FRAMOS Industrial Depth Camera D400e Series

USER MANUAL

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www.framos.com

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List of Abbreviations

Abbreviation	Explanation
AR	Anti-Reflective
DC	Direct Current
DHCP	Dynamic Host Communication Protocol
DOF	Degrees of Freedom
FOV	Field of View
FOP	Field of Projection
GND	Ground

I/O	Input/Output
IN	Input
IP	Internet Protocol
IR	Infrared
ISP	Image Signal Processor
LLA	Link-Local Address
NIC	Network Interface Card
OUT	Output
PHY	Physical Layer
POE	Power Over Ethernet
RMA	Return Material Authorization
SDK	Software Development Kit
TBD	To Be Determined

1. Description and Features

1.1 Description

The FRAMOS Industrial Depth Camera D400e Series (D400e Series) are built with Intel® RealSense™ technology. The depth cameras have industrial M12 ethernet and M8 power connectors. Its water and dust resistant housing is optimized for industrial environments. The D400e Series are ideal for OEMs and integrators who need 3D as well as 2D vision in their products and applications. The D400e Series are compatible with the Cross-platform SDK for Intel® RealSense™ devices, enabling multiple programming languages, wrappers, sample code and tools. D435e and D455e camera models, featuring global shutter, wide field of view sensors, are especially suitable for applications with fast motion.

1.2 Features

- Gigabit Ethernet data transmission
- Data transfer up to 100m in length
- Single cable solution for both power & data via PoE
- Increased data transmission reliability with packet resend functionality
- Intel® RealSense™ SDK 2.0 compatible
- Onboard depth calculation with Intel® RealSense™ Vision Processor D4
- Projector with unstructured light in IR spectrum for enhanced depth quality
- IP66 dust and water-proof housing for industrial environments, IP67 on project basis
- Secure cable connections with threaded M12 and M8 plugs
- Synchronization with external events
- Simultaneous depth and RGB streaming at profile 1280 x 720 @ 30fps

1.3 System Requirements

Host PC Operating System:

- Microsoft® Windows® 10
- Linux Ubuntu 16.04 (or newer)

Host PC Architecture:

- x86_64
- ARM64 (NVIDIA® Jetson™ platform)

Hardware:

- Gigabit Network Interface Card (NIC)

2. Introduction

2.1 Purpose of this Document

This document captures the specifications and the design–in details for the FRAMOS Industrial Depth Camera D400e Series. 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 D400e camera, the left imager is 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.

Table 1 - Terminology

2.3 Stereo Vision Depth Technology Overview

The FRAMOS Industrial Depth Camera D400e Series use 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

The information provided in this chapter on Intel RealSense components are taken from the *Intel® RealSense™ D400 Series Product Family* datasheet.

For mechanical drawings and further details please refer to *Intel® RealSense™ D400 Series Product Family* [Ref-1].

3.1 Stereo Depth Module

The stereo depth module used in the D435e camera is the Intel® RealSense™ D430, D415e implements Intel® RealSense™ D410 depth module, while D455e implements Intel® RealSense™ D450 depth module. Properties of the Intel® RealSense™ depth modules are as follows:

D430	
Baseline	50mm
Left/Right Imagers Type	Wide
Depth FOV HD	H:87°±3° / V:58°±1° / D:95°±3°
Depth FOV VGA	H:75°±3° / V:62°±1° / D:89°±3°
IR Projector	Wide
Module Dimensions (mm)	X=70.7mm / Y=14mm / Z=10.53mm

Table 2 – D430 Depth Module Properties

D410	
Baseline	55mm
Left/Right Imagers Type	Standard
Depth FOV HD	H:65°±2° / V:40°±1° / D:72°±2°
Depth FOV VGA	H:50°±2° / V:40°±1° / D:61°±2°
IR Projector	Standard
Module Dimensions (mm)	X:74.7mm / Y:10mm / Z:4.7mm

Table 3 – D410 Depth Module Properties

D450	
Baseline	95mm
Left/Right Imagers Type	Wide
Depth FOV HD	H:87°±3° / V:58°±1° / D:95°±3°
Depth FOV VGA	H:75°±3° / V:62°±1° / D:89°±3°
IR Projector	Wide
Module Dimensions (mm)	X:119.5mm / Y:17.4mm / Z:10.53mm

Table 4 – D450 Depth Module Properties

Notes:

- H – Horizontal, V – Vertical, D – Diagonal, 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°

3.2 Left and Right Imagers

D430	
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
Imager Field of View	H:91.2° / V:65.5° / D:100.6°
Distortion	<=1.5%

Table 5 – D430 Imager Properties

D410	
Image Sensor	OmniVision OV2740
Active Pixels	1920 X 1080
Sensor Aspect Ratio	16:9
Format	10-bit RAW
F Number	f/2.0
Focal Length	1.88mm
Filter Type	None
Focus	Fixed
Shutter Type	Rolling Shutter
Imager Field of View	H:69.4° / V:42.5° / D:77.0°
Distortion	<=1.5%

Table 6 – D410 Imager Properties

D450	
Image Sensor	OmniVision OV9272
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
Imager Field of View	H:90.0° / V:65.0° / D:98.0°
Distortion	<=1.5%

Table 7 – D450 Imager Properties

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.

D430 / D450	
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
Field of Projection	H:90°±3° / V:63°±3° / D:99°±3°

Table 8 – D430 infrared projector properties

D410	
Projector	Infrared
Pattern Type	Static
Illuminating Component	Vertical-cavity surface-emitting laser (VCSEL) + Optics
Laser Controller	PWM
Optical Power	360mW average, 440mW 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
Field of Projection	H:64°±3° / V:41°±3° / D:72°±3°

Table 9 – D410 infrared projector properties

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.

D415e / D435e	
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
Imager Field of View	H: 69.4° / V:42.5° / D:77.0°
Distortion	<=1.5%

Table 10 – D415e/D435e Color Sensor Properties

D455e	
Image Sensor	OmniVision OV9782
Color Image Signal Processor	Discrete
Active Pixels	1280 X 800
Sensor Aspect Ratio	16:10
Format	10-bit RAW RGB
F Number	f/2.0
Focal Length	1.88mm
Filter Type	IR Cut Filter
Focus	Fixed
Shutter Type	Global Shutter
Imager Field of View	H:90.0° / V:65.0° / D:98.0°
Distortion	<=1.5%

Table 11 – D455e Color Sensor Properties

3.5 Inertial Measurement Unit

Inertial Measurement Unit (IMU) contains sensors which allow measurement of both directional movement and rotation. Framos D400e depth cameras generate and transmit the gyro and accelerometer samples independently, as the inertial sensors exhibit different FPS rates (200/400Hz for gyro, 63/250Hz for accelerometer).

D435e / D415e / D455e	
Degrees of Freedom	6
Acceleration Range	±4g
Accelerometer Sample Rate[1]	62.5, 250 (Hz)
Gyroscope Range	±1000 deg/s
Gyroscope Sample Rate[2]	200, 400 (Hz)

Table 12 – IMU Specifications

NOTES:
1. The sample rate may differ from the absolute specified sample rate by ±5%. It is advised to rely on the sample timestamp.
2. The sample rate may differ from the absolute specified sample rate by ±0.3%.

3.6 Image Signal Processor

The color sensor data is sent to an Image Signal processor (ISP) for a color image quality enhancement. The enhanced image is sent to the onboard SoC for further processing.

D435e / D415e / D455e	
ISP	RTS5845
Interface to Color Sensor	MIPI CSI-2, 1x Lane
Interface to SoC	MIPI CSI-2, 2x Lanes

Table 13 – ISP Properties

3.7 FRAMOS D4 Visual Processing Board

FRAMOS D4 Visual Processing Board with integrated Intel® RealSense™ Vision Processor D4 for depth calculation, provides a Gigabit Ethernet interface, Power over Ethernet (PoE) and additional GPIOs for external triggering or user output.

For a module variant, ethernet, power supply and GPIOs can be connected directly to the board without soldering via wire to board connectors (see Chapter 5.2).

FRAMOS D4 Visual Processing Board Key Components	
System on Chip (SoC)	Processing unit that implements the control and image data processing, external triggering and data link layer of the Ethernet

D4 Vision Processor	Intel® RealSense™ Vision Processor D4 for depth calculation
Color Image Signal Processor (ISP)	Image processing functions to enhance color image quality
Inertial Measurement Unit (IMU)	Inertial Measurement Units allow measurement of directional movement and rotation
Gigabit Ethernet Transceiver	Implements the physical layer of the Ethernet (Ethernet PHY)

Table 14 – FRAMOS D4 Visual Processing Board Key Components

FRAMOS D4 Visual Processing Board Dimensions	
Module Dimensions (mm)	X=93mm / Y=40mm / Z=15mm

Table 15 – FRAMOS D4 Visual Processing Board Dimensions

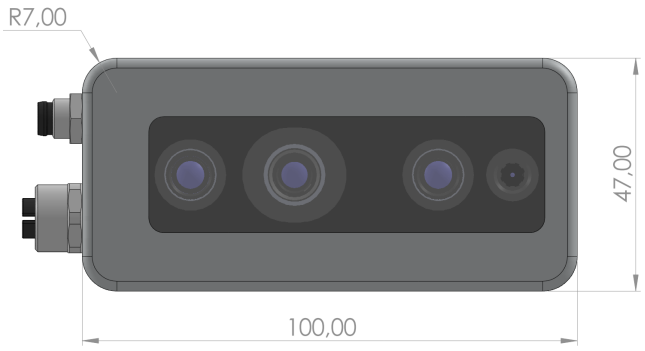
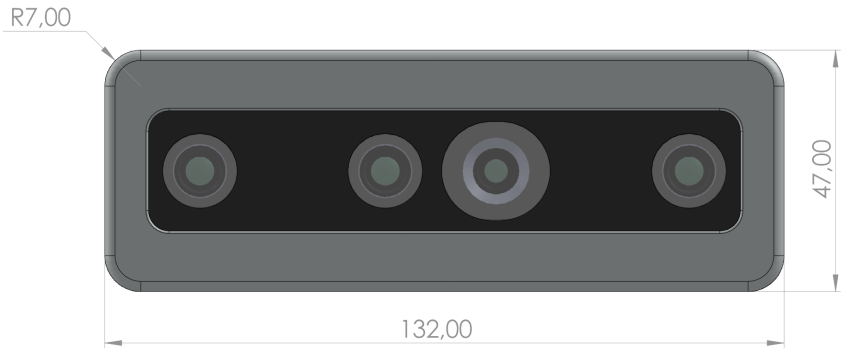
4. FRAMOS Depth Camera D400e Series

4.1 Depth Camera Properties

	FRAMOS Depth Camera D415e	FRAMOS Depth Camera D435e	FRAMOS Depth Camera D455e
Depth Module	Intel® RealSense™ Depth Module D410	Intel® RealSense™ Depth Module D430	Intel® RealSense™ Depth Module D450
Left/Right Imagers Type	Standard	Wide	Wide
Depth Resolution	1280 x 720 px (rolling shutter)	1280 x 720 px (global shutter)	1280 x 720 px (global shutter)
Depth FOV HD	H:65°±2° / V:40°±1° / D:72°±2°	H:87°±3° / V:58°±1° / D:95°±3°	H:87°±3° / V:58°±1° / D:95°±3°
Depth FOV VGA	H:50°±2° / V:40°±1° / D:61°±2°	H:75°±3° / V:62°±1° / D:89°±3°	H:75°±3° / V:62°±1° / D:89°±3°
IR Projector	Standard	Wide	Wide
IR Projector FOP	H:64°±3° / V:41°±3° / D:72°±3°	H:90°±3° / V:63°±3° / D:99°±3°	H:90°±3° / V:63°±3° / D:99°±3°
Color Sensor	OV2740	OV2740	OV9782
Color Resolution	1920 x 1080 px (rolling shutter)	1920 x 1080 px (rolling shutter)	1280 x 720 px (global shutter)
Color Camera FOV	H: 69.4° / V:42.5° / D:77.0°	H: 69.4° / V:42.5° / D:77.0°	H:90.0° / V:65.0° / D:98.0°
IMU	Bosch BMI055 6-axis inertial sensor	Bosch BMI055 6-axis inertial sensor	Bosch BMI055 6-axis inertial sensor
Operating range	0,2m – 10m	0,2m – 10m	0,3m – 20m
Power consumption	6W (AUX) / 7W (PoE)	6W (AUX) / 7W (PoE)	6W (AUX) / 7W (PoE)
Dimensions (L x H x W)	100mm x 47mm x 38mm	100mm x 47mm x 38mm	132mm x 47mm x 41mm
Mounting holes (backside)	4 x M3 ↧ 3,2mm	4 x M3 ↧ 3,2mm	4 x M4 ↧ 5,0mm
Camera Weight	250 grams	250 grams	395 grams
Protection Glass	AR coating, scratch resistant (6H)		
Housing material	Aluminum, anodized		

Table 16 – FRAMOS Depth Camera D400e Series Properties

4.2 Mechanical Dimensions

Front View D435e	
Front View D415e	
Front View D455e	

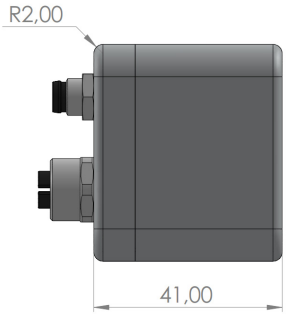
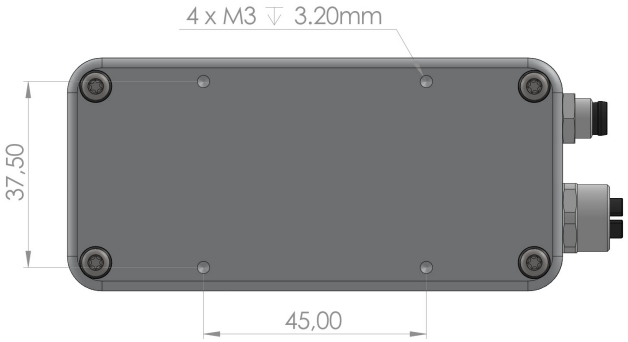
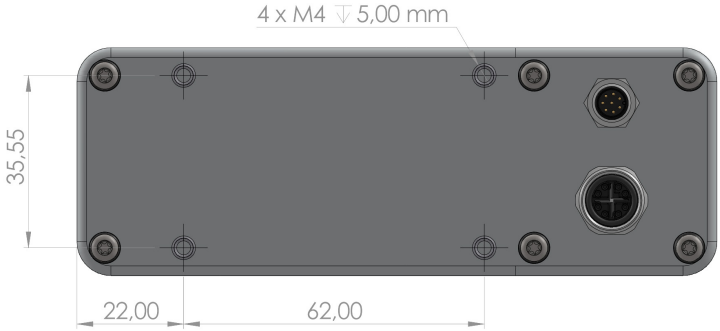
Side View D435e/D415e	
Side View D455e	
Back View D435e/D415e	
Back View D455e	

Table 17 – D400e Series Camera Dimensions

4.3 Physical Interfaces

FRAMOS D400e series cameras are equipped with two physical interfaces:

- M12 Ethernet connector for data interface
- M8 Power connector for power and I/O interfaces

4.3.1 Ethernet M12 connector, X-Coded, Female

The Ethernet interface provides configuration access to the camera and is also used for image data transmission.

