



xIMEU

[ksi-mju: or sai-mju:]

- subminiature USB2.0 camera series



- subminiature USB3.1 Gen 1 camera series

Technical Manual

Version 2.10, June 2021

1. Introduction

1.1. About This Manual

Dear customer,

Thank you for purchasing a product from XIMEA.

We hope that this manual can answer your questions, but should you have any further questions or if you wish to claim a service or warranty case, please contact your local dealer or refer to the XIMEA Support on our website:

www.ximea.com/support

The purpose of this document is to provide a description of the XIMEA xiMU-Series cameras and to describe the correct way to install related software and drivers and run it successfully. Please read this manual thoroughly before operating your new camera for the first time. Please follow all instructions and observe the warnings.

This document is subject to change without notice.

1.2. About XIMEA

XIMEA is one of the worldwide leaders for innovative camera solutions with a 25-year history of research, development and production of digital image acquisition systems. Based in Slovakia, Germany and the US and with a global distributor network, XIMEA offers their cameras worldwide. In close collaboration with customers XIMEA has developed a broad spectrum of technologies and cutting-edge, highly competitive products.

XIMEA's camera centric technology portfolio comprises a broad spectrum of digital technologies, from data interfaces such as USB 2.0, USB 3.1 and PCIe to cooled digital cameras with CCD, CMOS and sCMOS sensors, as well as X-ray cameras.

XIMEA has three divisions – generic machine vision and integrated vision systems, scientific imaging and OEM/custom.

XIMEA cameras find use in many industrial applications, such as motion control, robotics, or quality control in manufacturing. The broad spectrum of cameras also includes thermally stabilized X-ray cameras, and specialty cameras for medical applications, research, surveillance and defense.

1.2.1. Contact XIMEA

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Sales	sales@ximea.com
Support	https://www.ximea.com/support/wiki/allprod/Contact_Support

1.3. Standard Conformity

The xiMU cameras MU9Px-MH have been tested using the following equipment:

- MU-MINIUSB-Adapter
- A shielded USB 2.0 cable (1.5m)

The xiMU cameras MU181CR-ON have been tested using the following equipment:

- ADPT-MU-TC-V
- A shielded USB 3.0 cable (3.0m)

Warning: Changes or modifications to this unit not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.

XIMEA recommends to use the same configuration to ensure the compliance with the following standards:

1.3.1. CE Conformity



The xiMU MU9Px-MH and MU181CR-ON cameras described in this manual comply with the requirements of the

- EC EMC Directive 2014/30/EU electromagnetic compatibility of equipment

1.3.2. For customers in the US: FCC Conformity



The xiMU MU9Px-MH and MU181CR-ON cameras described in this manual have been tested and found to comply with Part 15 of the FCC rules, which states that:

Operation is subject to the following two conditions:

- This device may not cause harmful interference, and
- This device must accept any interference received, including interference that may cause undesired operation.

This equipment has been tested and found to comply with the limits for Class A digital device, pursuant to part 15 of the FCC rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the users will be required to correct the interference at their own expense.

You are cautioned that any changes or modifications not expressly approved in this manual could void your authority to operate this equipment under above jurisdictions. The shielded interface cable recommended in this manual must be used with this equipment in order to comply with the limits for a computing device pursuant to Subpart J of Part 15 of FCC Rules.

1.3.3. For customers in Canada

The xiMU MU9Px-MH and MU181CR-ON cameras comply with the Class A limits for radio noise emissions set out in Radio Interference Regulations.

1.3.4. RoHS Conformity



The xiMU cameras comply with the requirements of the RoHS (Restriction of Hazardous Substances) Directive 2011/65/EU.

1.3.5. WEEE Conformity



The xiMU cameras comply with the requirements of the WEEE (waste electrical and electronic equipment) Directive 2012/19/EU.

1.3.6. GenlCam GenTL API

GEN<i>CAM

GenlCam standard transport layer interface, grabbing images. **GenlCam/GenTL** provides an agnostic transport layer interface to acquire images or other data and to communicate with a device. Each XIMEA camera can be GenTL Producer.

1.4. Helpful Links

- XIMEAHomepage <http://www.ximea.com/>
- xiAPI stable versions download <https://www.ximea.com/support/documents/4>
- xiAPI beta versions download <https://www.ximea.com/support/documents/14>
- Frequently Asked Questions http://www.ximea.com/support/wiki/allprod/Frequently_Asked_Questions
- Knowledge Base http://www.ximea.com/support/wiki/allprod/Knowledge_Base
- Vision Libraries <http://www.ximea.com/support/projects/vision-libraries/wiki>
- XIMEA Registration <http://www.ximea.com/en/products/register>
- XIMEA Live Support http://www.ximea.com/support/wiki/allprod/XIMEA_Live_Support
- XIMEA General Terms & Conditions <http://www.ximea.com/en/corporate/generaltc>

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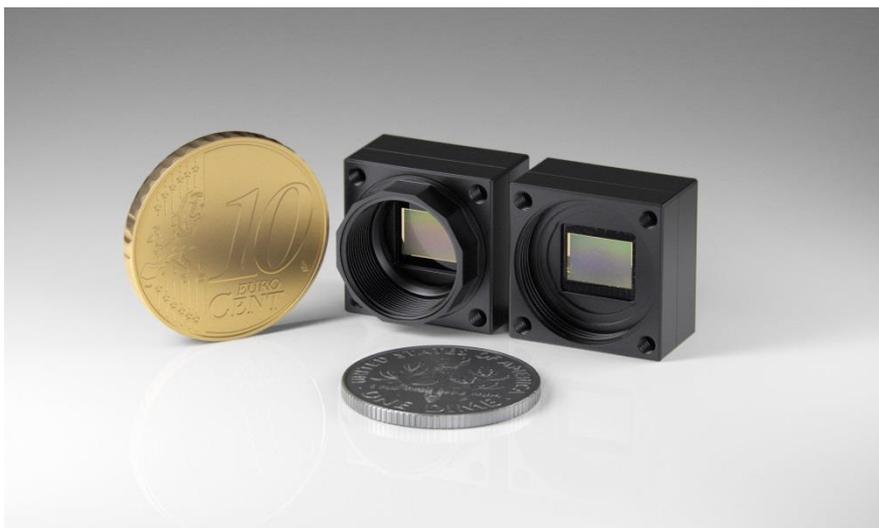
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2. xiMU USB2.0 and USB3.1 Gen 1 Camera Series



2.1. What is xiMU

xiMU [ksi-mju: or sai-mju:] is a subminiature USB Industrial camera family with outstanding features:

- Incredibly small: World smallest USB 2.0 and USB3.1 Gen 1 cameras with GenICam/GenTL support.
- Low power consumption
- triggerable, fully industrial grade
- sensors: OnSemi 5MPixel MT9P031 and ONSEMI 18MPixel AR1820HS.
- frame rates: up to 4.6 frames/sec for USB2.0 version and 21.9 frames/sec for USB3.1 Gen 1 version. Multiple binning and skipping modes with higher frame rates.

2.2. Advantages

smallest	fits into places where no other camera can fit
Robust	full metal housing, no sheet metal covers
Lightweight	facilitates increased performance of robotic arms and handheld devices
Connectivity	Programmable input and output
Compatibility	support for Windows, Linux and MacOS, various Image Processing Libraries
Software interfaces	GenCam / GenTL and highly optimized xiAPI SDK
Economical	excellent value and price, low TCO and fast ROI
Images	Excellent image quality and low light sensitivity

table 2-1, advantages

2.3. Camera Applications

- 3D dental applications
- Miniature and fast robotic arms
- Mobile devices
- In-situ and endoscopic inspection camera
- Ophthalmology and Retinal imaging

2.4. Common features

Sensor Technology	CMOS, rolling shutter with Global Reset Release
Acquisition Modes	Continuous, software trigger, hardware trigger
Partial Image Readout	ROI, Skipping and Binning modes supported
Image data formats	8, 10 or 12 bit RAW pixel data
Color image processing	Host based de-Bayering, sharpening, Gamma, color matrix, true color CMS
Hot/blemish pixels correction	On camera storage of 5000+ pixel coordinates, host assisted correction
Auto adjustments	Auto white balance, auto gain, auto exposure
Flat field corrections	Host assisted pixel level shading and lens corrections
Image Data and Control Interface	USB2.0 model: Micro connector with USB 2.0 High-speed and digital I/O USB3.1 Gen 1 model: Various connectors with USB 3.0 Super-speed and digital I/O
General Purpose I/O	4x IO configurable as input or output
Synchronization	Hardware trigger input, software trigger, exposure active, frame active, trigger ready, exposure active pulse, busy
Housing and lens mount	Standard S-mount (M12). Two lens mount adapters available
Power requirements	USB2.0 model: Typ. 0.76 W, supplied via USB 2.0 interface USB3.1 Gen 1 model: Typ. 1.4W, supplied via USB 3.0 interface
Environment	Operating 0°C to 50°C on housing, RH 80% non-condensing, -30°C to 70°C storage Ingress Protection: IP40
Operating systems	Windows 10 (x86 and x64), Windows 7 SP1 (x86 and x64), Linux Ubuntu, MacOS 10.8 and newer
Software support	xiAPI SDK, adapters and drivers for various image processing packages
USB standard compatible	USB 2.0, Universal Serial Bus Specification Revision 2.0, April 27, 2000 USB 3.0, Universal Serial Bus 3.1 Specification Revision 1.0, July, 2013

table 2-2, common features

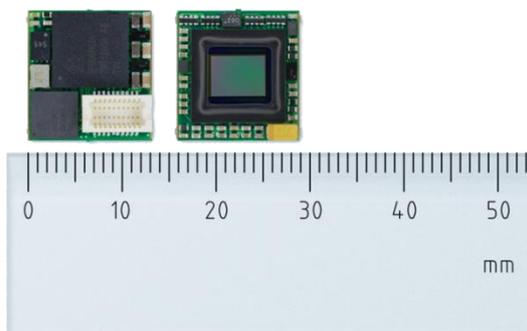
2.5. Models Overview

2.5.1. USB2.0 models

Model		Resolution	Pixel size	ADC [bit]	DR	Optical size	Sensor diagonal	FPS
MU9PM-MH	b/w	2592 x 1944	2.2 μ m	12	59 dB	1 / 2.5"	7.1 mm	4.46
MU9PC-MH	Color							

table 2-3, USB2.0 model overview

USB2.0 models available in board level version as well



Order numbers name conventions for the different models:

Camera with housing:

MU9Px-MH

- x: x=C: color model
- x=M: black & white model

Board level camera:

MU9Px-MBRD

- x: x=C: color model
- x=M: black & white model

2.5.2. USB3.1 Gen 1 models

Model		Resolution	Pixel size	ADC [bit]	DR	Optical size	Sensor diagonal	FPS
MU181CR-ON	Color	4912 \times 3680	1.25 μ m	12	57.6 dB	1 / 2.3"	7.6 mm	21.9

table 2-4, USB3.1 Gen 1 model overview

Order numbers name conventions for the different models:

Camera with housing:

- MU181CR-ON (for OEM projects)
- MU181CR-ON-TC with mounted Type-C adapter
- MU181CR-ON-FL with mounted -FL adapter

2.6. Accessories

The following accessories are available for the USB2.0 models:

Item P/N	Description
MU-MINIUSB	Mini-USB Extension Board for MU9Px-MH
ADPT-MU9P-USB2-UB-V	Expansion board with micro-B USB 2.0 connector and IO connector for MU9px-MH
CBL-MQSYNC-3M0	3.0m xiQ series I/O sync cable can be used with ADPT-MU9P-USB2-UB-V
ME-ADPT-MU-T-KIT	xiMU series tripod mounting bracket with Screws Kit

table 2-5, MU9 accessories

The following accessories are available for the USB3.1 Gen 1 models:

Item P/N	Description
ADPT-MU-TC-V	Type-C adapter with IO for xiMU USB3.1 Gen 1 cameras
ADPT-MU-FL	Flat-flex cable adapter for xiMU USB3.1 Gen 1 connecting from the bottom of the camera
ADPT-MU-FV	Flat-flex cable adapter for xiMU USB3.1 Gen 1 connecting perpendicular to sensor
CBL-MQSYNC-3M0	3.0m xiQ series I/O sync cable can be used with ADPT-MU-TC-V
CBL-MQ-FL-0M1	Cable FPC MQ/MC Flex-Line, 0.1m (gold color)
CBL-MQ-FL-0M25	Cable FPC MQ/MC Flex-Line, 0.25m (gold color)
CBL-USB3FLEX-0M10	Cable FPC MQ/MC Flex-Line, 0.1m (white color)
CBL-USB3FLEX-0M25	Cable FPC MQ/MC Flex-Line, 0.25m (white color)
CBL-USB3FLEX-0M50	Cable FPC MQ/MC Flex-Line, 0.5m (white color)
BOB-MQ-FL	Break Out Board, Flex-Line, Simple Board Level Micro-B USB3.0
ME-ADPT-MU-T-KIT	xiMU series tripod mounting bracket with Screws Kit

table 2-6, MU181 accessories

3. xiMU Hardware Specification

3.1. General Specification

3.1.1. Environment

Description	Symbol	Value
Optimum ambient temperature operation	T_{opt}	+10 to +25°C
Housing temperature operation	T_{max}	0 - +50°C
Ambient temperature for storage and transportation	$T_{storage}$	-30 - +70°C
Relative Humidity, non-condensing	RH	80 %

table 3-1, environment

Housing temperature must not exceed +65°C. The following parameters are not guaranteed if the camera is operated outside the optimum range:

- Dark current
- Dynamic Range
- Linearity
- Acquisition
- Readout noise
- S/N ratio
- Durability

Please refer to chapter [3.1.2 Heat dissipation](#)

3.1.2. Heat dissipation

XIMEA strives to offer the smallest cameras with the highest performance. Although the cameras are first in terms of power efficiency, the high packing density of components can lead to elevated temperatures, and an adequate dissipation of this heat must be ensured. The cameras rely on adequate surface contact with a thermal mass (tripod, lens, heat sink) of sufficient size for heat dissipation and this must be provided ensured by the user.

3.1.3. Firmware / Host driver / API features

Description	Value
Interpolation methods	9331, SHT advanced
White balance coefficients ranges	0.0 to 3.9
Sharpness filter	0 to 100 %
Gamma	0.3 to 1.0
Full color correction matrix (3+1)x3 coefficients ranges	-3.9 to 3.9

table 3-2, firmware / API features

More details on API/SDK features are available at [XIMEA support pages: https://www.ximea.com/support/wiki/apis/APIs](https://www.ximea.com/support/wiki/apis/APIs)

3.1.4. Power Supply

The xiMU cameras are powered via the USB connector.

The input voltage is 5 V DC ($\pm 10\%$). The typical power consumption is 0.76W for the USB2.0 version and 1.4W for the USB3.1 Gen 1 version.

3.1.5. Optical path

No additional filter glass.

3.2. xiMU USB2.0 specification

3.2.1. Sensor and camera parameters

xiMU model	MU9PC-MH	MU9PM-MH
Sensor parameter		
Brand	Aptina, MT9P031112STC	Aptina MT9P031112STM
Color filter	RGB Bayer mosaic	None
Type	Rolling shutter, Global Reset Release	
Pixel Resolution (H × V) [pixel]	2592 × 1944	
Active area size (H × V) [mm]	5.7 × 4.3	
Sensor diagonal [mm]	7.1	
Optical format [inch]	1 / 2.5 (4:3)	
Pixel Size (H × V) [µm]	2.2 x 2.2	
ADC resolution [bit]	12	
FWC [ke-]	4.9	
Dynamic range [dB]	59	
SNR Max [dB]	37	
Conversion gain [e-/LSB ₁₂]	0.82	
Dark noise [e-]	5	
DSNU [e-]	0.92	
PRNU [%]	2	
Linearity [%]	<0.2	
Camera parameters		
Digitization [bit]	12	
Supported bit resolutions [pit/pixel]	8, 10, 12	
Exposure time (EXP) ²	20µs ... 10sec	
Variable Gain Range (VGA) [dB]	18	
Refresh rate (MRR) ¹ [fps]	4.6	
Power consumption		
typical [W]	0.76	
Maximum [W]	0.9	
Idle [W]	0.3	
Dimensions/Mass MU9Px-MH (with housing)		
Height × width × depth [mm]	15 × 15 × 8.5	
mass [g]	3.4 (without lens mount adapter) / 4.0 (with MECH-MU9-MH-ADAPT-M) / 4.2 (with MECH-MU9-MH-ADAPT-L)	
Dimensions/Mass MU9Px-MBRD (board)		
Height × width × depth [mm]	14 × 13.2 × 3.7 (measured w/o connector) 14 × 13.2 × 5.5 (measured with connector)	
mass [g]	1.2	

table 3-3, MU9 sensor and camera parameters

Notes:

- 1) The figure indicates the maximum achievable frame rate for full frame readout. The real performance will be affected by USB controller, number and type of USB devices attached to this controller, system processor and memory speed and configuration.

- 2) Minimal exposure depends on readout mode and bandwidth limitation. For full resolution minimal exposure is 110 μ s

Binning/skipping	pixels	fps	Bit/px
1x1	2592 x 1944	4.6	12
2x2 bin	1296 x 972	14.3	12
4x4 bin	648 x 486	31.6	12
2x2 skip	1296 x 972	18.3	12
4x4 skip	648 x 486	71.9	12
6x6 skip	430 x 324	142	12
7x7 skip	368 x 376	172	12
7x7 skip/clip	320 x 240	200	12

table 3-4, MU9 readout modes (with compatible USB packet size – see 4.7.2 Packet Size Setting)

3.2.2. Quantum efficiency curves [%]

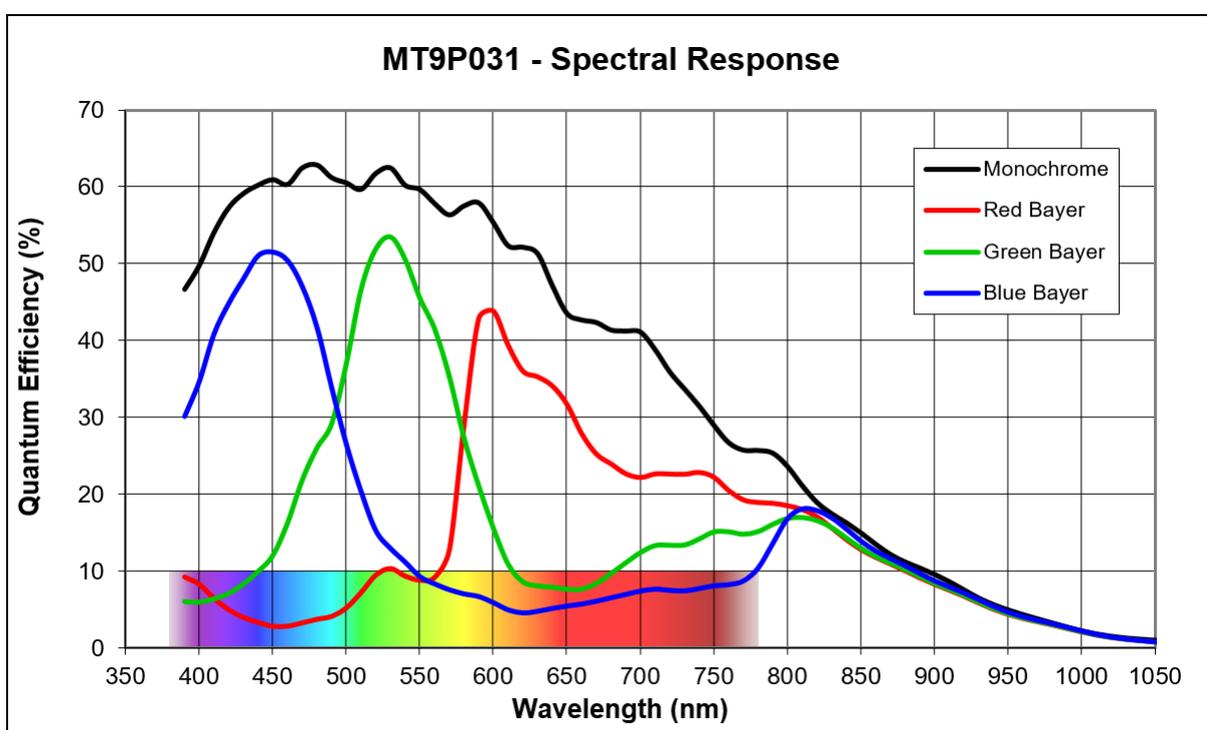


figure 3-1, MT9P031 mono and color, quantum efficiency curve, ©Aptina

3.2.3. Dimensional drawings (without Lens Mount Adapter)

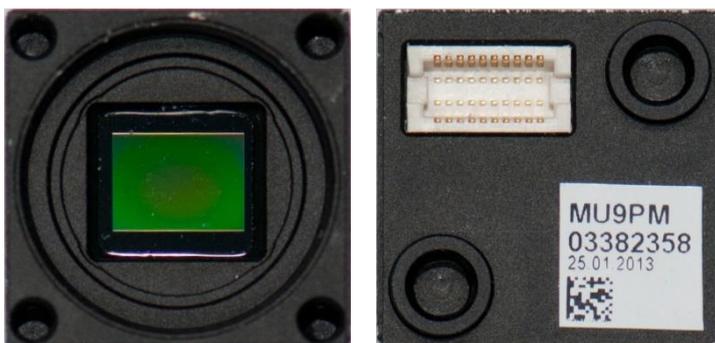


figure 3-2, MU9Px-MH, image front and rear side

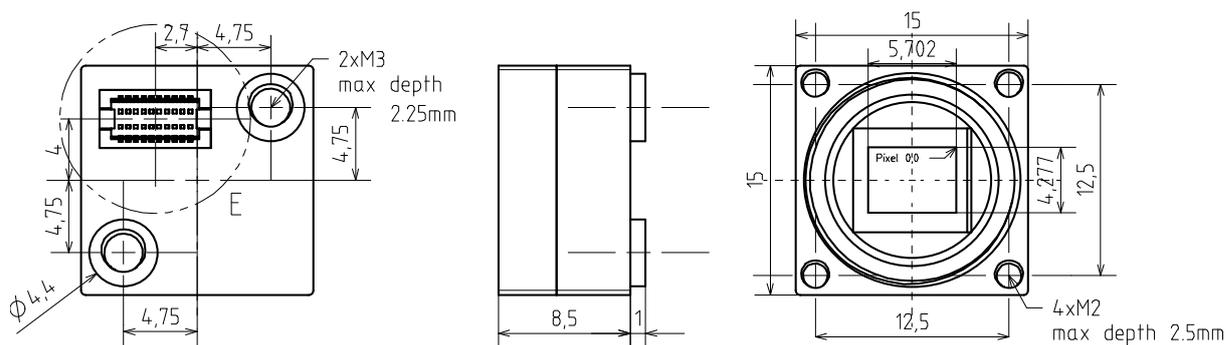


figure 3-3, MU9Px-MH, dimensional drawing

3.2.4. Referenced documents

- Aptina Datasheet MT9P031_DS - Rev. F 5/11 EN
- Aptina Outgoing Defect Specification, MT9P031_ODS.fm - Rev. A 9/07 EN

3.2.5. Camera features

feature	Note
Binning	Yes: 2x2 and 4x4
Skipping	Yes: 2x2, 4x4, 6x6, 7x7 and 7x7 skip/clip
ROI	Yes, 4-pixel granularity
HW Trigger	Trigger without overlap usable (see 4.3.2.3 Triggered mode)
Image formats	RAW, (RGB24, RGB32 – only color models)

table 3-5, MU9 sensor features

3.2.6. MU9 Lens Mount Adapters

There are two lens mount adapters available (S-Mount, M12 x 0.5 thread).

