User Manual

FRAMOS Industrial Depth Camera D435e

V1.00
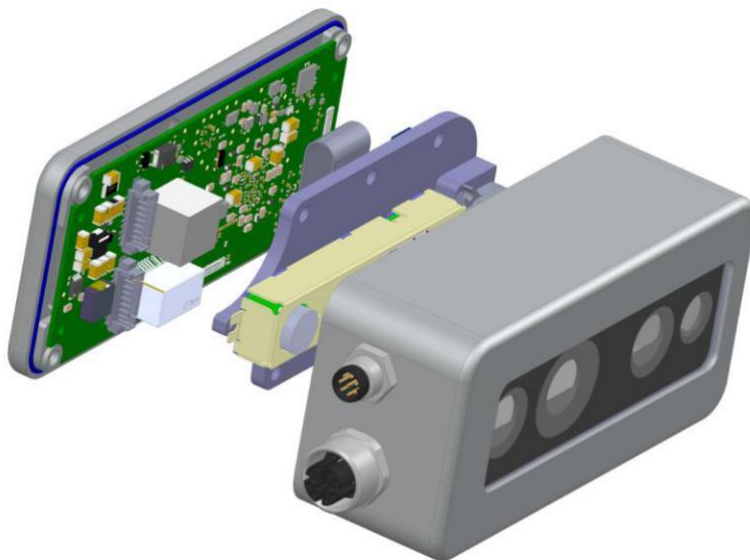
Revisions

Version	Datum	Description
V1.00	05.09.2019	Initial documentation for zero series release
V1.00	20.9.2019	Added pictures of the camera connectors

Referenced Documents

1. Intel® RealSense™ D400 Series Product Family, Revision 006, published in June 2019

Inhalt

1. Description and Features

1.1. Description

The FRAMOS Industrial Depth Camera D435e is built with Intel® RealSense™ technology. The depth camera has industrial M12 ethernet and M8 power connectors and features a wide field of view for depth and RGB sensors. Its water- and dust resistant housing is optimized for industrial environments. The FRAMOS Industrial Depth Camera D435e is ideal for OEMs and integrators who need 3D as well as 2D vision in their products and applications. The global shutter of the depth sensors allows for applications with fast motion. The FRAMOS Industrial Depth Camera D435e is compatible with the Cross-platform SDK for Intel® RealSense™ devices, enabling multiple programming languages, wrappers, sample code and tools.

1.2. Features

Resolution depth	1280 x 720 px (global shutter)
Resolution RGB	1920 x 1080 px (rolling shutter)
FOV depth (HxVxD)	86° x 57° x 94° (+/- 3°)
FOV RGB (HxVxD)	69° x 43° x 77° (+/- 3°)
Projector	Unstructured light in IR spectrum to enhance depth quality
Operating range	0,2m – 10m+
Streaming speed	30 fps for simultaneous RGB and depth streams @ 1280 x 720 px
Power consumption	6W (AUX) / 7W (PoE)
Housing material	Aluminium, anodized
Dimensions (LxHxW)	100mm x 47mm x 38mm
Mounting holes (backside)	4 x M3 ⌲ 3,20mm
Connector 1*	M12 Ethernet, X-Coded (Datastream + PoE possible)
Connector 2*	M8, 8 pin, A-Coded (Power supply + GPIO)
Housing Grade	IP66 / IP67 possible on project basis
Protection glass	AR coating, scratch resistant (6H)
Physical Interface	Gigabit ethernet
Camera weight	Ca. 250 grams

Recommendation: Cable connectors should be fixed with a tool (wrench/key) so that the connectors do not rotate under force.

1.3. Minimum System Requirements

- Linux Ubuntu 16.04 / Windows 10

- Gigabit Network Interface Card

2. Introduction

2.1. Purpose of this Document

This document captures the specifications and the design–in details for the FRAMOS Depth Camera D435e. This document provides information necessary to understand and implement the camera system.