Figure 1 – M12 Connector PIN Layout

The M12 connector is a circular connector, pins assigned like shown in Table 18.

Ethernet 1000BaseT, 802.3 compliant, ANSI/TIA-568 T568B termination

M12 Pin	Signal ID/T568B color	Description
1	1 (BI_DA+, White/orange stripe)	Bi-directional pair A+
2	2 (BI_DA-, Orange solid)	Bi-directional pair A-
3	3 (BI_DB+, White/green stripe)	Bi-directional pair B+
4	6 (BI_DB-, Green solid)	Bi-directional pair B-
5	7 (BI_DD+, White/brown stripe)	Bi-directional pair D+
6	8 (BI_DD-, Brown solid)	Bi-directional pair D-
7	5 (BI_DC-, White/blue stripe)	Bi-directional pair C-
8	4 (BI_DC+, Blue solid)	Bi-directional pair C+

Table 18 – M12 Connector PIN Layout and Description

Example of connecting the M12 to RJ45 with the T568B termination is shown in the Figure 2.

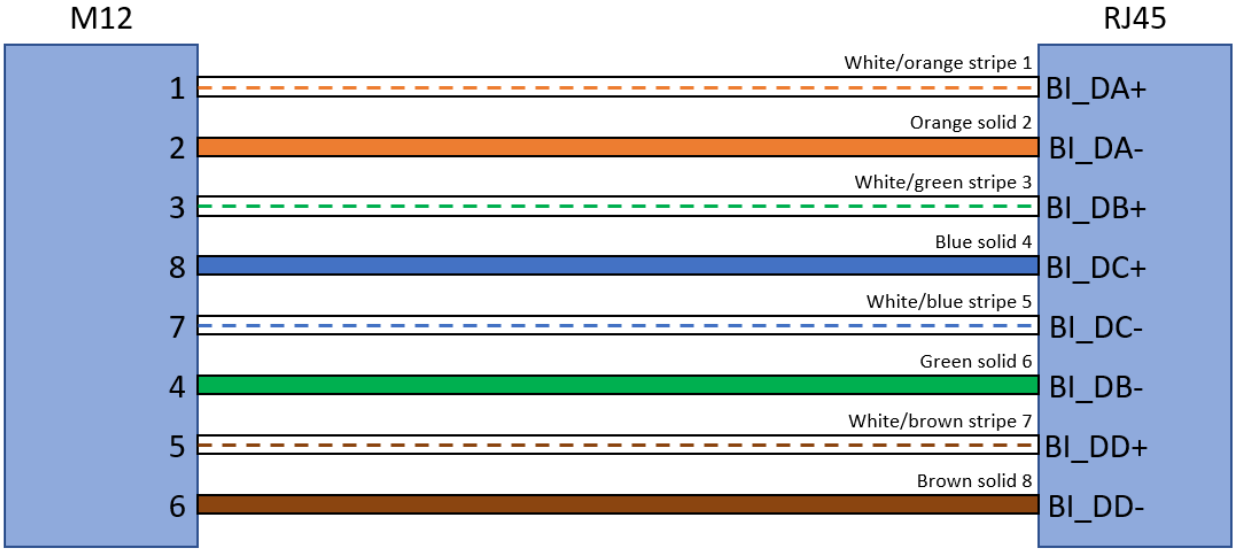


Figure 2 – Example of connecting M12 to RJ45, T568B termination

4.3.2 Power M8 connector, A-Coded, Male

Beside the Ethernet interface for communication and data transmission, FRAMOS D400e series cameras are equipped with M8 connector providing I/O-interface and power input.

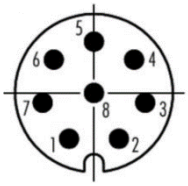


Figure 3 – M8 Connector PIN Layout

Via this interface cameras provide access to opto-isolated input and opto-isolated output.

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	Not connected
6	Not connected
7	Not connected
8	Power GND

Table 19 – M8 Connector PIN Layout and Description

4.4 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.

4.5 Storage and Operating Conditions

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

Table 20 – Storage and Operating Conditions

4.6 Power Consumption

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

Table 21 – D400e Series Camera Power Consumption

Information: FRAMOS D400e Series Camera is IEEE 802.3af compliant PD (Powered Device) so it requires IEEE 802.3af compliant PSE (Power Sourcing Equipment).

4.7 Depth Camera Depth Origin Reference

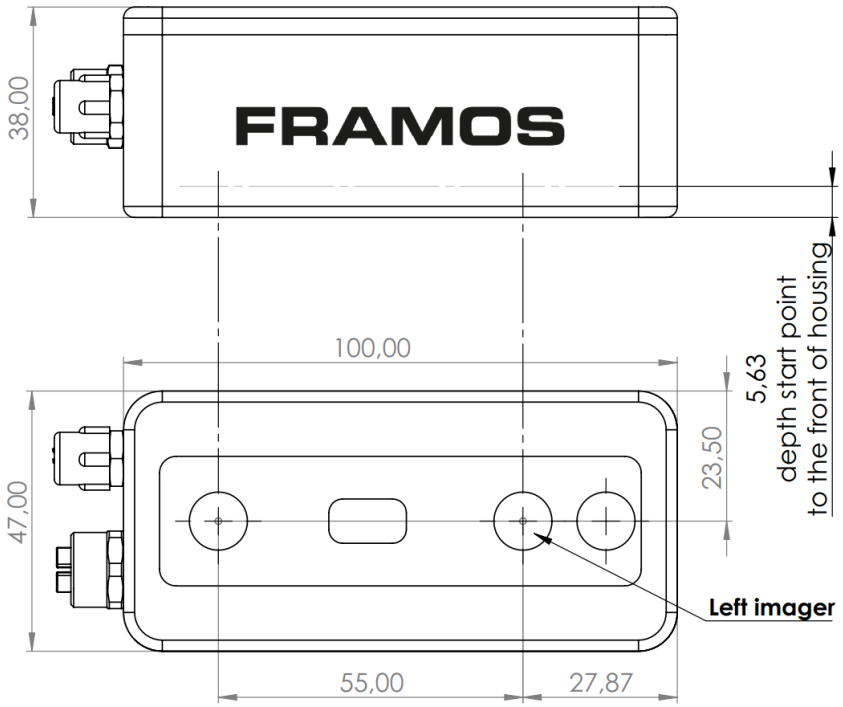


Figure 4 – Depth Camera D415e Depth Origin Reference

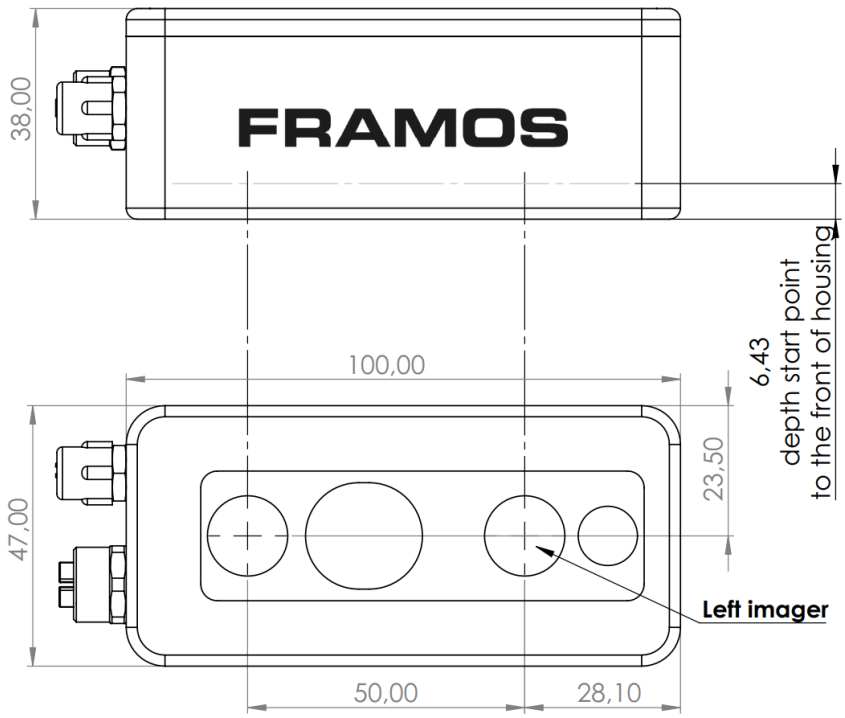


Figure 5 – Depth Camera D435e Depth Origin Reference

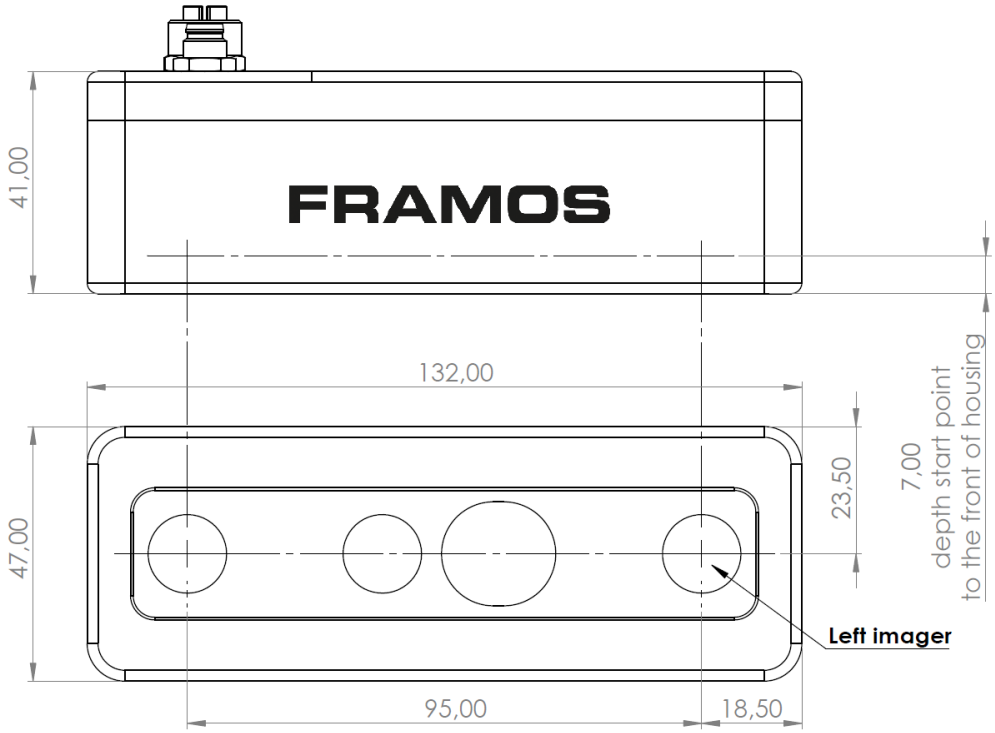


Figure 6 – Depth Camera D455e Depth Origin Reference

4.8 Labels on the Camera

The information about camera Product Code and Serial Number is available on camera label:

	FRAMOS Depth Camera D415e	FRAMOS Depth Camera D435e	FRAMOS Depth Camera D455e
PC = Product Code	10009031	10007930	300433
SN = Serial Number	This is the unique identifier of a single camera. For support and RMA cases, this number is necessary.		

Table 22 – Camera Label Information

5. FRAMOS Depth Camera D400e Module Variant

FRAMOS Depth Camera D400e module variant is a module version of the D400e series camera, providing the same functionality and connectivity without housing. The module variant aims for the easy design-in and integration into compact form factor products.

The module variants have the same technical specifications as housed camera variants.

