC or the other way around like **Firewalls** or **Antivirus** software.
2. **Connect the sensor** directly or over a switch to the PC. Identify which network interface card (NIC) is linked to the sensor.
3. **Disable** not needed **filter drivers** and **protocols** of the NIC port.
4. **Set** the computer Internet Protocol Version 4 (TCP/IPv4) to a **fix IP address** and a fix subnet mask. For example: 169.254.64.1, 255.255.0.0.
5. **Enable Jumbo Frames** if possible.
6. **Starting the cxExplorer** lead to the *Device Selection*. Chose the camera over the available Transport Layer and open the device. If the camera isn´t visible check the IP address or search for subnets.

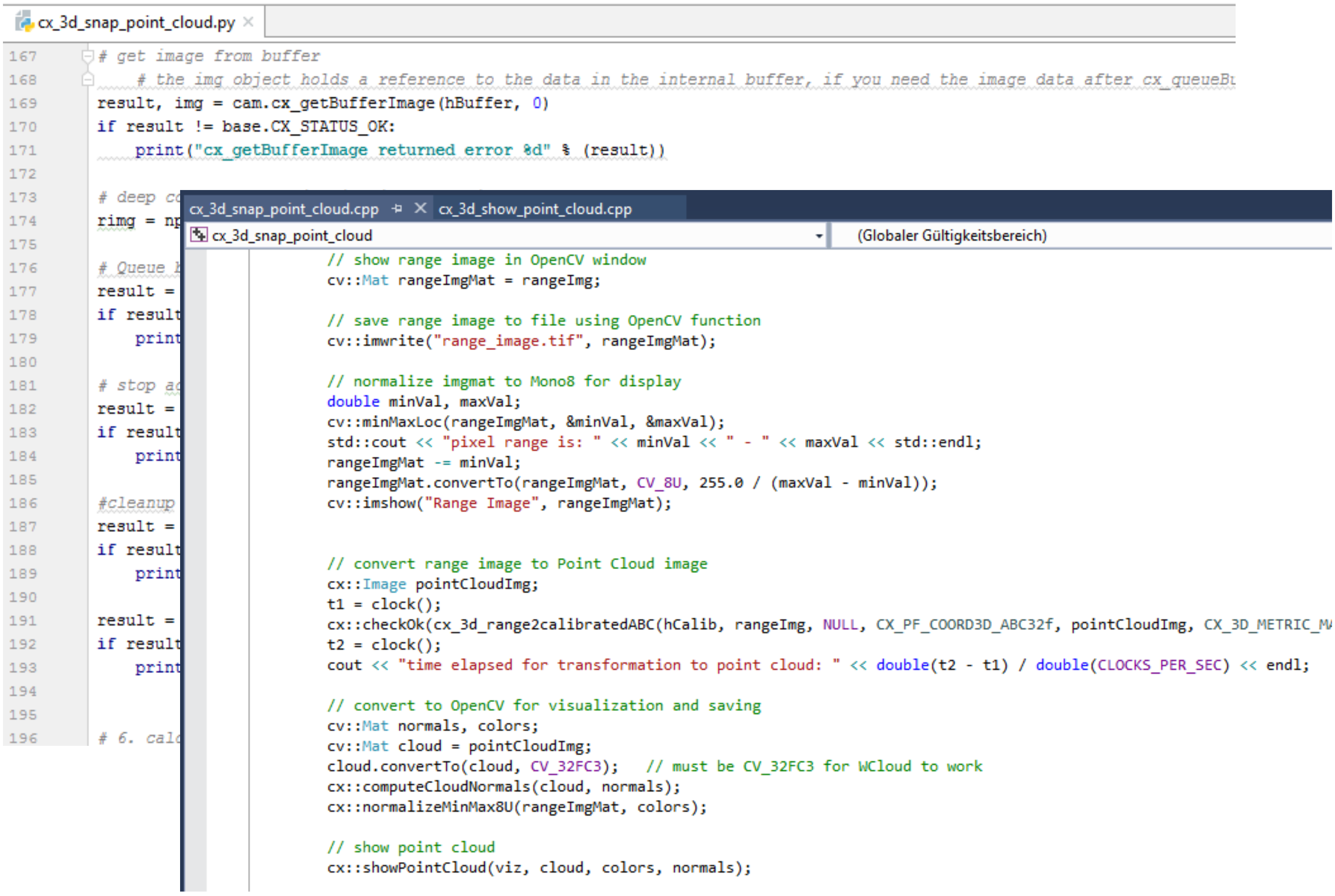


By default the sensor starts in the factory mode. For the C5-CS sensor the factory mode is either the COG or the FIR Peak mode. **Start** the continuous **image grab** over  or do a snapshot over .

