Edge.Auto Hardware Reference Manual

TIER IV

Sep 06, 2024

Contents

1

C1 Camera Technical Reference Manual

1.1 Overview

The C1 camera is a GMSL (Gigabit Multimedia Serial Link) camera specifically designed for automotive applications. It has a resolution of 2.5 MP at 1920 x 1280 px.

Featuring Sony Semiconductor Solutions' ISX021 back-side illumination stacked CMOS image sensor SoC, this camera enables HDR imaging over 120dB, LED flicker mitigation (LFM), and motion artifact-free image capturing at a frame rate of up to 30fps.

With a variety of lens options available, the C1 camera can be adapted to many applications. The lens undergoes a 6-axis active adjustment during installation, allowing it to achieve optimal sharpness even in harsh temperature environments.

The ISP (Image Signal Processor) built into the C1 camera's image sensor performs various image processing tasks, including lens distortion correction, to achieve optimal image quality for automotive applications. The C1 camera also supports an external triggering mechanism, which is essential to achieve capture synchronization with other sensor modalities such as LiDAR or RADAR, enabling sensor fusion.

Designed for automotive mass production, the C1 camera is ready to use. All key components comply with AEC-Q100 (Grade 2), Q101, and Q200 standards, and are designed to pass automotive-grade reliability tests.

1.2 Mechanical specifications

1.2.1 Camera size

Model Name	C1-046	C1-085	C1-120	C1-198
Camera size	38.5mm x 38.5mm x 42.19mm	38.5mm x 38.5mm x 43.21mm	38.5mm x 38.5mm x 48.93mm	38.5mm x 38.5mm x 40.44mm

1.2.2 Connector

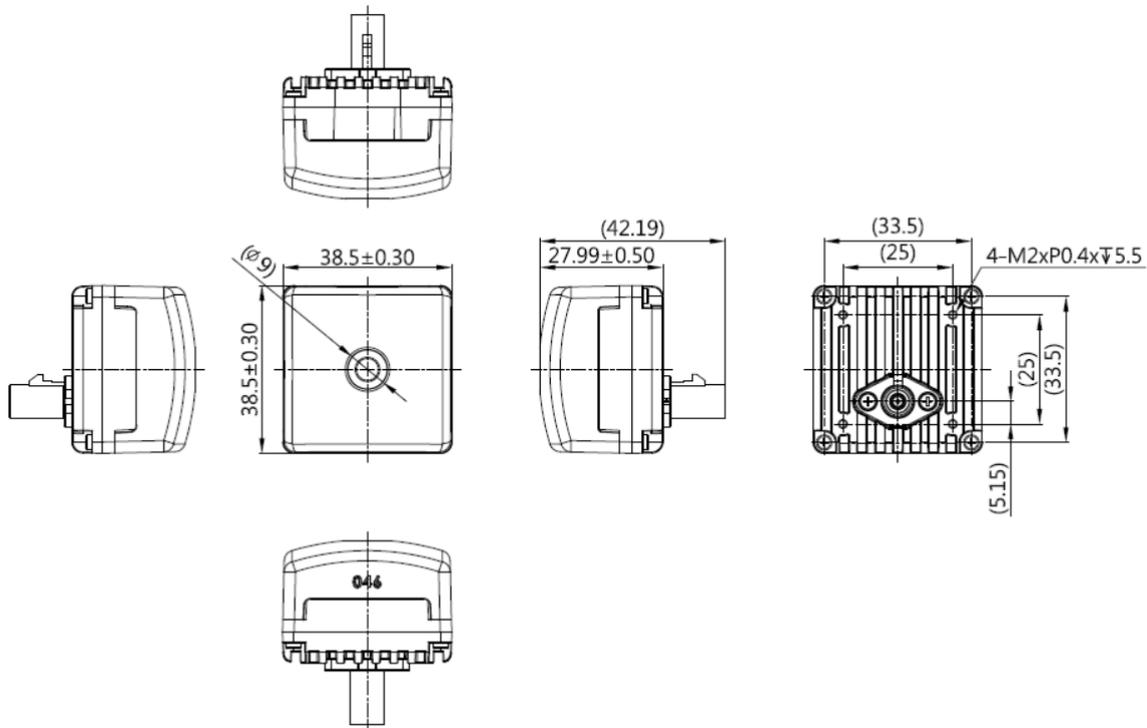Fakra Z code with metal shielding

1.2.3 Outline diagram

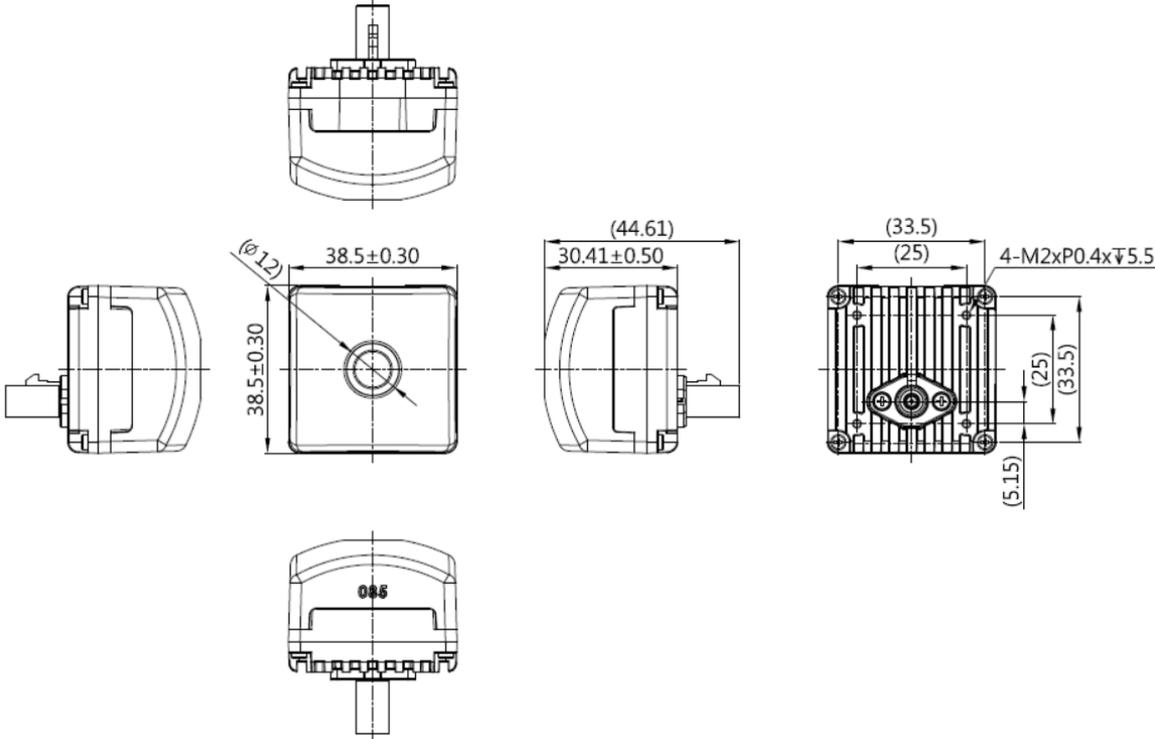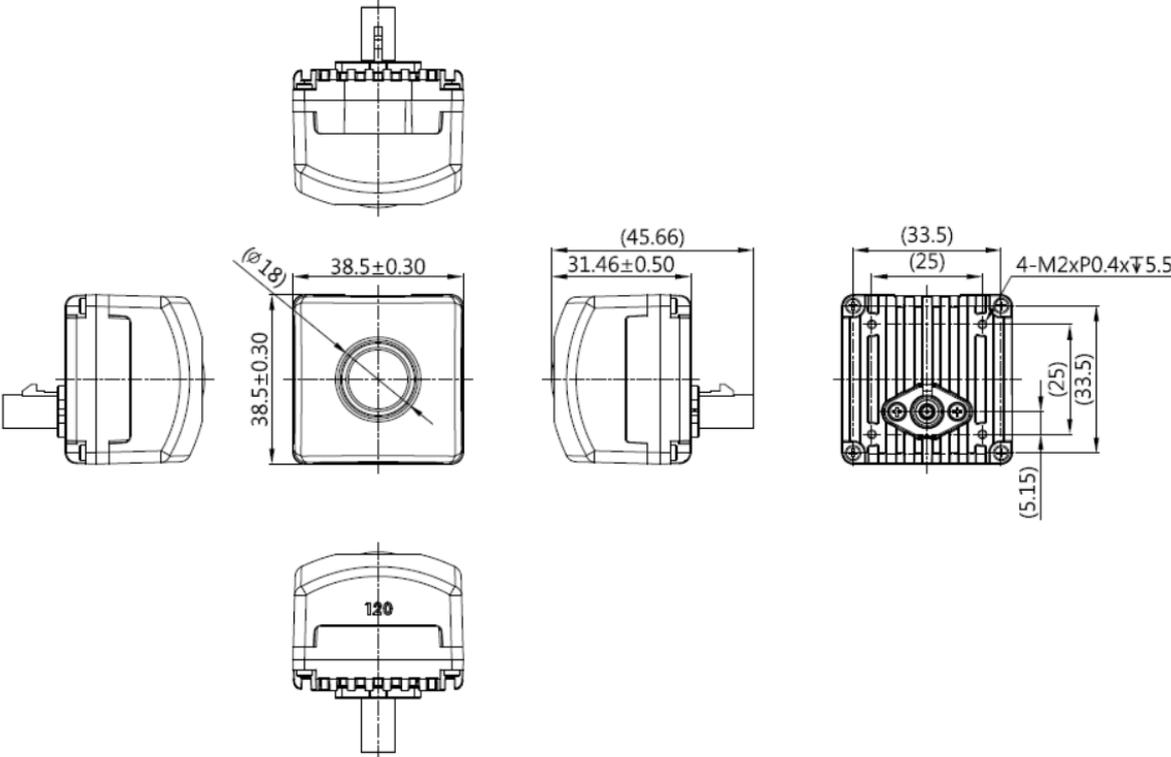Fig. 1.1   C1-046 (46°)