2.2. Terminology

Term	Description
6DOF	Six degrees of freedom (6DoF) refers to the freedom of movement of a rigid body in three-dimensional space. Forward/back, up/down, left/right, pitch, yaw, roll.
Stereo Depth Baseline	The distance between the center of the left and right imagers in a stereo camera.
Depth	Depth video streams are like color video streams except each pixel has a value representing the distance away from the camera instead of color information.
FOV	Field of View (FOV) describes the angular extent of a given scene that is imaged by a camera. A camera's FOV can be measured horizontally, vertically, or diagonally.
IR Projector	This refers to the source of infrared (IR) light used for illuminating a scene, object, or person to collect depth data.
Imagers	Depth camera system uses a pair of cameras referred as imagers to calculate depth. They are identical cameras configured with identical settings.
Image Signal Processor (ISP)	Image processing functions to enhance color image quality.
Left imager	From the perspective of the stereo camera looking out at the world, the left imager is on the left side of the camera module. Thus, when the user is facing the D4 camera, the left imager is actually, on the right side of the camera module.
Lens	This refers to the optical component of an imager in the D4 camera. Its purpose is to focus the incoming light rays onto the CMOS chip in the imager.
Platform camera	This refers to the two-dimensional (2D) color camera on platform.
RMA	Return material authorization.
TBD	To Be Determined. In the context of this document, information will be available in a later revision.
DHCP	Dynamic Host Communication Protocol, it is used for network configurations of clients by a server.
LLA	Link-local address, a network address that is valid only for communications within the network segment or the domain that the host is connected to.

2.3. Stereo Vision Depth Technology Overview

The FRAMOS Industrial Depth Camera D435e uses stereo vision to calculate depth. The stereo vision implementation consists of a left imager, right imager, and an optional infrared projector. The infrared projector projects non-visible static IR pattern to improve depth accuracy in scenes with low texture. The left and right imagers capture the scene and send image data to the vision processor. The vision processor calculates depth values for each pixel in the image by correlating points on the left image to the right image. The depth pixel values are processed to generate a depth frame. Subsequent depth frames create a depth video stream.

3. Component Overview

3.1. Stereo Depth Module

The stereo depth module is the Intel® RealSense™ D430 with the following specification:

Baseline	50mm
Left/Right Imagers Type	Wide
Depth FOV HD (degrees)	H:87±3 / V:58±1 / D:95±3
Depth FOV VGA (degrees)	H:75±3 / V:62±1 / D:89±3
IR Projector	Wide
IR Projector FOV	H:90 / V:63 / D:99
Module Dimensions (mm)	X=70.7mm / Y=14mm / Z=10.53mm

NOTE:

H – Horizontal FOV, V – Vertical FOV, D – Diagonal FOV, X – Length, Y – Breadth, Z – Thickness

Depth FOV specified at 2 meters

Due to mechanical tolerances of +/-5%, Max and Min FOV values can vary from lens to lens and module to module by ~ +/- 3 degrees.

3.2. Left and Right Imagers

Image Sensor	OmniVision OV9282
Active Pixels	1280 X 800
Sensor Aspect Ratio	8:5
Format	10-bit RAW
F Number	f/2.0
Focal Length	1.93mm
Filter Type	None
Focus	Fixed
Shutter Type	Global Shutter
Horizontal Field of View	91.2 deg
Vertical Field of View	65.5 deg
Diagonal Field of View	100.6 deg
Distortion	<=1.5%

3.3. Infrared Projector

The infrared projector improves the ability of the stereo camera system to determine depth by projecting a static infrared pattern on the scene to increase texture on low texture scenes. The infrared projector meets class 1 laser safety under normal operation. The power delivery and laser safety circuits are on the stereo depth module. The infrared projector is referred as Standard or Wide based on field of projection.

Projector	Infrared
Pattern Type	Static
Illuminating Component	Vertical-cavity surface-emitting laser (VCSEL) + Optics
Laser Controller	PWM
Optical Power	360mW average, 4.25W peak
Laser Wavelength	850nm ± 10 nm nominal @ 20°C
Laser Compliance	Class 1, IEC 60825-1:2007 Edition 2, IEC 60825-1:2014 Edition 3
H. Field of Projection	86°±3°
V. Field of Projection	57°±3°
D. Field of Projection	94°±3°

3.4. Color Sensor

The color sensor on the stereo depth module in addition to color image provides texture information. Usages for the texture information include overlay on a depth image to create a color point cloud and overlay on a 3d model for reconstruction.