The first images were acquired.

cxSoftware Development Kit

Automation Technology´s Software Development Kit (cxSDK) is free of charge and allows the programmatically access and control of C5-CS sensors and further the usage of the 3D calibration.
The cxSDK provides a C-based application-programming interface (API) with language wrappers for C++, Python, Matlab and Octave.
The cxSDK consists of the cxCam and cx3d library.
The cxCam library provides functions for discovering and enumerating connected devices via the GEV standard as well as the camera configuration, image acquisition and event handling.
The cx3d library provides functions for intrinsic and extrinsic calibration models to transform the height images (range maps) from the camera to 3D point cloud images or rectified images.



For more information about the handling and the integration of the cxSDK, please refer to the documentation and to various example programs contained in the cxSDK.

Service Information

Product Information and Updates

Contact

AT-Automation Technology GmbH
Hermann-Bössow-Str. 6-8
D-23843 Bad Oldesloe, Germany
Phone: +49 4531/88011-0
Fax: +49 4531/88011-20

Updates

www.AutomationTechnology.de

Service and Support

service@AutomationTechnology.de

In order to process your support inquiries immediately, we always need the serial number of the camera, the firmware version, the device version, the camera configuration file (*.cfg), a snapshot and a precise problem description.

Product Inquiries and Price Quotations

info@AutomationTechnology.de

Warranty Conditions

Only the manufacturer can recognize the conditions of warranty. Should other parties than the manufacturer be responsible for the malfunctioning, we consider the right of warranty as void. This is the case if the unit is modified electrically or mechanically, particularly in its wiring/soldering, or if the unit is used for purposes not intended by the manufacturer, or if the unit's external wiring is faulty, or if the unit is used under conditions outside those stated in its manual.

Warranty Period

The sensors warranty for the C5-CS series is 1-year starting from the date of purchase from AT – Automation Technology GmbH.

Extended Warranty

The warranty period can be extend to maximum 36 months.

Return Policy

Before returning a sensor for repair (warranty or non-warranty) to AT – Automation Technology GmbH, AT must provide a Return Material Authorization (RMA) number. Please get in contact with AT to receive a RMA.
Ship the sensor carefully packed in its original shipping box or an equivalent box back to our destination in Germany, 23843 Bad Oldesloe, Hermann-Bössow-Straße 6-8.
If you purchased a camera over a distributor, please get in contact with them to start the RMA process.

Document Revision

Rev. No.	Date	Modification
1.0	02.06.2015	First Draft
1.1	03.03.2017	Revised Model Overview with Measurement Specification Added new GenICam features Added new C5-CS Model Revised Laser safety guideline Added some new chapters: The Web Interface, I/O Schematics, CX Explorer Overview, Quickstart a C5-CS Sensor, Return Policy
1.2	09.03.2017	Minor change
1.3	13.11.2017	Added new laser options Changed 3DExplorer Overview
1.4	12.03.2018	Added new compact sensors Removed obsolete Laser option Added new Laser option Added Master/Slave example Changed sensor label Corrected Encoder/Resolver Input signals Corrected I/O Schematics
1.5	23.01.2019	Add warning not to connect C5 cameras to C5-CS-I/O Panels Add description for Trigger Control – RS422 Resolver Add LED description for Model 1B, Model 4 and Model 6 Add Definition Working Distance and Field of View (FOV) Add Definition Coordinate Plane Correct mechanical drawings Add cxSDK information Delete extended GenICam feature list for C5-2040CS Add Orientation of Angled Adapter Cables Add and correct Model Overview Add new Multiple Slope image examples
1.6	11.07.2019	Add digital input and encoder input information Correct mechanical drawing image of CS-IO-Panel Change part number and description for C5-CS series cables Correct color wire assignment for M12 17 pin pigtail cable Renamed and modify cxExplorer overview Modify Quickstart information Correct MTBF values for laser options Add subpixel limitations Add Model Overview

Automation Technology GmbH – All rights reserved. Subject to change without prior notification.

Automation Technology
Vision Sensors and Systems