Fig. 1.2   C1-085 (85°)
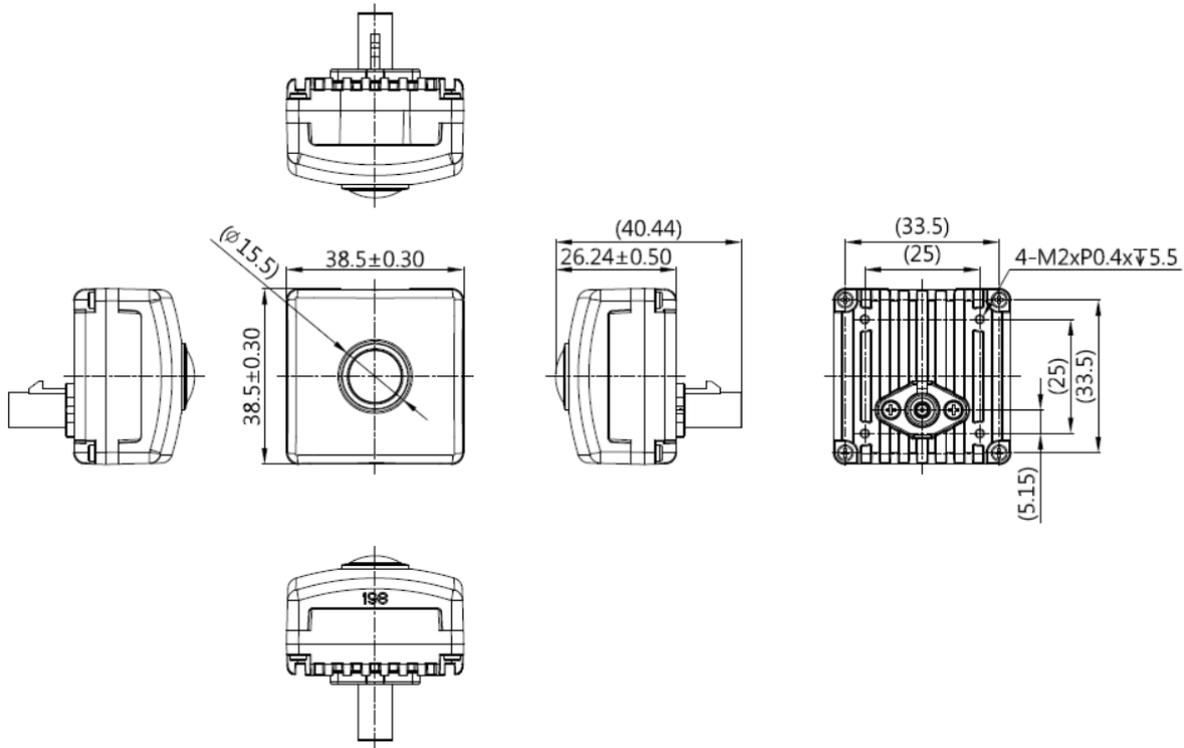

Fig. 1.3   C1-120 (120°)

Fig. 1.4   C1-198 (198°)

1.2.4 3-dimensional CAD data

3-dimensional CAD data can be downloaded. Refer to the download link

1.3 Lens specifications

Model Name	C1-046	C1-085	C1-120	C1-198
Field of View (FoV) Horizontal / Vertical	LDC off 46deg / 32deg on 46deg / 32deg	LDC off 85deg / 56deg on 78deg / 56deg	LDC off 120deg / 77deg on 111deg / 77deg	LDC off 198.6deg / 128.2deg on 162deg / 125deg
F#	2.2	1.7	1.8	2
EFL	6.72mm	3.955mm	2.9mm	1.723mm
TTL	14.9mm	18.59mm	21.01mm	15.79mm
Image Circle	ϕ 7.942mm	ϕ 7.84mm	> ϕ 7.2mm	ϕ 5.9mm Max
IRCF	650±10nm	648±10nm	650±15nm	650±10nm
Resolution (TV Line)	750TVL @ Center, 500TVL @ 70% Image height	750TVL @ Center, 500TVL @ 70% Image height	750TVL @ Center, 500TVL @ 70% Image height	750TVL @ Center, 500TVL @ 70% Image height
Depth of Field	185cm - Infinity Focus peaking distance: 400cm	112cm - Infinity Focus peaking distance: 400cm	106.7cm - Infinity Focus peaking distance: 400cm	33cm - Infinity Focus peaking distance: 100cm

1.3.1 Lens Mount

Glued, active alignment applied.