Image Sensor	OmniVision OV2740
Color Image Signal Processor	Discrete
Active Pixels	1920 X 1080
Sensor Aspect Ratio	16:9
Format	10-bit RAW RGB
F Number	f/2.0
Focal Length	1.88mm
Filter Type	IR Cut Filter
Focus	Fixed
Shutter Type	Rolling Shutter
Horizontal Field of View	69.4 deg
Vertical Field of View	42.5 deg
Diagonal Field of View	77 deg
Distortion	<=1.5%

3.5. Labels on the Camera

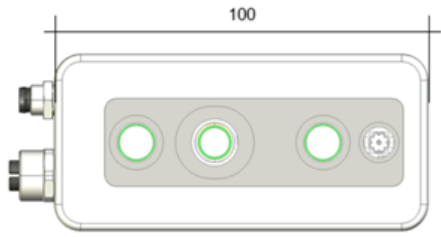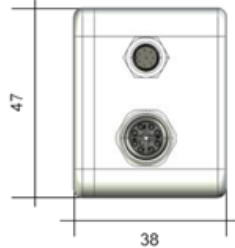The label on the sticker of the camera indicates two numbers:
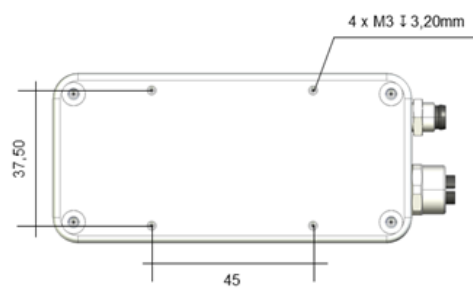
PC = Product Code	With this number you can purchase the exact same product at FRAMOS.
SN = Serial Number	This is the unique identifier of a single camera. For support and RMA cases, this number is necessary.

3.6. Thermal Control

The camera has thermal sensors implemented that prevent the camera from taking damage by overheating. The temperature is mainly regulated by the measured housing temperature. Once it exceeds 60°C, the intensity of the projector is reduced and eventually it will be switched OFF.

Most of the heat is conducted to the rear plate of the camera. Therefore, heat conductive material for mounting the camera is recommended.

3.7. Mechanical Dimensions

Front View	
Side View	
Back View	

support@framos.com

3.8. Storage and Operating Condition

Condition	Description	Min	Max	Unit
Storage (not operating)	Temperature (Sustained, Controlled)	-20	70	°C
	Relative Humidity	5	95	% non condensing
Case Temperature (operating)	Temperature	0	60	°C

3.9. Connectors and PINs of M12 and M8

Ethernet M12 connector, X-Coded, Female

M12 Pin	RJ 45
1	1 (MX0+)
2	2 (MX0-)
3	3 (MX1+)
4	6 (MX1-)
5	7 (MX3+)
6	8 (MX3-)
7	5 (MX2-)
8	4 (MX2+)

Power M8 connector, A-Coded, Male
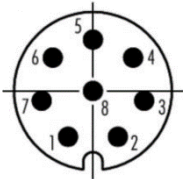
M8 Pin	Description
1	DC Power supply, 12-24V DC (+/- 10%)
2	Opto isolated IN
3	Opto isolated OUT
4	GND for opto isolated I/O
5	Direct coupled I/O 1 (optional)
6	Direct coupled I/O 2 (optional)
7	Not used
8	Power GND

3.10. Power consumption

Condition	Typical	Max
Power via M8	5.5W	7W
Power via M12 (PoE)	6.9W	8W

4. Functional Specification

4.1. Image Formats

Possible Streams with Gigabit Ethernet

Depth	RGB	90fps	60fps	30fps	25fps	15fps	6fps
1280x720	1920x1080	-	-	-	-	ok	ok
1280x720	1280x720	-	-	ok	ok	ok	ok
960x540	960x540	-	-	ok	ok	ok	ok
848x480	848x480	-	ok	ok	ok	ok	ok
848x480	1920x1080	-	-	-	-	ok	ok
640x480	640x480	ok	ok	ok	ok	ok	ok
640x360	640x360	ok	ok	ok	ok	ok	ok
424x240	424x240	ok	ok	ok	ok	ok	ok

NOTE: The zero series firmware (v.1.3.4) will have only 1280x720 @ 30fps implemented. The other options will follow with later firmware releases.

4.2. Depth Field of View (FOV)

Format	FOV
Horizontal FOV (VGA 4:3)	74
Vertical FOV (VGA 4:3)	62
Diagonal FOV (4:3)	88
Horizontal FOV (HD 16:9)	86
Vertical FOV (HD 16:9)	57
Diagonal FOV (HD 16:9)	94

NOTE:

Due to mechanical tolerances of +/-5%, Max and Min FOV values can vary from lens to lens and module to module by ~ +/- 3 degrees.