3.2.6.1. MECH-MU9-MH-ADAPT-M, dimensional drawing



figure 3-4, lens mount adapter MECH-MU9-MH-ADAPT-M, image

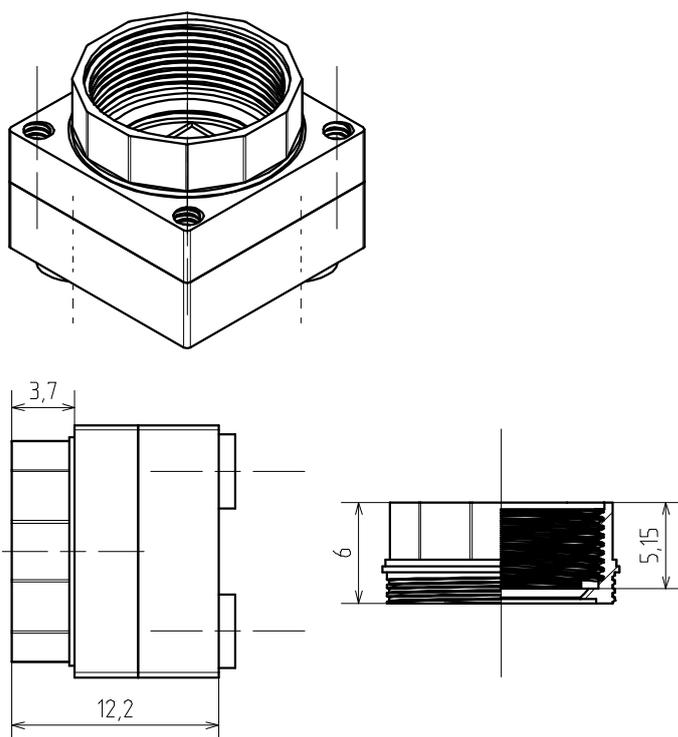


figure 3-5, lens mount adapter MECH-MU9-MH-ADAPT-M, drawing

Geometric Back-focal Distance (measured from the top of the flange to the top of the sensor die): 7.39 mm.

3.2.6.2. MECH-MU9-MH-ADAPT-L, dimensional drawing



figure 3-6, lens mount adapter MECH-MU9-MH-ADAPT-L image

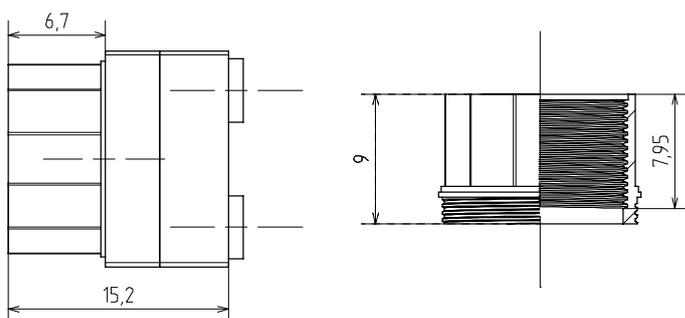
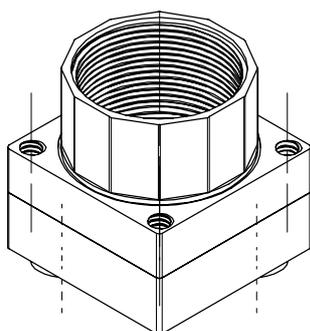


figure 3-7, lens mount adapter MECH-MU9-MH-ADAPT-L, drawing

Geometric Backfocal Distance (measured from the top of the flange to the top of the sensor die): 10.39 mm.

3.2.7. MU9 Camera connector (USB / IO Interface)



figure 3-8 MU9 camera connector

The connector mounted on the camera PCB is a

- HRS DF12E(3.5)-20DP

3.2.7.1. Location and Pinout

The camera connector is located on the back side of the camera:

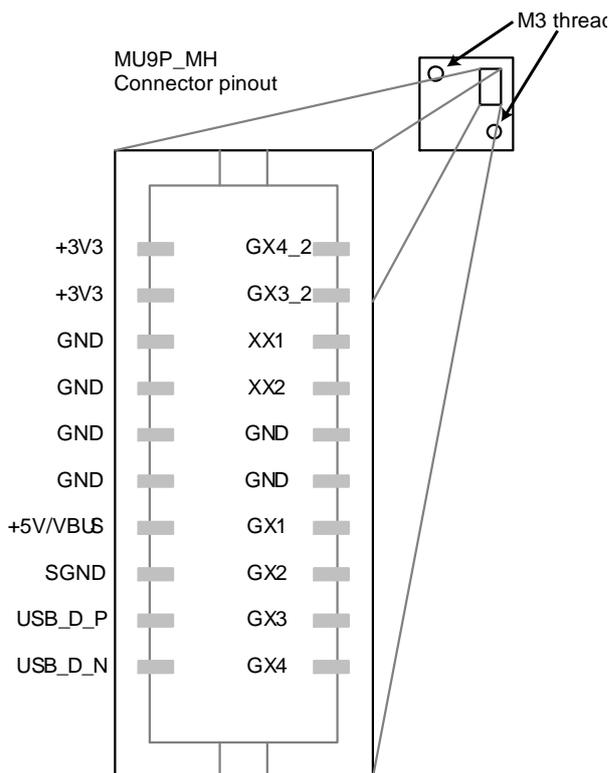


figure 3-9, MU9 camera connector, location and pin-out

3.2.7.2. Signal description

MU9 camera connector pin assignment and signal description:

Pin	Signal	Description	Electrical type	Function
1	GX4	Programmable IO	IO	defined by user, default setting: OFF
2	USB_D_N	USB data -	IO	USB data wire
3	GX3	Programmable IO	IO	defined by user, default setting: OFF
4	USB_D_P	USB data +	IO	USB data wire
5	GX2	Programmable IO	IO	defined by user, default setting: exposure active (XI_GPO_EXPOSURE_ACTIVE)
6	SHLD	Camera Shield	Power	Chassis ground - Connected to GND via 1M/10nF
7	GX1	Programmable IO	IO	defined by user, default setting: trigger input (XI_GPI_TRIGGER)
8	+5V	USB bus Power	Power	Camera Power supply
9	GND	Ground	Power	Signal Ground
10	GND	Ground	Power	Signal Ground
11	GND	Ground	Power	Signal Ground
12	GND	Ground	Power	Signal Ground
13	XX2	Do not use	IO	defined by firmware, do not connect
14	GND	Ground	Power	Signal Ground
15	XX1	Do not use	IO	defined by firmware, do not connect
16	GND	Ground	Power	Signal Ground
17	GX3_2	Programmable IO	IO	Shared functionality with GX3, only one could be connected
18	+3V3	Internal power rail +3V	Power	No external connection allowed, used for testing purposes only
19	GX4_2	Programmable IO	IO	Shared functionality with GX4, only one could be connected.
20	+3V3	Internal power rail +3V	Power	No external connection allowed, used for testing purposes only

table 3-6, MU9 camera connector, signal description

Notes:

- None of the pins is galvanically isolated
- The IO pins are connected to the FPGA via 1K serial resistor
- GX1 and GX2 are ESD protected

3.2.7.2.1. Ground

This signal connected to the internal signal ground

3.2.7.2.2. +3V

Connected internally to the camera +3V power supply. Used only for testing purposes. This pin must be left open and no load can be connected to it.

3.2.7.2.3. GX1, GX2, GX3, GX4, GX3_2, GX4_2 – Programmable IO

These pins are connected to the FPGA pins via serial resistors of 1K Ω . GX1 and GX2 are ESD protected. GX3 and GX4 are NOT ESD protected.

Functionality of these pins is defined by firmware. Generic camera firmware puts pins into high impedance state.

All output functions have inverted polarity.

3.2.7.3. GXn DC electrical characteristics

Parameter	Symbol	Min	Nom	Max
Input voltage that indicates a Low logic level [V]	V _{IL}	-	-	0.8
Input voltage that indicates a High logic level [V]	V _{IH}	2.0	-	-
Input leakage current [μA]	I _L	-10	-	+700
Input voltage extremes to avoid turning on I/O protection diodes [V]	V _{IN}	-0.5	-	3.8
Output voltage that indicates a Low logic level [V]	V _{OL}			0.4
Output voltage that indicates a High logic level [V]	V _{OH}	2.9		
Output current condition under which V _{OL} is tested [mA]	I _{OL}		0.4	
Output current condition under which V _{OH} is tested [mA]	I _{OH}		-1.0	

table 3-7, MU9 IO ports GXn, electrical characteristics

3.2.8. MU9 Patch cable

MU USB 2.0 Patch Cable 1.0m

The camera side connector of the cable is DF12C-20DS which is mounted on a special jumper board, from which a split flat-ribbon cable is wired to a standard USB Series “A” connector (J2) and a trigger connector (J3) Molex PN: 0510210600 Female Housing.

Recommended mating part for trigger connection are Molex PNs: 0532610671 or 0510470600 or 0530470610 or 0533980671.



figure 3-10, MU9 Patch cable

3.2.8.1. Signal Description (USB 2.0 connector)

Pin	Signal	Description
1	+5V	USB bus Power
2	USB-	USB data -
3	USB+	USB data +
4	GND	Ground

table 3-8, patch cable USB 2.0 connector, signal description

3.2.8.2. Signal Description (IO connector)

Pin	Signal	Description
1	GX2	Programmable IO
2	GX1	Programmable IO
3	GND	Ground
4	GX3_2	Programmable IO parallel function with GX3
5	GX4_2	Programmable IO parallel function with GX4

table 3-9, patch cable IO connector, signal description

For details please see [3.2.7.2 Signal description](#)

3.2.8.3. Connection of patch cable

Note: The cable must always be inserted in the orientation shown below!!

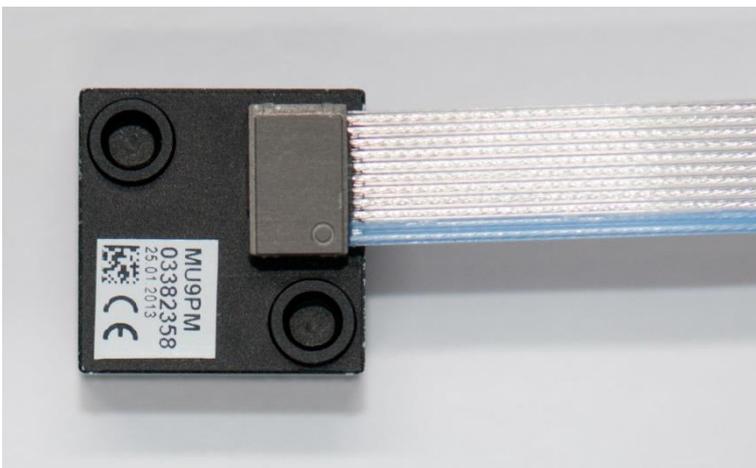


figure 3-11, connection of patch cable

3.2.9. MU-MINIUSB

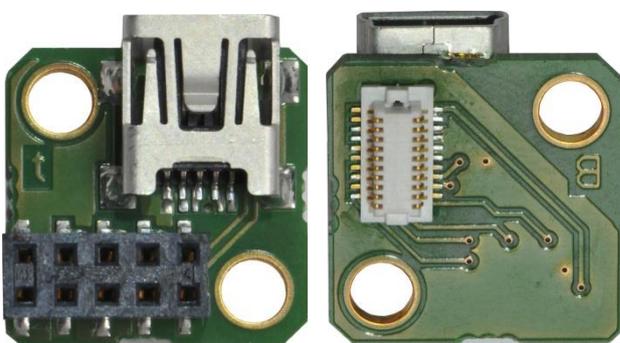


figure 3-12, MU-MINIUSB, image connector and camera side

The Mini-USB Extension Board for MU9Px-MH provides

- standard Mini-USB connector
- IO connector with all four digital IO-ports. Dual row female socket connector, 2MM 10POS, NPPN052FFKP-RC

Weight (with screws): 2.9 g (please see [3.2.16 Scope of delivery MU-MINIUSB](#))

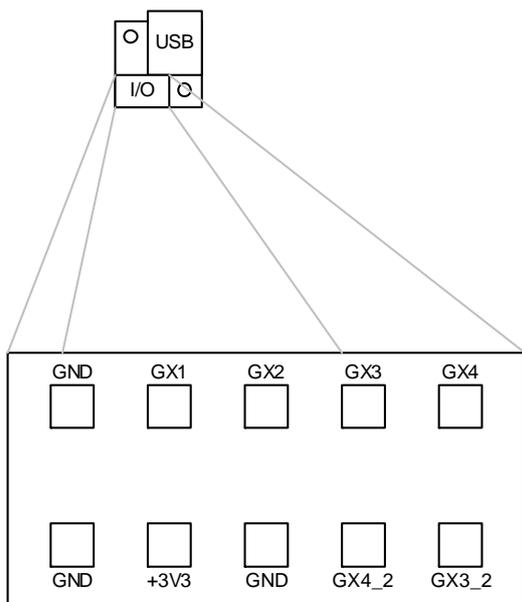


figure 3-13, MINIUSB IO pinout

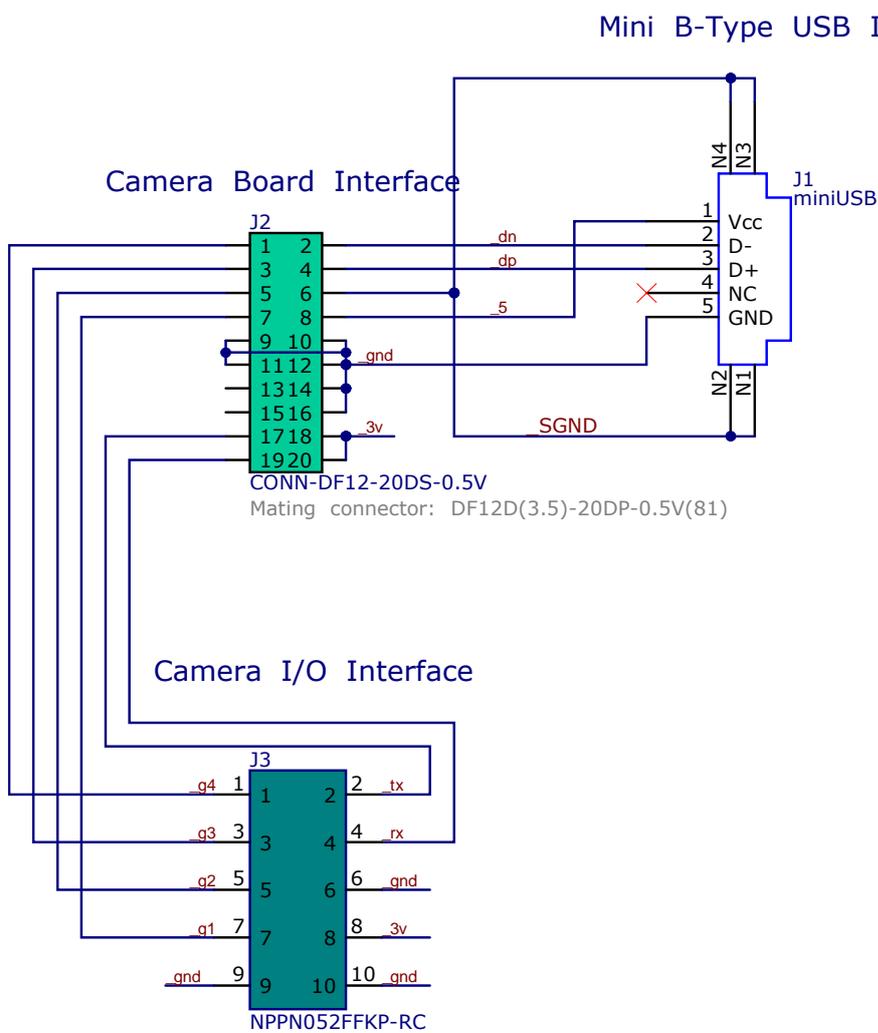


figure 3-14, MINIUSB connection diagram

For details about the signal description please see [3.2.7.2 Signal description](#).

3.2.10. ADPT-MU9P-USB2-UB-V

This adapter provides standard microB USB 2.0 connector and IO connector (SR38) for connection to GX1 and GX2 GPIO ports..

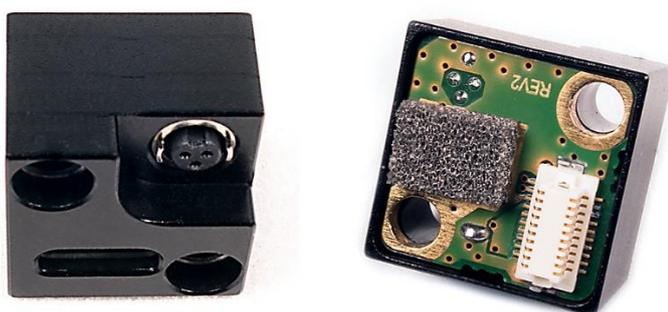


figure 3-15, ADPT-MU9P-USB2-UB-V connection diagram

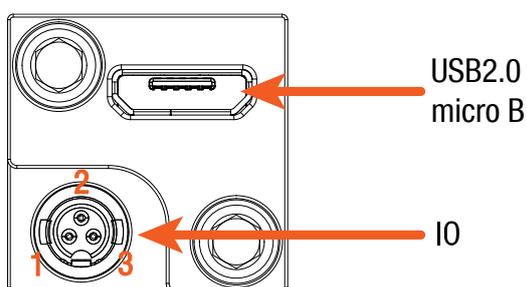


figure 3-16, ADPT-MU9P-USB2-UB-V IO pinout

I/O connector Pin Assignment:

Pin	Signal	Technical description
1	GPIO 1	Programmable IO
2	Common (IO Ground)	
3	GPIO 2	Programmable IO
(Shell)	Chassis ground	

table 3-10, ADPT-MU9P-USB2-UV-V I/O connector, Pin Assignment

Camera Board Interface

MicroB - Type USB Interface

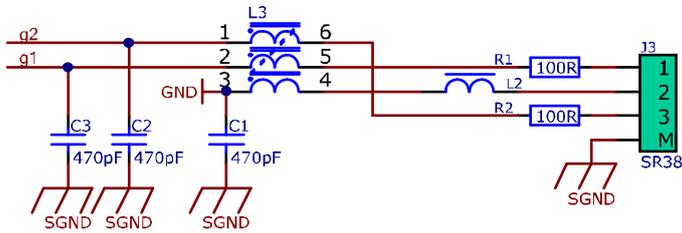
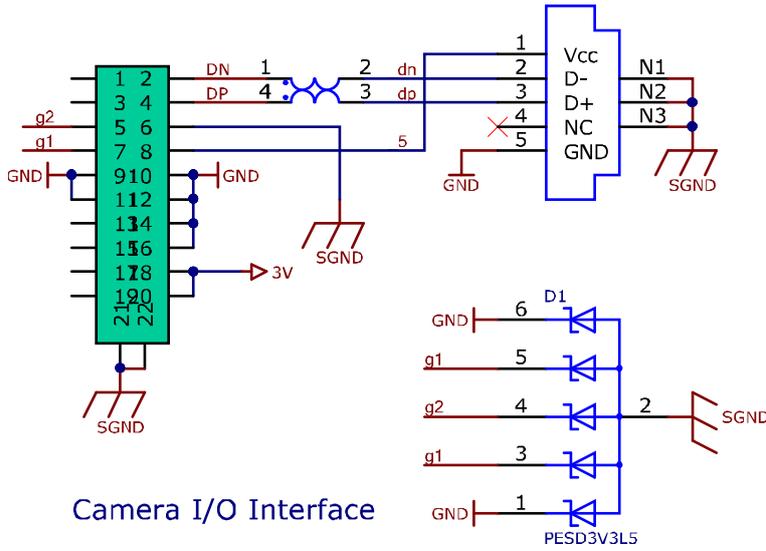


figure 3-17, ADPT-MU9P-USB2-UB-V connection diagram

3.2.11. ME-ADPT-MU-T

xiMU series tripod mounting bracket

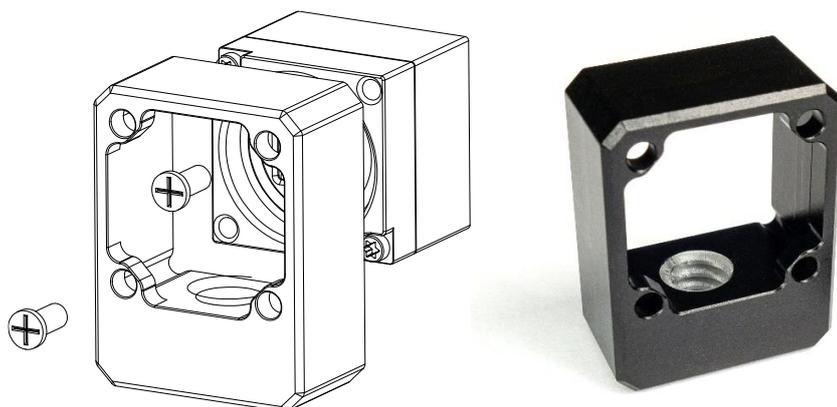


figure 3-18, ME-ADPT-MU-T Mounting tripod bracket

Use 2x SROB-M2x4-CUST screws (included) for mounting. The camera can be mounted in all four orientations in the bracket.

3.2.11.1. Dimensional drawing

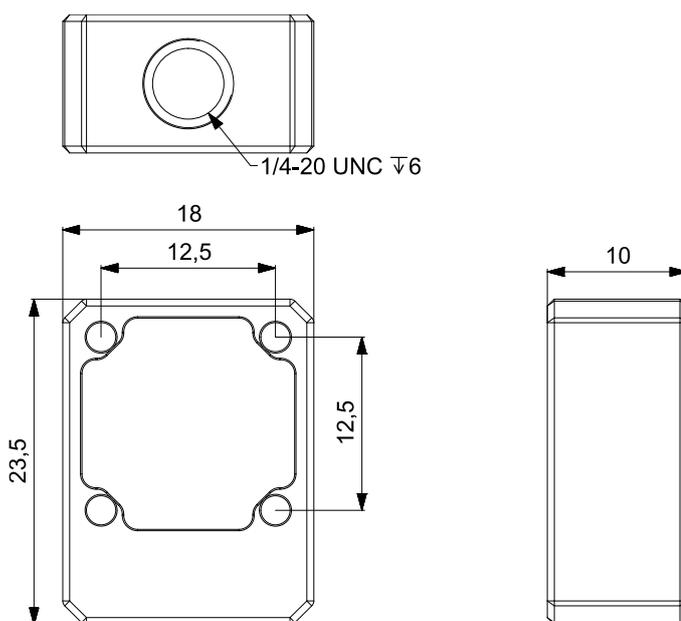


figure 3-19 ME-ADPT-MU-T, dimensional drawing

3.2.12. CBL-MQSYNC-3M0

3.0m xiQ series I/O sync cable can be used with ADPT-MU9P-USB2-UB-V, pig tail

Cable drawing

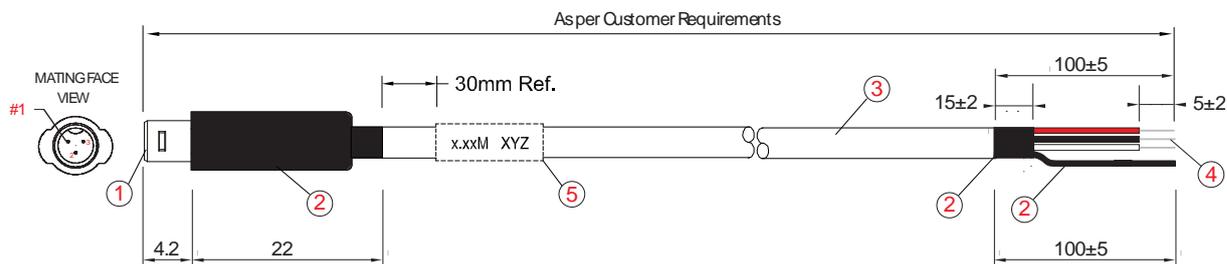


figure 3-20, drawing sync cable

Cable components

Item	Description
1	HRS SR38-4P-3P (71) Hirose SR38 Series Male Connector
2	Heat Shrink Tube
3	A12-1709 [OD=3.30mm] <BLK> (10/0.120x3C) + 32/0.120 27AWG 3Core Line Cord
4	Process end with wire end Striped and tin-plated soldering
5	Cable Label

table 3-11, sync cable, components

Sync cable wiring

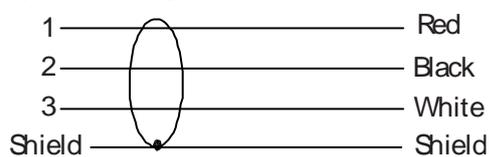


figure 3-21, wiring sync cable

Pin Assignment:

Pin	color	Signal
1	Red	GPIO 1
2	Black	Common (IO Ground)
3	White	GPIO 2

table 3-12, sync cable, pin assignment

3.2.13. Scope of delivery (MU9Px-MH)

Standard delivery of the camera includes:

- Camera MU9Px-MH

3.2.14. Scope of delivery (MU9Px-MH-KIT)

Standard delivery of the camera kit includes:

- Camera MU9Px-MH
- Lens mount adapter MECH-MU9-MH-ADAPT-M (see [3.2.6.1 MECH-MU9-MH-ADAPT-M, dimensional drawing](#))
- Lens mount adapter MECH-MU9-MH-ADAPT-L (see [3.2.6.2 MECH-MU9-MH-ADAPT-L, dimensional drawing](#))

3.2.15. Scope of delivery (MU9PX-MBRD)

Standard delivery of the camera includes:

- Board level camera MU9Px-MBRD

Please see the pictures below:

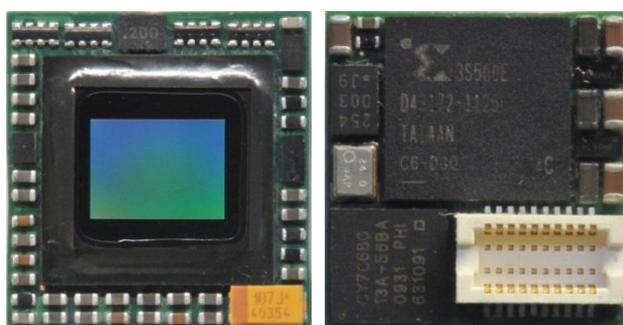


figure 3-22, MU9Px-MBRD

3.2.16. Scope of delivery MU-MINIUSB

Standard delivery of the MU-MINIUSB-board includes

- MU-MINIUSB adapter board
- 2 screws M3

Please see the picture below:

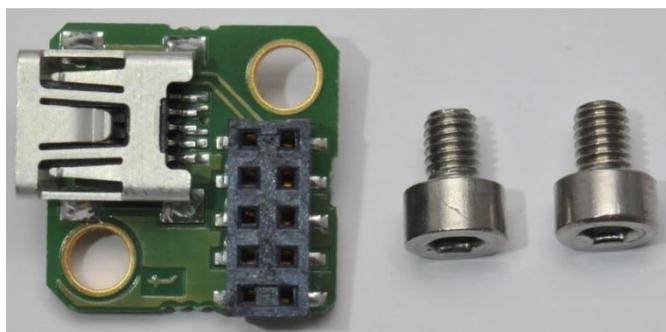


figure 3-23 MU-MINIUSB with screws

3.2.17. Scope of delivery ADPT-MU9P-USB2-UB-V

Standard delivery of the ADPT-MU9P-USB2-UB-V includes

- ADPT-MU9P-USB2-UB-V adapter board
- 2 screws M3x10

Please see the picture below:

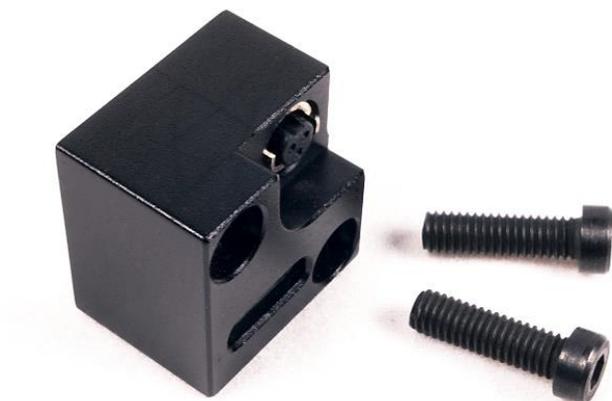


figure 3-24 ADPT-MU9P-USB2-UB-V with screws

3.3. xiMU USB3.1 Gen1 Specification

3.3.1. Sensor and camera parameters

xiMU model	MU181CR-ON	
Sensor parameter		
Brand	Onsemi AR1820HSSC12SHEA0-DP	
Color filter	RGB Bayer mosaic	
Type	Rolling shutter, Global Reset Release	
Pixel Resolution (H × V)	[pixel]	4912 × 3680
Active area size (H × V)	[mm]	6.1 × 4.6
Sensor diagonal	[mm]	7.6
Optical format	[inch]	1/2.3
Pixel Size (H × V)	[μm]	1.25
ADC resolution	[bit]	12
FWC	[ke-]	4.5
Dynamic range	[dB]	57.6
SNR Max	[dB]	36.3
Conversion gain	[e-/LSB ₁₂]	1.18
Dark noise	[e-]	6
DSNU	[e-]	1.2
PRNU	[%]	<1.5
Linearity	[%]	<1
Camera parameters		
Supported bit resolutions	[bit/pixel]	8,10,12
Exposure time ²	[μs]	18 - 5000000
Variable gain range	[dB]	0-24
Maximum frame rate ¹	[fps]	21.9 / 17.5 / 14.6
Power consumption		
typical	[W]	1.4
Maximum	[W]	1.6
Idle	[W]	0.7
Dimensions/Mass		
Height × width × depth	[mm]	15 × 15 × 13.6
mass	[g]	5.1 (without lens mount adapter)

table 3-13, MU181 sensor and camera parameters

Notes:

- 1) The figure indicates the maximum achievable frame rate for full frame readout for 12,10- and 8-bit resolutions. The real performance will be affected by USB controller, number and type of USB devices attached to this controller, system processor and memory speed and configuration.
- 2) Minimal exposure depends on readout mode and bandwidth limitation.

Binning/skipping	pixels	fps	Bit/px
1x1	4896 x 3680	21.9	8
1x1	4896 x 3680	17.5	10
1x1	4896 x 3680	14.6	12
2x2 bin	2448 x 1842	59.4	8
2x2 bin	2448 x 1842	59.4	10
2x2 bin	2448 x 1842	58.3	12
4x4 bin+skip	1224 x 920	115.9	8
4x4 bin+skip	1224 x 920	115.9	10
4x4 bin+skip	1224 x 920	115.9	12

table 3-14, MU181 readout modes

3.3.2. Quantum efficiency curves [%]

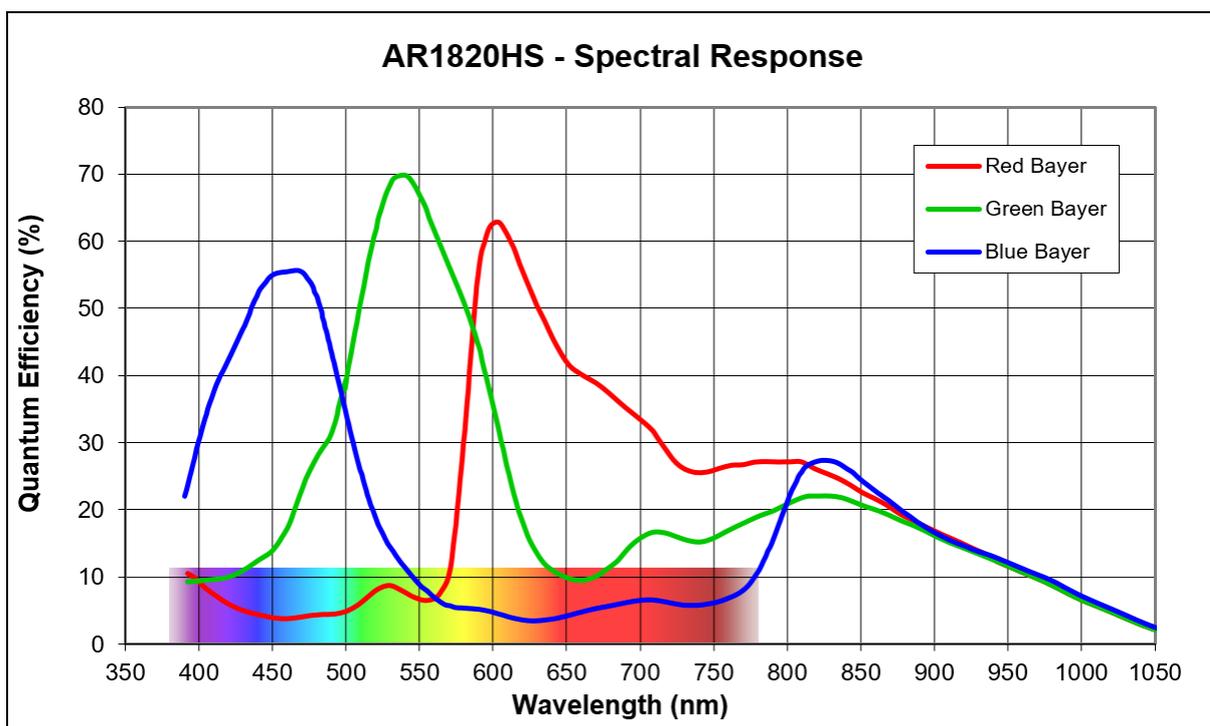


figure 3-25, AR1820HS color, quantum efficiency curve, ©Onsemi

3.3.3. Dimensional drawings

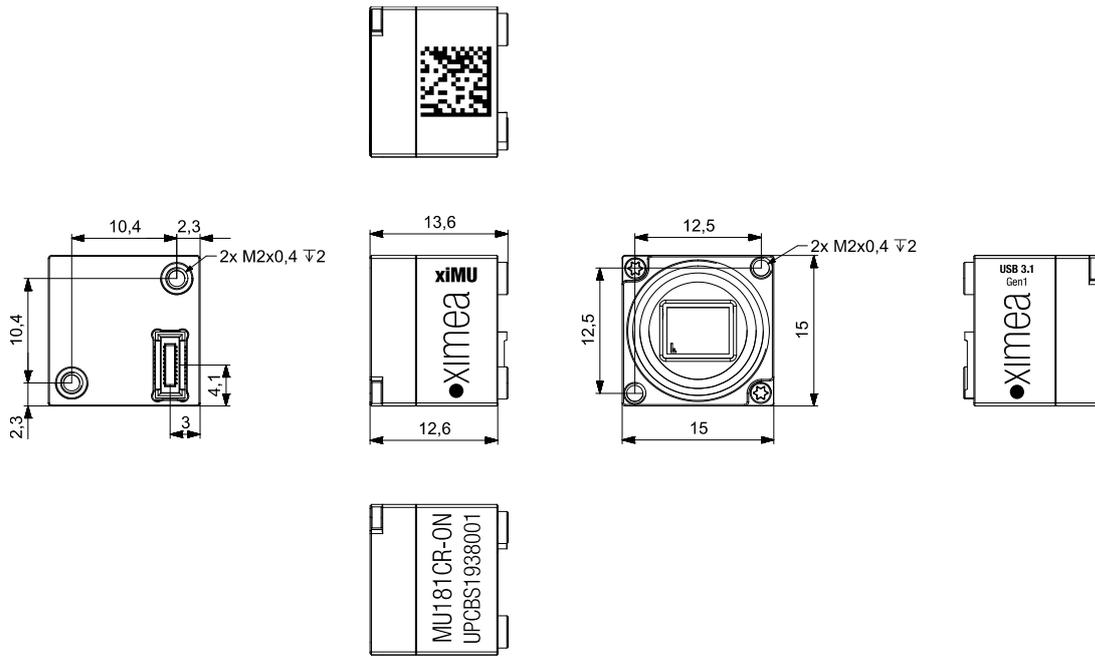


figure 3-26, MU181CR-ON, dimensional drawing

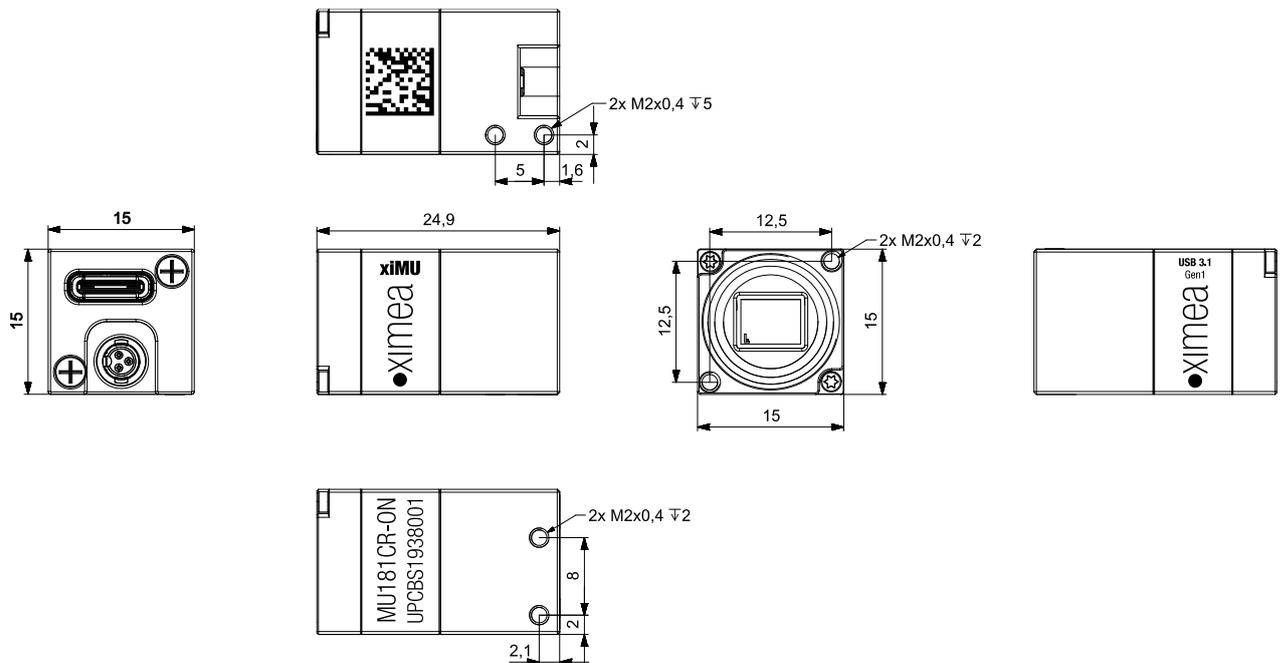


figure 3-27, MU181CR-ON with ADPT-MU-TC-V, dimensional drawing

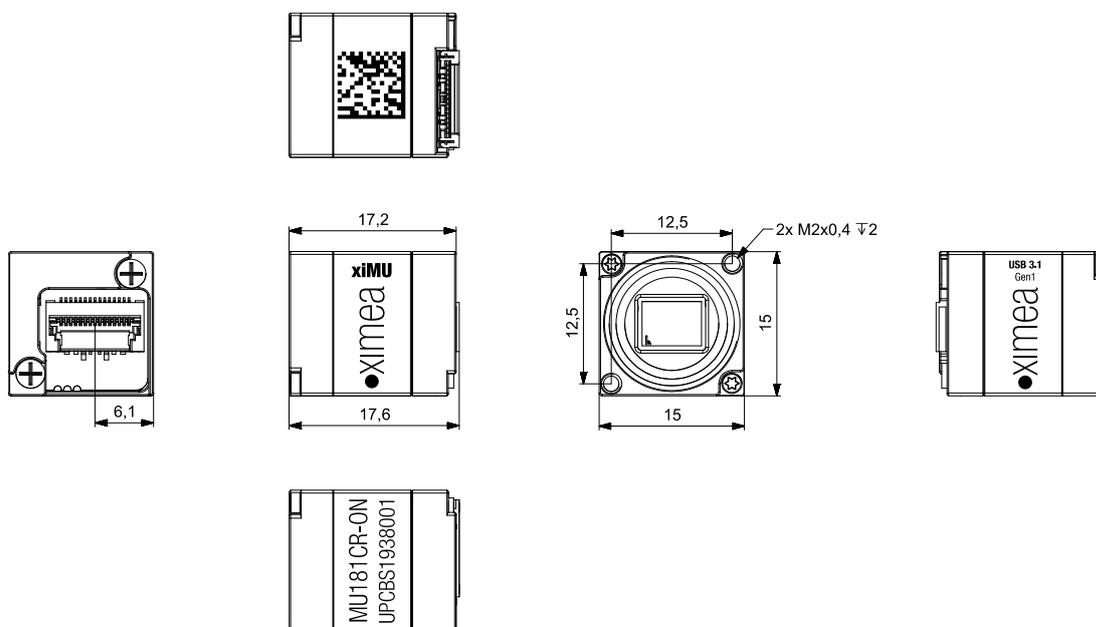


figure 3-28, MU181CR-ON with ADPT-MU-FL, dimensional drawing

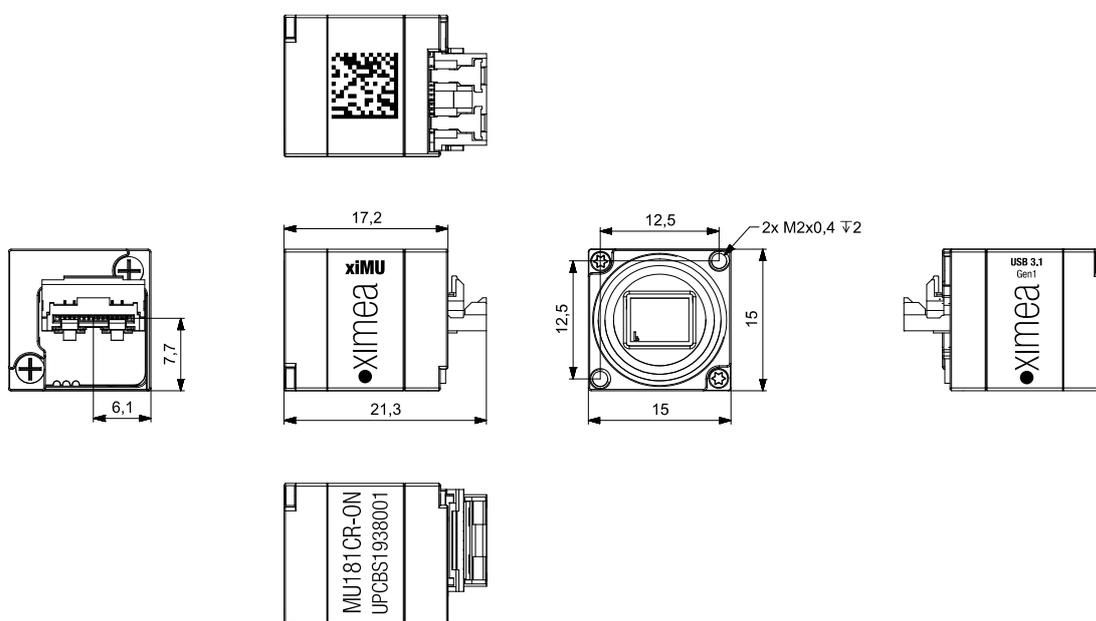


figure 3-29, MU181CR-ON with ADPT-MU-FV, dimensional drawing

3.3.4. Camera features

feature	Note
Binning	Yes: 2x2
Skipping	Yes: 2x2, only if binning 2x2 is enabled
ROI	Yes, 16-pixel granularity
HW Trigger	Trigger without overlap usable (see 4.3.2.3 Triggered mode)
Image formats	RAW, (RGB24, RGB32 – only color models)

table 3-15, MU181 sensor features

3.3.5. MU181 Lens Mount Adapters

There are two lens mount adapters available (S-Mount, M12 x 0.5 thread).

3.3.5.1. ME-LA-MU-M12-M, dimensional drawing



figure 3-30, lens mount adapter ME-LA-MU-M12-M, image

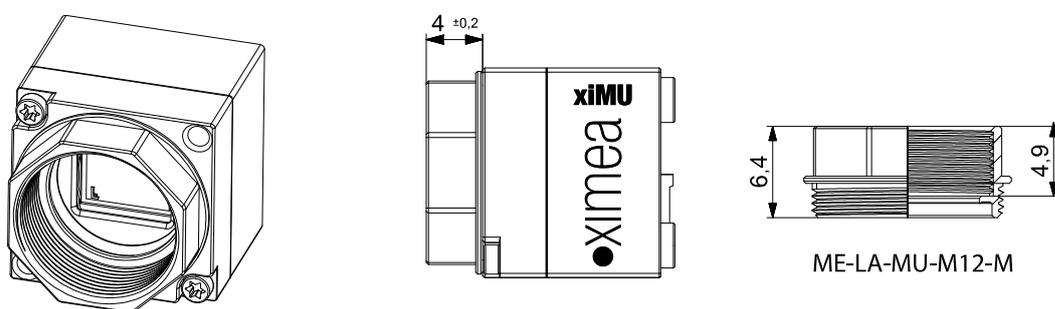


figure 3-31, lens mount adapter ME-LA-MU-M12-M, drawing

Geometric Back focal Distance (measured from the top of the flange to the top of the sensor die): 8 mm.

3.3.5.2. ME-LA-MU-M12-L, dimensional drawing



figure 3-32, lens mount adapter ME-LA-MU-M12-L, image

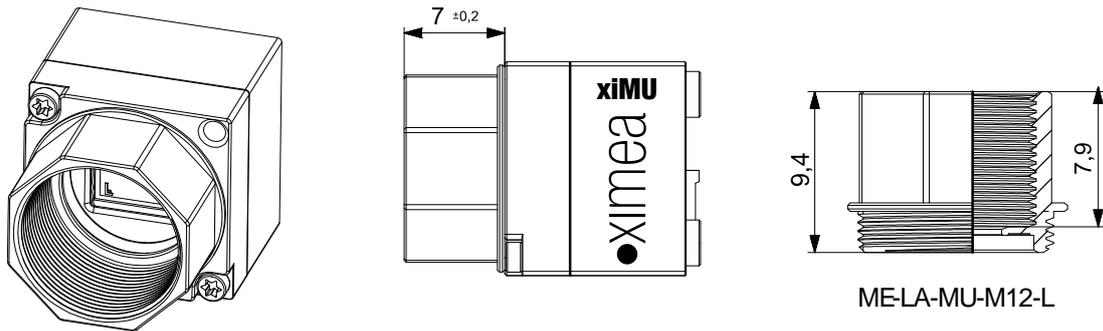


figure 3-33, lens mount adapter ME-LA-MU-M12-L, drawing

Geometric Back focal Distance (measured from the top of the flange to the top of the sensor die): 11 mm.

3.3.6. MU181CR-ON Camera connector (USB / IO Interface)

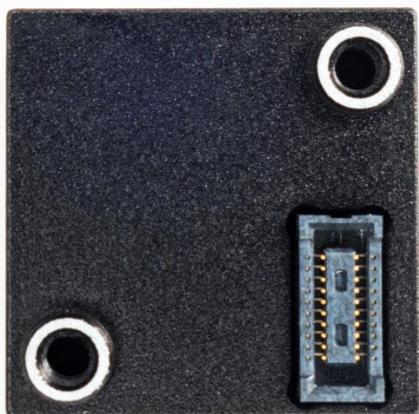


figure 3-34 MU181CR-ON Camera connector, image

The connector mounted on the camera PCB is a

- HRS DF40HC(3.5)-20DS-0.4V(51)

3.3.6.1. Location and Pinout

The camera connector is located on the back side of the camera:

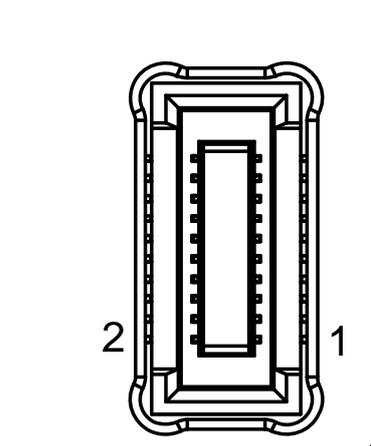


figure 3-35, MU181CR-ON camera connector, location and pin-out

3.3.6.2. Signal description

MU181 camera connector pin assignment and signal description:

Pin	Signal	Description	Function
1	GX1	Programmable IO	default setting exposure active output (Vin-High 2V MAX)
2	SGND	Chassis ground -	
3	GX2	Programmable IO	defined by user; default setting trigger input (Vin-High 2V MAX)
4	GND	Ground	Ground for power and data lines
5	GX3	Programmable IO	defined by user; default setting OFF (Vin-High 2V MAX)
6	SS_RX_N	USB 3.0 interface	USB 3.0 super speed LVDS receiver neg.
7	TCX_INT	NC	(do not connect)
8	SS_RX_P	USB 3.0 interface	USB 3.0 super speed LVDS receiver pos.
9	SCL	(NC)	(do not connect)
10	GND	Ground	Ground for power and data lines
11	SDA	(NC)	(do not connect)
12	SS_TX_P	USB 3.0 interface	USB 3.0 super speed LVDS transmitter pos.
13	GND	Ground	Ground for power and data lines
14	SS_TX_N	USB 3.0 interface	USB 3.0 super speed LVDS transmitter neg.
15	SS_D_P	USB 2.0 interface	USB 2.0 LVDS pair pos.
16	GND	Ground	Ground for power and data lines
17	SS_D_N	USB 2.0 interface	USB 2.0 LVDS pair neg.
18	VBUS	USB power supply	Power input 5V (1.9W max)
19	GND	Ground	Ground for power and data lines
20	VBUS	USB power supply	Power input 5V (1.9W max)

table 3-16, MU181CR-ON camera connector, signal description

Notes:

- None of the pins is galvanically isolated
- The IO pins are connected to the FPGA via 100 Ω serial resistor and ESD protection

3.3.6.2.1. Ground

This signal connected to the internal signal ground

3.3.6.2.2. GX1, GX2, GX3 – Programmable IO

These pins are connected to the FPGA pins via serial resistors of 100 Ω , all signals are ESD protected.