> **Attention:** The lens cannot be exchanged.

1.4 Electrical specifications

1.4.1 Power supply method

Power over coax cable

1.4.2 Power consumption

1.7W (under room temperature)

1.4.3 Power supply level

9 - 12 [V]

1.5 Key components

1.5.1 Image Sensor

Sony Semiconductor Solutions ISX021

1.5.2 Optical format

Diagonal 6.99mm, type 1/2.57

1.5.3 Pixel size

3.0um

1.5.4 High dynamic range

Available, 120dB equivalent

1.5.5 LED flicker mitigation

Available.

See also:

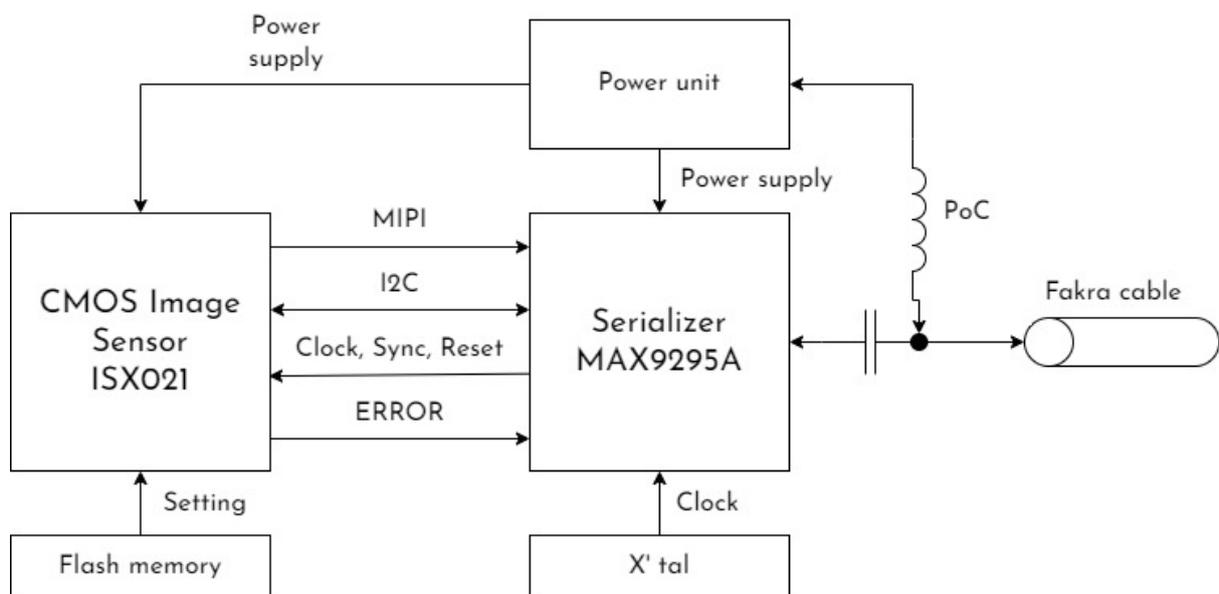What is the LED Flicker Mitigation (LFM)?

1.5.6 Serializer

Analog Devices MAX9295A

1.5.7 ISP

Integrated on the image sensor

1.6 Block diagram

1.7 Camera function

1.7.1 Output interface

GMSL2

1.7.2 Output image format

YUV422 8bit. 16bit/pixel bit depth.

1.7.3 Output image size

1920 x 1280

1.7.4 Framerate

Up to 30fps

1.7.5 Shutter type

Rolling Shutter

Note: Shutter type cannot changed

1.7.6 Drive mode

- Master mode: The camera operates based on its framerate setting.
- Shutter trigger mode: See below for the details.

1.7.7 Synchronization

C1 camera supports trigger-based synchronization. The host (e.g., ECU) sends a synchronization signal (FSYNC) via the GMSL interface to the image sensor. When the image sensor receives an FSYNC signal, the exposure starts. After the exposure time which is controlled by the camera or user, the readout will start. Then, the MIPI packet is transmitted by the camera.
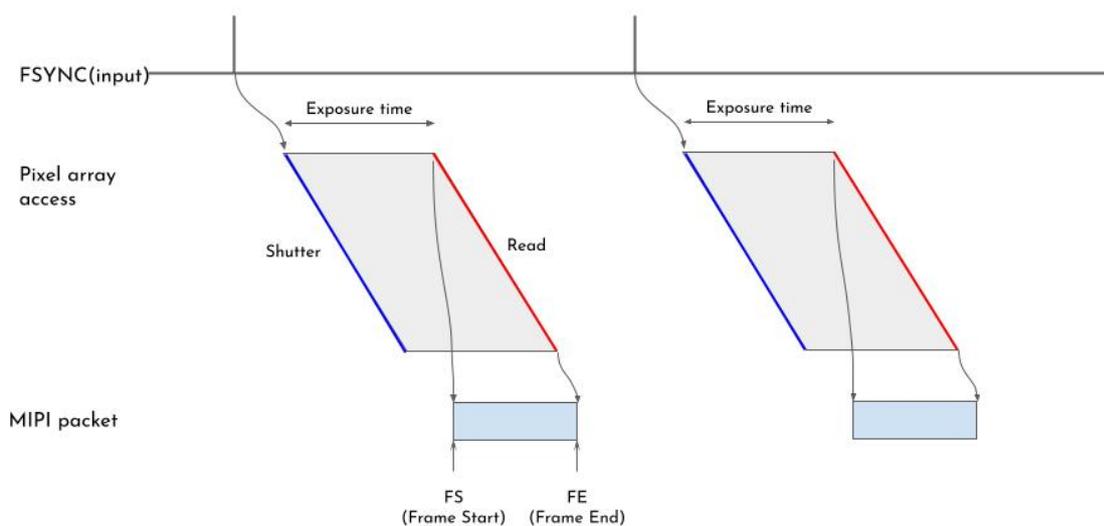
In this mode, an FSYNC input is required to output an image frame. Without FSYNC input, the camera will not output the image data.

The FSYNC pin of the image sensor is connected to the **MFP3** GPIO of the serializer. The user needs to configure the deserializer so the synchronization output pin on the ECU is mapped to this pin.

1.7.8 Embedded data output

Supported.

New in version camera: driver v1.4.1

Supports embedded data for C1

1.8 ISP function

ISP setting can be controlled by using T4cam-ctrl software.

- AE (Auto Exposure)
- AWB (Auto White Balance)
- Basic image-tuning interfaces
    - Hue
    - Saturation
    - Contrast
    - Brightness
    - Sharpness

1.9 Quality/Environmental specifications

1.9.1 Operating temperature range

- -40° ~ 85°

1.9.2 Storage temperature range

- -40°C ~ 105°C

1.9.3 Product reliability

- Please contact our authorized agency for the details.