The Depth FOV specified is at 2 meters distance.

Depth Field of View (Depth FOV) at any distance (Z) can be calculated using the equation:

$$Depth\ FOV = \frac{HFOV}{2} + \tan^{-1}\left\{\tan\left(\frac{HFOV}{2}\right) - B/Z\right\}$$

Depth FOV = Depth Field of View

HFOV = Horizontal Field of View of Left Imager on Depth Module

B = Baseline

Z = Distance of Scene from Depth Module

4.3. Minimum-Z Depth

The Minimum-Z Depth is the minimum distance from depth camera to scene for which Vision Processor D4 provides depth data.

Resolution	Min-Z (mm)
1280x720	280
960x540	195
848x480	175
640x480	150
640x360	120
424x240	105

NOTE: The zero series firmware (v. 1.3.4) will have only 1280x720 @ 30fps implemented. The other options will follow with later firmware releases.

4.4. Depth Accuracy

For depth accuracy and the optimum settings of the camera, please refer to:

https://dev.intelrealsense.com/docs/tuning-depth-cameras-for-best-performance

Generally, z-accuracy of the camera should be < 2% of the measured distance.

4.5. Depth Camera Functions

Control	Description	Min	Max
Manual Exposure(1) (ms)	Control sensor exposure period	1	165
Manual Gain(1) (Gain 1.0 = 16)	Control sensor digital gain	16	248
Laser Power (on/off) (On = 1)	Power to IR Projector	0	1
Manual Laser Power (mW)	Laser Power setting (30mW steps)	0	360
Auto Exposure Mode (Enable = 1)	Auto Exposure Mode. When Auto Exposure is enabled, Exposure and Gain are set based on the environment condition	0	1
Auto Exposure ROI	Auto Exposure on a selected ROI	T-0 L-0 B-1 R-1	T-719 L-1279 B-720 R-1280

NOTES:

(1) – Not supported in Auto Exposure Mode

T - Top, L – Left, B - Bottom, R – Right

4.6. Color Camera Functions

Control	Description	Min	Max
Auto-Exposure Mode	Automatically sets the exposure time and gain for the frame.	0x1	0x8
Manual Exposure Time	Sets the absolute exposure time when autoexposure is disabled.	41	10000
Brightness	Sets the amount of brightness applied when autoexposure is enabled.	-64	64
Contrast	Sets the amount of contrast based on the brightness of the scene.	0	100
Gain	Sets the amount of gain applied to the frame if autoexposure is disabled.	0	128
Hue	Sets the amount of hue adjustment applied to the frame.	-180	180
Saturation	Sets the amount of saturation adjustment applied to the frame.	0	100
Sharpness	Sets the amount of sharpening adjustment applied to the frame.	0	100
Gamma	Sets amount of gamma correction applied to the frame.	100	500
White Balance Temperature Control	Sets the white balance when AWB is disabled.	2800	6500
White Balance Temperature Auto (AWB)	Enables or disables the AWB algorithm.	0	1
Power Line Frequency	Specified based on the local power line frequency for flicker avoidance.	0	3
Backlight Compensation	Sets a weighting amount based on brightness to the frame.	0	1
Low Light Comp	Low Light	0	1

5. Firmware Updates

The firmware contains the operational instructions. Firmware on the camera can be upgraded via Ethernet interface. This allows implementing new features and potential bug fixes using the firmware update tool.

Firmware update tool

The firmware update tool is used to update the firmware on FRAMOS Industrial Depth Cameras. The firmware update file is verified by the tool for compatibility with selected camera before firmware update process is initiated.

Usage example on Linux:

./UpdateFirmware FRAMOS_D435e_r1111_v1_3_4_0.fw_update

```
framos@Ubuntu16x64:/usr/src/framos/camerasuite/Tools$ ./UpdateFirmware ~/Desktop/FRAMOS_D435e_r1111_v1_3_4_0.fw_update

FRAMOS Camera Firmware Update Tool (v1.1.0.0)
=============================================

Index    Vendor    Model       IP              MAC                 Version            Available
   0     Framos    D435e       169.254.43.1    6C:D1:46:03:00:2A   HW:1.1_FW:1.3.4.0  Yes

Connect on camera by entering index number (enter "r" for device rescan).
Index: █
```