5.1 D400e Module Components

FRAMOS D400e Module consist of:

1. Intel RealSense Depth Module:
    - D415e: Intel D410 Depth Module
    - D435e: Intel D430 Depth Module
    - D455e: Intel D450 Depth Module
2. Depth Module Cable Bracket
3. Depth Module Interposer
4. RGB Module Interposer (D415e/D435e only)
5. RGB Module (D415e/D435e only)
6. RGB Module Cover (D415e/D435e only)
7. FRAMOS D4 Visual Processing Board

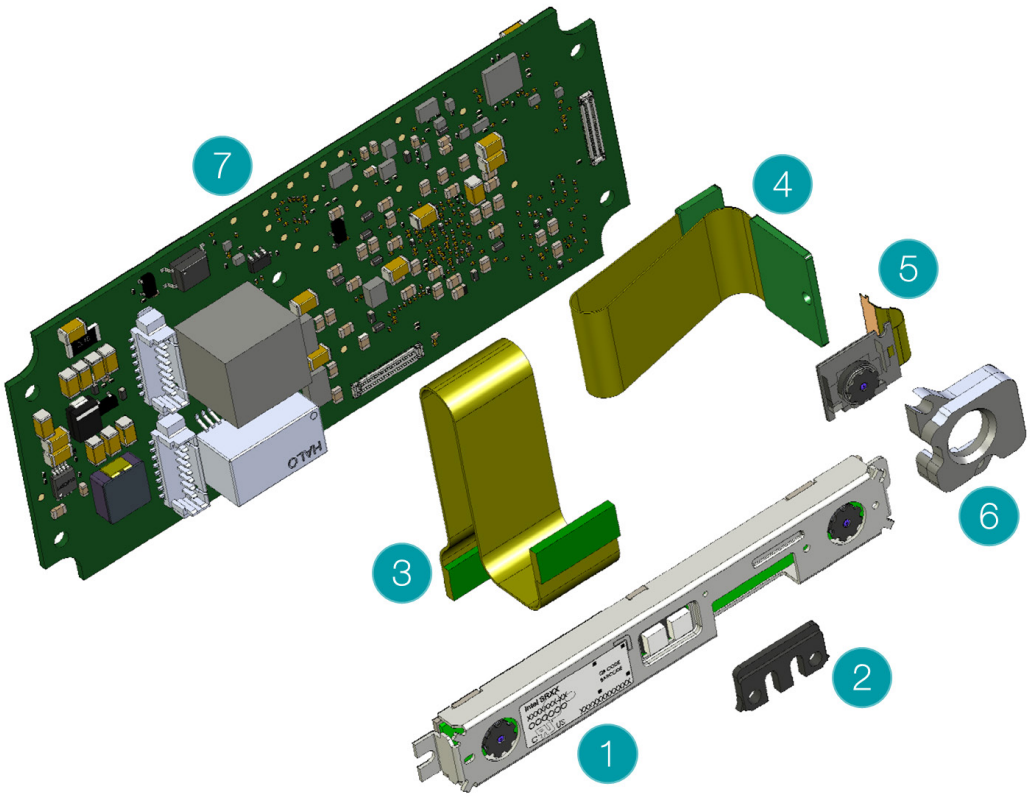


Figure 7 – FRAMOS D400e Module Components Overview

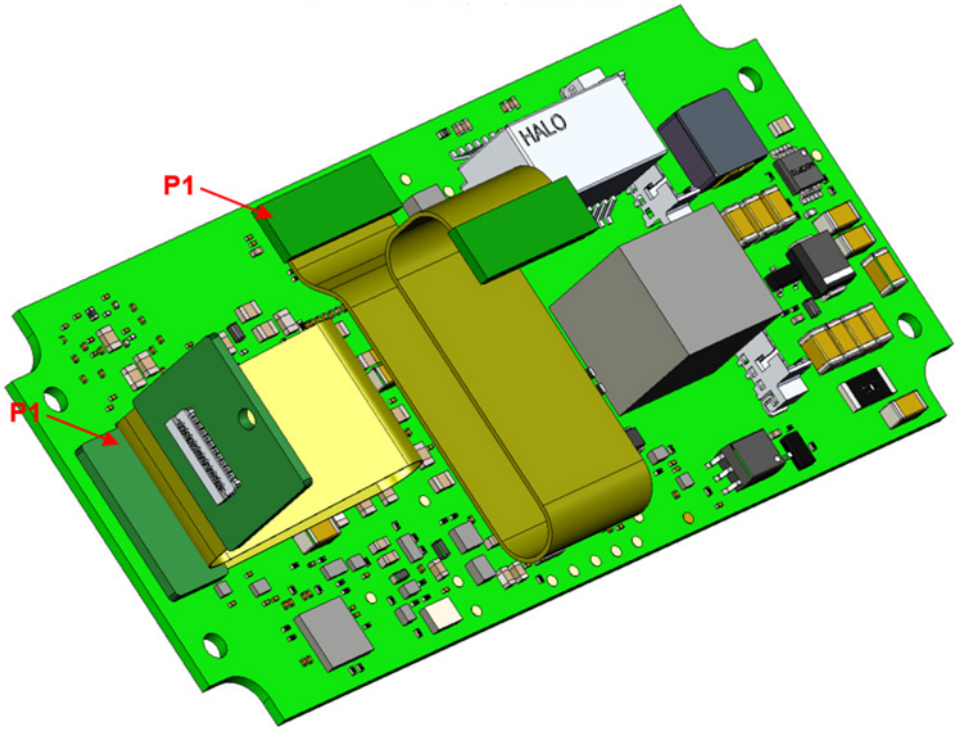


Figure 8 – Connecting Interposer Cables to FRAMOS D4 Visual Processing Board

Caution: Care should be taken when connecting RGB and Depth Interposer cables to FRAMOS D4 Visual Processing Board, as the wrong connection, position or orientation, can cause permanent damage to the device. The correct cables position and orientation are shown in the Figure 8.

5.2 D400e Module Variant Connectors Pinout

Molex Pico Blade Standard Connector 53398-0871 is an interface connector for the ethernet, power supply and GPIOs:

- J3 Ethernet Connector
- J6 Power and IO Connector

5.2.1 Ethernet Connector J3

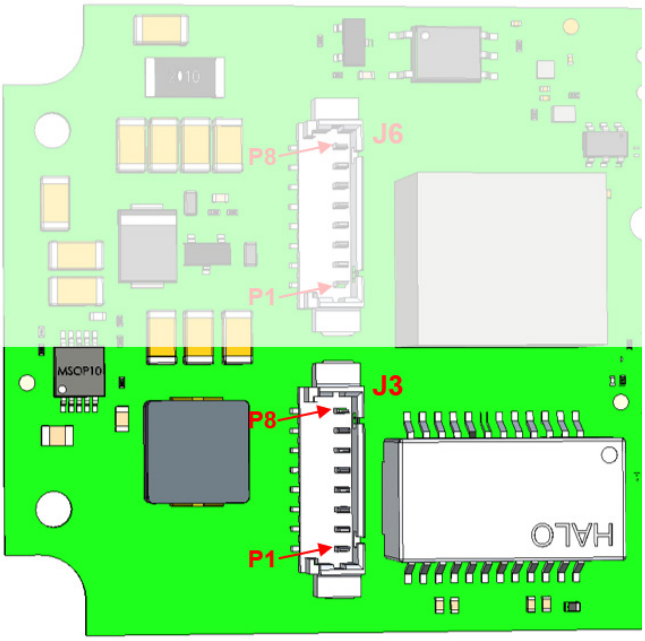


Figure 9 – FRAMOS D4 Visual Processing Board Ethernet Connector

J3 Pin	Description
P1	BI_DA+
P2	BI_DA-
P3	BI_DD+
P4	BI_DD-
P5	BI_DC+
P6	BI_DC-
P7	BI_DB+
P8	BI_DB-

Table 23 – J3 Pin Assignment

5.2.2 Power and IO Connector J6

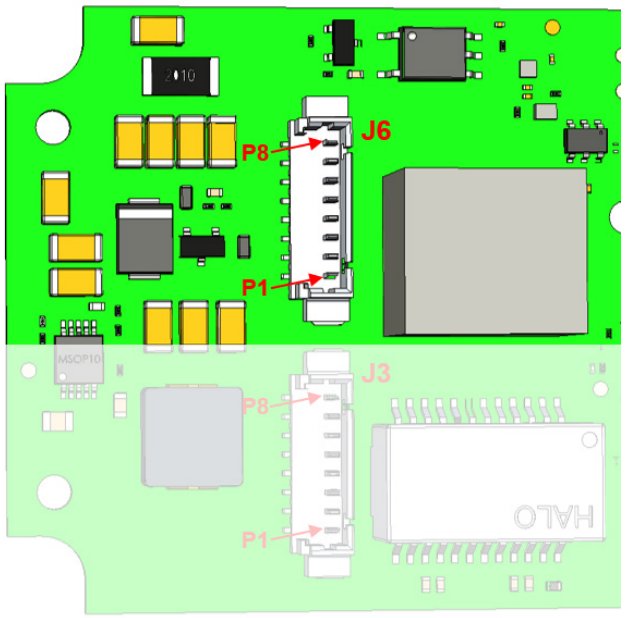


Figure 10 – FRAMOS D4 Visual Processing Board Power and IO Connector

J6 Pin	Description
P1	DC Power supply, 12-24V DC (+/-10%)
P2	Power GND
P3	Not connected
P4	Not connected
P5	Not connected
P6	GND for opto-isolated I/O
P7	Opto-isolated OUT
P8	Opto-isolated IN

Table 24 – J6 Pin Assignment

5.3 Thermal Design Consideration

When integrating D400e Module variant in a custom design, thermal mechanical design must be considered.

Recommendation: A heat sink should be designed to have optimal contact with all elements of the PCBs backside. The back cover of the housed version can be used as reference design. When designed according to the recommendation, the D400e Module Variant can achieve the thermal conditions described in the "Optimum Thermal Conditions" chapter.

5.4 Mechanical Drawings

5.4.1 FRAMOS D4 Visual Processing Board

Top and side views and dimensions [mm] for the FRAMOS D4 Visual Processing Board are shown in the image below.

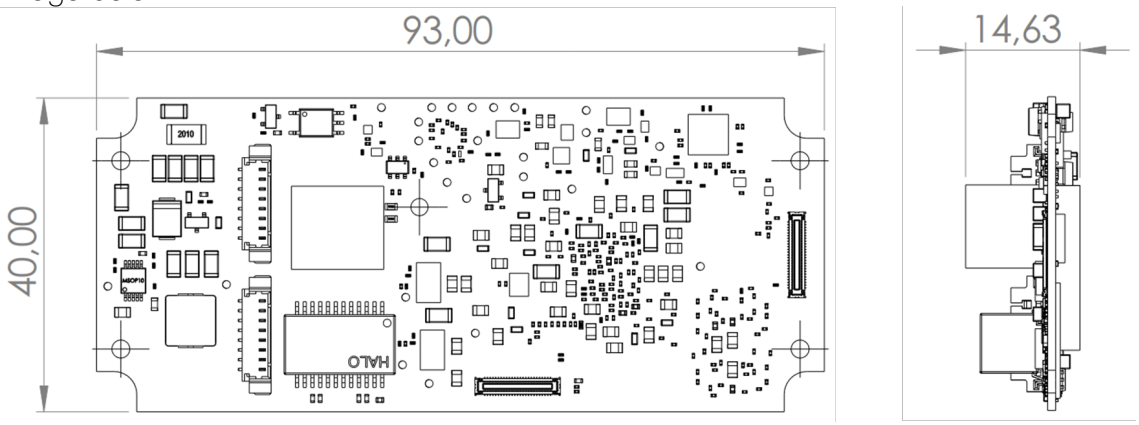


Figure 11 – FRAMOS D4 Visual Processing Board Dimensions

5.4.2 Depth Module Interposer

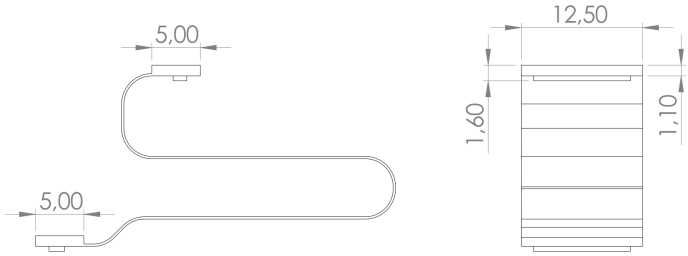


Figure 12 – Depth Module Interposer Dimensions

5.4.3 Depth Module Cable Bracket

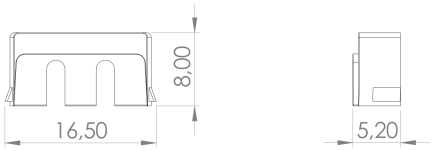


Figure 13 – D435e Depth Module Cable Bracket Dimensions

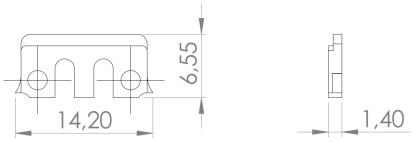


Figure 14 – D415e Depth Module Cable Bracket Dimensions

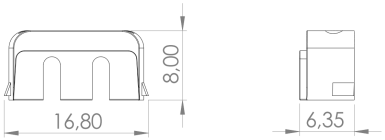


Figure 15 – D455e Depth Module Cable Bracket Dimensions

5.4.4 RGB Module Including Cover

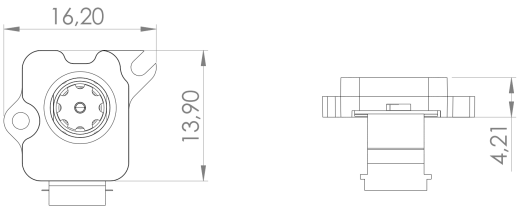


Figure 16 – RGB Module Including Cover Dimensions

5.4.5 RGB Interconnect

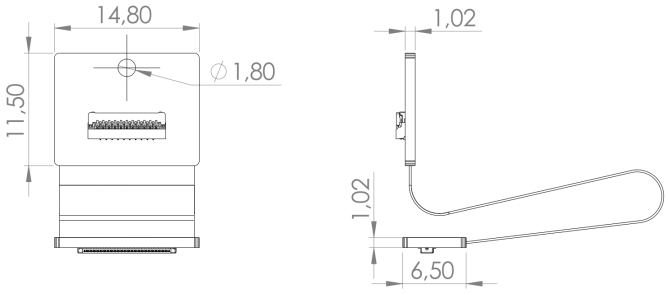


Figure 17 – RGB Interconnect Dimensions

6. Optimum Thermal Conditions

6.1 Fundamentals of the Camera's Heat Dissipation

The power consumption of the D400e cameras is the main determining factor for heat creation inside the camera, which depends on the operation mode of the camera. In the case that all available functionality of the camera (i.e. frame rates or projector intensity) is used at maximum capacity, the power consumption and thus the heat generation increases accordingly. Aside from the resource utilization of the camera, the power supply option also has a large effect on power consumption. PoE (power over Ethernet) has a higher power consumption due to the uneven efficiency of circuitry compared to the circuitry used when powering the camera via the M8 connector.

Power Supply Option	Max.
Power via M8	7W
Power via M12 (PoE)	8W

Table 25 – D400e Maximum Power Consumption

Most of the power consumed by the camera is converted to heat and consequently, the camera will generate heat that is released to the ambient via the camera's housing.
Due to the internal structure of the camera, most heat dissipation will happen via the back side. Therefore, this part of the camera body is intended for thermal coupling with an external dissipative element such as a camera holder or stand. In tabletop applications, a simple heatsink element can be used. It is recommended to use metal parts for camera mounts to assure a good thermal conductivity on the back side of the camera body. Four threaded holes (M3 for D415e/D435e, M4 for D455e) are available on the camera back side to attach the camera to a mounting facility. It is recommended to use thermal paste on the contact surface between the camera and the heatsink for maximum thermal conductivity.