3.3.6.3. GXn electrical characteristics

Item	Parameter	Note
Number of digital lines	3	Each line can be configured by application separately as input or output
Maximal input voltage	2V DC	
Common pole	YES	
Effect of incorrect input terminal connection	Reverse voltage can damage the camera	
Effects when withdrawing/inserting input module under power	May damage camera electronics	
Protection	ESD and EMI protection	ESD IEC 61000-4-2 (Level 4), PI-filter (R = 100 Ω, CTOTAL = 30 pF)
Maximal output sink current	2mA	
Inductive loads	NO	
Output Level logical 0	< 0.2V	Load 100kOhm
Output Level logical 1	> 1.5V	Load 100kOhm
Output delay - rising edge	<10ns	Load 100kOhm threshold 1.5V
Output delay - falling edge	<10ns	Load 100kOhm threshold 0.5V
Input Impedance- minimum	15kOhm	
Input Level for logical 0	< 0.3V	
Input Level for logical 1	> 0.9V	
Input debounce filter	NO	
Input delay - rising edge	<10ns	VINPUT=1.8V
Input delay - falling edge	<10ns	VINPUT=1.8V
Input functions	Trigger	Both edges are supported for trigger
Output functions	Off, On, Exposure active, Frame active	Signal inversion supported

table 3-17, MU181CR-ON IO ports GXn, electrical characteristics

3.3.7. ADPT-MU-FL, ADPT-MU-FV



figure 3-36, ADPT-MU-FL,



figure 3-37, ADPT-MU-FV,

Weight (with screws): 1.4 g (please see [3.3.15 Scope of delivery ADPT-MU-FL/ADPT-MU-FV](#))

3.3.7.1. Flex Connection Location

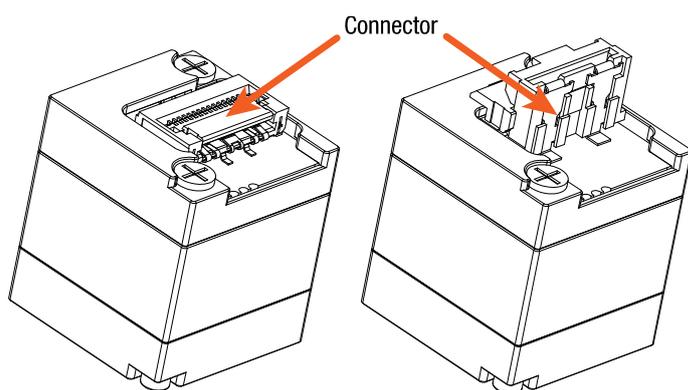


figure 3-38, ADPT-MU-FL/ ADPT-MU-FV

Variant	Connector	Note
-FL	Molex 502244-1530	
-FV	Molex 502231-1500	

table 3-18 Connectors

3.3.7.2. Pinning

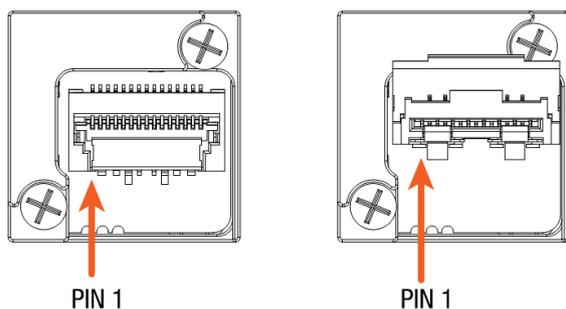


figure 3-39, ADPT-MU-FL/ ADPT-MU-FV pin one location

Pin	Signal	Technical description
1	GND	Ground for power return and for SuperSpeed signal return
2	SSRX-	SuperSpeed receiver dif. pair (accepts reverse polarity)
3	SSRX+	SuperSpeed receiver dif. pair (accepts reverse polarity)
4	GND	Ground for power return and for SuperSpeed signal return
5	SSTX+	SuperSpeed transmitter dif. pair (accepts reverse polarity)
6	SSTX-	SuperSpeed transmitter dif. pair (accepts reverse polarity)
7	GND	Ground for power return and for SuperSpeed signal return
8	D+	USB 2.0 differential pair
9	D-	USB 2.0 differential pair
10	GND	Ground for power return and for SuperSpeed signal return
11	VBUS	+5V Power input
12	VBUS	+5V Power input
13	OUT1	Trigger/sync digital Output (GPO) - Open collector NPN
14	IN/OUT GND	Common pole (IO Ground)
15	IN1	Trigger/sync digital Input (GPI) Current limited input
Ground pins	SGND	Shield of FPC cable connected to shield of host controller

table 3-19 Pin list for flex cable

3.3.7.3. IO lines specification

Item	Parameter	Note
Number of digital lines	1	
Maximal input voltage	24V DC	
Common pole	YES	
Effect of incorrect input terminal connection	Reverse voltage polarity protected	
Effects when withdrawing/inserting input module under power	no damage, no lost data	
Protection	Reverse voltage, ESD	
Input Impedance- minimum	15k Ω	
Input Level for logical 0	< 0.3V	
Input Level for logical 1	> 1.3V	
Input debounce filter	NO	
Input delay - rising edge	<300ns	VINPUT=2V
Input delay - falling edge	<450ns	VINPUT=2V
Input functions	Trigger	Both edges are supported for trigger

table 3-20, Digital Input (IN1), electrical characteristics

Item	Parameter	Note
Number of digital lines	1	
Common pole	YES	
Effects when withdrawing/inserting input module under power	no damage, no lost data	
Protection	ESD and short circuit	ESD HBM ANSI/ESDA/JEDEC JS-001 Class 2 exceeds 2 kV; CDM JESD22-C101E exceeds 1000 V
Output Level logical 0	< 0.8V	Load 100kOhm
Output Level logical 1	> 3.7V	Load 100kOhm
Output delay - rising edge	<20ns	Load 100kOhm threshold 1.5V
Output delay - falling edge	<20ns	Load 100kOhm threshold 0.5V
Output functions	Off, On, Exposure active, Frame active	Signal inversion supported

table 3-21, Digital Output (OUT1), electrical characteristics

3.3.7.4. IO Connection to camera

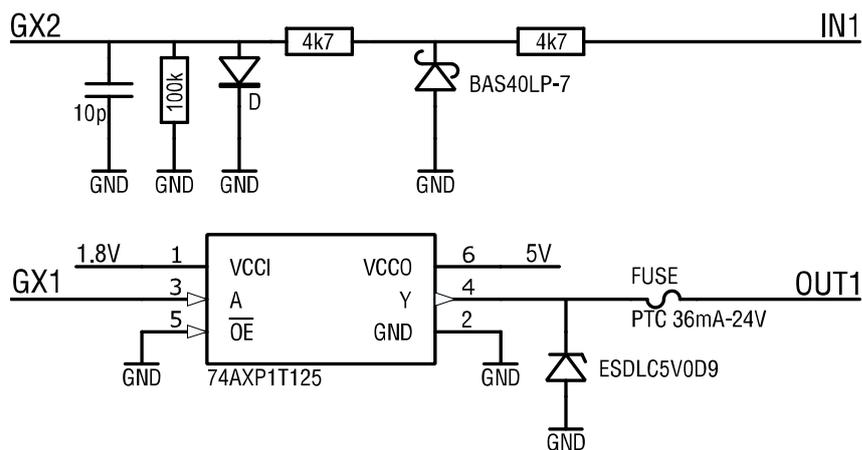


figure 3-40, ADPT-MU-FL ADPT-MU-FV and ADPT-MU-TC-V, IO connection diagram

For details about the signal description please see. [3.3.7.3 IO lines specification](#)

3.3.7.5. Inserting / detaching FPC cable

When inserting or detaching cables increased caution need to be taken, to prevent connector or cable damage. MU181 cameras interface connectors are equipped with locking mechanism. Do not pull on the cable if connector is locked as it may damage the connector or the camera. When manipulating with cable the power supply for the camera must be turned off.



Cables PN: CBL-MQ-FL-xxx (gold) have marked ends. It is important to connect the end marked “CAM” to the camera and end marked “BOB” to host or adapter. Swapped orientation can cause damage to camera. It is important that the power is turned off when inserting/detaching the cable.

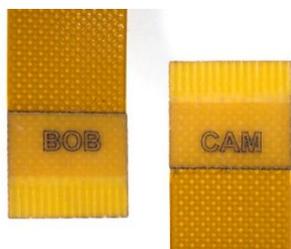


figure 3-41, FPC cable CBL-MQ-FL-xxx laser marking

Cables PN: CBL-USB3FLEX-xxx (white) are not polarized therefore the orientation of the cable between camera and host is not important.

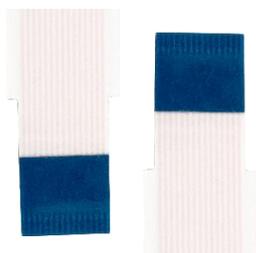


figure 3-42, FPC cable CBL-USB3FLEX-xxx ends

Inserting FPC cable MU option -FL



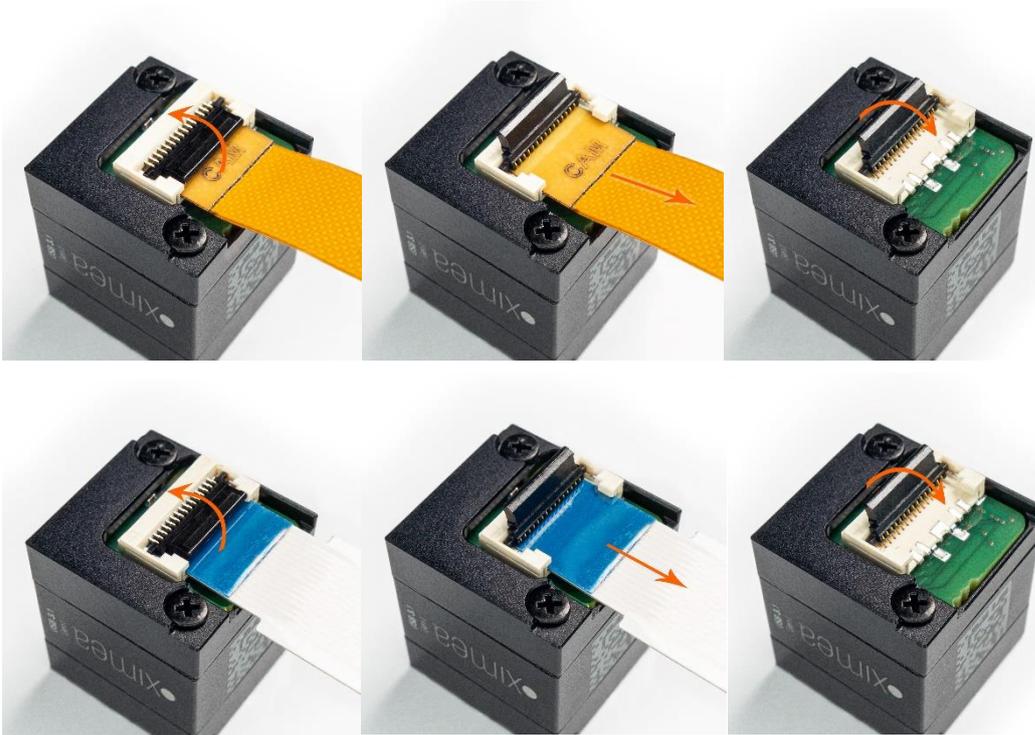
1. Open connector lock

2. Insert cable (contact facing down)

3. Close connector lock

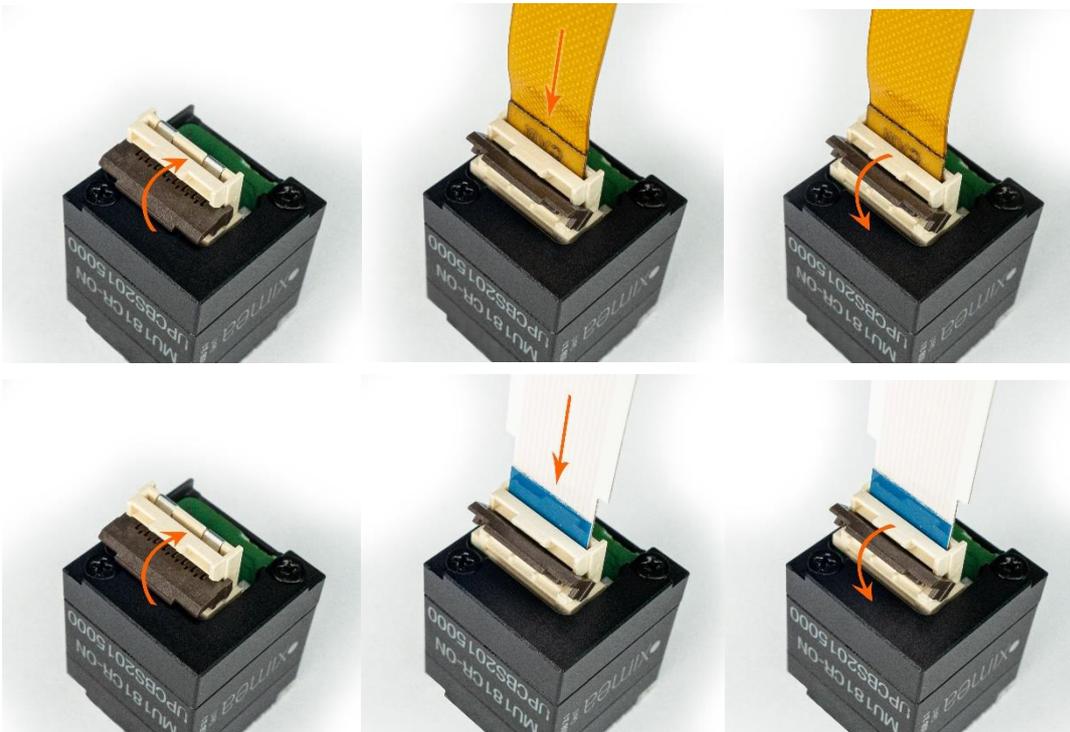
figure 3-43, FPC insert procedure option -FL

Detaching FPC cable MU option -FL



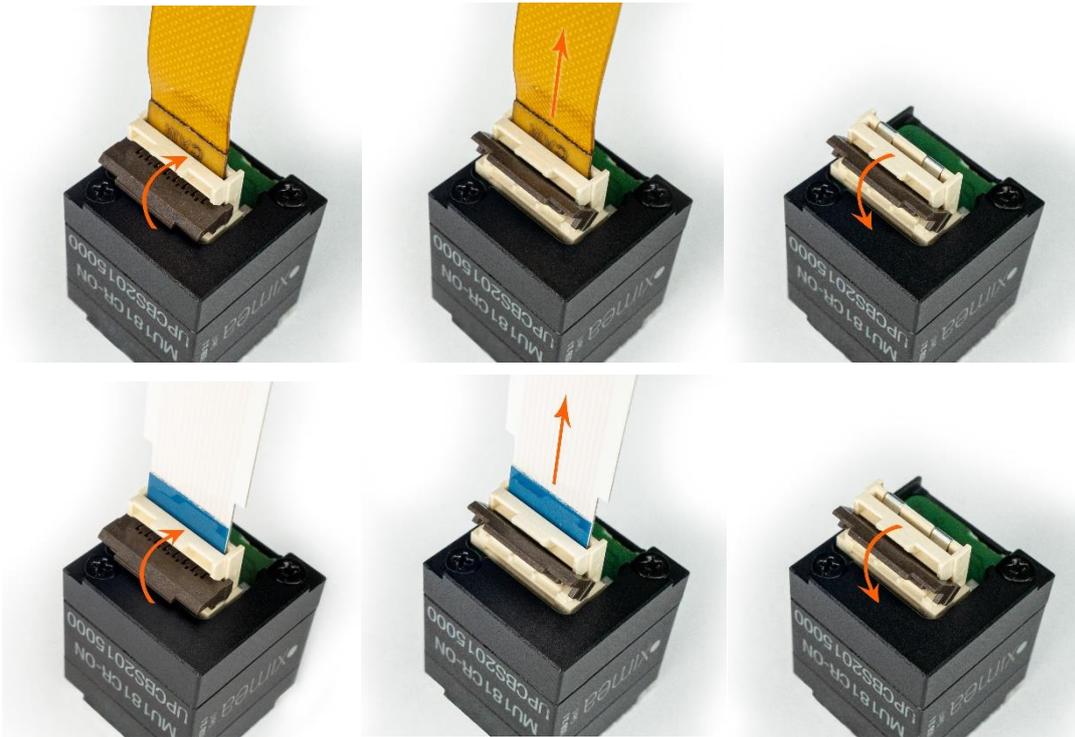
1. Open connector lock 2. Pull cable gently in marked direction 3. Close connector lock
figure 3-44, FPC detach procedure option -FL

Inserting FPC cable MU option -FV



1. Open connector lock 2. Insert cable 3. Close connector lock
figure 3-45, FPC insert procedure option -FV

Detaching FPC cable MU option -FV



1. Open connector lock
 2. Pull cable gently in marked direction
 3. Close connector lock
- figure 3-46, FPC detach procedure option -FV*

3.3.8. ADPT-MU-TC-V

This adapter provides standard Type-C USB 3.1 Gen 1 connector and IO connector (SR38) with IN1 and OUT1 accessible.

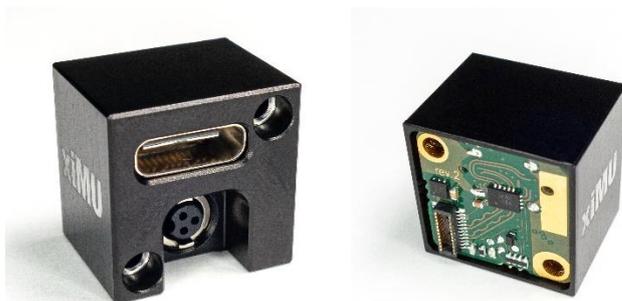


figure 3-47, ADPT-MU-TC-V

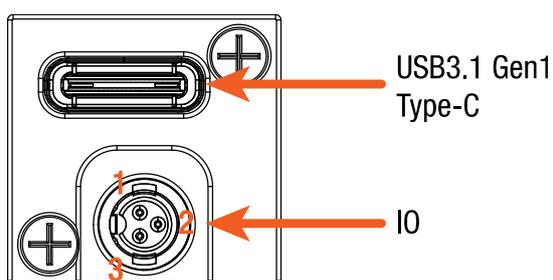


figure 3-48, ADPT-MU-TC-V IO pinout

3.3.8.1. IO connector Pinout

I/O connector Pin Assignment:

Pin	Signal	Technical description
1	IN 1	Non isolated input connected with GX2
2	Common (IO Ground)	
3	OUT 1	Non isolated output connected with GX1
(Shell)	Chassis ground	

table 3-22, ADPT-MU-TC-V I/O connector Pin Assignment

For IO lines connection and specification please see chapter [3.3.7.4 IO Connection to camera](#) and [3.3.7.3 IO lines specification](#)

3.3.9. ME-ADPT-MU-T

Please refer to section [3.2.11 ME-ADPT-MU-T](#)

3.3.10. CBL-MQSYNC-3M0

Please refer to section [3.2.12 CBL-MQSYNC-3M0](#)

3.3.11. CBL-MQ-FL-0M1, CBL-MQ-FL-0M25

Cable FPC MQ Flex-Line, 0.1m/0.25m can be used for connecting xiMU flex line models to carrier board or trough adapter and standard USB 3.0 cable to the host computer. Minimal advised bending radius is 2mm. Cable thickness 0.16mm.



figure 3-49, flex cable gold color



Cable have marked ends. It is important to connect the end marked “CAM” to the camera and end marked “BOB” to host or adapter. Swapped orientation leads to nonoperational state. Connecting camera to powered host can cause destruction of camera. For detaching the cable the connector needs to be unlocked, otherwise connector soldering may be damaged.

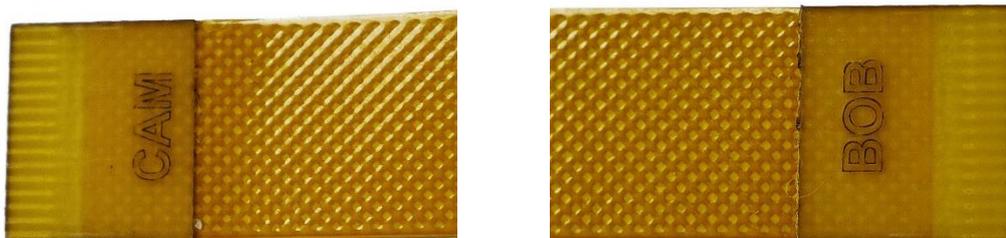


figure 3-50, flex cable ends

3.3.12. CBL-USB3FLEX-0M10, CBL-USB3FLEX-0M25, CBL-USB3FLEX-0M50

The newer generation of FFC cable with available lengths 0.1m, 0.25m and 0.5m can be used for connecting camera to carrier board or through adapter to the host computer (see [3.3.7.5 Inserting / detaching FPC cable](#)). Minimal advised bending radius is 5mm. Cable thickness 0.38mm. This cable is NOT polarized and either end can be used for the camera or the host.



figure 3-51, flex cable white color

3.3.13. BOB-MQ-FL

Break Out Board, Simple Board Level. Enables access to the input and output. FPC cable connector pinout is exactly mirrored from camera pinout. Please refer to

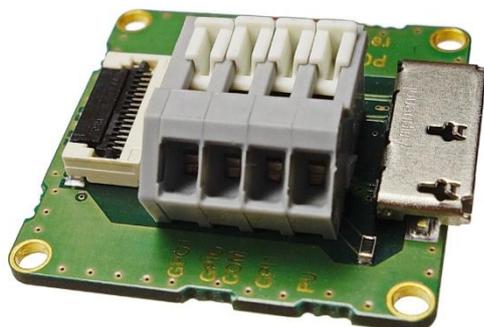


figure 3-52, drawing USB3 cable

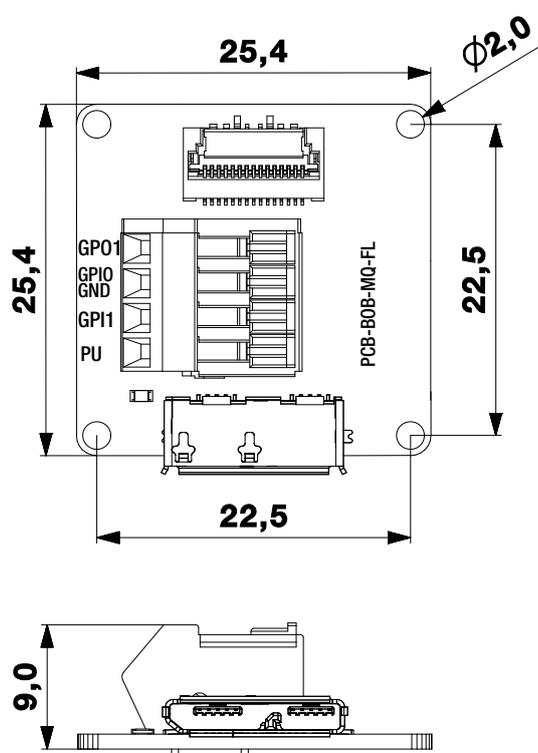


figure 3-53, BOB-MQ-FL dimensions

Pin	Signal	Description
1	IN 1	Non isolated input connected with GX2 (TTL 5V)
2	Common (IO Ground)	
3	OUT 1	Non isolated output connected with GX1 (TTL 5V) push-pull
4	PU	Pull up 1kOhm to OUT1 – Do not use for these cameras

table 3-23, IO connector (WAGO 218-104), pin assignment

3.3.14. Scope of delivery MU181CR-ON models

Standard delivery of the various camera models includes:

- MU181CR-ON: MU181CR-ON camera (only available for OEM projects)
- MU181CR-ON-FL: MU181CR-ON camera + ADPT-MU-FL adapter screwed together
- MU181CR-ON-TC: MU181CR-ON camera + ADPT-MU-TC-V screwed together

3.3.15. Scope of delivery ADPT-MU-FL/ADPT-MU-FV

Standard delivery of the camera includes:

- ADPT-MU-FL or ADPT-MU-FV in mechanics
- 2 screws M2x4 custom

Please see the pictures below:

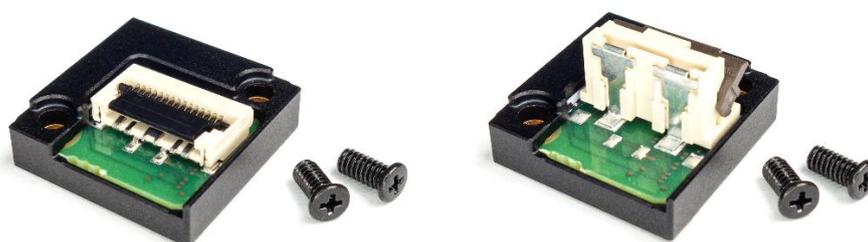


figure 3-54, ADPT-MU-FL/ADPT-MU-FV

3.3.16. Scope of delivery ADPT-MU-TC-V

Standard delivery of the ADPT-MU-TC-V includes

- ADPT-MU-TC-V adapter with mechanics
- 2 screws M2x10 custom

Please see the picture below:



figure 3-55 ADPT-MU-TC-V with screws

3.3.17. Scope of delivery ME-ADPT-MU-T kit

Standard delivery of the ME-ADPT-MU-T includes

- ME-ADPT-MU-T adapter board
- 2 screws M2x3 custom

Please see the picture below:



figure 3-56 ME-ADPT-MU-T with screws

4. Operation

For a proper operation of your xiMU camera certain requirements must be met. You will read more about these requirements in the following chapters, as well as a description of how to use a xiMU camera.