1.9.4 Compliances

- CE
- RoHS
- FCC
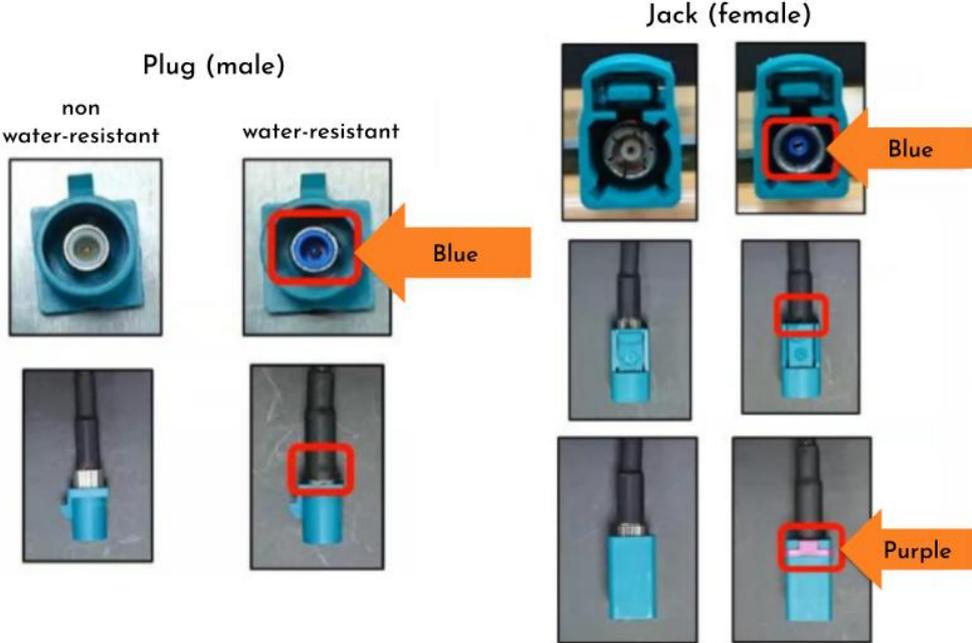- Can ICES-3
- UKCA
- RCM

1.9.5 Safety

LVD compliant

1.9.6 Ingress protection

The camera has IP69K-grade ingress protection.

Note: To realize IP69K, the user needs to use a water-resistant Fakra cable. To distinguish the water-resistant and non-water-resistant cable, please refer below.

2

C2 Camera Technical Reference Manual

2.1 Overview

The C2 camera is a GMSL (Gigabit Multimedia Serial Link) camera specifically designed for automotive applications. It has a resolution of 5.4 MP at 2880 x 1860 px.

Featuring Sony Semiconductor Solutions' IMX490 back-side illumination stacked CMOS image sensor SoC, this camera enables HDR imaging over 120dB, LED flicker mitigation (LFM), and motion artifact-free image capturing at a frame rate of up to 30fps. The C2 camera is suitable for a variety of applications, such as object recognition and signal recognition, thanks to its simultaneous high sensitivity and high resolution.

With a variety of lens options available, the C2 camera can be adapted to many applications. The lens undergoes a 6-axis active adjustment during installation, allowing it to achieve optimal sharpness even in harsh temperature environments.

Indie-semiconductor's GW5300 ISP (Image Signal Processor) built into the C2 camera performs various image processing tasks, including lens distortion correction, to achieve optimal image quality for automotive applications. The C2 camera also supports an external triggering mechanism,

which is essential to achieve capture synchronization with other sensor modalities such as LiDAR or RADAR, enabling sensor fusion.

Designed for automotive mass production, the C2 camera is ready-to-use. All key components comply with AEC-Q100 (Grade 2), Q101, and Q200 standards, and are designed to pass automotive-grade reliability tests.

2.2 Mechanical specifications

2.2.1 Camera size

Model Name	C2-30	C2-062	C2-120	C2-176
Camera size	45mm x 45mm x 48.6mm	45mm x 45mm x 53.55mm	45mm x 45mm x 53.04mm	45mm x 45mm x 45.9mm

2.2.2 Connector

Fakra Z code with metal shielding
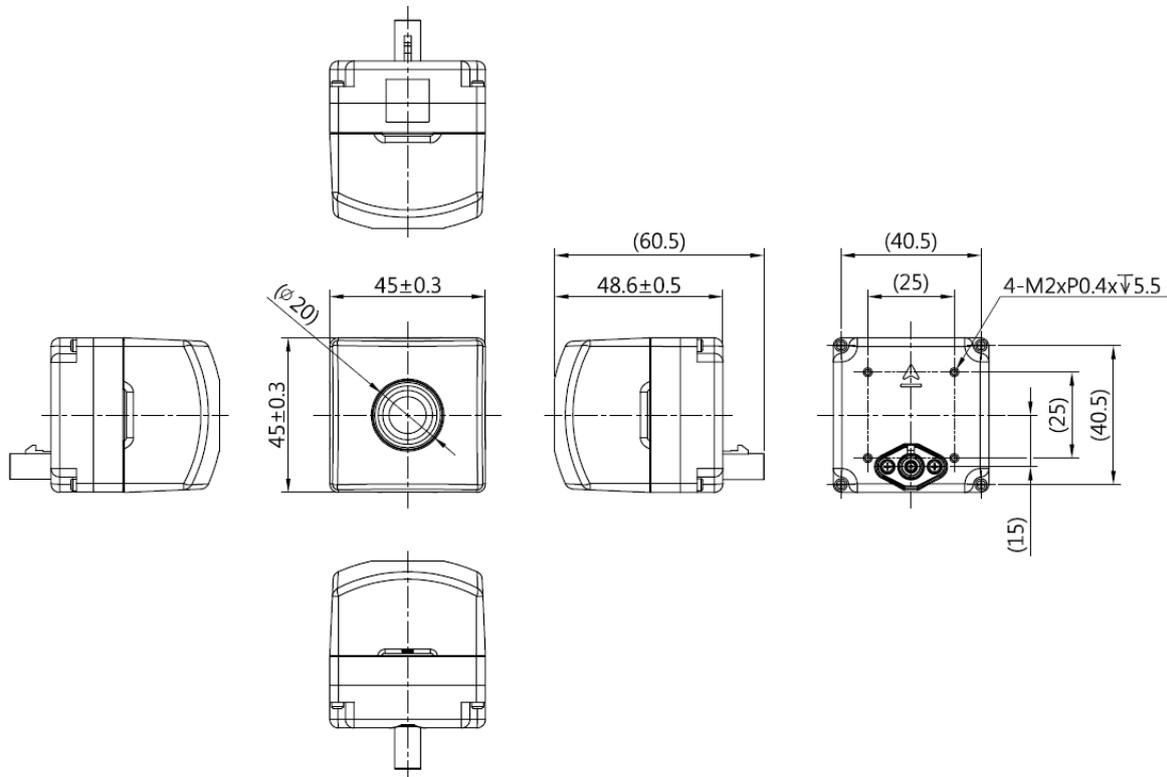
2.2.3 Outline diagram
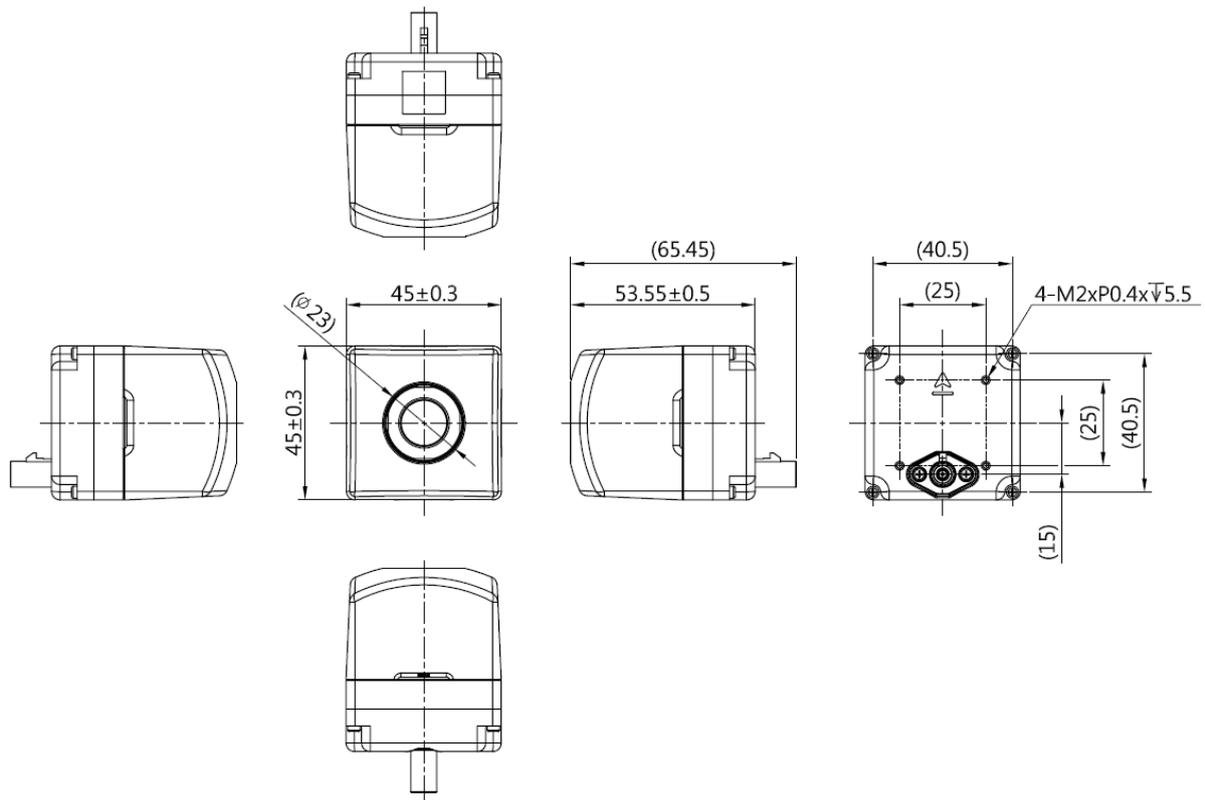