Select camera from list, and confirm to initiate firmware update procedure:

```
framos@Ubuntu16x64:/usr/src/framos/camerasuite/Tools$ ./UpdateFirmware ~/Desktop/FRAMOS_D435e_r1111_v1_3_4_0.fw_update

FRAMOS Camera Firmware Update Tool (v1.1.0.0)
=============================================

Index    Vendor    Model       IP              MAC                 Version            Available
   0     Framos    D435e       169.254.43.1    6C:D1:46:03:00:2A   HW:1.1_FW:1.3.4.0  Yes

Connect on camera by entering index number (enter "r" for device rescan).
Index: 0

Successfully connected to device:

Vendor    Model     IP            Version
Framos    D435e     169.254.43.1  HW:1.1_FW:1.3.4.0

Loaded Firmware Update file from disk:
 /home/framos/Desktop/FRAMOS_D435e_r1111_v1_3_4_0.fw_update

Download above Firmware Update file to connected device? [y/N]
y
Firmware Update procedure begins...
Completion: 7%
Completion: 15%
Completion: 23%
Completion: 30%
Completion: 38%
Completion: 46%
Completion: 53%
Completion: 54%
Completion: 55%
Completion: 56%
Completion: 57%
Completion: 58%
Completion: 59%
Completion: 60%
Completion: 61%
Completion: 69%
```

When the progress information reaches 100%, firmware update is complete.

6. Software

Instructions how to quickly start up the camera can be found in the quick start guide: LINK

6.1. FRAMOS Camera Suite SDK

The FRAMOS CameraSuite Software Development Kit (SDK) provides a set of tools, guides and samples, used for configuration and image acquisition from GigE Vision cameras. The CameraSuite SDK consists of the following components:

- CameraSuite API - Application Programming Interface (API) for configuration and image acquisition from GigE Vision cameras
- FRAMOS GigE Vision filter driver - High-performance network filter driver designed to ensure optimal performance of the GigE Vision cameras
- Sample code - Example source code for various CameraSuite API functions
- Tools - tools used for operating the FRAMOS Industrial Depth Cameras

FRAMOS CameraSuite API, assisted by FRAMOS GigE Vision filter driver, acts as a middleware between FRAMOS Industrial Depth Camera D435e and Intel® RealSense™ SDK 2.0, allowing D435e camera to be used by tools based on the Intel® RealSense™ SDK 2.0.

Set IP Configuration

ConfigureIP tool is used to configure the IP address of a FRAMOS Industrial Depth Camera. Supported IP configurations are:

- Persistent IP - fixed IP address which is stored in camera non-volatile memory
- DHCP - camera attempts to acquire IP address via DHCP protocol
- LLA - camera attempts to acquire IP address via LLA protocol, always enabled

The camera and network interface card (NIC) that is used to connect to the camera need to be on the same subnet for the camera to be accessible by the software. For this reason, the ConfigureIP tool allows to temporarily change the current IP address of the camera. This is useful in situations where NIC and camera are on different subnets, and IP configuration of the NIC cannot be changed.

Usage example on Linux - setting persistent IP address, disable DHCP:

./ConfigureIp

```
framos@Ubuntu16x64:/usr/src/framos/camerasuite/Tools$ ./ConfigureIp
FRAMOS Camera Set IP Tool (v1.0.0.0)
=============================================
Index    Vendor    Model       IP               MAC                Version             Available
   0     Framos    D435e       169.254.43.1     6C:D1:46:03:00:2A  HW:1.1_FW:1.3.4.0   Yes
Connect on camera by entering index number (enter "r" for device rescan).
Index: █
```

Select camera from list, and then set the desired IP configuration:

```
framos@Ubuntu16x64:/usr/src/framos/camerasuite/Tools$ ./ConfigureIp

FRAMOS Camera Set IP Tool (v1.0.0.0)
============================================
Index   Vendor   Model        IP             MAC                Version            Available
  0     Framos   D435e        169.254.43.1   6C:D1:46:03:00:2A  HW:1.1_FW:1.3.4.0  Yes

Connect on camera by entering index number (enter "r" for device rescan).
Index: 0

Vendor      Model      IP               Version
Framos      D435e      169.254.43.1     HW:1.1_FW:1.3.4.0

Set temporary IP? [Y/n]
n
Enable DHCP? [Y/n]
n
Enable permanent IP? [Y/n]
y
Enter IP address [169.254.43.1]
169.254.43.2
Enter subnet mask [255.255.0.0]

Enter default gatweay [0.0.0.0]

IP address sucessfully set.

Press enter to continue ...

framos@Ubuntu16x64:/usr/src/framos/camerasuite/Tools$
```

Note that the newly set IP configuration will not be active until camera is restarted.