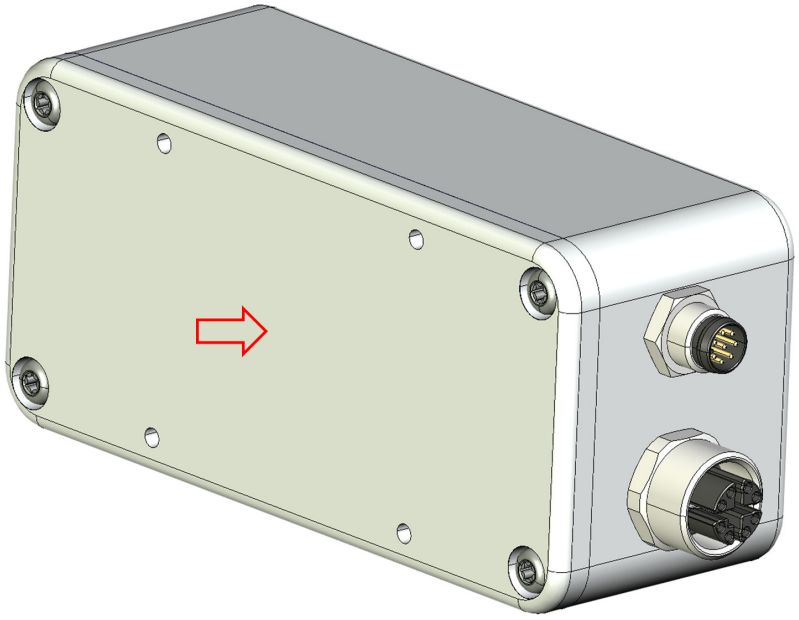


Figure 18 – Hottest Part of the Camera Housing

The maximum allowed operating temperature of the camera is defined as the temperature measured on the camera housing on the back side of the case, as shown in the figure above.

Operating Temperature	Min.	Max.
Temperature of the case (measured on the back side of the camera)	0 °C	60 °C

Table 26 – D400e Operating Temperature

Exceeding the maximum operating temperature defined in the table above can lead to permanent damage of the camera. The thermal dynamic of the camera is relatively slow due to the mass of the housing and its internal construction. Therefore, more than 1.5h of steady operation under an unchanged ambient condition, is necessary for the camera to reach the thermal steady state.
The camera operator should be aware of the camera settings that affect power consumption (framerate, laser usage, …), the power supply options and environmental conditions, to assure that the camera remains in a safe temperature range at all time. Examples of using appropriate heatsinks are discussed in the following chapter.

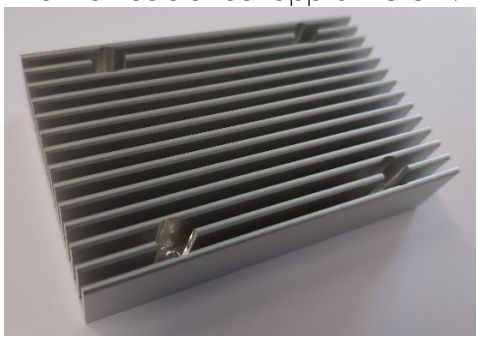
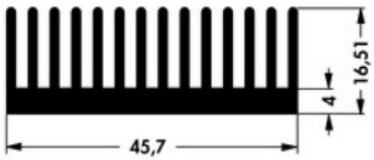
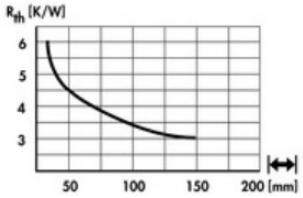
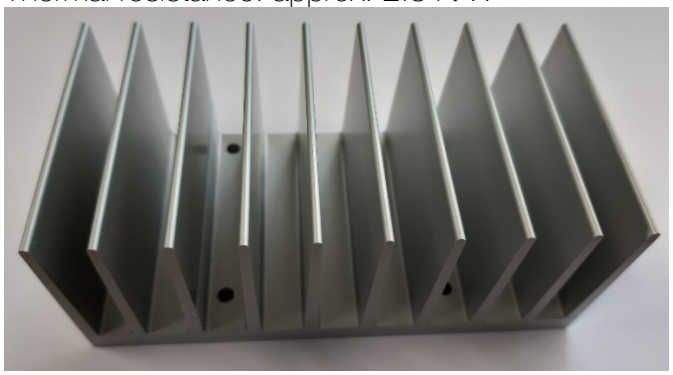
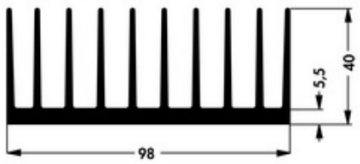
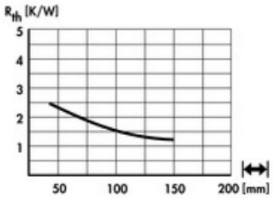
6.2 Operating Conditions for Different Temperatures

Depending on the ambient conditions, the camera can either operate without any additional heat dissipation element or with an adequate heatsink attached. The allowed maximum ambient temperatures are given for different operating modes of the camera, to indicate at which configuration the camera can run in several application use cases.

Use case:	Description:
Typical1	Power supply: M8, 12V Exposure time: 5 ms Framerate: 30 fps Laser projector power: 150 mW
Typical2	Power supply: M12, PoE Exposure time: 5ms Framerate: 30 fps Laser projector power: 150mW
Max1	Power supply: M8, 12V Exposure time: 30 ms Framerate: 30 fps Laser projector power: 360 mW
Max2	Power supply: M12, PoE Exposure time: 30 ms Framerate: 30 fps Laser projector power: 360 mW

Table 27 – Operating Conditions for Different Temperatures

The table below lists several heat dissipation elements that can be used to keep the camera in a safe operation mode.

Heatsink:	Description:
H0	No heatsink attached
H1 - passive	SK 424 75 ME Heatsink length: 75 mm Thermal resistance: approx. 3.8 K/W   
H2 - passive	SK 408 50 ME Heatsink length: 50 mm Thermal resistance: approx. 2.3 K/W   
H3 - passive	SK 530 100 AL Heatsink length: 100 mm Thermal resistance: approx. 0.38 K/W

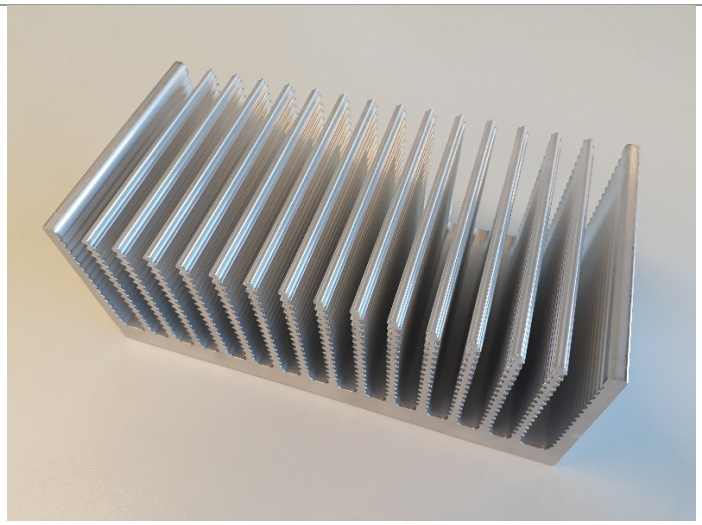
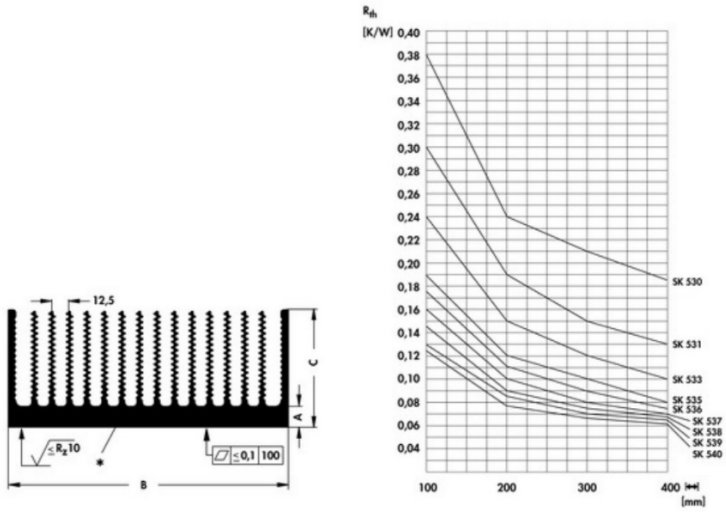
	  A: **15 mm** B: **200 mm** C: **84 mm**
H4 - active	SK 424 75 ME Heatsink length: 75 mm Cooling fan: Xilence XPF40

Table 28 – Heat Dissipation Elements

6.3 Maximum Operating Ambient Temperatures

The table below is showing maximal allowed ambient temperatures that keep the camera working within its safe operating temperature range. These results can be used when defining a cooling solution for a specific camera use case.
The given information is based on testing the camera in its thermal steady state using a thermal test chamber. In the chamber, there was no airflow at all. A temperature measurement error of ±1°C is possible.

Operating mode / Cooling option	Typical1	Typical2	Max1	Max2
H0 – no heatsink	32 °C	28 °C	26 °C	25 °C
H1 – passive	37 °C	33 °C	33 °C	31 °C
H2 – passive	45 °C	44 °C	44 °C	42 °C
H3 – passive	53 °C	52 °C	52 °C	51 °C
H4 – active	54 °C	53 °C	53 °C	52 °C

Table 29 – Maximum Operating Ambient Temperatures

6.4 Summary of Operating Conditions and Temperatures

Depending on the operation mode of the camera and the applied heat dissipation elements, ambient temperatures between 25°C and 54°C are possible. Table 29 shows that camera can operate in normal indoor environments (up to 31°C – 37°C) with very small heatsink such as H1. For moderately increased ambient temperatures, larger heat sinks must be used. H2 is showing the tradeoff between heatsink size and maximal allowed ambient temperatures at 42°C – 45°C. For very high ambient temperatures either large heatsink elements (H3) or active cooling (H4) must be used.
Without any heatsink attached, the camera can sustain ambient temperature 25°C – 32°C, depending on its utilization rate. Considering the fact, that in most cases the camera will be fixed on a mount, the inherent heat dissipation will likely be better than shown in H0. Consequently, the allowed ambient temperature will be higher than indicated in the H0 column. By choosing the appropriate camera holder, sufficient thermal conductivity for most typical applications can be achieved.
The specific customer application will differ from the examples shown above and every solution will require a thermal analysis to ensure safe and reliable operation of the camera. Given information should be used as a guideline at customers system design time.

Recommendation: Use metal camera mount to assure optimal heat conductivity (avoid plastic mounts).

Recommendation: In case there is a problem with overheating it is recommended to supply power to the camera via M8 connector rather than using PoE.

Recommendation: Minimize the resource utilization (i.e. fps, exposure, projector intensity) of the camera, which will positively affect heat generation and longevity of the product.

7. Mounting and Deployment

7.1 Camera Mounting

D400e cameras are designed to support mounting on the back side of the housing. The internal structure of the device is designed to dissipate most of the generated heat through this part of camera housing. Therefore, it is recommended to use a holder or stand which will ensure good mechanical stability of the camera but also act as a thermal drain. For this purpose, metal parts with high thermal conductivity and which are physically connected to a large part of the camera back side, are recommended. Please avoid materials like plastic, rubber or similar materials with high thermal resistance.
On the back side of the D415e/D435e camera body, four M3 thread holes are available for mounting. Since the housing is made of aluminum and M3 thread holes depth is 3.2mm, care is required when tightening the screws to avoid thread damage. Applied tightening torque should not exceed 100 cNm for these screws.

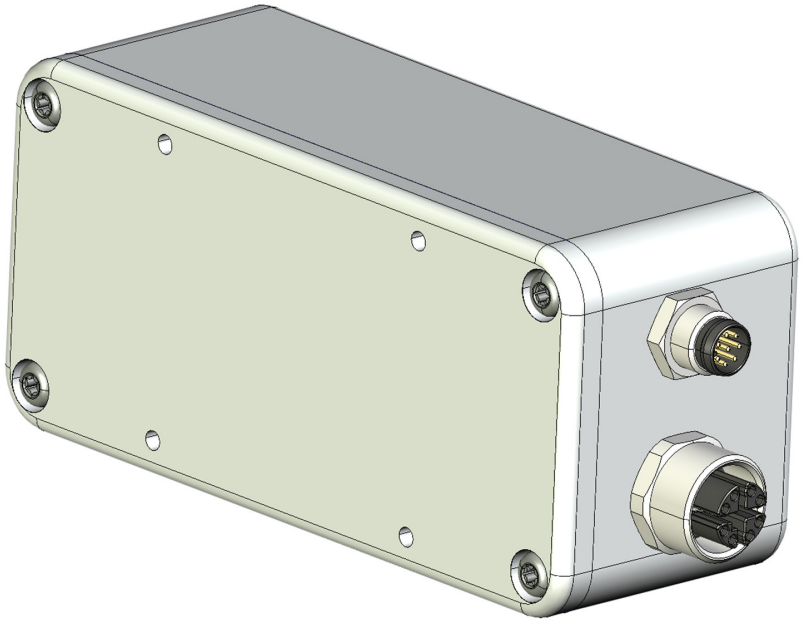


Figure 19 – D400e Series Camera Body Back Side

The D455e camera features four robust M4 thread holes for mounting, with stainless steel thread inserts and maximum insertion depth of 5mm. Applied tightening torque for mounting screws should not exceed 100 cNm, to avoid thread damage.

The camera is constructed for operation in industrial environments and can be used with moving objects. For this purpose, it is tested and compliant according to: EN 60068-2-6, EN 60068-2-64 and EN 60068-2-27 norms. However, stronger shock and vibration can lead to damage of sensitive optical and electronic components inside the camera. Dropping the camera or colliding it with any surface can lead to severe damage.

7.2 Application of External Cabling

The camera interface has a M8 and a M12 industrial grade connector. The M8 connector is used for power supply and external synchronization while the M12 connector serves for data transmission and power over Ethernet (in case the M8 connector is not used for power supply). Both are receptacles for relatively large external cable connectors.

When connecting the camera with external cable connectors (either M8 or M12), the corresponding camera connector nut should be held with an appropriate wrench. In the case the nut is not held by a wrench, the respective connector could be turned together with the cable if excessive force is applied. This should be prevented as it could cause damage to the internal camera wiring.
The FRAMOS D400e series camera is supplied with the M8 connector covered with a protective plastic cap. The function of the protective cap is to protect the M8 connector against impurities and moisture in the case the connector is not used, thus keeping it clean and ready for future.

Recommendation: When attaching M8 and M12 cables to camera, connectors should be fixed with a tool (wrench/key) so that the connectors do not rotate under force.

Recommendation: Use the protective cap on the M8 connector in the case the M8 connector is not used to protect it from environmental influences (exposure of connector pins to humidity, dust, and other particles). Note that protective cap does not influence the IP rating of the camera.