4.1. System Requirements

4.1.1. Software Requirements

The xiMU cameras are compatible with the following operating systems:

- Windows 7 SP1
- Windows 10
- Linux Ubuntu
- MacOS 10.8 or newer



All XIMEA cameras are compatible with the most advanced Vision and Image Processing Libraries.

See chapter [5 Software](#) for more information about the options to access a xiMU cameras, as well as a list of currently supported libraries and frameworks supported under Windows.

4.1.2. Hardware Requirements

The XIMEA xiMU USB2.0 cameras are compatible with USB 2.0. System Configuration. The computer system must have a USB 2.0 High-speed interface. For the xiMU USB3.1 Gen1 the computer must have a supported USB3.0 controller. The list of supported USB3.0 controllers can be found on our [Compatible USB3 Hardware](#) support page.

4.2. Video Formats

4.2.1. Full Resolution

By default, each camera outputs a full resolution image based on its sensor specification.

4.2.2. ROIs – Region Of Interest

ROI, also called area-of-interest (AOI) or windowing, allows the user to specify a sub-area of the original sensor size for read-out. xiMU cameras support the definition of one single ROI by specifying the size (width and height) as well as the position (based on upper left corner) of the sub-area.

Since the utilized CMOS sensors rely on the output of full lines, only the decrease of lines, i.e. the vertical resolution, results in an increase of frame rate.

4.2.3. Downsampling Modes

Downsampling describes the possibility of reducing the image resolution without affecting the sensors physical size, ie. Without cropping the image. This feature is useful when optics are used, that are particularly fitted to a certain sensor size and if it is necessary to maintain the full image circle on the sensor.

Downsampling can be achieved in two ways: binning and skipping/decimation.

4.2.3.1. Binning

When binning is applied, the image is divided into cluster of $k \times k$ pixels, where all pixel values in each cluster are summed or averaged and treated as one output pixel. For example, a 2×2 binning produces 2×2 pixel clusters and results in images with 1/2 of the original horizontal and vertical resolution.

4.2.3.2. Skipping/Decimation

When skipping is chosen, only every n -th pixel is used to create the output image.

For example, with a 2×2 skipping the sensor is divided into 2×2 pixel arrays, and only one pixel of the array is read and transmitted, the rest are discarded. Skipping/Decimation is usually faster than binning mode, but also introduces more aliasing effects.

4.2.4. Color and Mono Modes

All modes are provided by the xiAPI or standard interfaces using the xiAPI (please see section [5.1 Accessing the Camera](#)).

Each xiMU cameras supports several mono (black-and-white) output modes.

Mode	Description
RAW8	Raw sensor data, 8 Bit per pixel, single channel
RAW16	Raw sensor data, 16 Bit per pixel, single channel 10 or 12 Bit sensor output (LSB)
MONO8	Intensity output, 8 Bit per pixel, single channel
MONO16	Intensity output, 16 Bit per pixel, single channel

table 4-1, image formats, mono

Color camera models also support additional color modes.

Mode	Description
RGB24	RGB filtered output, 24 Bit per pixel, 3 channels Sequence: [Blue][Green][Red]
RGB32	RGBA filtered output, 32 Bit per pixel, 4 channels, Alpha channel equals 0. Sequence: [Blue][Green][Red][0]
RGB_PLANAR	RGB filtered output with planar-oriented channels. Format: [R][R]...[G][G]...[B][B]...

table 4-2, image formats, color

Note1: For color modes **RGB32** and **RGB24** the image from sensor needs to be pre-processed (de-bayering). CPU load is higher in these modes. Setting this parameter will reset current region of interest. **RGB24** is being processed from the **RGB32** by removing the unused Alpha channel creating a slightly higher CPU load than the **RGB32** format.

4.3. Acquisition modes

4.3.1. Free-Run

Also known as continuous acquisition. In this mode the sensor delivers a constant stream of image data at the maximum speed available by the current bandwidth, without any external trigger. Each image exposition is started automatically when possible.

For all sensors the exposure of the next frame overlaps with the data readout of the previous frame.

This Overlapped mode gives the highest number of frames per second (FPS).

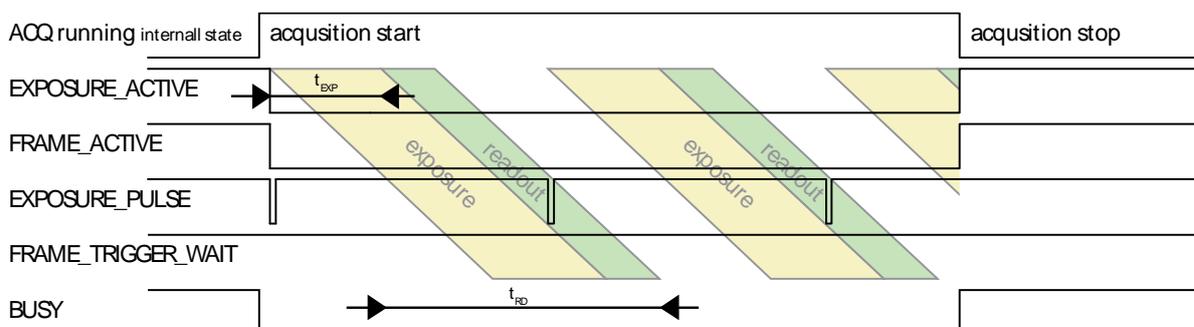


figure 4-1, acquisition mode - free run

In this mode the timing depends on minimum of Exposure Time and Data Readout Time.

4.3.2. Triggered Acquisition

Unlike in the free-run, each image exposition can also be triggered with an input trigger signal. In this mode, the sensor waits in stage until the trigger signal arrives. Only then, the exposure is started, which is followed by the data readout.

4.3.2.1. Software Trigger

The trigger signal can be sent to the sensor using a software command. In this case, common system related latencies and jitter apply.

4.3.2.2. Hardware Trigger

A hardware trigger can be sent to the sensor using the digital input described in [3.2.7.2 Signal description](#) and [3.3.6.2 Signal description](#). Triggering by hardware is usually used to reduce latencies as well as jitter in applications that require the most accurate timing.

4.3.2.3. Triggered mode

This mode gives lower FPS compared to *Free-Run* mode. Sensor support two modes of exposure which have impact on camera signaling.

Sensor timing in global reset release mode

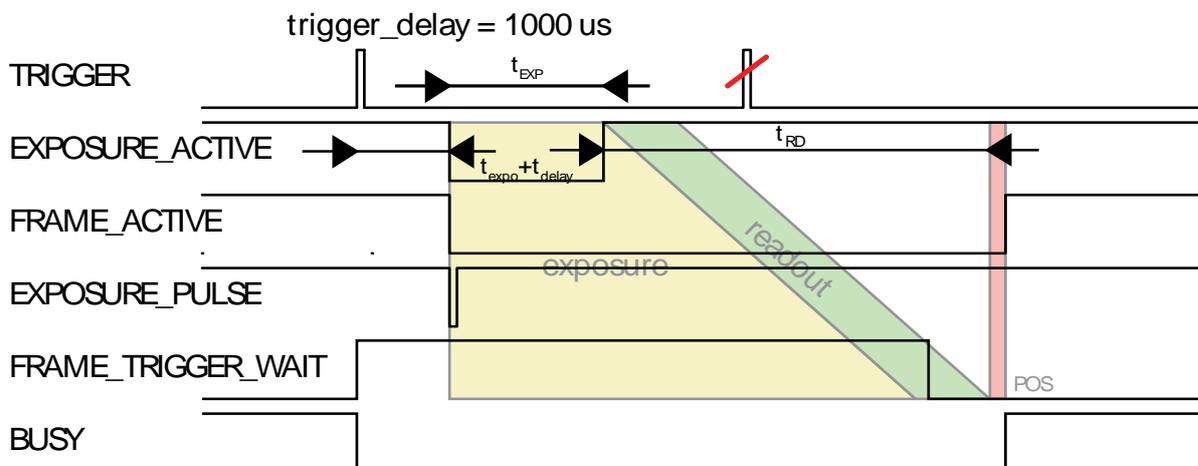


figure 4-2, acquisition mode – triggered global reset release

In this mode the timing depends on sum of:

- Input transition time (t_{tr}), depends on:
 - Digital Input Delay - time for changing internal circuit to active state. It is constant for each camera model. For this camera it is negligible.
 - Trigger delay (t_{delay}) – delay set in camera to postpone trigger to sensor.
- Exposure time (t_{exps}) – Exposure time.
- Data Readout time (t_{rd}) – Depends on mode of operation, no direct calculation possible.
- Post image timeout (t_{pos}) – time after image readout need by sensor to be ready for next exposure.

Typical times for selected camera models

Camera Model	DownS	t_{tr} [μs]	t_{exp} [μs]	t_{eio} [μs]	t_{expo} [μs]	t_{rd} [μs]	Notes
MU9Px-MH	any		2	0.5	1.5		--
MU181CR-ON							

table 4-3, trigger mode w/o overlap, timing

Description:

- DownS = Current camera DownSampling (XI_PRM_DOWNSAMPLING)
- t_{eio} = Trigger (Digital Input) to Strobe (Digital Output)
- t_{exp} = Strobe (Sensor) to Digital Output
- t_{delay} = Trigger delay
- t_{expo} = Start of exposition to Exposure Active Digital Output
- LC = Current Line Count (XI_PRM_HEIGHT)
- t_{exps} = Current Exposure Time set (XI_PRM_EXPOSURE)

Minimum trigger period (T_{trig_min})

Minimum trigger period can be calculated using the following formula:

$$t_{trig_min} = t_{exps} + t_{rd} + t_{pos}$$

Example for MU9P full resolution, Exposure time = 500μs, image = 500 pixels width x 200 pixels height (Full line length is readout each time including optical black pixels = 2624pixel. Additional lines are readout as well):

$$t_{trig_min} = 500\mu s + 110\mu s * 211lines + 200\mu s = 23.91ms$$

Sensor timing in rolling shutter mode

Similar to global reset release mode, except exposure is done in rolling shutter mode

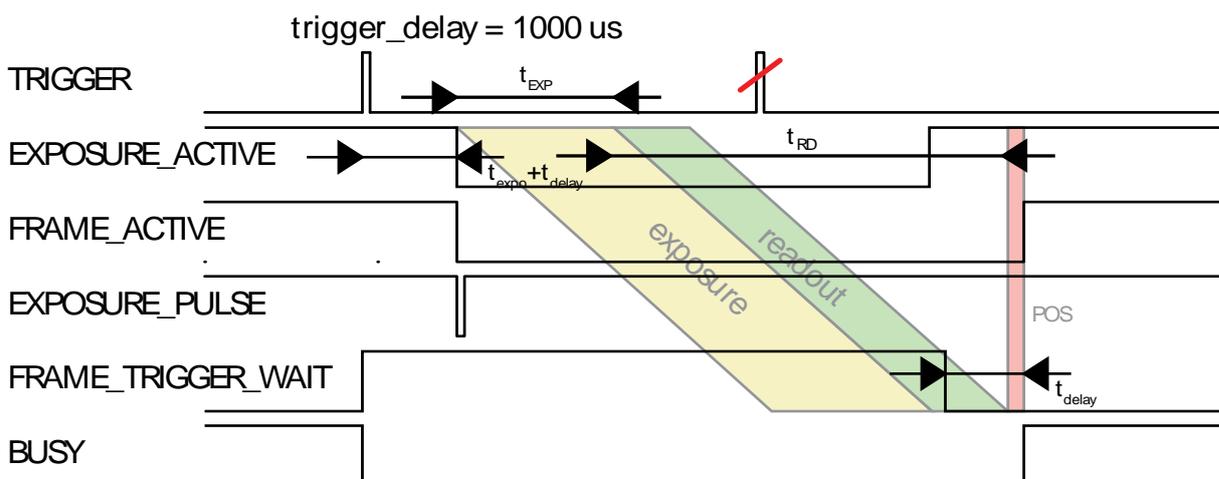


figure 4-3, acquisition mode – triggered rolling shutter mode

For description please see previous page.

4.4. Sensor Shutter Modes

XiMu cameras can be operated in two shutter modes, *Rolling Shutter* or *Global Reset Release*.

The *Rolling Shutter* mode is used if the camera is operated in free-run mode. If the camera is triggered, either by hardware trigger or through software, the sensor uses the *Global Reset Release mode*.

4.4.1. Rolling Shutter Mode

- Line by line integration state
 - Line by line transfer and readout
- Integration of next line is delayed by readout time of one line

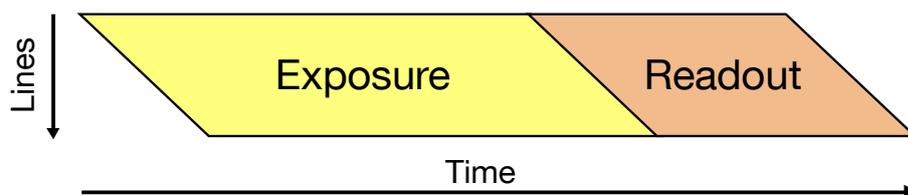


figure 4-4, rolling shutter mode - schematic

Artifacts caused by subject movement

Because of the sequential start of the exposure, the rolling shutter mode may introduce artifacts effect if objects move. In the direction of the lines (horizontal) the image will be sheared. When moving in vertical direction, the object may appear longer or shorter.



figure 4-5, rolling shutter mode, image of a horizontally moved object

When the exposure is longer also motion blur may occur



figure 4-6, rolling shutter mode, image of a horizontally moved object, long exposure time

Rolling shutter artifacts may be prevented by using a flash or stroboscopic light. The flash or strobe must occur when all lines are exposed simultaneously. The exact timing depends on sensor type and readout timing.

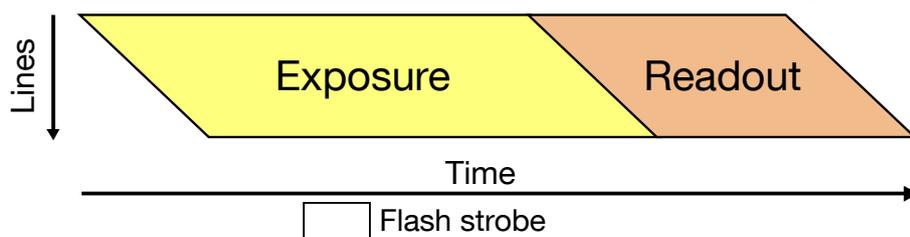


figure 4-7, rolling shutter mode with flash - schematic

In Rolling shutter mode all lines are triggered consecutively, and a strobe must be timed so that it does not start before all lines are open. The delay can be calculated from the highest frame rate and is 1/fps. The strobe must also end before the first lines are closed again for exposure, which sets a lower limit for the exposure time, as can be seen in the figure above.

4.4.2. Global Reset Release Mode

- Global reset of all photo diodes
- Integration stage
- Transfer, conversion and readout line by line starts at the end of the integration of the first line. Not transferred line stays in integration stage until readout of particular line starts. This leads to different exposure time for individual lines. Each next line has exposure longer by readout of one line.

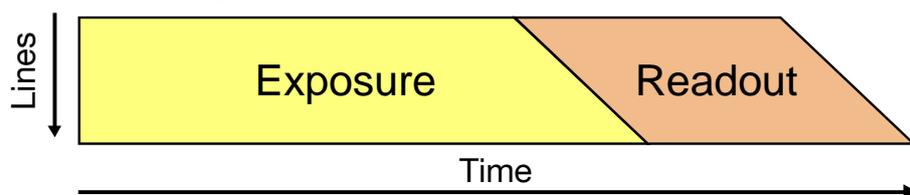


figure 4-8, global reset release mode - schematic

Artifacts caused by subject movement

Because of the longer exposure of the lower lines they may be show increased blurring if the object moves.



figure 4-9, global reset release mode, image horizontally moved object

To freeze the motion, a flash may be used. In contrast to rolling shutter mode the flash strobe does not need to be delayed.

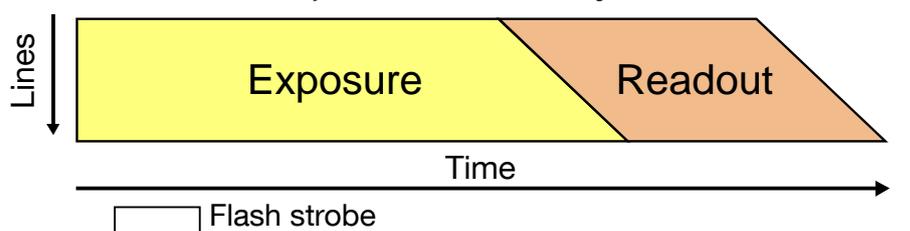


figure 4-10, global reset release mode with flash - schematic

4.4.3. How to Freeze the Motion

When a moving object (e.g. on a conveyor belt) is imaged with a longer exposure time, the resulting image will show Motion Blur. To avoid Motion Blur the short exposure times or flash illumination should be used.

Example of a setup with MU9 camera:

```
Sensor width (W) 0.0057m
2520 pixel horizontally (PX)
Field of view (FOV) 0.2m
Conveyor speed (CS) 0.1m/s
```

To contain Motion Blur to within one image pixel the following calculation for the flash light duration may be used:

```
Pixel distance (PD) W/PX -> 0.0057m/2592pixels = 2.2um.
Pixel distance recalculated FOVPD = FOV/PX = 0.2m/2592 = 77.2um
During exposure the object should not move more than 77.2um
Flash Time (FT) should be less than FOVPD/CS = 77.2um/0.1m/s = 0.772ms
```

4.5. Camera Parameters and Features

4.5.1. Exposure

Also known as shutter speed. This parameter defines the length of the integration period for each frame.

Most of CMOS sensors generate the exposure interval internally. For some it is possible to control it by external signaling. The sensor internal timing depends on the provided system clock. Most sensors are using dividers to generate slower clocks for internal usage.

The exposure time is mostly defined by number row times, where the row time is dependent on various internal settings. Very few sensors support exposure times equal to zero. There is defined minimal exposure time as well as steps between possible exposure times.

4.5.2. Gain

The gain value influences the analog-to-digital conversion process of the image sensor pipeline and acts as a multiplier of the output signal. Using gain values greater than 0 will increase the pixel intensities but may also increase the overall noise level.

4.6. Host-Assisted Image Processing Parameters Available in xiAPI.

4.6.1. Auto Exposure – Auto Gain

When AEAG is used, every captured image is evaluated for its mean intensity. Based on the result, the exposure and gain values are modified with the objective to achieve a target intensity level for the following image. Further, the maximum applicable exposure and gain values can be defined. Since both, exposure and gain, have an influence on the intensity, the ratio between those two parameters in their contribution to the algorithm can also be set (exposure priority).

4.6.2. White Balance

Only for color models: The white balance can be adjusted with three coefficients kR, kG and kB, one for each color channel. These coefficients can be set individually in order to increase or decrease each channel's contribution and therefore allow the user to control the color tint of the image.

4.6.2.1. Assisted Manual White Balance

This feature measures the white balance a single time and sets the white balance coefficient to achieve a mean grey (neutral) tint.

The measurement is performed on the central rectangle of the image, with 1/8th of its width and height. The function expects a white sheet of paper exposed to 50% of the intensity values (8 Bit RGB values should be around 128) to be visible.

4.6.2.2. Auto White Balance

The white balance is measured across the full image for every 4th image that is acquired and the white balance coefficients are set to achieve a neutral color tint.

4.6.3. Gamma

Only for color models: As a part of the color filtering process, it is possible to adjust the gamma level of the image. The adjustment can be set separately for the luminosity and the chromaticity.

4.6.4. Sharpness

Only for color models: As a part of the color filtering process, it is possible to adjust the sharpness of the image.

4.6.5. Color Correction Matrix

The color correction matrix is a 4x4-matrix which is applied on each pixel of an image in a host-assisted port-processing step. This Matrix can be used for example to adjust the brightness, contrast, and saturation.

4.6.6. Bad pixel Correction

During manufacturing, every camera is going through a testing procedure where hot pixels are measured based on dark field images. The measured hot pixels are stored inside the camera and are used for the correction of the acquired images during operation. The correction is active by default but can be turned off by the user if a non-processed output is required.

4.7. MU9 USB2.0 Transfer Modes

4.7.1. Transfer mode

MU9 cameras are connected to PC with USB 2.0. BULK data transfer is used. It guaranties data delivery, but it doesn't guarantee constant bandwidth.

4.7.2. Packet Size Setting

Only for Windows operating systems.

The MU9 cameras have two transfer packet sizes:

- Compatible-Size - packets with 512 bytes are used (default)
- Enhanced-Size - packets with 1024 bytes are used

With Compatible-Size packets the camera will work correctly on more USB controllers. With Enhanced-Size packet setting - the camera can deliver an approx. 25% higher frame-rate and lower CPU usage.

Note - not all controllers and operating systems support Enhanced-Size packets. Please test your configuration first for stability issues.

Note -Since API V3_17_05, the communication settings were changed on MU9 cameras to Compatible-Size with 512 bytes per packet mode as default.

To change the camera to Enhanced-Size - where packets with 1024 bytes are used use the registry settings below:

```
[HKEY_CURRENT_USER\SOFTWARE\SoftHard\mm40api]
    "usb20pktsize"=dword:00000001
```

To change the camera to Compatible-Size - where packets with 512 bytes are used (default) use the registry settings below:

```
[HKEY_CURRENT_USER\SOFTWARE\SoftHard\mm40api]
```

```
"usb20pktsize"=dword:00000000
```

4.7.3. Bandwidth control

Different USB host controllers can have different maximum data throughputs. The default behavior of the API is to measure the value of the maximum data throughput of the host controller (available bandwidth) when the camera is opened and limit the data rate (bandwidth limit) to the 80% of the maximum measured value. In case multiple cameras are connected to the same USB controller or target data rates higher than 80% of the maximum throughput are needed, application can manually change the limit the data rate by setting the value of the `XI_PRM_LIMIT_BANDWIDTH` parameter. For more information see our [xiApi manual](#) and the [Multiple Cameras Setup](#) support page.