Fig. 2.1   C2-030 (30°)
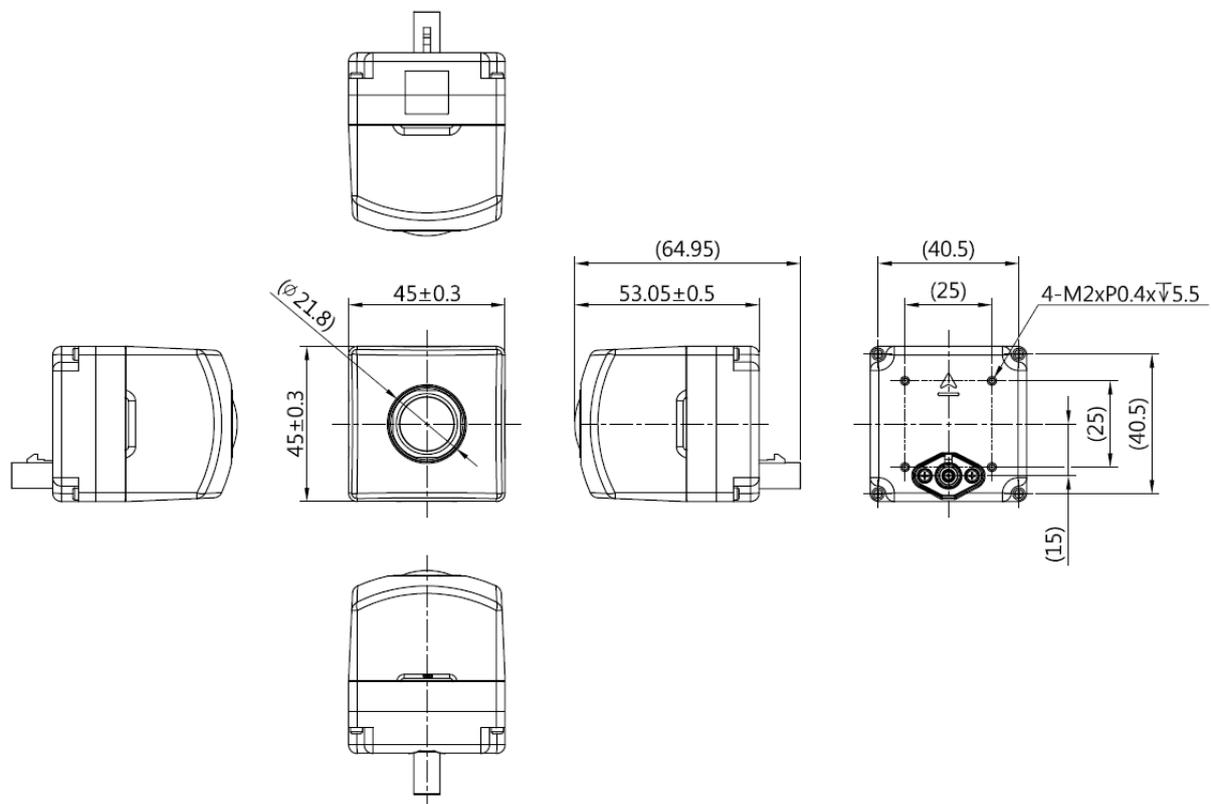
Fig. 2.2　C2-062 (62°)
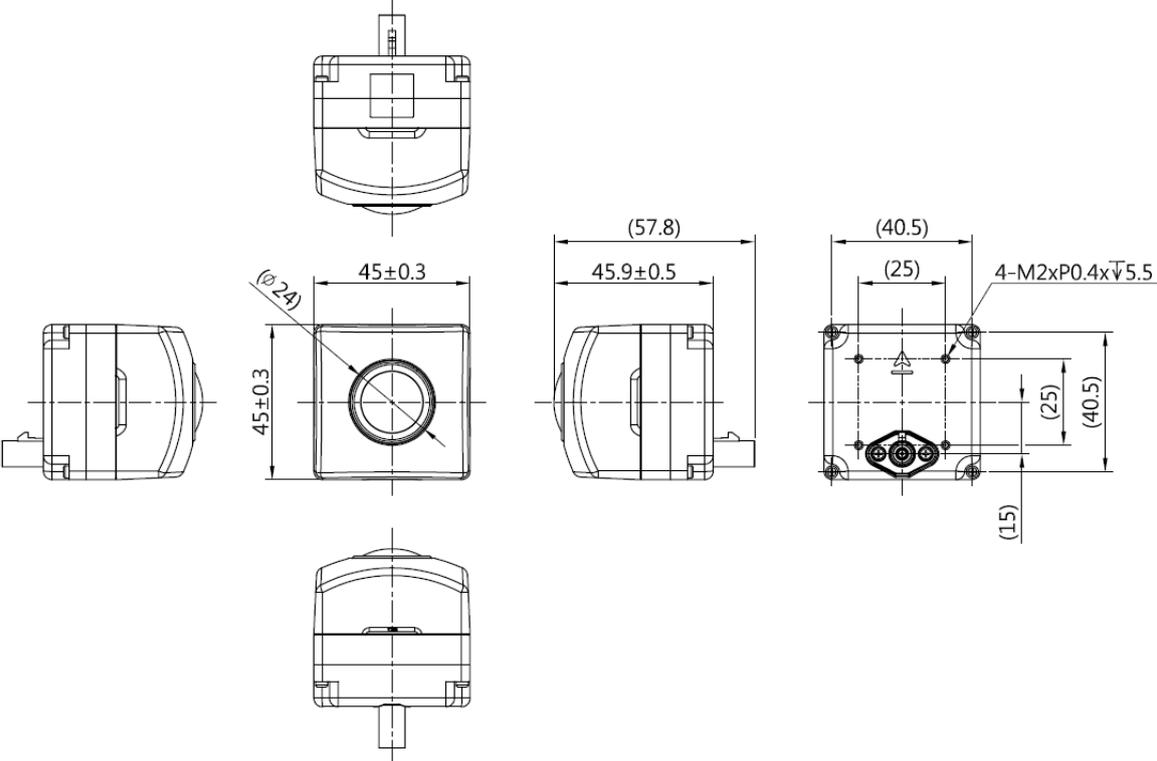