7.3 Cleaning Procedures

Depending on the operating environment, the camera needs to be cleaned from time to time. For cleaning the camera housing, it is recommended to use a soft camera cleaning brush or a soft cleaning cloth.

Using an eyeglass cleaning cloth is recommended for cleaning the camera glass window. Although the hardness of used glass is grade 6H, special attention is required when cleaning the window to prevent long term decreasing of optical properties. Using inadequate cleaning materials can cause micro scratches of the camera window.
Ethyl alcohol can be used for light wiping of the entire camera housing. Using strong solvents is not recommended and can lead to aesthetic or functional damage of the camera.

8. Functional Specification

8.1 Stream Configurations Possible

The theoretical maximum throughput on a Gigabit Ethernet link is 125 MB/s. To calculate the bandwidth required for specific stream configuration on D400e camera use the following formula:

$$BPP = Bytes\ per\ pixel$$
$$Depth_{BPP} = 2\ BPP$$
$$Infrared1_{BPP} = 1\ BPP$$
$$Infrared2_{BPP} = 1\ BPP$$
$$RGB_{BPP} = 2\ BPP$$

$$Bandwidth_{REQ} = Depth_{BPP} * Depth_{WIDTH} * Depth_{HEIGHT} * Depth_{FPS} + Infrared1_{BPP} * Infrared1_{WIDTH} * Infrared1_{HEIGHT} * Infrared1_{FPS} + Infrared2_{BPP} * Infrared2_{WIDTH} * Infrared2_{HEIGHT} * Infrared2_{FPS} + RGB_{BPP} * RGB_{WIDTH} * RGB_{HEIGHT} * RGB_{FPS}$$

Example of a bandwidth calculation is given below (Depth profile 640x480@30fps with both left and right infrared streams enabled, RGB profile 848x480@30fps):

$$Depth_{WIDTH} = Infrared1_{WIDTH} = Infrared2_{WIDTH} = 640$$
$$Depth_{HEIGHT} = Infrared1_{HEIGHT} = Infrared2_{HEIGHT} = 480$$
$$RGB_{WIDTH} = 848$$
$$RGB_{HEIGHT} = 480$$
$$Depth_{FPS} = Infrared1_{FPS} = Infrared2_{FPS} = RGB_{FPS} = 30$$

$$Bandwidth_{REQ} = 2 * 640 * 480 * 30 + 1 * 640 * 480 * 30 + 1 * 640 * 480 * 30 + 2 * 848 * 480 * 30 = 61286400\ B/s = 61.29\ MB/s$$

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

Table 30 – Example of Possible Streams on Gigabit Ethernet Network

8.2 Depth Field of View (FOV)

Format	D435e / D455e	D415e
Horizontal FOV (VGA 4:3)	74°	48°
Vertical FOV (VGA 4:3)	62°	40°
Diagonal FOV (VGA 4:3)	88°	60°
Horizontal FOV (HD 16:9)	86°	64°
Vertical FOV (HD 16:9)	57°	41°
Diagonal FOV (HD 16:9)	94°	72°

Table 31 – Depth FOV

Information: The Depth FOV specified is at 2 meters distance. Due to mechanical tolerances of +/-5%, Max and Min FOV values can vary from lens to lens and module to module by ~ +/- 3 degrees.

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

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

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

8.3 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	D435e Min-Z (mm)	D415e Min-Z (mm)	D455e Min-Z (mm)
1280x720	280	450	520
848x480	195	310	350
640x480	175	310	320
640x360	150	240	260
480x270	120	180	200
424x240	105	160	180

Table 32 – Minimum-Z Depth

8.4 Depth Quality Specifications

Set of standard metrics based on accuracy, data validity and temporal stability are used to determine the depth quality.

FRAMOS D400e series camera depth quality specifications are the same as the corresponding Intel D400 series camera specifications.

Metric	D435e/D415e (up to 2 meters and 80% ROI, HD Resolution)	D455e (up to 4 meters and 80% ROI, HD Resolution)
Z-accuracy (or absolute error)	$\pm 2\%$	$\pm 2\%$
Fill rate	$\geq 99\%$	$\geq 99\%$
RMS Error (or Spatial Noise)	$\leq 2\%$	$\leq 2\%$
Temporal Noise	$\leq 1\%$	$\leq 1\%$

Table 33 – Depth Quality Specifications for FRAMOS D400e Series Camera

For depth accuracy and the optimum settings of the camera, please refer to *Best-Known-Methods for Tuning Intel® RealSense™ D400 Depth Cameras for Best Performance* [Ref-5].

For more information on depth quality specifications please refer to *Intel® RealSense™ D400 Series Product Family* [Ref-1], Chapter "Depth Quality Specification".

For depth quality metrics definitions and test methodology, please refer to *Intel® RealSense™ Camera Depth Testing Methodology* [Ref-7].

Information: The depth quality specifications apply to all FRAMOS D400e series cameras. All FRAMOS D400e cameras are factory calibrated; Intel OEM Calibration Target and Tool is used in D400e factory calibration procedure.

Information: Calibration parameters may become invalid and depth quality may decrease if camera has been subjected to force or impact. In such cases Intel RealSense calibration tools can be used to improve depth quality by re-calculating the calibration parameters. Please refer to released calibration guides and white papers [Ref-8].

Intel® RealSense™ Self-Calibration for D400 Series Depth Cameras feature is not applicable for the FRAMOS D400e series cameras.

8.5 Depth Camera Functions

Control	Description	Min	Max
Manual Exposure(1) (µs)	Control sensor exposure period	1	165000
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

Table 34 – Depth Camera Functions

NOTES:

(1) – Not supported in Auto Exposure Mode

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

8.6 Color Camera Functions

Control	Description	Min	Max
Auto-Exposure Mode	Automatically sets the exposure time and gain for the frame.	0	1
Auto Exposure ROI	Auto Exposure on a selected ROI	T-0 L-0 B-1 R-1	T-1079 L-1919 B-1080 R-1920
Manual Exposure Time (100µs unit)	Sets the absolute exposure time when autoexposure is disabled.	1	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	4
Backlight Compensation	Sets a weighting amount based on brightness to the frame.	0	1
Low Light Comp	Low Light	0	1

Table 35 – Color Camera Functions

8.7 Inertial Measurement Unit Streams

Stream	Description	Format	FPS	Unit
Accel	Acceleration data from IMU sensor	MOTION_XYZ32F	63, 250	meter/sec^2
Gyro	Gyroscope data from IMU sensor	MOTION_XYZ32F	200, 400	radian/sec

Table 36 - Inertial Measurement Unit Streams

8.8 D400e Camera Specific Features

8.8.1 Packet Size

The Packet Size feature specifies the stream packet size in bytes. It can be configured separately for Depth and RGB streams. Optimum value of the Packet Size feature is automatically calculated by the software, but it can be manually overridden. Increasing Packet Size is generally beneficial for the overall system performance. For more information, please refer to *FRAMOS Industrial Depth Camera D400e Series - Tuning System For Best Performance* [Ref-4].

Recommendation: Enable Jumbo Frames in the Network Adapter Advanced settings to allow using larger Packet Size values. This reduces the number of packets sent by the camera, thus reducing the packet overhead and workload of the host NIC.

8.8.2 Inter Packet Delay

The Inter Packet Delay is the delay introduced by the camera between sending two consecutive packets on the stream channel. This delay reduces the effective network load (on NIC or switch) and creates timeslots for processing packets from other devices on the network. The Inter Packet Delay is very useful when multiple cameras are streaming to one PC on the same Network Interface Card (NIC). For more information, please refer to *FRAMOS Industrial Depth Camera D400e Series - Tuning System For Best Performance* [Ref-4].

8.8.3 Heartbeat Time

Heartbeat mechanism is used to determine whether the logical link between D400e camera and application running on host is active. Host sends the heartbeat command to the camera in regular intervals and the camera sends a response. If the camera does not respond in a certain interval, the host considers the camera disconnected. If the camera does not receive a heartbeat command in the same interval, it considers the host disconnected.
For more information, please refer to document d400e_api_extensions.md (part of the D400e software package).

8.8.4 Inter Cam Sync Mode

Enables synchronous streaming of multiple cameras and stream synchronization to an external event. FRAMOS D400e camera provides the following Inter Cam Sync modes:

- Default
- Master
- Slave
- Genlock Mode (only FRAMOS D400e Global Shutter based cameras)
- External Event
- External Event Burst

Inter Cam Sync Mode feature in conjunction with Output Trigger Enabled and User Output Level features defines the state of the M8 power connector pin 3 (Opto-Isolated Output).

Information: When camera operates in "External Event Mode" or "External Event Burst Mode", camera internal streams and laser projector are active even if no external event pulse is applied and no stream is sent to the host. This should be taken into consideration when designing applications using those operating modes.

For more information please refer to *FRAMOS Industrial Depth Camera D400e Series - External Event Camera Synchronization* [Ref-2] and *FRAMOS Industrial Depth Camera D400e Series - Multi-Camera Synchronization* [Ref-3].

8.8.5 Output Trigger Enabled

Output Trigger Enabled feature switches between the synchronization signal VSYNC (described in *FRAMOS Industrial Depth Camera D400e Series - External Event Camera Synchronization* [Ref-2]) and user controllable output.

When enabled VSYNC is selected as M8 Pin 3 driver. VSYNC drives pin in all Inter Cam Sync modes.

When disabled, user can change the state of the M8 Pin 3 with the User Output Level feature.

8.8.6 User Output Level

Enables the user to set the signal level of a M8 Pin 3 (Opto-Isolated Output) to the low or high voltage level. This can be used to control the external lighting or other devices.
User Output Level is active in all Inter Cam Sync modes when Output Trigger Enabled is disabled.

Output Trigger Enabled and User Output Level features behavior are shown in Figure 20.

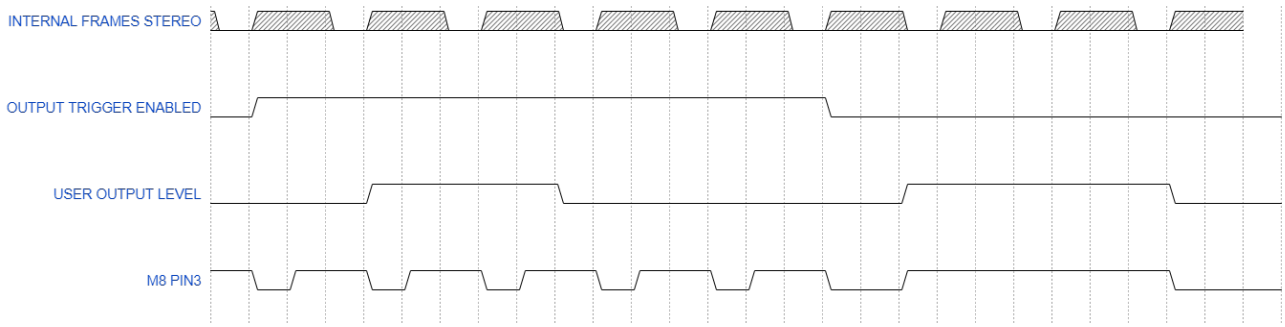


Figure 20 – D400e M8 Pin 3 Behavior

8.8.7 Line Debouncer Time

The Line Debouncer Time feature defines the minimum interval in microseconds that an input signal on camera digital input pin must remain active to be recognized as a valid signal. The Line Debouncer Time is used to prevent possible unwanted trigger events by eliminating short pulses or noise that could easily be interpreted as a trigger signal.
The Line Debouncer Time functionality is shown in Figure 21. Trigger signal has three glitches that are ignored because the width of these signals is shorter than the Line Debouncer Time. The fourth signal is accepted as a valid trigger signal as its width is longer than the Line Debouncer Time.
The Line Debouncer Time effectively increases delay time between the external trigger (signal on digital input pin) and the internal trigger that is used to start the camera event, so it should be set large enough to filter unwanted glitches, but small enough to keep the delay as small as possible.

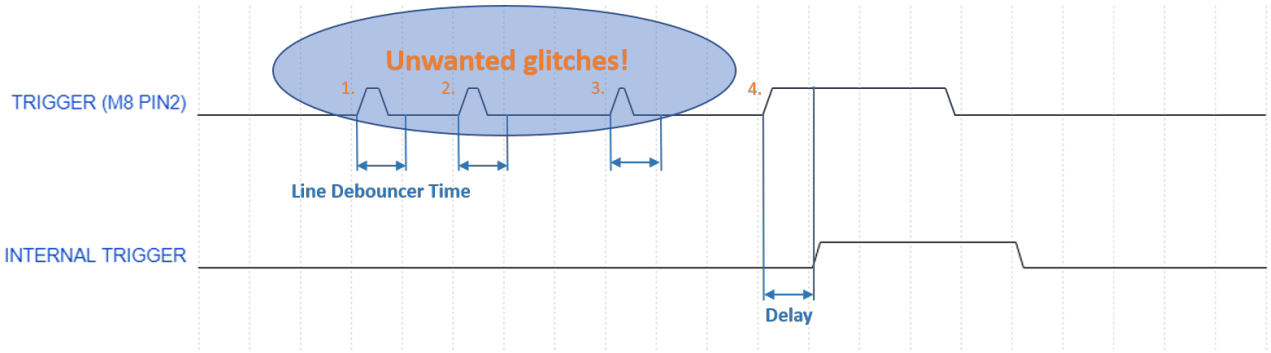


Figure 21 – D400e Line Debouncer Time

Information: The Line Debouncer Time feature continuously filters signals on the camera digital input pin so it may affect the camera behavior when the camera is operating in “Slave”, “Genlock”, “External Event” or “External Event Burst” operating modes.
For optimal operation, set the Line Debouncer Time to a value larger than the width of noise pulses expected or observed on the signal line, but smaller than the width of the trigger signal applied on the camera digital input pin.

8.8.8 RGB/Stereo Synchronization

By default, FRAMOS D400e camera operates in the "Default" operating mode, with asynchronous streams from the RGB and Stereo sensor. For explanation on the camera operating modes please refer to *FRAMOS Industrial Depth Camera D400e Series - Multi-Camera Synchronization* [Ref-3].

To achieve synchronization between the RGB and Stereo stream make sure of the following:

- Inter Cam Sync Mode is set to "Default Mode" or "External Event Mode"
- RGB Auto Exposure Priority option is disabled
- RGB and Stereo framerates matches

When streams are synchronized, there is a constant delay between the frames as shown in Figure 22.