4.7.4. USB HUBs

The maximum possible bandwidth is limited when the xiMU camera is connected through a USB hub. If possible - connect the camera directly to the USB port of the PC.

4.7.5. Using multiple MU9 cameras

In case multiple MU9 cameras are used, each camera must be connected to a separate USB2 controller, otherwise streaming will not work properly and the user will observe the "Fifo overflow" message in debug output of the application.

4.8. Connecting Two MU9 Cameras with Synchronized Acquisition

Two or more MU9 cameras can be connected with synchronized acquisition of images. To decrease the delay between images the cameras should be interconnected via the strobe/trigger signal.

4.8.1. Interconnect Cameras

MU9Px-MH cameras could be synchronized from external source. In this case electrical characteristics in [GXn DC electrical characteristics](#) need to be observed. In similar way cameras could be connected with each other. In this case one camera will be used as master to trigger all slave cameras. As the output strength of GPO is limited maximum 2 inputs of MU9Px-MH could be connected to one output as depicted on figure 4-11. This setup ensures low latency between two camera exposures. Latency should be less than 10us.

Two cameras interconnection

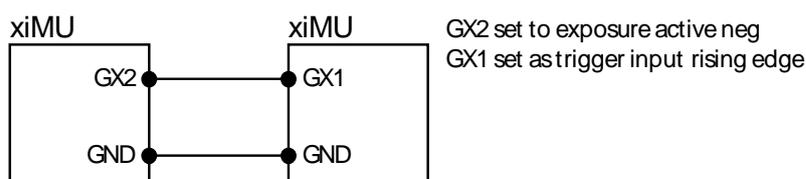


figure 4-11, connecting two MU9 cameras in MASTER-SLAVE (SLAVE on right)

Interconnect the cameras with 2 signals:

- GND (pin 3 on Trigger Plug of MU9 Patch cable [see [3.2.8 MU9 Patch cable](#)])
 - Connect this pin to same pin on the other camera (GND)
- GX2 (pin 1 on Trigger Plug of MU9 Patch cable [see [3.2.8 MU9 Patch cable](#)])
 - Connect this pin to pin set as trigger input on other MU9 camera (GX1)
 - For connecting different model of XIMEA camera signal conditioning may be needed.

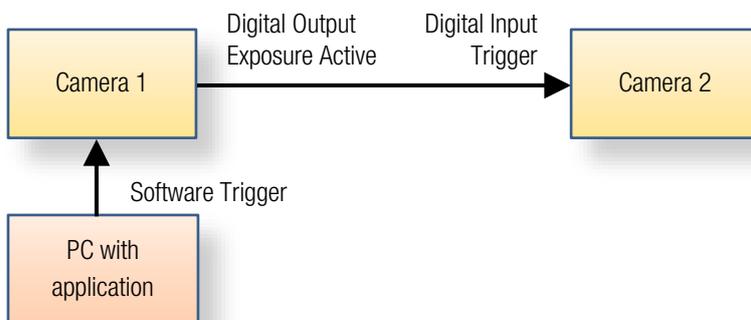


figure 4-13, synchronized acquisition - schematic

xiAPI Example:

```

HANDLE handle1, handle2;
// open both cameras
xiOpenDevice(0, &handle1);
xiOpenDevice(1, &handle2);
// set trigger mode on camera1 - as master
xiSetParamInt(handle1, XI_PRM_TRG_SOURCE, XI_TRG_SOFTWARE);
xiSetParamInt(handle1, XI_PRM_GPO_SELECTOR, 1);
xiSetParamInt(handle1, XI_PRM_GPO_MODE, XI_GPO_FRAME_ACTIVE);
// set trigger mode on camera2 - as slave
xiSetParamInt(handle2, XI_PRM_TRG_SOURCE, XI_TRG_EDGE_FALLING);
xiSetParamInt(handle2, XI_PRM_GPI_SELECTOR, 1);
xiSetParamInt(handle2, XI_PRM_GPI_MODE, XI_GPI_TRIGGER);
// start
xiStartAcquisition(handle1);
xiStartAcquisition(handle2);
Sleep(1234); // wait for right moment to trigger the exposure
// trigger acquisition on Master camera
xiSetParamInt(handle1, XI_PRM_TRG_SOFTWARE, 0);
// get image from both cameras
xiGetImage(handle1, 100, &image1);
xiGetImage(handle2, 100, &image2);
// process images here
xiCloseDevice(handle1);
xiCloseDevice(handle2);
  
```

Timing diagram shows the Trigger event, Camera1 and Camera2 Status, Exposure Active Signal from Camera1:

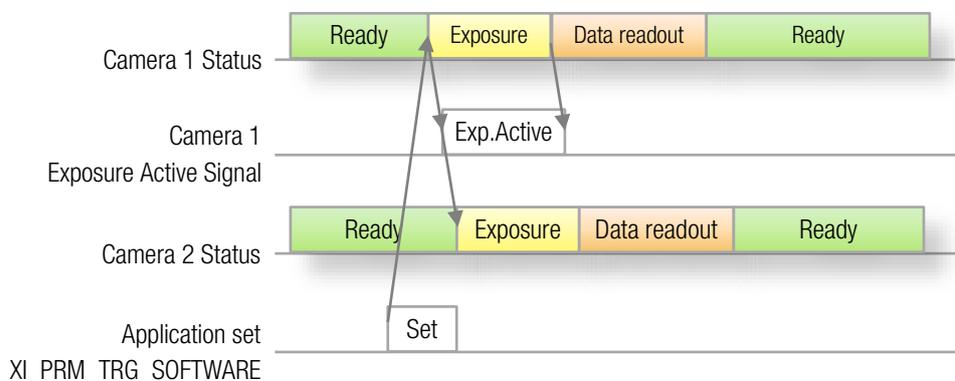


figure 4-14, synchronized acquisition – timing diagram

5. Software

5.1. Accessing the Camera

Depending on the target application, the user can choose between several ways of accessing and controlling the camera. These can be divided into two categories: a programmatic approach, through programming code, or an integrated approach, through a supported, GUI based software package. The programmatic approach is generally used for the development of a custom application or image processing pipeline. The integrated approach is favored, if the specific toolset of a certain software package is sufficient and the camera serves as an integrated capture device.

5.1.1. Proprietary API

All XIMEA cameras are supported by the same unified APIs (application programming interface). The API is a software interface between the camera system driver and the application. Different APIs are available for different programming environments, e.g. *xiAPI* (see [5.7.1 XIMEA APIs](#)) for C/C++ developments and *xiAPI.Net* for C#.Net based developments

5.1.2. Standard Interface

As an alternative to the proprietary API, the camera can be accessed through a set of standard interfaces. These interfaces decouple a specific hardware design (e.g. physical interface) of a camera from its control in software. Therefore, multiple camera classes and types can be used in a unified way.

5.1.2.1. GenICam

GenICam/GenTL provides a camera-agnostic transport layer interface to acquire images or other data and to communicate with a device. Each camera serves as a *GenTL Producer* which can be accessed in all software packages that are compatible with the GenICam standard, as well as through custom developments which implement this standard interface.

5.1.3. Vision Library Integration

All XIMEA cameras are compatible with the most advanced vision and image processing libraries. For GUI based software packages, the cameras can be directly accessed without the need of programming. Code libraries are generally used in conjunction with one of our APIs, in order to add additional functionality (e.g. image processing, communication, data storage).

5.2. XIMEA CamTool

The CamTool is a cross-platform application showcasing the features of all XIMEA camera families.



Short description

It runs on Windows, Linux, macOS systems offering a substantial imaging tool set, which can be further extended with custom modules using a plugin infrastructure. CamTool is based on Qt for the UI and xiAPI for the camera control. Its camera settings menu resembles the parameter set of the xiAPI

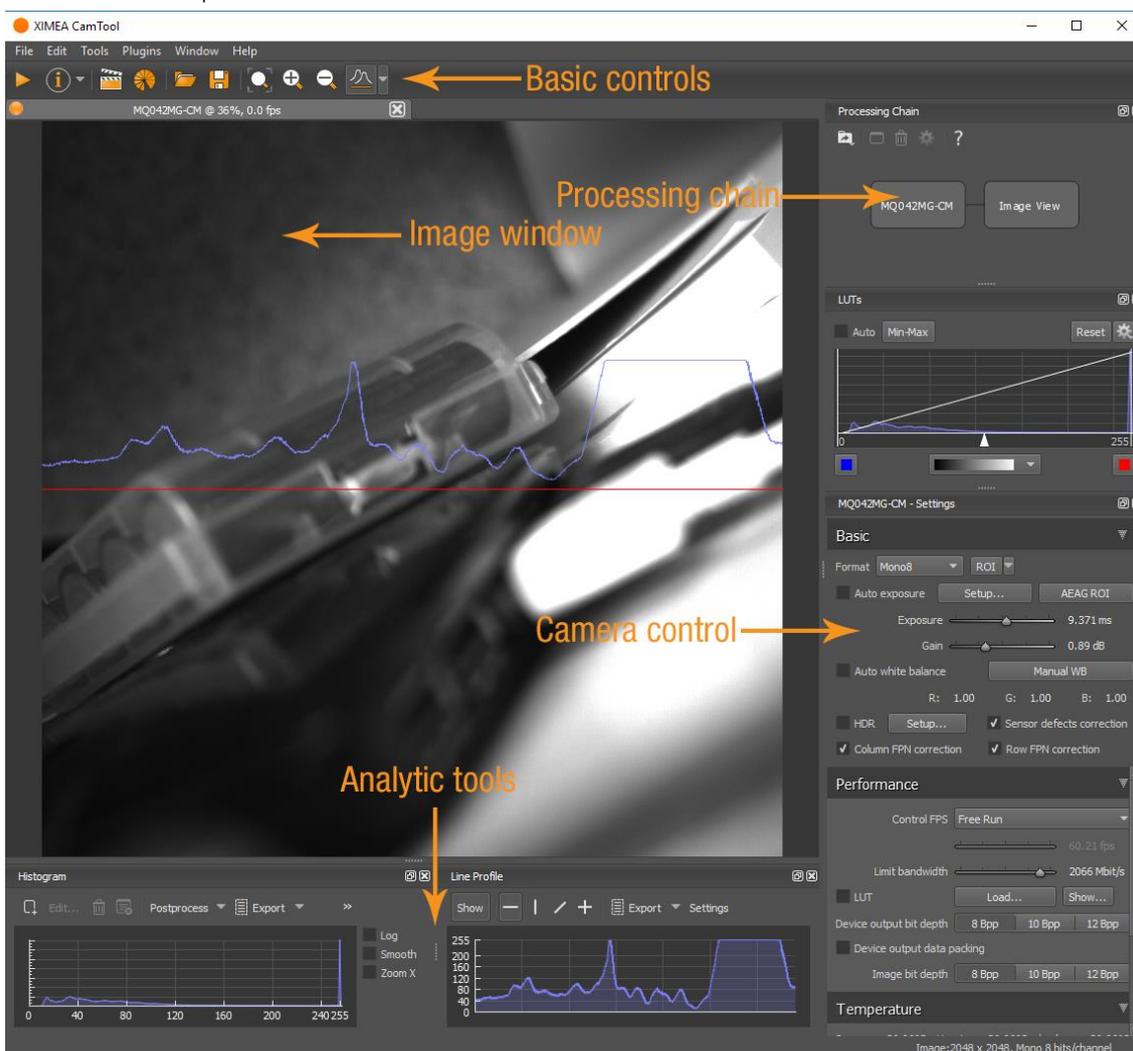


figure 5-1, CamTool Layout

Functions

- to see live image from multiple XIMEA cameras connected
- control the camera parameters
- store of camera image and video
- analyze the image properties
- histogram and line profile
- image averaging, image flip/mirror
- software trigger timer, save/load camera and program settings
- LUT (Look up table)
- Lua scripting

CamTool allows to operate all connected cameras simultaneously. In this case all control are layered for the cameras. Basic controls are placed as tabs in upper part of the window. Image window can be detached from application if needed. Amount of visible camera controls depend on visibility level which can be set in edit→Options.

For more information, please refer to: https://www.ximea.com/support/wiki/allprod/XIMEA_CamTool

5.3. Supported Vision Libraries

For an up-to-date listing of the supported vision libraries and software packages, visit our web site <http://www.ximea.com/support/projects/vision-libraries/wiki>.

5.3.1. Libraries maintained by XIMEA

All cameras listed in the section Products are supported with these libraries.

XIMEA commits to update the API within twelve months after a new major release.

XIMEA warranties backwards compatibility of these software packages for two major releases.

5.3.1.1. MathWorks MATLAB



MathWorks® is the leading developer and supplier of software for technical computing and Model-Based Design.

More: <http://www.mathworks.de/> or https://www.ximea.com/support/wiki/vision-libraries/MathWorks_Matlab

5.3.1.2. MVTec HALCON



HALCON is the comprehensive standard software for machine vision with an integrated development environment (IDE) that is used worldwide.

More: <http://www.mvtec.com/halcon/> or https://www.ximea.com/support/wiki/vision-libraries/MVTec_HALCON

5.3.1.3. National Instruments LabVIEW Vision Library



LabVIEW is a graphical programming environment.

More: <http://www.ni.com/labview/>

https://www.ximea.com/support/wiki/vision-libraries/National_Instruments_LabVIEW

5.3.1.4. OpenCV



OpenCV is an open source library of programming functions mainly aimed at real time computer vision, developed by Intel and now supported by Willow Garage.

More: <https://opencv.org/>

<https://www.ximea.com/support/wiki/vision-libraries/OpenCV>

5.4. XIMEA Windows Software Package

XIMEA API Software Package can be installed on: Microsoft Windows 10, Microsoft Windows 8, Microsoft Windows 7 (and Microsoft Windows 7 Embedded), Microsoft Windows 2008 R2.

5.4.1. Contents

The package contains:

- OS Drivers of all XIMEA camera types for OS Microsoft Windows 7 SP1 32/64 bit, Windows 8 32/64 bit, Windows Server 2008 R2 x86-64, Windows 10 32/64 bit.
- APIs ([xiAPI](#), [xiAPI.NET](#), [xiApiPython](#))
- Examples
- CamTool
- xiCop
- *GenTL Producer* - for connection of *GenTL Consumer* applications.
- **Vision Libraries** integration demonstrations:
 - NI LabView interface - xiLib

5.4.2. Installation

- Download and execute the **XIMEA API Software Package** installer (EXE-file, approx. 100 MB):
http://www.ximea.com/downloads/recent/XIMEA_Installer.exe
- Read the License Agreement.
- Start the installer

Be sure that you have administrator privileges or start the Installer with administrator rights (right click and select “run as administrator”):

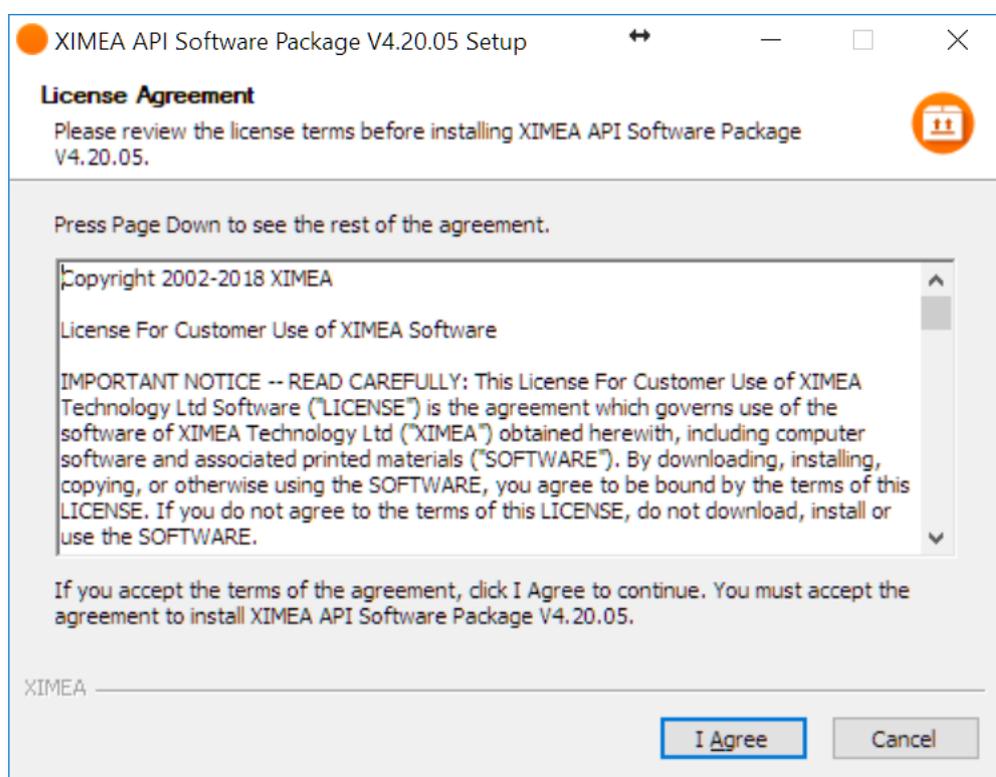


figure 5-2, XIMEA Windows Software Package installation - 1

- Select the Software components you want to install. You can uncheck the components you don't want to install, but it is recommended to leave them all checked.

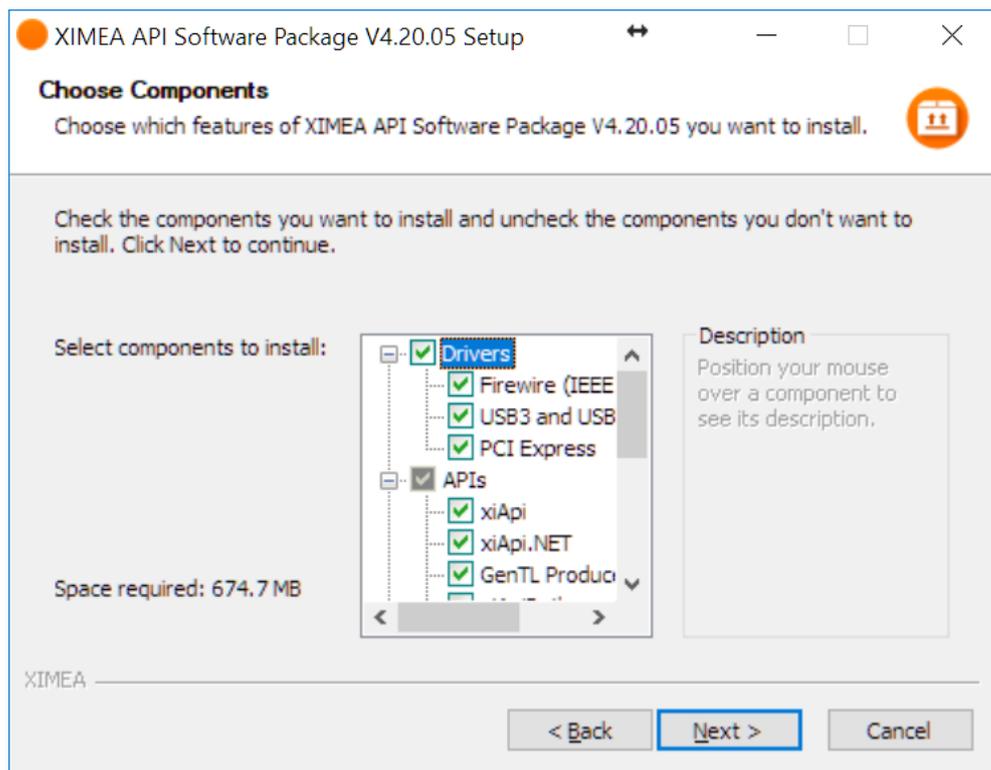


figure 5-3, XIMEA Windows Software Package installation - 2

- Specify the install location - you can leave the default location or change it to your desired location.

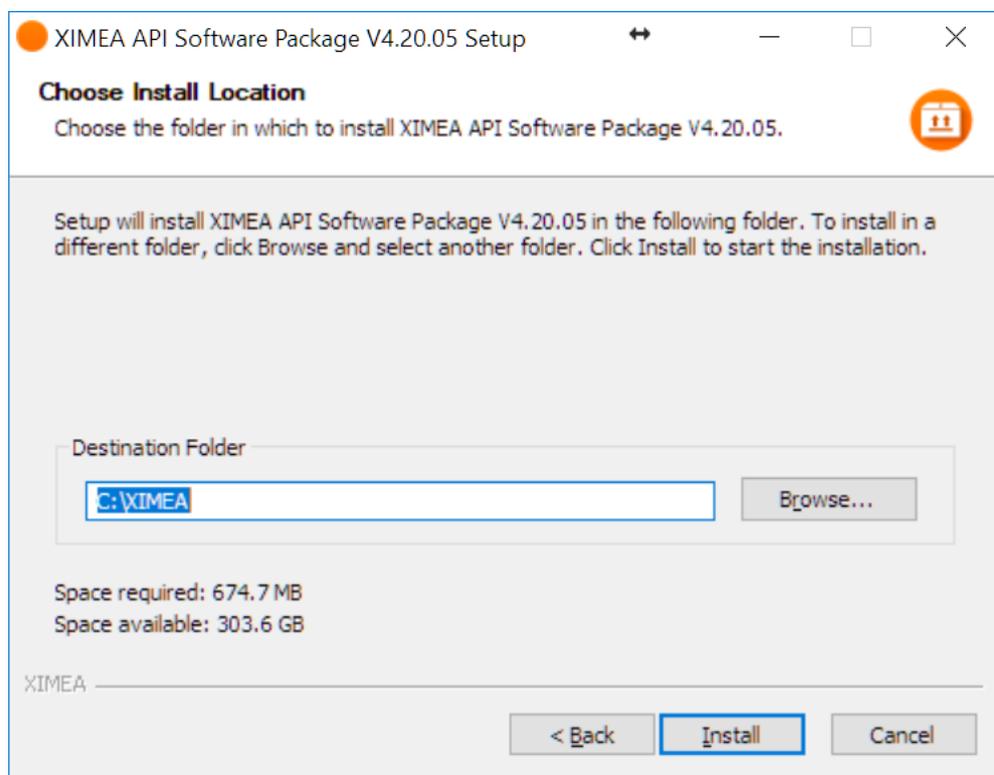


figure 5-4, XIMEA Windows Software Package installation - 3

- Now the XIMEA API Software Package should start copying files, updating System Variables and installing drivers if necessary.

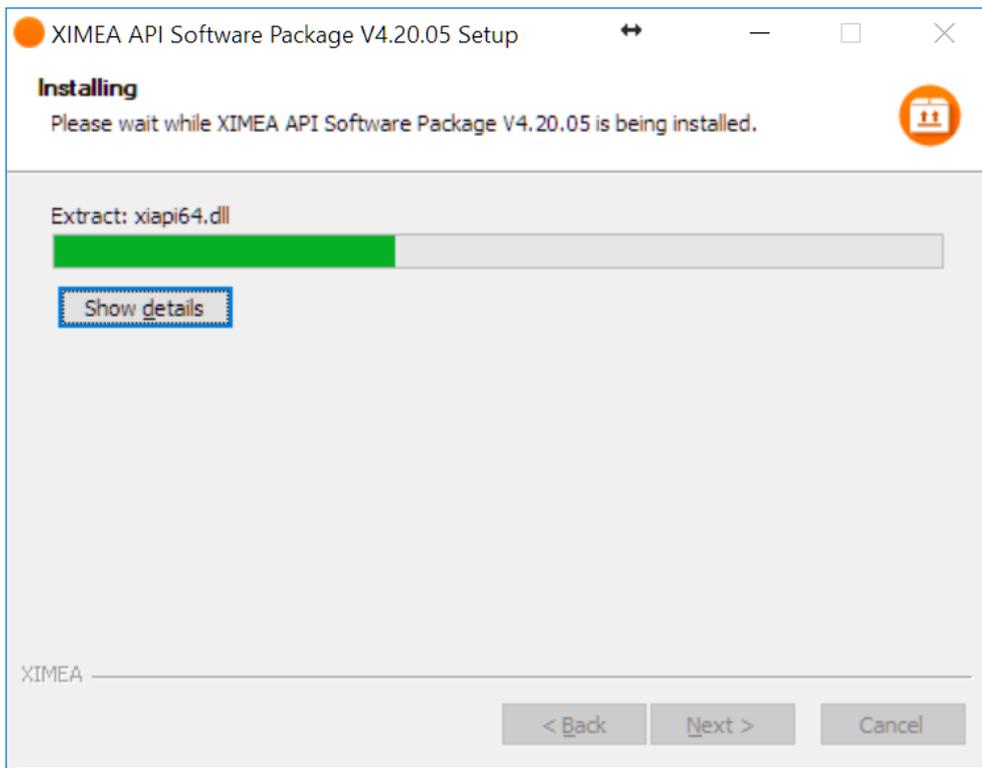


figure 5-5, xiAPI installation, Windows - 4

- Installation is completed.