Fig. 2.3　C2-120 (120°)

Fig. 2.4   C2-176 (176°)

2.2.4 3-dimensional CAD data

3-dimensional CAD data can be downloaded. Refer to the download link

2.3 Lens specifications

Model Name		C2-30	C2-062	C2-120	C2-176
	Field of View (FoV) Horizontal / Vertical	LDC off 30deg / 19.5deg (no distortion correction applied)	LDC off 63.5deg / 40deg on 63deg / 40deg	LDC off 120deg / 73deg on 107deg / 73deg	LDC off 176.4deg / 105.8deg on 143deg / 102deg
	F#	1.6	1.7	1.6	1.8
	EFL	16.3mm	7.9mm	4.63mm	3.1mm
	TTL	30.01mm	35mm	35mm	27.86mm
	Image Circle	ϕ 10.5mm	ϕ 10.66mm	ϕ 10.6mm Max	ϕ 9.1mm Max
	IRCF	650nm @ 50% transmission	650nm @ 50% transmission	650nm @ 50% transmission	650nm @ 50% transmission
	Resolution (TV Line)	1000TVL @ Center, 700TVL @ 70% Image height	1000TVL @ Center, 700TVL @ 70% Image height	1000TVL @ Center, 600TVL @ 70% Image height	900TVL @ Center, 500TVL @ 70% Image height
	Depth of Field	14m - Infinity Focus peaking distance: 28m	309cm - Infinity Focus peaking distance: 620cm	250cm - Infinity Focus peaking distance: 400cm	45cm - Infinity Focus peaking distance: 90cm

2.3.1 Lens Mount

Glued, active alignment applied.

> **Attention:** The lens cannot be exchanged.

2.4 Electrical specifications

2.4.1 Power supply method

Power over coax cable

2.4.2 Power consumption

4.6W (at 30fps operation, under room temperature)

2.4.3 Power supply level

9 - 12 [V]

2.5 Key components

2.5.1 Image Sensor

Sony Semiconductor Solutions IMX490

2.5.2 Optical format

diagonal 10.36mm, type 1/1.55''

2.5.3 Pixel size

3.0um

2.5.4 High dynamic range

Available, 120dB equivalent

2.5.5 LED flicker mitigation

Available.
See also:
What is the LED Flicker Mitigation (LFM)?

2.5.6 Serializer

Analog Devices MAX9295A

2.5.7 ISP

Indie semiconductor GW5300
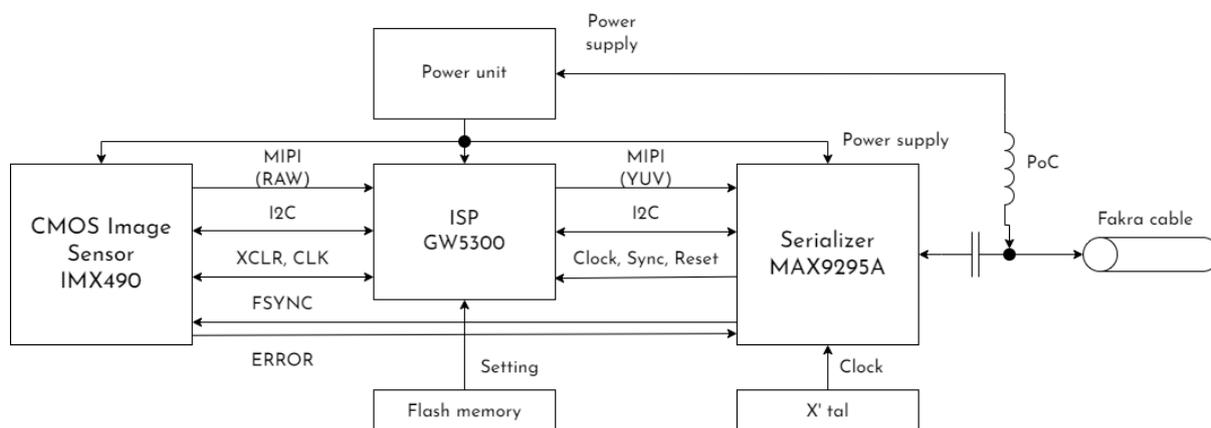
2.6 Block diagram

Fig. 2.5   Block diagram of C2 camera

2.7 Camera function

2.7.1 Output interface

GMSL2

2.7.2 Output image format

YUV422 8bit. 16bit/pixel bit depth.

2.7.3 Output image size

2880 x 1860

2.7.4 Framerate

Up to 30fps

2.7.5 Shutter type

Rolling Shutter

Note: Shutter type cannot changed

2.7.6 Drive mode

- Master mode: The camera operates based on its framerate setting.
- Trigger mode: See below for the details.

2.7.7 Synchronization

Attention: Please note that the trigger specification differs between the C1 and C2 cameras due to the different specifications of their image sensors. When developing a synchronization system using both C1 and C2 cameras, please take this difference into account. Refer to the the specification of C1 camera for the details.