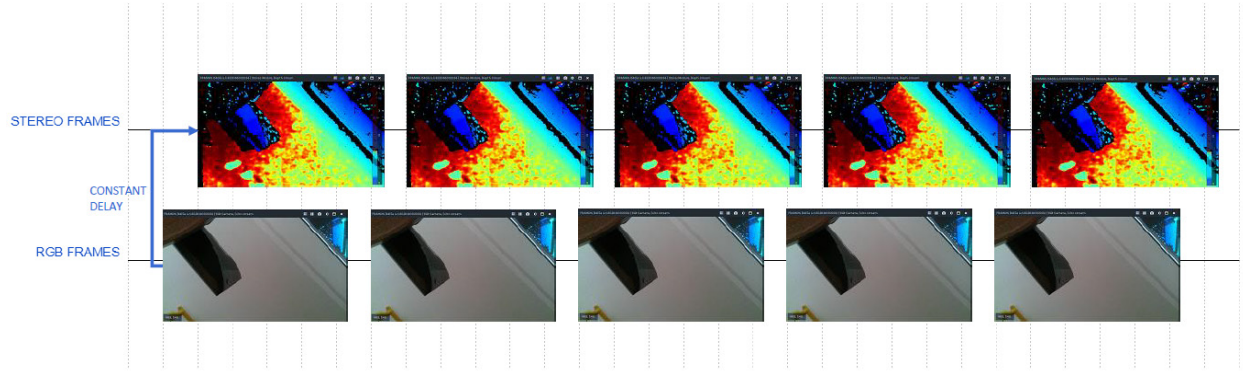


Figure 22 – D400e Series Camera Synchronized Streams

With streams out of synchronization, RGB and Stereo streams drift apart over time as shown in Figure 23.

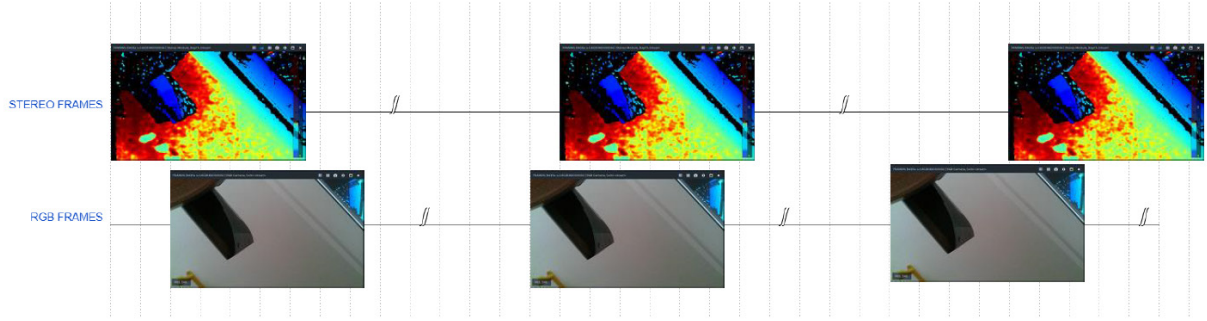


Figure 23 – D400e Series Camera Streams out of Synchronization

Recommendation: Use synchronization with Auto Exposure option enabled for both RGB and Stereo sensor.

8.8.9 Syncer Mode

D400e cameras have a possibility to synchronize streams to an external event (using Inter Cam Sync Mode External Event operating mode).

As the frequency of external events is not known in front, "syncer module" in librealsense2 is extended to handle this case. Available syncer options in the librealsense2 API are listed in the `rs2_syncer_mode` enumeration available in the `librealsense2/h/rs_types.h` header file:

```
// Syncer Mode
typedef enum rs2_syncer_mode
{
    RS2_SYNCER_MODE_DEFAULT, //default syncer mode
    RS2_SYNCER_MODE_WAIT_FRAMESET, // wait-for-full-frameset syncer mode
    RS2_SYNCER_MODE_COUNT
};
```

The `RS2_SYNCER_MODE_DEFAULT` enumerator represents the default working mode of the syncer module (original librealsense2 syncer implementation) in which the same frame, in certain situations, can be returned in consecutive framesets by "wait_for_frames" call, as shown in Figure 24.

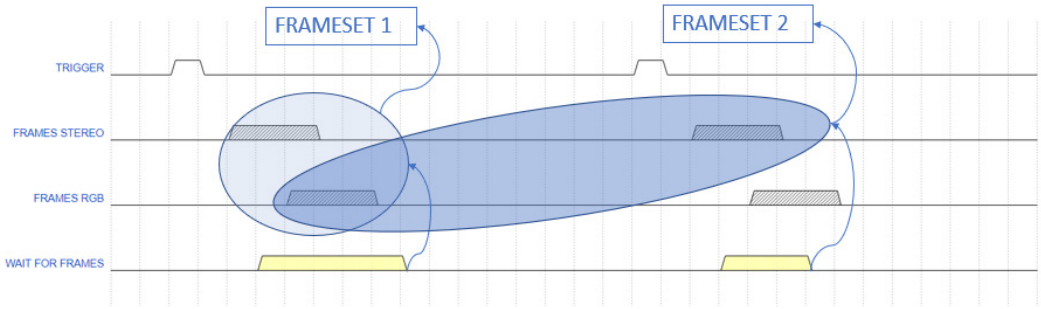


Figure 24 – Syncer Default Mode

The `RS2_SYNCER_MODE_WAIT_FRAMESET` enumerator represents the wait-for-full-frameset mode of the syncer module with the support for external events specific to D400e cameras. In this mode, syncer returns synchronized frameset only when frames from all enabled streams have arrived, as shown in Figure 25.

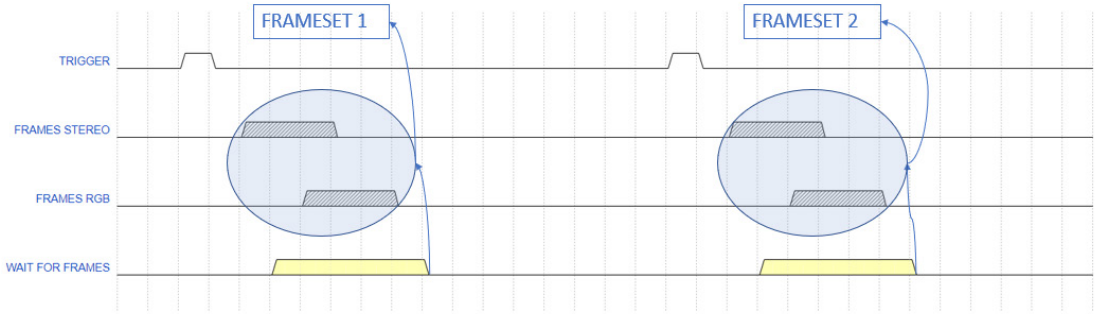


Figure 25 – Syncer Wait-For-Frameset Mode

Syncer mode can be set only through API using the following code snippets:

```cpp
rs2::config cfg; //config object
cfg.set_syncer_mode(RS2_SYNCER_MODE_WAIT_FRAMESET);
```

```c
rs2_error* e = 0;
rs2_config* config = rs2_create_config(&e);
check_error(e);
rs2_config_set_syncer_mode(config, RS2_SYNCER_MODE_WAIT_FRAMESET, &e);
```

```python
config = rs.config()
config.set_syncer_mode(rs.syncer_mode.wait_frameset)
```

9. 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.

The UpdateFirmware 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. Tool can be run in two modes: interactive and non-interactive.

9.1 Firmware Update Interactive Mode

This is the default running mode of the UpdateFirmware tool. User must manually select the camera by index from the list of connected cameras and follow the on-screen instructions to perform firmware update on selected camera.

Usage example on Linux:

```
./UpdateFirmware FRAMOS_D435e_r1111_v1_10_0_0.fw_update
```

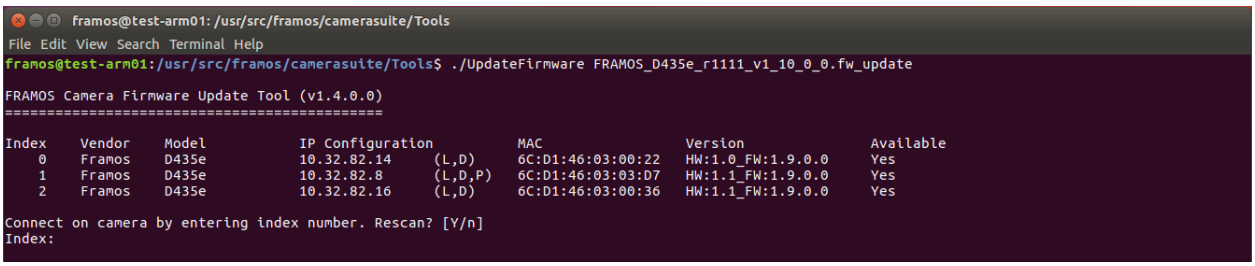


Figure 26 - Tool UpdateFirmware Part 1

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

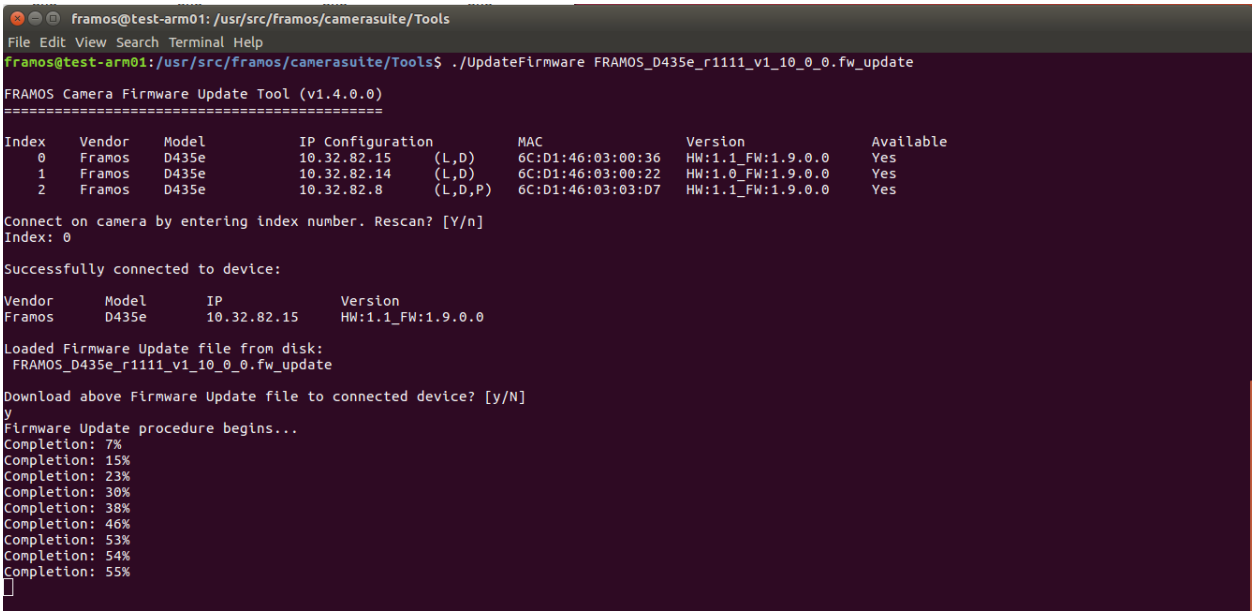


Figure 27 – Tool UpdateFirmware Part 2

9.1.1 Parallel Firmware Update

The UpdateFirmware tool can upgrade multiple cameras at the same time.

Usage example on Linux:

```
./UpdateFirmware FRAMOS_D435e_r1111_v1_10_0_0.fw_update
```

Enter keyword “all” to select all available cameras:

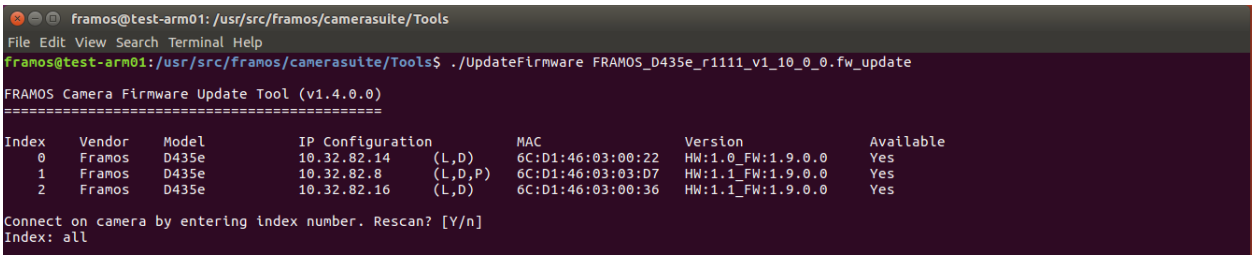


Figure 28 - Tool UpdateFirmware Parallel Part 1

Firmware update procedure will start on all cameras that are compatible with the selected firmware update file. If there are cameras in the list that are not compatible with firmware update file, the *UpdateFirmware* tool will simply ignore these cameras and will inform user about incompatibility at the end of the firmware update procedure.

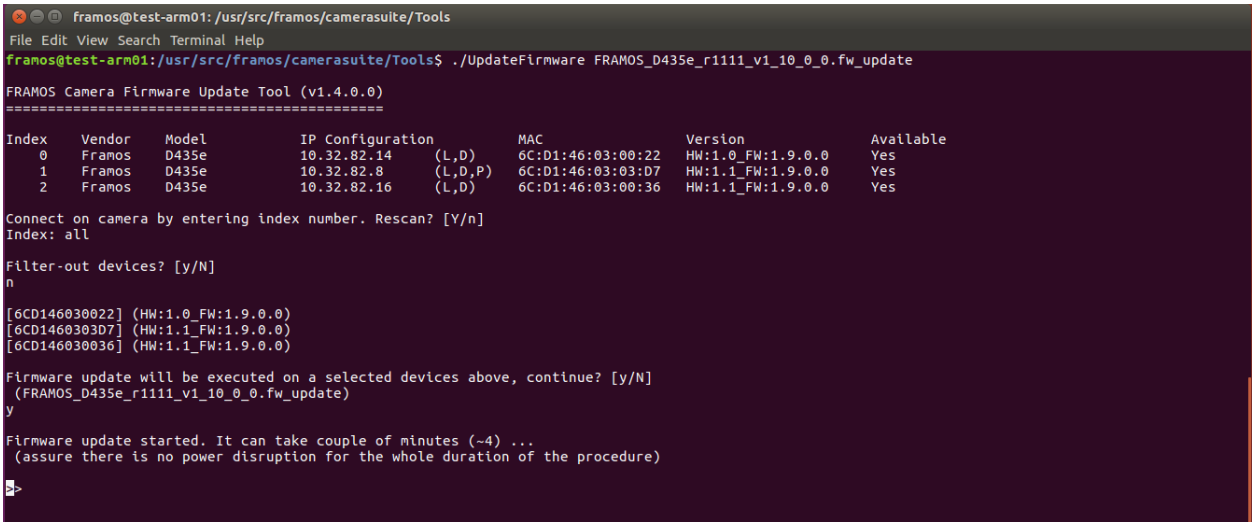


Figure 29 – Tool UpdateFirmware Parallel Part 2

On firmware update procedure completion, the *UpdateFirmware* tool will list cameras with corresponding firmware update status message (firmware update pass / fail).