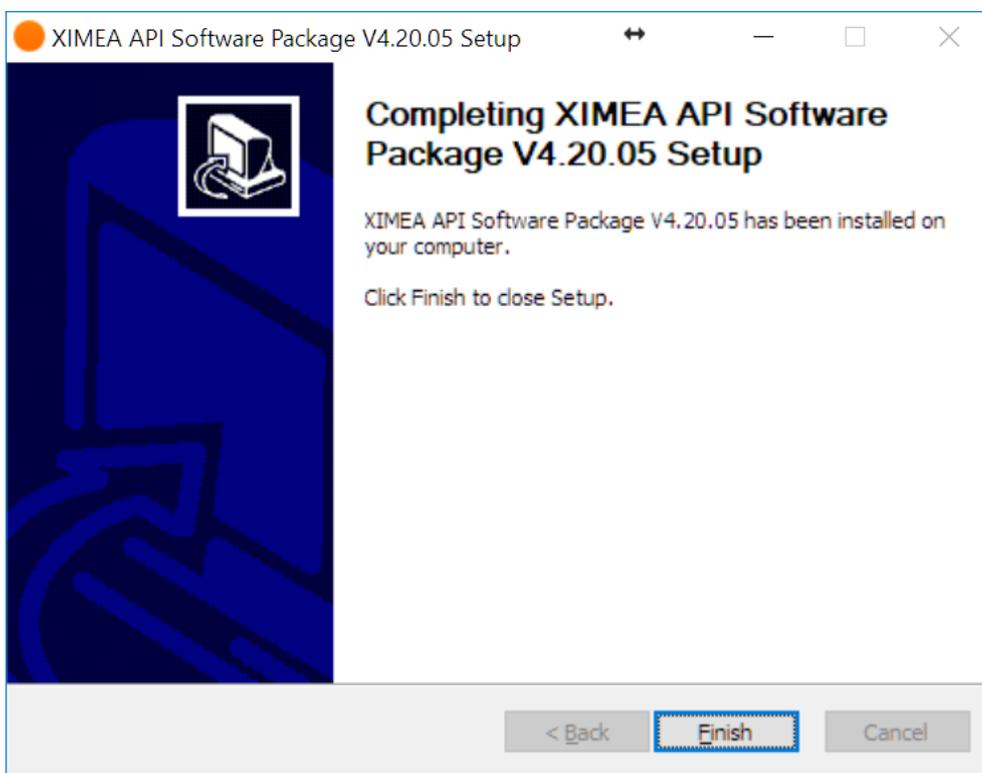


figure 5-6, xiAPI installation, Windows - 5

- Finish.

5.5. XIMEA Linux Software Package

XIMEA Linux Software Package is tarred installer with files that can be run on Linux Ubuntu 14.04 and 16.04 (32 and 64 Bit) and newer releases.

5.5.1. Contents

The package contains:

- Driver (beta version) for XIMEA USB2 and USB3 cameras
- xiAPI
- Ximea CamTool
- Examples:
 - xiSample - sample showing basic image acquisition in xiAPI

5.5.2. Installation

- Download **XIMEA Linux Software Package**

```
wget http://www.ximea.com/downloads/recent/XIMEA_Linux_SP.tgz
```



```
ximea@ximea-Linux64: ~
ximea@ximea-Linux64:~$ wget http://www.ximea.com/downloads/recent/XIMEA_Linux_SP.tgz
--2013-06-05 17:06:29-- http://www.ximea.com/downloads/recent/XIMEA_Linux_SP.tgz
Resolving www.ximea.com (www.ximea.com)... 91.143.80.251
Connecting to www.ximea.com (www.ximea.com)|91.143.80.251|:80... connected.
HTTP request sent, awaiting response... 301 Moved Permanently
Location: http://www.ximea.com/support/attachments/271/XIMEA_Linux_SP.tgz [following]
--2013-06-05 17:06:30-- http://www.ximea.com/support/attachments/271/XIMEA_Linux_SP.tgz
Connecting to www.ximea.com (www.ximea.com)|91.143.80.251|:80... connected.
HTTP request sent, awaiting response... 200 OK
Length: 3885021 (3.7M) [application/octet-stream]
Saving to: `XIMEA_Linux_SP.tgz'

100%[=====>] 3,885,021  2.09M/s  in 1.8s

2013-06-05 17:06:31 (2.09 MB/s) - `XIMEA_Linux_SP.tgz' saved [3885021/3885021]

ximea@ximea-Linux64:~$
```

figure 5-7, XIMEA Linux Software Package installation - 1

- Untar


```
tar xzf XIMEA_Linux_SP.tgz
cd package
```
- Start installation script


```
./install
```

```
ximea@ximea-Linux64: ~/package
ximea@ximea-Linux64:~$ tar xzf XIMEA_Linux_SP.tgz
ximea@ximea-Linux64:~$ cd package
ximea@ximea-Linux64:~/package$ ./install -cam_usb30
This will install XIMEA Linux Package after 5 seconds
To abort installation - press Ctrl-C
Installing x64 bit version
[sudo] password for ximea:
This is installation of package for platform -x64
Checking if user is super user
OK
-----
WARNING!!!
You have enabled experimental USB3 support! It may affect USB2 support too.
DO NOT downgrade the kernel to versions older than 3.4!!!
Advised way of enabling USB3 support is upgrading kernel to version at least as new as 3.6.
If you decide to do it in the future, rerun this installation script after rebooting into new kernel.
-----
Installing libusb
OK
Installing Firewire support - libraw1394
OK
Checking Firewire stack

Installing API library
OK
OK
OK

Rebuilding linker cache
Installing XIMEA-GenTL library
OK
Installing vaViewer
OK
Installing streamViewer
OK
Installing xiSample
OK
Creating desktop link for vaViewer
Creating desktop link for streamViewer
Installing udev rules for USB and Firewire cameras
OK
-----
Note:
You may need to reconnect your USB and/or Firewire cameras
Also check that you are in the "plugdev" group

More info:
http://www.ximea.com/support/wiki/apis/Linux_USB20_Support
-----
For GeniCam - please add GENICAM_GENTL64_PATH=/opt/XIMEA/lib/libXIMEA_GenTL.so to Your .bashrc to enable GenTL
Now applications can be started. E.g. /opt/XIMEA/bin/xiSample
-----
Done OK
ximea@ximea-Linux64:~/package$
```

figure 5-8, XIMEA Linux Software Package installation - 2

- 1) **Note:** If logged in user is not root, you will be asked for your password to get root access, because the installation runs with root account using *sudo*.

5.6. XIMEA macOS Software Package

XIMEA macOS Software Package is native DMG installer that can be run on macOS 10.8 (Mountain Lion) or newer.

5.6.1. Contents

The package contains:

- Driver (beta version) for XIMEA USB2 and USB3 cameras
- xiAPI
- XIMEA CamTool
- Examples:
 - xiSample - sample showing basic image acquisition in xiAPI

5.6.2. Installation

Before installing XIMEA macOS Software Package it may be necessary to modify security settings on your computer. The new feature of OS X 10.8 called GateKeeper can prevent you from using our macOS Software Package due to the fact that the current version is unsigned.

Open System Preferences application and click on Security & Privacy.



figure 5-9, XIMEA macOS Software Package installation - 1

On the General Tab select the option Anywhere under Allow applications downloaded from:



figure 5-10, xiAPI installation, MacOS - 2

- Download XIMEA macOS Software. Package: http://www.ximea.com/downloads/recent/XIMEA_OSX_SP.dmg
- Mount it by double-clicking this file in Finder.
- Run the install script to install XiAPI on your macOS system
- A window with package contents will open.

5.6.3. Start XIMEA CamTool

- Connect camera
- Start Applications / XIMEA CamTool
- Start acquisition by clicking on orange triangle at upper left corner of CamTool

5.7. Programming

5.7.1. XIMEA APIs

- **xiAPI** - Streamlined API. The standard API for C/C++ based projects, see [5.7.2 xiAPI Overview](#).
- **xiAPI.NET** - Managed .NET Common Language Runtime (CLR) API.
xiAPI.NET is designed as a wrapper around xiAPI and therefore shares most of its functionality.
- **xiApiPython** – Integrated API into PYTHON.

5.7.2. xiAPI Overview

xiAPI stands for XIMEA Application Programming Interface. It is a common interface for all XIMEA cameras.

Architecture

API is a software interface between the camera system driver and application.

- On Windows: xiAPI is compiled into xiapi32.dll or xiapi64.dll
- On Linux: xiAPI is compiled into /usr/lib/libm3api.so

Installation

xiAPI is part of all current XIMEA software packages for Windows, Linux and MacOS.

For information on the software packages, see 5 Software

5.7.3. xiAPI Functions Description

The core of xiAPI consists of the following functions, which allow controlling of the camera functionality.

```
// get the number of discovered devices.
XI_RETURN xiGetNumberDevices(OUT DWORD *pNumberDevices);

// open interface
XI_RETURN xiOpenDevice(IN DWORD DevId, OUT PHANDLE hDevice);

// get parameter
XI_RETURN xiGetParam(IN HANDLE hDevice, const char* prm, void* val,
DWORD * size, XI_PRM_TYPE * type);

// set parameter
XI_RETURN xiSetParam(IN HANDLE hDevice, const char* prm, void* val,
DWORD size, XI_PRM_TYPE type);

// start the data acquisition
XI_RETURN xiStartAcquisition(IN HANDLE hDevice);

// acquire image and return image information
XI_RETURN xiGetImage(IN HANDLE hDevice, IN DWORD TimeOut, INOUT XI_IMG
* img);

// stop the data acquisition
XI_RETURN xiStopAcquisition(IN HANDLE hDevice);

// close interface
XI_RETURN xiCloseDevice(IN HANDLE hDevice);
```

5.7.4. xiAPI Parameters Description

For a complete list of available parameter, please visit the xiAPI online manual at http://www.ximea.com/support/wiki/apis/XiAPI_Manual

Note: Since xiAPI is a unified programming interface for all of XIMEA's cameras, not all of the described parameters apply for every camera and sensor model.

All functions in xiAPI return status values in form of the *XI_RETURN* structure which is defined in *xiApi.h*. If a parameter is not supported by a certain camera, the return value will represent a respective error code (e.g. *106 - Parameter not supported*).

5.7.5. xiAPI Examples

5.7.5.1. Connect Device

This example shows the enumeration of available devices. If any device was found the first device (with index 0) is opened.

```
HANDLE xiH = NULL;

// Get number of camera devices
DWORD dwNumberOfDevices = 0;
xiGetNumberDevices(&dwNumberOfDevices);

if (!dwNumberOfDevices)
{
    printf("No camera found\n");
}
else
{
    // Retrieving a handle to the camera device
    xiOpenDevice(0, &xiH);
}
```

5.7.5.2. Parameterize Device

This example shows how an exposure time is set. Next, the maximum possible downsampling rate is retrieved and the result is set as new downsampling rate.

```
// Setting "exposure" parameter (10ms)
int time_us = 10000;
xiSetParam(xiH, XI_PRM_EXPOSURE, &time_us, sizeof(time_us),
xiTypeInteger);

// Getting maximum possible downsampling rate
int dspl_max = 1;
xiGetParamInt(xiH, XI_PRM_DOWNSAMPLING XI_PRM_INFO_MAX, &dspl_max);

// Setting maximum possible downsampling rate
xiSetParamInt(xiH, XI_PRM_DOWNSAMPLING, dspl_max);
```

5.7.5.3. Acquire Images

This example shows how the acquisition is started on the device with the handle xiH, ten images are acquired in a row and the acquisition is stopped.

```
xiStartAcquisition(xiH);

#define EXPECTED_IMAGES 10
for (int images=0;images < EXPECTED_IMAGES;images++)
{
    // getting image from camera
    xiGetImage(xiH, 5000, &image);
    printf("Image %d (%dx%d) received from camera\n", images,
        (int)image.width, (int)image.height);
}
xiStopAcquisition(xiH);
```

5.7.5.4. Control Digital Input / Output (GPIO)

Hardware Trigger and Exposure Active output

In this setup each image is triggered by a Digital Input Trigger. After the image is triggered, it can be transferred using xiGetImage.

This setup ensures a low latency between the trigger signal and image Exposure start. This time should be less than 10 μ s.

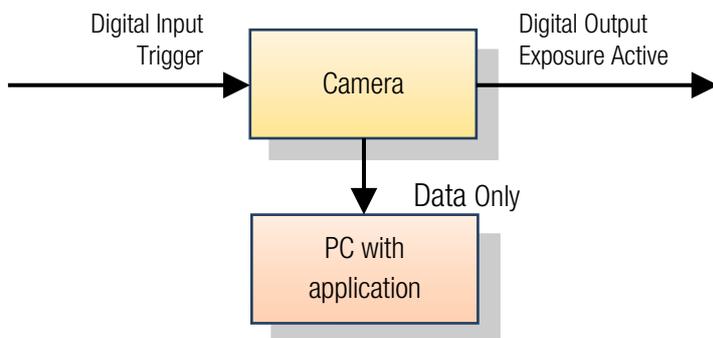


figure 5-11, GPIO - schematic

```
HANDLE xiH;
xiOpenDevice(0, & xiH);

// select trigger source
xiSetParamInt(xiH, XI_PRM_TRG_SOURCE, XI_TRG_EDGE_RISING);

// select input pin 1 mode
xiSetParamInt(xiH, XI_PRM_GPI_SELECTOR, 1);
xiSetParamInt(xiH, XI_PRM_GPI_MODE, XI_GPI_TRIGGER)

// set digital output 2 mode
xiSetParamInt(xiH, XI_PRM_GPO_SELECTOR, 2);
xiSetParamInt(xiH, XI_PRM_GPO_MODE, XI_GPO_EXPOSURE_ACTIVE);

xiStartAcquisition(handle1);

// Trigger signal should start image exposure within timeout
#define TIMEOUT_IMAGE_WAITING_MS 10000
xiGetImage(handle, TIMEOUT_IMAGE_WAITING_MS, &image);
// process image here..
```

5.7.6. xiAPI Auto Bandwidth Calculation

xiAPI uses Auto Bandwidth Calculation (ABC) before the opening of each camera by default. After the measurement, 90% of the measured value is used as the maximum allowed transfer speed of the camera to ensure the stability of transfer.

It is important to set this parameter to XI_OFF to ensure highest possible data transfer speed.

To disable ABC, the application should set parameter XI_PRM_AUTO_BANDWIDTH_CALCULATION to XI_OFF before the first xiOpenDevice is used. This setting disabled ABC and the camera stream is not limited.

5.7.7. GenICam

For more information on programming according the GenICam standard, please visit the standard's website at <http://www.emva.org/standards-technology/genicam/>

5.8. XIMEA Control Panel

The XIMEA Control Panel, or short xiCOP, is a diagnostics and management tool for all XIMEA cameras. xiCOP is currently only available for Windows operating system.

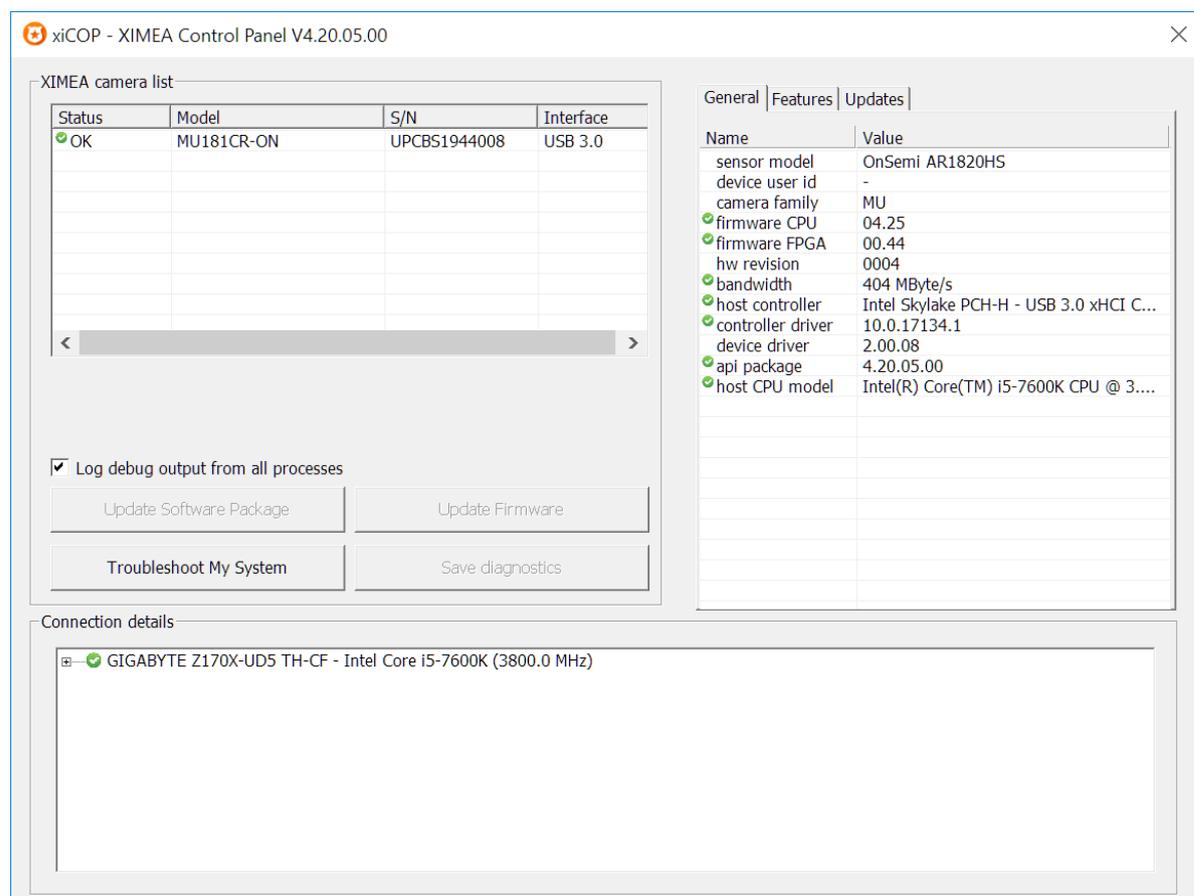


figure 5-12, xiCOP

Features

- Facilitates diagnostics of system performance bottlenecks. xiCOP is capable of retrieving the system's hardware tree, thus problematic hardware configurations can be identified.
- Diagnosis of firmware and software compatibility. xiCOP checks relevant firmware and software versions and warns if a component is not up-to-date.
- List all currently attached XIMEA devices and their features.
- Suggests solution for diagnosed issues.
- One click update to the latest XIMEA API Software Package.
- One click update of firmware in selected cameras. (not applicable for MU9)

6. Appendix

6.1. Troubleshooting and Support

This chapter explains how to proceed, if you have issues in getting your xiMU camera to a proper operation. At first, please make sure, that you have installed the latest version of the following XIMEA software:

- **XIMEA API Software Package** http://www.ximea.com/downloads/recent/XIMEA_Installer.exe

Please make sure, that you have connected your xiMU camera with the XIMEA USB 2.0 cable to an appropriate USB 2.0 or USB 3.0 port. Ensure that the connections are carefully locked. Follow the instructions described in chapter [5.2 XIMEA CamTool](#) (run the xiMU camera with the Ximea CamTool). In case that you still have issues, please read the following chapters. If this does not at first work, please check all your connections to the camera and then try the latest 'beta' version of API with the most recent fixes: https://www.ximea.com/downloads/recent_beta/XIMEA_Installer.exe

In case that you still have issues, please read the following chapters.

6.1.1. Worldwide Support

We offer worldwide first level support to you by our partners.

Please refer to your local dealer if you need technical support for your xiMU camera.

6.1.2. Before Contacting Technical Support

There are a few steps to take before contacting your local dealer for technical support. In case you cannot display images from your xiMU camera, please open the XIMEA xiCOP software (please see [5.8 XIMEA Control Panel](#)). It will immediately start searching for connected cameras. Your camera will appear in the XIMEA camera list on the upper left side of the xiCOP window if it is connected properly and your USB interface meets the minimum system requirements described in [4.1 System Requirements](#). If the camera does not appear, please proceed with the following steps:

Step no:	Description
1	Click on the button "Troubleshoot My System" and follow the instructions that are suggested.
2	If step 1 does not lead to a positive result, please click the button "Save diagnostics". Keep the diagnostic file ready for providing it to support.
3	Contact your local dealer where you bought the camera either by phone or by email for first level support. He will decide if he can help you immediately or if more information is necessary for initiating the next steps.

table 6-1, use xiCOP before contacting technical support

6.1.3. Frequently Asked Questions

In this manual, we can list only a few FAQ. For more and updated information, please also note:

- **Frequently Asked Questions** http://www.ximea.com/support/wiki/allprod/Frequently_Asked_Questions
- **Knowledge Base** http://www.ximea.com/support/wiki/allprod/Knowledge_Base

6.2. Product service request (PSR)

If you experienced any unexpected behavior of your xiMU camera, please follow the steps described below:

6.2.1. Step 1 - Contact Support

If your xiMU camera is not working as expected, please contact your local dealer for troubleshooting the product and determine the eligibility of a Product Service Request (PSR).

In case you were asked to create a PSR by your local contact, please continue to STEP 2

NOTE: Your product must be UNDER WARRANTY in order to qualify for a free repair or replacement.

6.2.2. Step 2 - Create Product Service Request (PSR)

- Read the **XIMEA General Terms & Conditions** <http://www.ximea.com/en/corporate/generaltc>
- Open the **XIMEA Product Service Request form** <http://www.ximea.com/support/projects/service/issues/new>
- Fill in all fields
- Confirm with the button „Create“

6.2.3. Step 3 - Wait for PSR Approval

Our support personnel will verify the PSR for validity.

If your PSR is valid, it will be approved for sending the camera to us. This is done usually within 24 business hours. After that you will get a PSR Approval email (sent to the email address that you have entered in the field “Contact person – email”).

The email contains:

- shipping instructions
- attached document containing the Product Service Request Number (PSRN)

When you received the PSR Approval email - please continue to Step 4.

In case your PSR was rejected – please do not send your camera to XIMEA.

6.2.4. Step 4 - Sending the camera to XIMEA

If possible, send the camera back in the original package. If not possible, please pack the camera in a way that it cannot be damaged during shipment and send it back as described in the PSR Approval email that you have received.

6.2.5. Step 5 - Waiting for Service Conclusion

Once we have received the camera, we will send you a notification. The XIMEA Service will then check the status of the camera that you have sent for a possible repair. Depending on warranty conditions, product status and agreement one of the following operations will be performed:

Operation	Repair costs paid by	Return delivery costs paid by
repaired in warranty	XIMEA	XIMEA
replaced in warranty	XIMEA	XIMEA
repaired for cost	Customer	Customer
not repaired and returned	-	Customer
not repaired and discarded if requested by customer	-	-

table 6-2, service operations overview

If the camera will be returned, you will receive the tracking number. In this case, please continue to step 6

6.2.6. Step 6 - Waiting for return delivery

After you have received the return shipment, please confirm it by changing the status of the PSR to “Received by customer”.

6.3. Safety instructions and precautions

This chapter describes safety instructions and precautions valid for xiMU cameras and special considerations regarding XIMEA board level cameras. In order to avoid harm or damage your xiMU camera, please handle it like described in this manual, paying special attention to the cautions shown in the following table:

6.3.1. Disassembling

Do not disassemble the camera except lens mount adapters (see [Q MU9 Lens Mount Adapter](#) and [3.3.5 MU181 Lens Mount Adapter](#)).

There are no switches or parts inside the cameras that requires any kind of mechanical adjustment. Please note that the warranty is voided by opening the camera housing.