C2 camera supports trigger-based synchronization. The host (e.g., ECU) sends a synchronization signal (FSYNC) via the GMSL interface to the image sensor. When the image sensor receives an FSYNC signal, the **readout** starts.
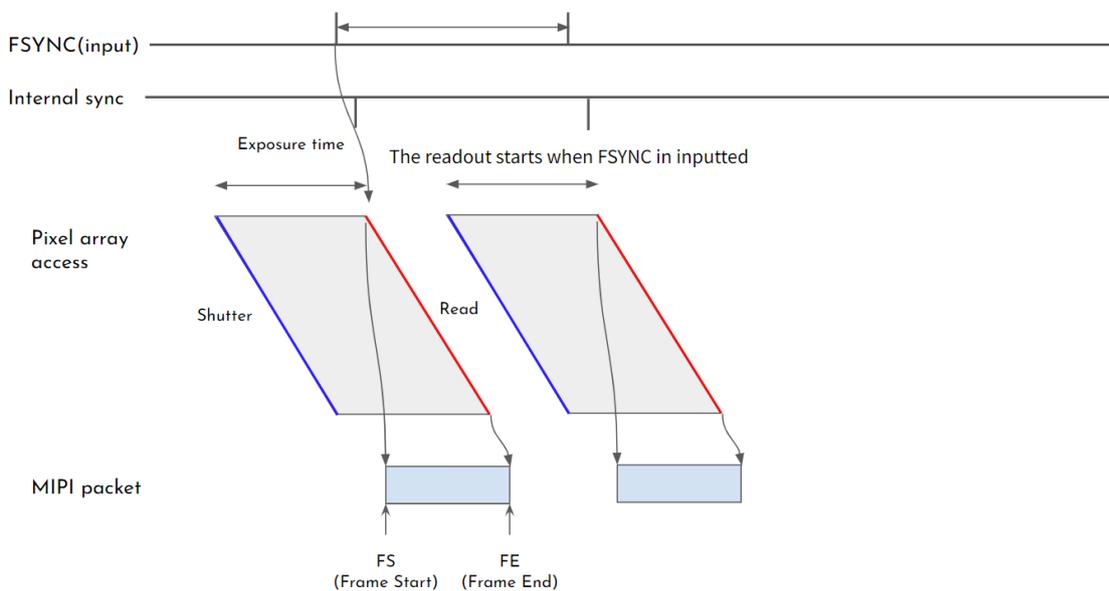

Fig. 2.6   FSYNC adjusts frame output timing

More precisely, the camera will adjust its start timing of readout by measuring the time difference between the internal synchronization timing and FSYNC reception timing. This adjustment occurs 2 frames after the FSYNC reception.

The exposure will start before the exposure time which is controlled by the camera or user.

In trigger mode, in case no FSYNC is inputted to the camera, the camera will output the image data based on its original frame rate setting.

The FSYNC pin of the image sensor is connected to the **MFP3** GPIO of the serializer. The user needs to configure the deserializer so the synchronization output pin on the ECU is mapped to this pin.
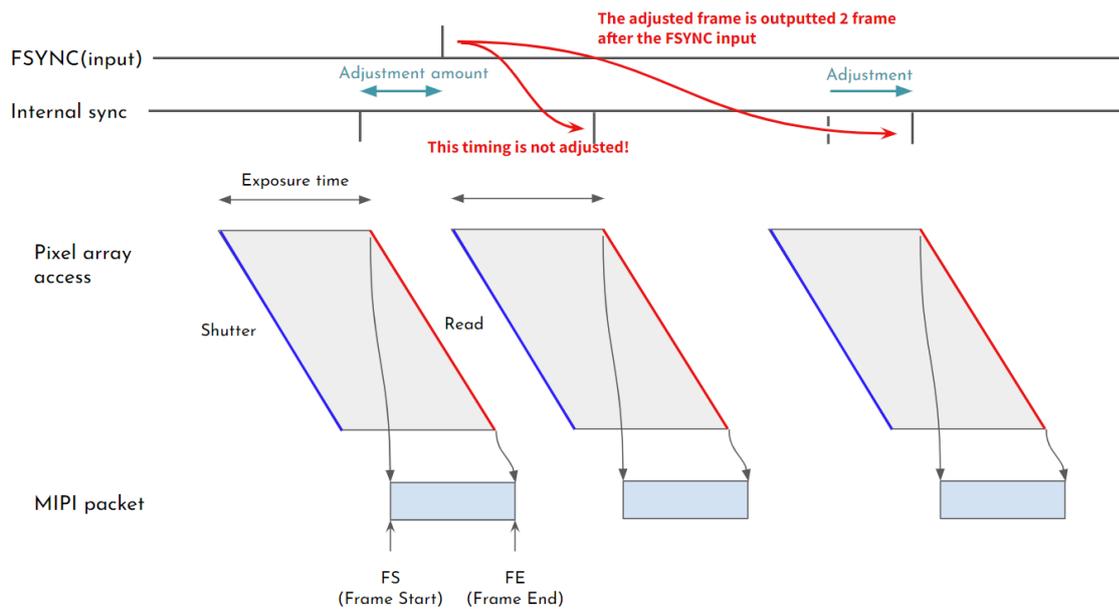
Fig. 2.7   Timing adjustment frame

2.7.8 Embedded data output

Not supported yet. To be supported in future driver/FW version.

2.8 ISP function

ISP setting can be controlled by using T4cam-ctrl software.

- AE (Auto Exposure)
- AWB (Auto White Balance)
- Basic image tuning interfaces
    - Hue
    - Saturation
    - Contrast
    - Brightness
    - Sharpness

2.9 Quality/Environmental specifications

2.9.1 Operating temperature range

- -40° ~ 85°

2.9.2 Storage temperature range

- -40°C ~ 105°C

2.9.3 Product reliability

- Please contact our authorized agency for the details.

2.9.4 Compliances

- CE
- RoHS
- FCC
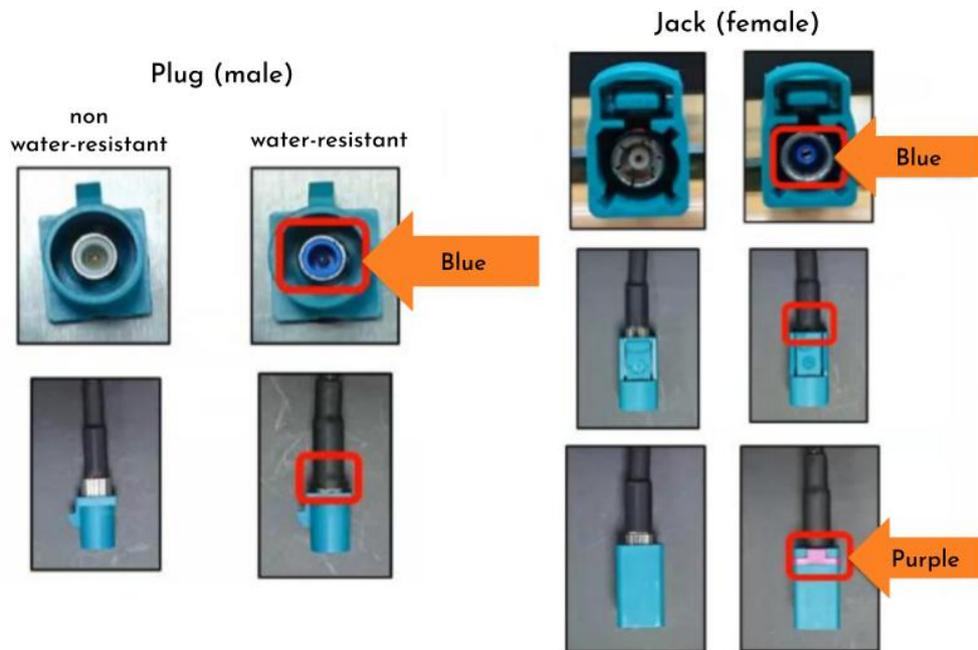- Can ICES-3
- UKCA
- RCM

2.9.5 Safety

LVD compliant

2.9.6 Ingress protection

The camera has IP69K-grade ingress protection.

Note: To realize IP69K, the user needs to use a water-resistant Fakra cable.   To distinguish the water-resistant and non-water-resistant cable, please refer below.