Recommendation: When performing firmware update on multiple cameras, it is recommended to perform firmware update on smaller batch first and verify result, and then update firmware on other cameras.

9.2 Firmware Update Non-Interactive Mode

In non-interactive mode no additional input from the user is required once the tool is started. User can select to perform firmware update on single camera, all available cameras, or a set of cameras specified by camera serial number. Serial number argument ("-sn") must be specified after the argument “-noninteractive”. Usage examples for Linux are shown below.

Perform firmware update on a single camera:

```
./UpdateFirmware FRAMOS_D435e_r1111_v1_10_0_0.fw_update -noninteractive -sn=6CD146030036
```

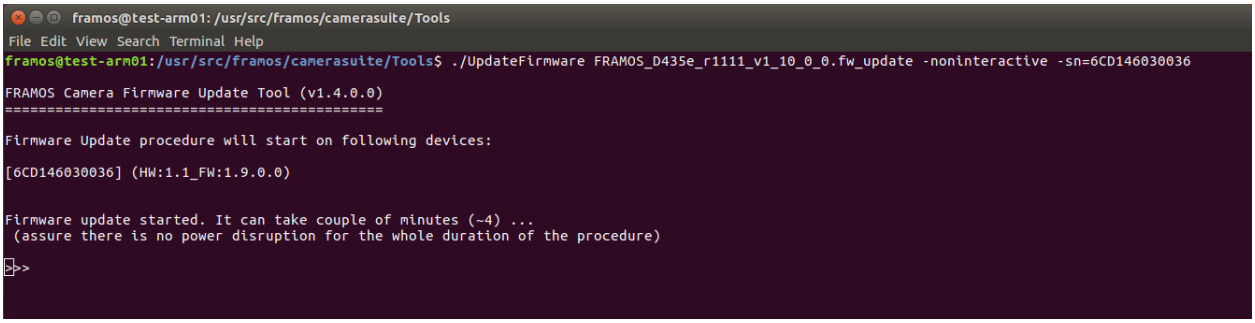


Figure 30 – Selecting one device in noninteractive mode

To perform firmware update on a set of cameras, specify serial numbers of the selected cameras after the "-sn" argument and separate them with comma sign delimiter (no spaces are allowed):

```
./UpdateFirmware FRAMOS_D435e_r1111_v1_10_0_0.fw_update -noninteractive -sn=6CD146030022,
6CD1460303D7,6CD146030036
```

To perform firmware update on all cameras:

```
./UpdateFirmware FRAMOS_D435e_r1111_v1_10_0_0.fw_update -noninteractive -sn=all
```

9.3 IP Address Conflict

9.3.1 Interactive Mode

If multiple devices with identical IP address were detected during discovery, the tool will display the warning about IP address conflict when started in interactive mode. In this case, firmware update procedure can be started only on cameras that are not in conflict. If camera that is in conflict is selected for firmware update, the procedure will be terminated, as shown on Figure 32.

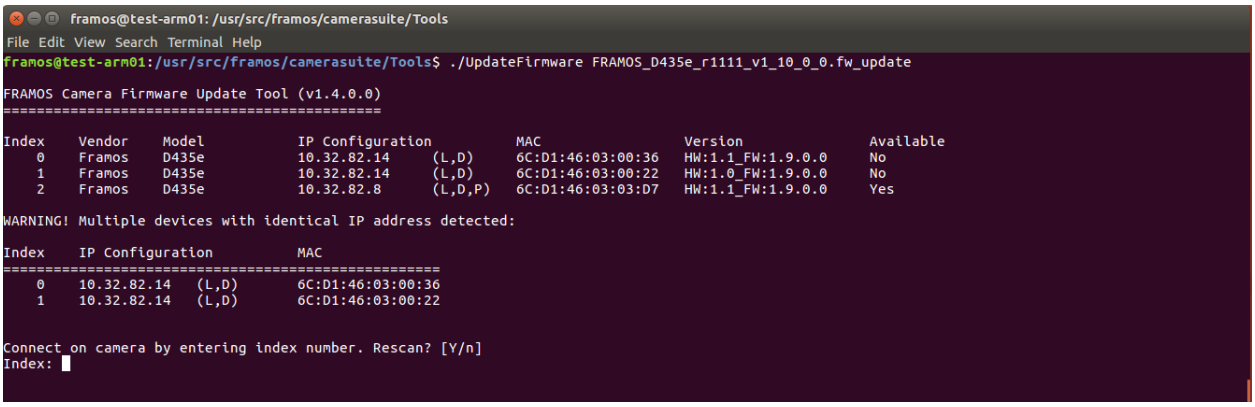


Figure 31 – IP address conflict

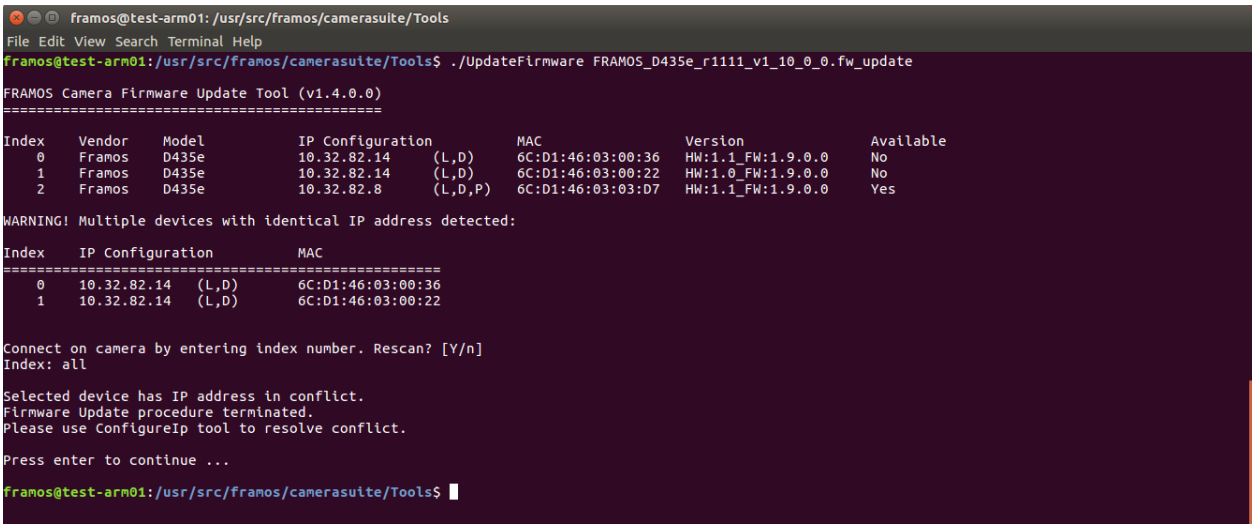


Figure 32 - IP address conflict when selecting all devices

9.3.2 Non-interactive Mode

In non-interactive mode, no warning will be displayed but selected cameras will be verified for IP address conflict. If the list contains a camera that is in IP address conflict, the firmware update procedure will be terminated.

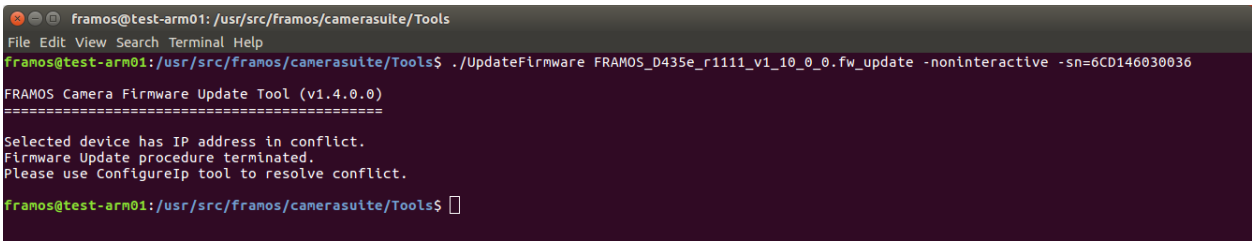


Figure 33 – IP address conflict, procedure terminated

10. Software

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

FRAMOS Industrial Depth Camera D400e Series - Getting Started [Ref-6].

10.1 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 D400e Series and Intel® RealSense™ SDK 2.0, allowing D400e Series camera to be used by tools based on the Intel® RealSense™ SDK 2.0.

10.1.1 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.

There are two ways to use the ConfigureIP tool: the *interactive mode*, that allows modification to camera IP configuration settings via the text interface, and the *noninteractive mode* where the arguments passed to the tool define the operation that will be performed. To learn more about the arguments that can be passed to the ConfigureIP tool, call the tool with the argument "-help".

Interactive mode

Usage example on Linux:

```
./ConfigureIp
```

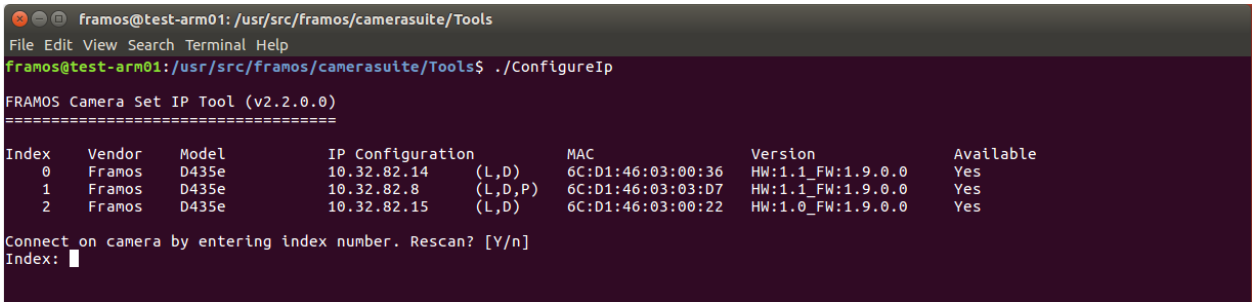


Figure 34 – Tool ConfigureIp Part 1

The IP Configuration column displays current IP address and additional flags in parentheses indicating the IP Configuration protocols enabled on each device:

- L = device has LLA protocol enabled (always enabled)
- D = device has DHCP protocol enabled
- P = device has Permanent IP address enabled

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

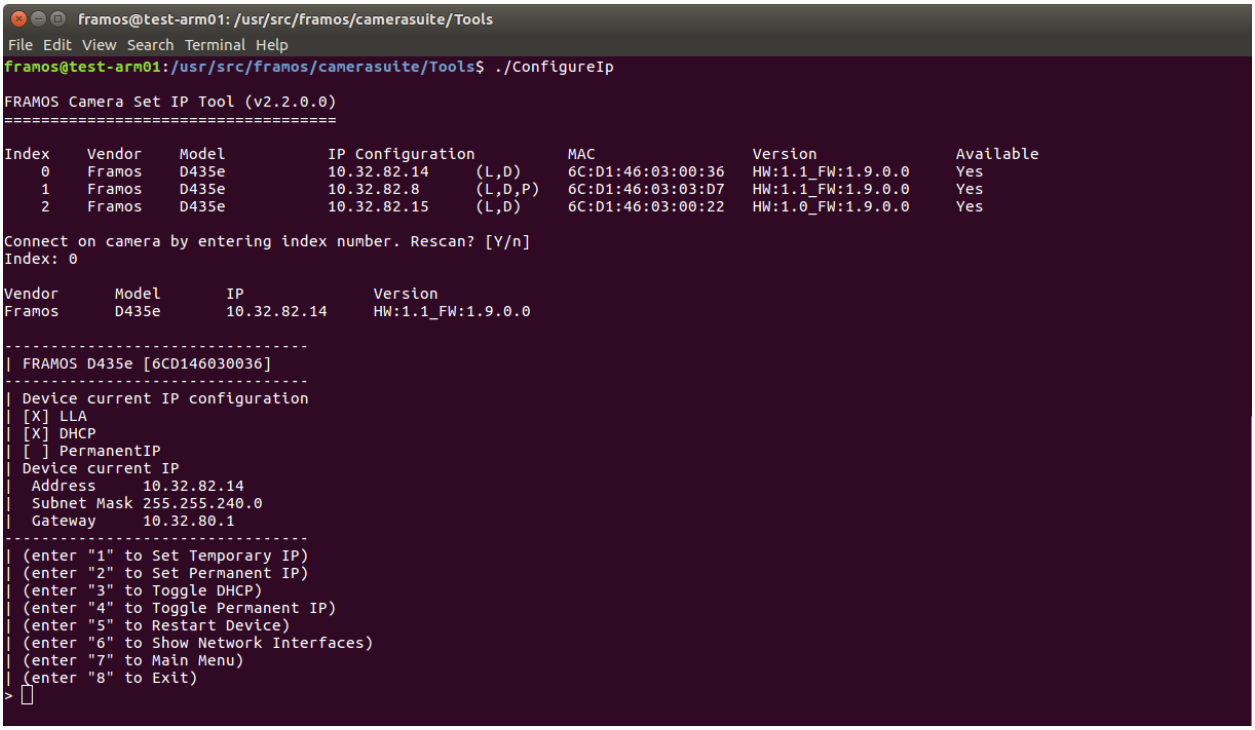


Figure 35 – Tool ConfigureIp Part 2

Note that the newly set IP configuration will not be active until the camera is restarted.
In certain cases, especially when using Permanent IP configuration, there is a possibility of IP address conflict between two or more cameras. If IP address conflict is detected, the ConfigureIp tool will display a warning message.