6.2. Intel® RealSense™ Software Development Kit 2.0

FRAMOS provides a modified version of the SDK 2.0, which includes a wrapper of the Camera Suite as described above. The modified version of the SDK 2.0 can be downloaded here: LINK

The SDK at a minimum includes:

Intel® RealSense™ Viewer - This application can be used view, record and playback depth streams, set camera configurations and other controls.

Depth Quality Tool - This application can be used to test depth quality, including: distance to plane accuracy, Z accuracy, standard deviation of the Z accuracy and fill rate.

Debug Tools - These command line tools gather data and generate logs to assist in debug of camera.

Code Examples - Examples to demonstrate the use of SDK to include D400 Series camera code snippets into applications.

Wrappers -Software wrappers supporting common programming languages and environments such as ROS, Python, Matlab, node.js, LabVIEW, OpenCV, PCL, .NET and more.

Additional documentation and instructions on the Intel SDK can be found here:
https://dev.intelrealsense.com/docs/docs-get-started

7. Regulatory Compliance

Certification statement

This product is classified as a Class 1 Laser Product under the EN/IEC 60825-1, Edition 3 (2014) internationally and IEC60825-1, Edition 2 (2007) in the US. This product complies with US FDA performance standards under 21 CFR 1040.10 for laser products except for deviations pursuant to Laser Notice No. 50 dated June 24, 2007.

CLASS 1 LASER PRODUCT
EN/IEC 60825-1, 2014 (EU & other)
IEC 60825-1, 2007 (US)

This device complies with US FDA performance standards for laser products except for deviations pursuant to Laser Notice No. 50 dated June24, 2007.

Cautionary Statement

Do not power on the product if any external damage was observed.

Do not attempt to open any portion of this laser product.

Invisible laser radiation when opened. Avoid direct exposure to beam.

There are no user serviceable parts with this laser product.

Modification or service of the stereo module, specifically the infrared projector, may cause the emissions to exceed Class 1.

No magnifying optical elements, such as eye loupes and magnifiers, are allowed.

Do not try to update camera firmware that is not officially released for specific camera module and revision.

Waste Electrical and Electronic Equipment (WEEE)

In the EU, this symbol means that this product must not be disposed of with household waste. It is your responsibility to bring it to a designated collection point for the recycling of waste electrical and electronic equipment. For more information, contact the local waste collection center or your point of purchase of this product.

Other Certifications

CE

FC

RoHS

Shock

DIN EN 60068-2-27

Vibration

DIN EN 60068-2-6, DIN EN 60068-2-64

8. Accessories

<u>Recommended Cables</u>

M12 - Connector

M12_to_RJ45 cable, 2m (Order Number: 79 9723 020 08) -> https://www.binder-connector.com/en/products/automation-technology-speciality-connectors/m12-d-m12-x/connecting-cable-male-cable-connector-m12-x-1-rj45-male-connector-shielded-ip67/#79972302008

Connection line M12 X-coded, 2.0 m M12 plug angled - RJ45 plug straight 8-pole, position of coding 225°" (https://www.metz-connect.com/en/products/142m2xc5020)

M8 - Connector

M8 female cable connector, Contacts: 8, 2m (Order Number: 77 3406 0000 50008-0200) -> https://www.binder-connector.com/en/products/automation-technology/m8/female-cable-connector-overmoulded-screw-type-m8x1-with-hexagonal-die-cast-threaded-ring-pur/#7734060000500080200

Sensor/actuator cable - SAC-8P- 1,5-PUR/M 8FS SH – 1404147 (https://www.phoenixcontact.com/online/portal/pi?uri=pxc-oc-itemdetail:pid=1404147&library=pien&tab=1)

M8: Sensor/actuator cable - SAC-8P- 1,5-PUR/M 8FR – 1404191 (https://www.phoenixcontact.com/online/portal/us/?uri=pxc-oc-itemdetail:pid=1404191&library=usen&pcck=P-18-01-01&tab=1&selectedCategory=ALL)