3

GMSL2-10GbE Conversion Module Hardware Reference Manual

3.1 Overview

The GMSL2-10GbE conversion module is an edge compute platform enabling low-latency data transfer from up to eight Gigabit Multimedia Serial Link™ (GMSL) interfaces to a host system via a 10Gb Ethernet link.

The system includes two MAX96724 Quad Tunneling GMSL2/1 to CSI-2 Deserializers, enabling connectivity of up to eight GMSL cameras. The video data from the cameras is fed via the MAX96724 MIPI-CSI2 interfaces to an AMD KV26 System-on-Module which implements the logic to aggregate the video data into a 10Gb Ethernet link to be sent to a central processing unit.

The IEEE1588 Precision Time Protocol (PTP) with hardware timestamping is supported, enabling accurate synchronization with host systems and other edge devices. The AD9545 Dual DPLL/IEEE1588, 1pps Synchronizer and Jitter Cleaner is used to generate the required clocks for the 10Gb Ethernet interface and the PTP logic.

16 general purpose I/O pins are available with software configurable functionality, operating at 3.3V voltage level.

A RS232 dedicated interface can be used to connect UART peripherals such as GNSS devices.
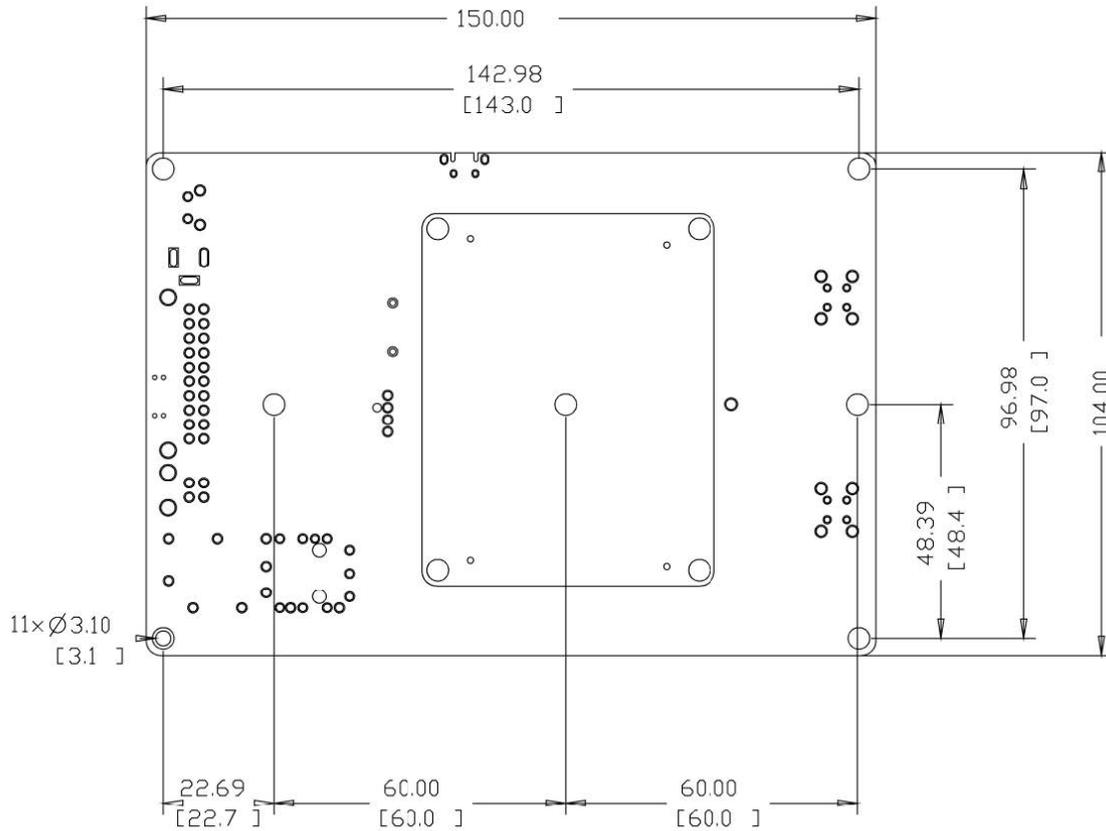
Fig. 3.1   Mechanical drawings

3.2 Mechanical specifications

3.3 Power and thermal

Parameter	Min	Typ	Max	Unit	Comments
Supply voltage	10	12	48	V	Main power connector combined with I/O connector. 1 x Barrel jack power connector, can be used for main power or for the auxiliary power
Power rating	5		24	W	Depends on system processing load
Operating temperature	-40		60	degC	Measured at carrier PCB level. Proper cooling must be implemented to ensure operating temperature range

3.4 Input / Output interface

3.4.1 SFP+ Optical 10Gb Ethernet

- 10Gb Ethernet MAC & PHY in FPGA
- IEEE 1588 with hardware timestamping
- SFP+ cage P/N : 2007194-1
- SFP+ connector P/N : 1888247-1

3.4.2 UART (RS232)

3.3V voltage level with current limit and overvoltage protection.

Functionalities:

- Camera trigger / Flash signal x8
- PPS output x1
- PPS input x1
- PWM output x1
- I2C Connector P/N: 430452023

3.4.3 GMSL

- 2 x HFM quad type mini-Fakra connector
- Conector P/N: 2304168-9

3.4.4 SD Card

- Micro SD card holder, push to eject

3.4.5 USB2.0

- Console interface for Linux OS

3.4.6 JTAG

- Kria SoC PL Debug interface

3.5 Processing

3.5.1 AMD Kria K26 SoM

Industrial grade SoM (P/N: SM-K26-XCL2GI). **Cooling solution not included**

3.6 Firmware & Software

3.6.1 Firmware

- Custom Linux image without desktop UI
- Linux image update over Ethernet
- Linux image stored in the Xilinx Kria SoM eMMC or on SD card

3.6.2 HTML User interface for system configuration and status

- Accessible over configurable IP address and port
- Provides remote control for system configuration and status
    - RTP Control
    - Camera Trigger Settings
    - Streaming Settings
    - PTP Settings
    - Camera Settings

3.6.3 Remote system configuration and status via ssh

- ssh access into the system via the Ethernet interface
- Provides access to all the system's functions via the Linux standard drivers interfaces and tools

3.7 Synchronization

3.7.1 IEEE1588

- Hardware timestamping
- Configurable as slave or master

3.8 Camera control & data format

3.8.1 Camera trigger control

- Each camera independently triggerable internally.
    - Using FSYNC + GPIO of deserializers for independent triggering of all four cameras on one deserializer
- Internal triggering relative to system ToS
    - Each internal trigger configurable for frequency, phase, and duty cycle: 1Hz to 200Hz
- External GPIO configured as output can be controlled in the same way as internal camera triggers
- External GPIO configured as input can trigger the individual cameras directly
- Trigger jitter at sub ms level
- Trigger delay can also be configured (phase setting + delay to compensate for different camera triggering and exposure peculiarities)

3.8.2 Data timestamping

- Video packets packets timestamped with PTP-synchronized system time. Timestamp format options:
    - 32bit NTP
    - 96bit PTP
- Images timestamps generated at trigger (FSYNC), end of frame or start of frame, using FPGA timestamping (PTP -synchronized system time)
- Configurable timestamp offset

3.8.3 Video data format

- UDP data output
- RTP compliant as per RFC3550 & RFC4175