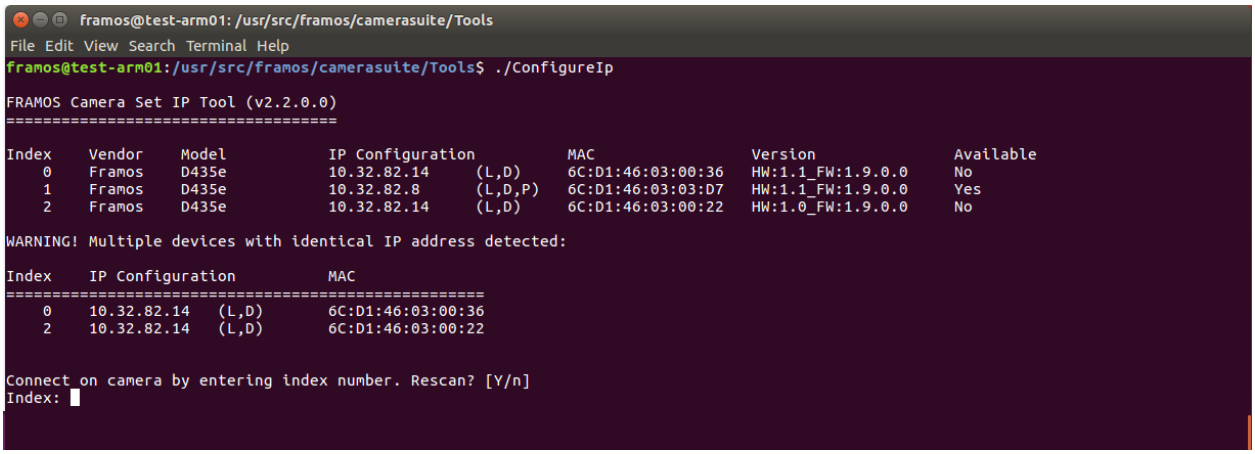


Figure 36 – IP address conflict warning message

Noninteractive mode

To get a list of all available arguments, run the tool with argument "-help":

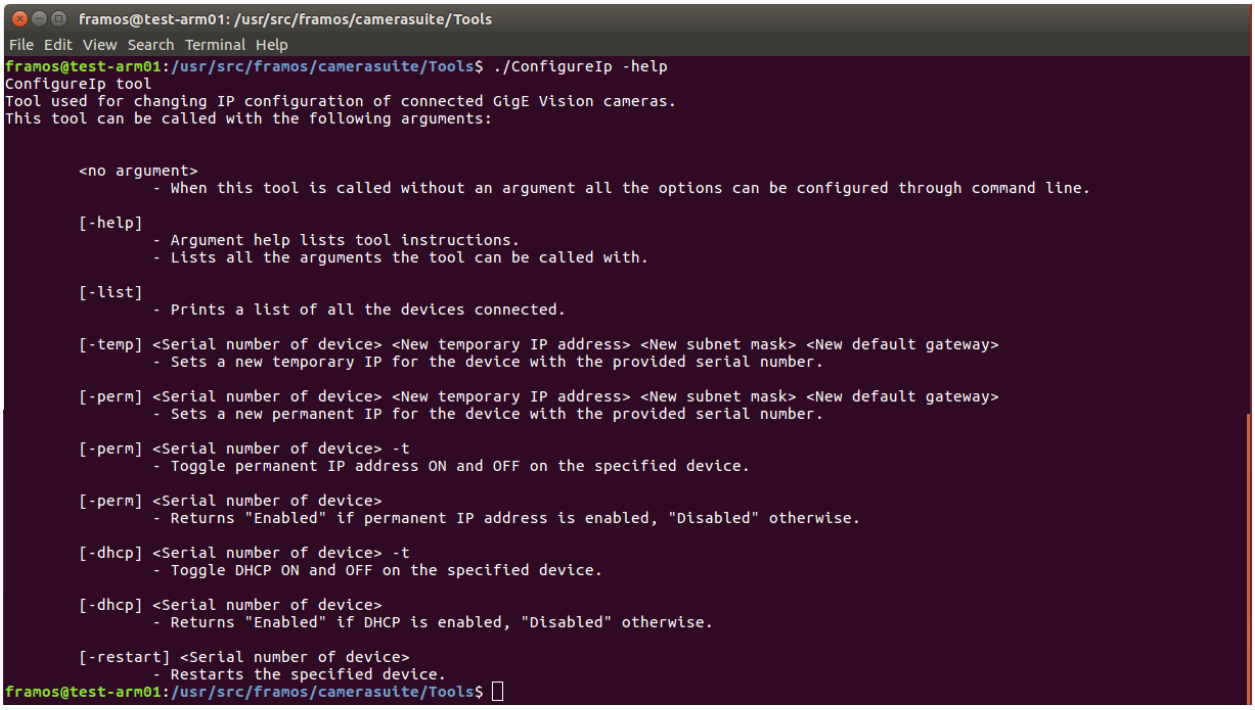


Figure 37 – ConfigureIp tool arguments

The following examples show how to run the tool with some of the available arguments.

To verify if the device has DHCP protocol enabled:

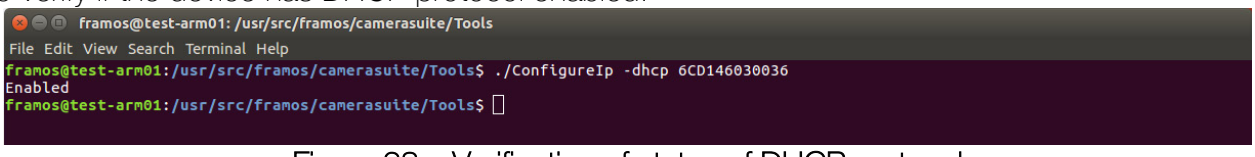


Figure 38 – Verification of status of DHCP protocol

To verify if the device has permanent IP address enabled:

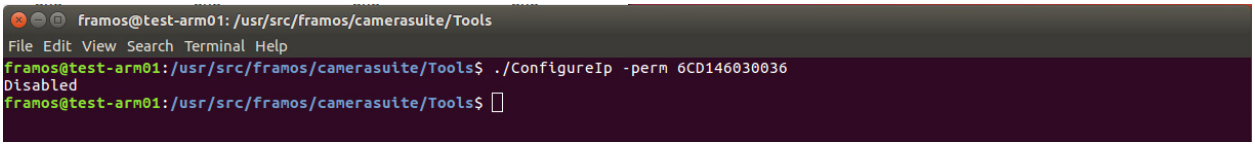


Figure 39 – Verification of status of permanent IP address

10.1.2 Manage Camera Calibration Tables

CalibrationTables tool is used to manage calibration tables on FRAMOS Industrial Depth Camera D400e Series. Following actions are supported:

- Read calibration tables from device
- Write calibration tables to device (active)
- Write calibration tables to device (active + gold)
- Reset calibration tables on device to default gold factory settings

Usage example on Linux – running CalibrationTables tool:

```
CalibrationTables
```

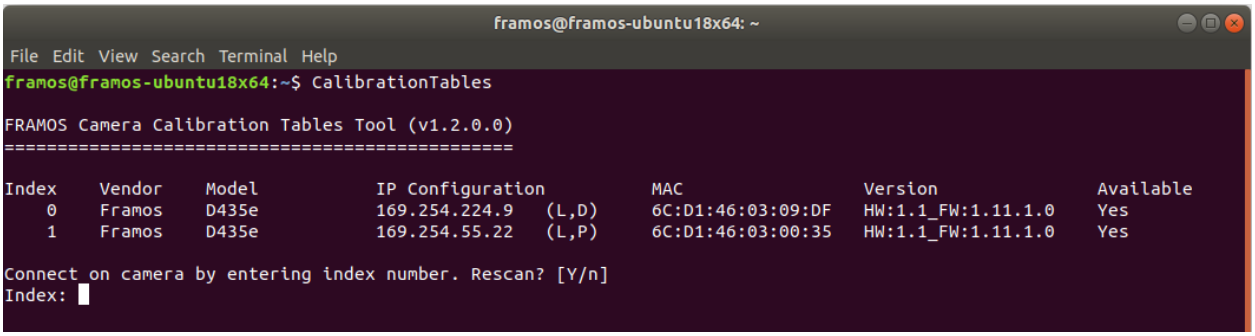


Figure 40 – Tool CalibrationTables Part1

Select a camera from the list and then choose desired action:

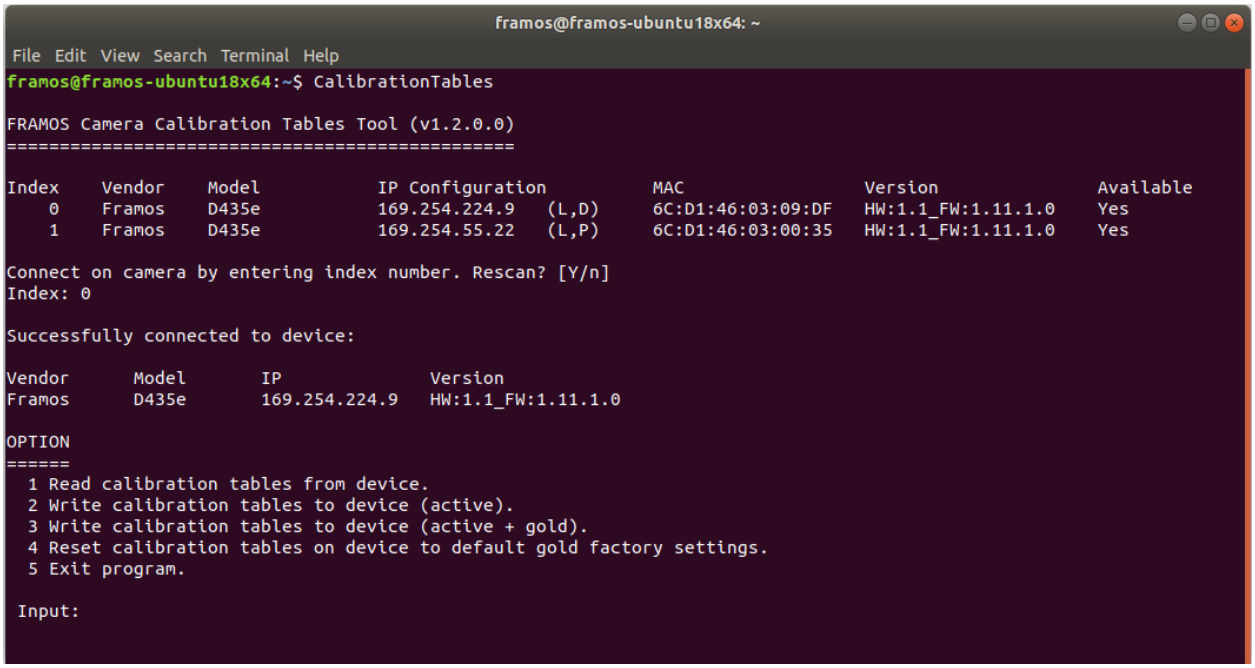


Figure 41 – Tool CalibrationTables Part2

10.2 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: https://www.framos.com/en/industrial-depth-cameras

The SDK at a minimum includes:

Intel® RealSense™ Viewer - This application can be used to 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

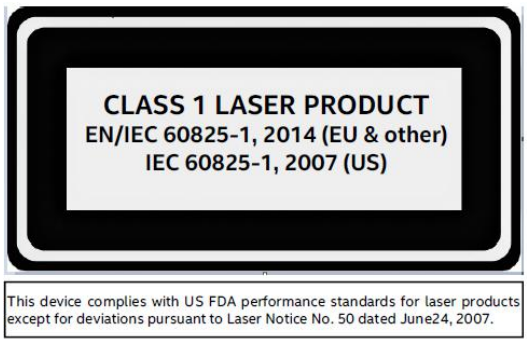
11. Troubleshooting

For troubleshooting problems related to FRAMOS D400e Series Camera please refer to *FRAMOS RealSense Cameras Knowledge Base* [Ref-9].

12. 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.



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

Shock

DIN EN 60068-2-27

Vibration

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

13. Accessories

Recommended Cables

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-x/connecting-cable-male-cable-connector-m12-x-1-rj45-connector-shielded#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/#77340600005000802 00

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

14. References

1. Intel® RealSense™ D400 Series Product Family, Revision 009, published in June 2020, Intel RealSense.
2. FRAMOS Industrial Depth Camera D400e Series - External Event Camera Synchronization, FRAMOS GmbH.
3. FRAMOS Industrial Depth Camera D400e Series - Multi-Camera Synchronization, FRAMOS GmbH.
4. FRAMOS Industrial Depth Camera D400e Series - Tuning System For Best Performance, FRAMOS GmbH.
5. Best-Known-Methods for Tuning Intel® RealSense™ D400 Depth Cameras for Best Performance v2.0, Intel RealSense.
6. FRAMOS Industrial Depth Camera D400e Series - Getting Started v1.1, FRAMOS GmbH.
7. Intel® RealSense™ Camera Depth Testing Methodology, Revision 1.0, published in January 2018.
8. Calibration Guides and White Papers, Intel.
9. FRAMOS RealSense Cameras Knowledge Base, FRAMOS GmbH.

15. Revision History

Date	Version	Changes
2020-06-30	1.0.0	Initial version
2020-09-01	1.1.0	Added chapter "Output Trigger Enabled"; Added chapter "User Output Level"; Added chapter "Syncer Mode"; Updated chapter "D400e Camera Specific Features"
2020-10-01	1.2.0	Added chapter "Line Debouncer Time"; Updated chapter "D400e Camera Specific Features"
2021-01-15	1.3.0	Updated chapter "Power Consumption"; Updated chapter “Firmware Updates”; Added chapter "Inertial Measurement Unit"; Added chapter "Physical Interfaces"; Added chapter "Depth Quality Specifications"; Updated chapter "Manage Camera Calibration Tables"; Added chapter "FRAMOS Depth Camera D400e Series"; Added chapter "FRAMOS Depth Camera D400e Module Variant"; Added chapter "Mechanical Drawings"; Updated chapter "Component Overview"; Added chapter "Troubleshooting"
2021-05-31	1.4.0	Added chapter “Depth Camera Depth Origin Reference”; Updated chapter “FRAMOS Depth Camera D400e Module Variant”; Updated chapter "Labels on the Camera"; Updated chapter "Accessories"
2021-07-15	1.5.0	Updated entire document with information related to D455e camera

Table 37 – Revision History

NOTE: *This document replaces and supersedes the user manual "FRAMOS Industrial Depth Camera D435e" v1.1.0.*