6.3.2. Mounting / Screwing

Use only the designated threaded holes for mounting the camera. Please note the camera / bracket drawings in sections [3.2.3 Dimensional drawings \(without Lens Mount Adapter\)](#), [3.3.3 Dimensional drawings](#) and [3.2.9 MU-MINIUSB](#).

6.3.3. Connections

Use only recommended connectors and cables. Please check the system requirements described in [4.1 System Requirements](#).

6.3.4. Power supply

Use only the recommended electrical power supply via the USB cable, see [3.1.4 Power Supply](#).
The I/O connection is not usable for powering the camera.

6.3.5. Environment / protect against water

Use camera in acceptable environment only, please note the descriptions in [3.1.1 Environment](#).

Protect the camera against contact with water. Do not let camera get wet.

Damages may be caused by:

- Overheating
- Contact with water
- Operation in an environment with condensing humidity
- Mechanical shock

6.3.6. Recommended light conditions.

Do not expose the camera to light sources with intense energy, e.g. laser beams or X-ray.

Light intensity or exposure time exceeding the saturation of the sensor may damage the sensor irreparably. This may occur e.g. in the following situations:

- High-energy laser light hitting the sensor directly
- Bright light sources hitting the sensor directly (burn-in)
- Camera is exposed to X-rays

The warranty does not cover damaged cameras caused by X-ray applications or too much light / laser light.

6.3.7. Protect the optical components

Do not touch the optical components with hard or abrasive objects.

When handling the camera, avoid touching the lenses and filter glasses. Fingerprints or other impurities may affect the image quality and may damage the surfaces.

Mount / dismount lenses and additional filters only in a dust free environment.

Do not use compressed air as this could push dust into the camera (and lenses).

6.3.8. Mechanical loads

Avoid excessive shaking, throwing, dropping or any kind of mishandling of the device.

6.3.9. Camera / lens cleaning

Please follow instructions described below.

- Use only optical quality tissue / cloth (dry cotton) a standard camera lens cleaning kit, if you must clean a lens or filter. Do not apply excessive force.
- Use only optics cleaner (e.g. 60% ethyl alcohol, 40% ether). Never use aggressive cleaners like gasoline or spirits. Such cleaners may destroy the surface.
- Do not use compressed air.

6.3.10. Protect against static discharge (ESD)

Image sensors and the PCB are easily damaged by static discharge (ESD).

- Please use anti-static gloves, clothes and materials. Also use conductive shoes.
- Wear an ESD protection wrist strap.
- Install a conductive mat on the floor and / or working table to prevent the generation of static electricity.

6.3.11. Safety instructions for board level cameras

Abuse or misapplication of the board level camera may result in limited warranty or cancelation of warranty. Due to the exposed electronics, special rules apply:

- Only qualified personnel is allowed to handle, install and operate the board level cameras.
- Board level cameras are delivered without housing. Handle the PCB and the sensor with care. Do not bend the boards. Do not touch the components or contacts on a board. Hold the board by its edges only.
- Protect the board level camera against static discharge (see [6.3.10 Protect against static discharge \(ESD\)](#)).
- Do not hold any components of your board level cameras against your clothing, even if you are wearing a wrist strap.
- Do not remove the board level camera from its anti-static packaging unless your body is grounded.
- To protect the boards from radiation of other modules or devices a housing or shielding may be required.
- Be sure that the board level camera has no contact to any electrical source before mounting or making connections to the board level camera.
- Do not connect or disconnect any cables or use the board level camera during an electrical storm.
- Avoid any mechanical forces to the board level cameras, especially torsional, tensile and compressive forces. Any of these forces may result in damage of the board level cameras.
- Always use clean boards.
- To protect the boards from dirt like dust or liquids always use the board level cameras in clean room environment or use a protective housing.

6.4. Warranty

In addition to the provisions of Article VIII of the Standard Terms & Conditions of XIMEA GmbH (see [6.7 Standard Terms & Conditions of XIMEA GmbH](#)) the following additions and specifications apply:

XIMEA warrants to the Original Purchaser that the Camera provided is guaranteed to be free from material and manufacturing defects for a period of two years. Should a unit fail during this period, XIMEA will, at its option, repair or replace the damaged unit. Repaired or replaced Products are covered for the remainder of the original Product warranty period.

Please note our explanations regarding the usage and handling of board level cameras and related restrictions of warranty (see [6.3.11 Safety instructions for board level cameras](#)).

Warranty is void if any proprietary labeling is removed. This warranty does not apply to units that, after being examined by XIMEA, have been found to have failed due to customer abuse, mishandling, alteration, improper installation or negligence. If the original camera module is housed within a case, removing the case for any purpose voids this warranty. This warranty does not apply to damage to any part of the optical path resulting from removal or replacement of the protective glass or filter over the camera, such as scratched glass or sensor damage. If the camera is disassembled, reworked or repaired by anyone other than a recommended service person, XIMEA or its suppliers will take no responsibility for the subsequent performance or quality of the camera.

XIMEA expressly disclaims and excludes all other warranties, express, implied and statutory, including, but without limitation, warranty of merchantability and fitness for a particular application or purpose. In no event shall XIMEA be liable to the Original Purchaser or any third party for direct, indirect, incidental, consequential, special or accidental damages, including without limitation damages for business interruption, loss of profits, revenue, data or bodily injury or death except in case of willful misconduct by XIMEA or employees of XIMEA.

6.5. Disclaimer of Warranty

In addition to the provisions of Article XII of the Standard Terms & Conditions of XIMEA GmbH (see [6.7 Standard Terms & Conditions of XIMEA GmbH](#)) the following apply:

Although XIMEA has taken care to ensure the accuracy of the information contained herein it accepts no responsibility for the consequences of any use thereof and also reserves the right to change the specification of goods without notice.

XIMEA does not assume any liability for damage that is the result of improper use of its products or failure to comply with the operating manuals or the applicable rules and regulations.

6.6. List Of Trademarks

XIMEA, xiC xiQ, xiMU, xiB, xiB-64, xiX, xSWITCH, xPLATFORM, xEC, xEC2, xiCool, xiRAY, xiCe, xiSpec, xiFLY, xiD, xiJ, xiLAB, xiAPI, xiCamTool, xiCOP and CURRERA are trademarks or registered trademarks of XIMEA GmbH in Germany, Slovakia, USA and other countries.

Microsoft, Windows, Windows10, Windows8, Windows 7, Windows Vista, and Windows XP are either registered trademarks or trademarks of Microsoft Corporation in the United States and/or other countries. Apple, the Apple logo, Macintosh, MacOS, OS X, Bonjour, the Bonjour logo and the Bonjour symbol are trademarks of Apple Computer, Inc. Linux is a trademark of Linus Torvalds. The USB3 Vision is trademark owned by the AIA.

All other brands, service provision brands and logos referred to are brands, service provision brands and logos belonging to their respective owners.

6.7. Standard Terms & Conditions of XIMEA GmbH

Printed here for your information is the version from May 2021. Please check the most current version at <http://www.ximea.com/en/corporate/generaltc>

General Conditions

for the Supply of Products and Services of the Electrical and Electronics Industry ("Grüne Lieferbedingungen" – GL)*
for commercial transactions between businesses
recommended by ZVEI-Zentralverband Elektrotechnik- und Elektronikindustrie e. V.
as of May 2021 (with 24 months warranty period), and listed below

Article I: General Provisions

1. Legal relations between Supplier and Purchaser in connection with supplies and/or services of the Supplier (hereinafter referred to as "Supplies") shall be solely governed by the present GL. The Purchaser's general terms and conditions shall apply only if expressly accepted by the Supplier in writing. The scope of delivery shall be determined by the congruent mutual written declarations.
2. The Supplier herewith reserves any industrial property rights and/or copyrights and rights of use pertaining to its cost estimates, drawings and other documents (hereinafter referred to as "Documents"). The Documents shall not be made accessible to third parties without the Supplier's prior consent and shall, upon request, be returned without undue delay to the Supplier if the contract is not awarded to the Supplier. Sentences 1 and 2 shall apply mutatis mutandis to the Purchaser's Documents; these may, however, be made accessible to those third parties to whom the Supplier has rightfully subcontracted Supplies.
3. The Purchaser has the non-exclusive right to use standard software and firmware, provided that it remains unchanged, is used within the agreed performance parameters, and on the agreed equipment. Without express agreement the Purchaser may make one back-up copy of standard software.
4. Partial deliveries are allowed, unless they are unreasonable to accept for the Purchaser.
5. The term „claim for damages" used in the present GL also includes claims for indemnification for useless expenditure.

Article II: Prices, Terms of Payment, and Set-Off

1. Prices are ex works and excluding packaging; value added tax shall be added at the then applicable rate.
2. If the Supplier is also responsible for assembly or erection and unless otherwise agreed, the Purchaser shall pay the agreed remuneration and any incidental costs required, e. g. for traveling and transport as well as allowances.
3. Payments shall be made free Supplier's paying office.
4. The Purchaser may set off only those claims which are undisputed or non-appealable.

Article III: Retention of Title

1. The items pertaining to the Supplies ("Retained Goods") for which the purchase price claim is due immediately or for which a payment period of up to and including 30 days after delivery, delivery with installation/assembly or receipt of invoice has been agreed for the due date of the purchase price claim shall remain the property of the Supplier until payment has been made in total.
2. In all other cases, the items pertaining to the Supplies ("Retained Goods") shall remain the Supplier's property until each and every claim the Supplier has against the Purchaser on account of the business relationship has been fulfilled. If the combined value of the Supplier's security interests exceeds the value of all secured claims by more than 20 %, the Supplier shall release a corresponding part of the security interest if so requested by the Purchaser; the Supplier shall be entitled to choose which security interest it wishes to release.
3. For the duration of the retention of title, the Purchaser may not pledge the Retained Goods or use them as security, and resale shall be possible only for resellers in the ordinary course of their business and only on condition that the reseller receives payment from its customer or makes the transfer of property to the customer dependent upon the customer fulfilling its obligation to effect payment.

4. Should Purchaser resell Retained Goods, it assigns to the Supplier, already today, all claims it will have against its customers out of the resale, including any collateral rights and all balance claims, as security, without any subsequent declarations to this effect being necessary. If the Retained Goods are sold on together with other items and no individual price has been agreed with respect to the Retained Goods, Purchaser shall assign to the Supplier such fraction of the total price claim as is attributable to the price of the Retained Goods invoiced by Supplier.

5. (a) Purchaser may process, amalgamate or combine Retained Goods with other items. Processing is made for Supplier. Purchaser shall store the new item thus created for Supplier, exercising the due care of a diligent business person. The new items are considered as Retained Goods.

(b) Already today, Supplier and Purchaser agree that if Retained Goods are combined or amalgamated with other items that are not the property of Supplier, Supplier shall acquire co-ownership in the new item in proportion of the value of the Retained Goods combined or amalgamated to the other items at the time of combination or amalgamation. In this respect, the new items are considered as Retained Goods.

(c) The provisions on the assignment of claims according to No. 4 above shall also apply to the new item. The assignment, however, shall only apply to the amount corresponding to the value invoiced by Supplier for the Retained Goods that have been processed, combined or amalgamated.

(d) Where Purchaser combines Retained Goods with real estate or movable goods, it shall, without any further declaration being necessary to this effect, also assign to Supplier as security its claim to consideration for the combination, including all collateral rights for the prorata amount of the value the combined Retained Goods have on the other combined items at the time of the combination.

6. Until further notice, Purchaser may collect assigned claims relating to the resale. Supplier is entitled to withdraw Purchaser's permission to collect funds for good reason, including, but not limited to delayed payment, suspension of payments, start of insolvency proceedings, protest or justified indications for overindebtedness or pending insolvency of Purchaser. In addition, Supplier may, upon expiry of an adequate period of notice disclose the assignment, realize the claims assigned and demand that Purchaser informs its customer of the assignment.

7. The Purchaser shall inform the Supplier forthwith of any seizure or other act of intervention by third parties. If a reasonable interest can be proven, Purchaser shall, without undue delay, provide Supplier with the information and/or Documents necessary to assert the claims it has against its customers.

8. Where the Purchaser fails to fulfill its duties, fails to make payment due, or otherwise violates its obligations the Supplier shall be entitled to rescind the contract and take back the Retained Goods in the case of continued failure following expiry of a reasonable remedy period set by the Supplier; the statutory provisions providing that a remedy period is not needed shall be unaffected. The Purchaser shall be obliged to return the Retained Goods. The fact that the Supplier takes back Retained Goods and/or exercises the retention of title, or has the Retained Goods seized, shall not be construed to constitute a rescission of the contract, unless the Supplier so expressly declares.

Article IV: Time for Supplies; Delay

1. Times set for Supplies shall only be binding if all Documents to be furnished by the Purchaser, necessary permits and approvals, especially concerning plans, are received in time and if agreed terms of payment and other obligations of the Purchaser are fulfilled. If these conditions are not fulfilled in time, times set shall be extended reasonably; this shall not apply if the Supplier is responsible for the delay.

2. If non-observance of the times set is due to:

(a) force majeure, such as mobilization, war, terror attacks, rebellion or similar events (e. g. strike or lockout);

(b) virus attacks or other attacks on the Supplier's IT systems occurring despite protective measures were in place that complied with the principles of proper care;

(c) hindrances attributable to German, US or otherwise applicable national, EU or international rules of foreign trade law or to other circumstances for which Supplier is not responsible; or

(d) the fact that Supplier does not receive its own supplies in due time or in due form such times shall be extended accordingly.

3. If the Supplier is responsible for the delay (hereinafter referred to as "Delay") and the Purchaser has demonstrably suffered a loss therefrom, the Purchaser may claim a compensation as liquidated damages of 0.5 % for every completed week of Delay, but

in no case more than a total of 5 % of the price of that part of the Supplies which due to the Delay could not be put to the intended use.

4. Purchaser's claims for damages due to delayed Supplies as well as claims for damages in lieu of performance exceeding the limits specified in No. 3 above are excluded in all cases of delayed Supplies, even upon expiry of a time set to the Supplier to effect the Supplies. This shall not apply in cases of liability based on intent, gross negligence, or due to loss of life, bodily injury or damage to health. Rescission of the contract by the Purchaser based on statute is limited to cases where the Supplier is responsible for the delay. The above provisions do not imply a change in the burden of proof to the detriment of the Purchaser.
5. At the Supplier's request, the Purchaser shall declare within a reasonable period of time whether it, due to the delayed Supplies, rescinds the contract or insists on the delivery of the Supplies.
6. If dispatch or delivery, due to Purchaser's request, is delayed by more than one month after notification of the readiness for dispatch was given, the Purchaser may be charged, for every additional month commenced, storage costs of 0.5 % of the price of the items of the Supplies, but in no case more than a total of 5 %. The parties to the contract may prove that higher or, as the case may be, lower storage costs have been incurred.

Article V: Passing of Risk

1. Even where delivery has been agreed freight free, the risk shall pass to the Purchaser as follows:
 - (a) if the delivery does not include assembly or erection, at the time when it is shipped or picked up by the carrier. Upon the Purchaser's request, the Supplier shall insure the delivery against the usual risks of transport at the Purchaser's expense;
 - (b) if the delivery includes assembly or erection, at the day of taking over in the Purchaser's own works or, if so agreed, after a successful trial run.
2. The risk shall pass to the Purchaser if dispatch, delivery, the start or performance of assembly or erection, the taking over in the Purchaser's own works, or the trial run is delayed for reasons for which the Purchaser is responsible or if the Purchaser has otherwise failed to accept the Supplies.

Article VI: Assembly and Erection

Unless otherwise agreed in written form, assembly and erection shall be subject to the following provisions:

1. Purchaser shall provide at its own expense and in due time:
 - (a) all earth and construction work and other ancillary work outside the Supplier's scope, including the necessary skilled and unskilled labor, construction materials and tools;
 - (b) the equipment and materials necessary for assembly and commissioning such as scaffolds, lifting equipment and other devices as well as fuels and lubricants;
 - (c) energy and water at the point of use including connections, heating and lighting;
 - (d) suitable dry and lockable rooms of sufficient size adjacent to the site for the storage of machine parts, apparatus, materials, tools, etc. and adequate working and recreation rooms for the erection personnel, including sanitary facilities as are appropriate in the specific circumstances; furthermore, the Purchaser shall take all measures it would take for the protection of its own possessions to protect the possessions of the Supplier and of the erection personnel at the site;
 - (e) protective clothing and protective devices needed due to particular conditions prevailing on the specific site.
2. Before the erection work starts, the Purchaser shall unsolicitedly make available any information required concerning the location of concealed electric power, gas and water lines or of similar installations as well as the necessary structural data.
3. Prior to assembly or erection, the materials and equipment necessary for the work to start must be available on the site of assembly or erection and any preparatory work must have advanced to such a degree that assembly or erection can be started as agreed and carried out without interruption. Access roads and the site of assembly or erection must be level and clear.
4. If assembly, erection or commissioning is delayed due to circumstances for which the Supplier is not responsible, the Purchaser shall bear the reasonable costs incurred for idle times and any additional traveling expenditure of the Supplier or the erection personnel.
5. The Purchaser shall attest to the hours worked by the erection personnel towards the Supplier at weekly intervals and the Purchaser shall immediately confirm in written form if assembly, erection or commissioning has been completed.

6. If, after completion, the Supplier demands acceptance of the Supplies, the Purchaser shall comply therewith within a period of two weeks. The same consequences as upon acceptance arise if and when the Purchaser lets the two-week period expire or the Supplies are put to use after completion of agreed test phases, if any.

Article VII: Receiving Supplies

The Purchaser shall not refuse to receive Supplies due to minor defects.

Article VIII: Defects as to Quality

The Supplier shall be liable for defects as to quality ("Sachmängel", hereinafter referred to as "Defects",) as follows:

1. Defective parts or defective services shall be, at the Supplier's discretion, repaired, replaced or provided again free of charge, provided that the reason for the Defect had already existed at the time when the risk passed.

2. Claims for repair or replacement are subject to a statute of limitations of 24 months calculated from the start of the statutory statute of limitations; the same shall apply mutatis mutandis in the case of rescission and reduction. This shall not apply:

- where longer periods are prescribed by law according to Sec. 438 para. 1 No. 2 (buildings and things used for a building), and Sec. 634a para. 1 No. 2 (defects of a building) German Civil Code ("Bürgerliches Gesetzbuch"),

- in the case of intent,

- in the case of fraudulent concealment of the Defect or

- non-compliance with guaranteed characteristic ("Beschaffenheitsgarantie").

Claims for the reimbursement of expenses on the part of the Purchaser in accordance with Sec. 445a BGB (entrepreneur's right of recourse) shall likewise be subject to a statute of limitations of 24 months from the start of the statutory statute of limitations, provided the last contract in the supply chain is not a sale of consumer goods. The legal provisions regarding suspension of the statute of limitations ("Ablaufhemmung", "Hemmung") and recommencement of limitation periods shall be unaffected.

3. Notifications of Defect by the Purchaser shall be given in written form without undue delay.

4. In the case of claims for Defects, the Purchaser may withhold payments to an amount that is in a reasonable proportion to the Defect. The Purchaser has no right to withhold payments to the extent that its claim of a Defect is time-barred. Unjustified notifications of Defect shall entitle the Supplier to demand reimbursement of its expenses by the Purchaser.

5. The Supplier shall be given the opportunity to repair or to replace the defective good ("Nacherfüllung") within a reasonable period of time.

6. If repair or replacement is unsuccessful, the Purchaser is entitled to rescind the contract or reduce the remuneration; any claims for damages the Purchaser may have according to No. 10 shall be unaffected.

7. There shall be no claims based on Defect in cases of insignificant deviations from the agreed quality, of only minor impairment of usability, of natural wear and tear, or damage arising after the passing of risk from faulty or negligent handling, excessive strain, unsuitable equipment, defective civil works, inappropriate foundation soil, or claims based on particular external influences not assumed under the contract, or from non-reproducible software errors. Claims based on defects attributable to improper modifications, installation/ removal, or repair work carried out by the Purchaser or third parties and the consequences thereof are likewise excluded.

8. The Purchaser shall have no claim with respect to expenses incurred in the course of supplementary performance, to the extent that expenses are increased because the subjectmatter of the Supplies has subsequently been brought to another location than the Purchaser's branch office, unless doing so complies with the normal use of the Supplies. This applies accordingly to claims for the reimbursement of expenses on the part of the Purchaser in accordance with Sec. 445a BGB (entrepreneur's right of recourse), provided the last contract in the supply chain is not a sale of consumer goods.

9. The Purchaser's right of recourse against the Supplier pursuant Sec. 445a BGB (entrepreneur's right of recourse) is limited to cases where the Purchaser has not concluded an agreement with its customers exceeding the scope of the statutory provisions governing claims based on Defects.

10. The Purchaser shall have no claim for damages based on Defects. This shall not apply to the extent that a Defect has been fraudulently concealed, the guaranteed characteristics are not complied with, in the case of loss of life, bodily injury or damage to health, and/or intentionally or grossly negligent breach of contract on the part of the Supplier. The above provisions do not imply a

change in the burden of proof to the detriment of the Purchaser. Any other or additional claims of the Purchaser exceeding the claims provided for in this Article VIII, based on a Defect, are excluded.

Article IX: Industrial Property Rights and Copyrights; Defects in Title

1. Unless otherwise agreed, the Supplier shall provide the Supplies in the country of the place of delivery only, without infringing any third-party industrial property rights and copyrights (hereinafter referred to as "IPR"). If a third party asserts a justified claim against the Purchaser based on an infringement of an IPR by the Supplies made by the Supplier and used in conformity with the contract, the Supplier shall be liable to the Purchaser within the time period stipulated in Article VIII No. 2 as follows:

(a) The Supplier shall choose whether to acquire, at its own expense, the right to use the IPR with respect to the Supplies concerned or whether to modify the Supplies such that they no longer infringe the IPR or replace them. If this would be impossible for the Supplier under reasonable conditions, the Purchaser may rescind the contract or reduce the remuneration pursuant to the applicable statutory provisions;

(b) The Supplier's liability to pay damages is governed by Article XII;

(c) The above obligations of the Supplier shall apply only if the Purchaser (i) immediately notifies the Supplier of any such claim asserted by the third party in written form, (ii) does not concede the existence of an infringement and (iii) leaves any protective measures and settlement negotiations to the Supplier's discretion. If the Purchaser stops using the Supplies in order to reduce the damage or for other good reason, it shall be obliged to point out to the third party that no acknowledgement of the alleged infringement may be inferred from the fact that the use has been discontinued.

2. Claims of the Purchaser shall be excluded if it is responsible for the infringement of an IPR.

3. Claims of the Purchaser are also excluded if the infringement of the IPR is caused by specifications made by the Purchaser, by a type of use not foreseeable by the Supplier or by the Supplies being modified by the Purchaser or being used together with products not provided by the Supplier.

4. In addition, with respect to claims by the Purchaser pursuant to No. 1 a) above, Article VIII Nos. 4, 5, 8, and 9 shall apply *mutatis mutandis* in the event of an infringement of an IPR.

5. Where other defects in title occur, Article VIII shall apply *mutatis mutandis*.

6. Any other claims of the Purchaser against the Supplier or its agents or any such claims exceeding the claims provided for in this Article IX, based on a defect in title, are excluded.

Article X: Conditional Performance

1. The performance of this contract is conditional upon that no hindrances attributable to German, US or otherwise applicable national, EU or international rules of foreign trade law or any embargos or other sanctions exist.

2. The Purchaser shall provide any information and Documents required for export, transport and import purposes.

Article XI: Impossibility of Performance; Adaptation of Contract

1. To the extent that delivery is impossible, the Purchaser is entitled to claim damages, unless the Supplier is not responsible for the impossibility. The Purchaser's claim for damages is, however, limited to an amount of 10 % of the value of the part of the Supplies which, owing to the impossibility, cannot be put to the intended use. This limitation shall not apply in the case of liability based on intent, gross negligence or loss of life, bodily injury or damage to health; this does not imply a change in the burden of proof to the detriment of the Purchaser. The Purchaser's right to rescind the contract shall be unaffected.

2. Where events within the meaning of Article IV No. 2 (a) to (c) substantially change the economic importance or the contents of the Supplies or considerably affect the Supplier's business, the contract shall be adapted taking into account the principles of reasonableness and good faith. To the extent this is not justifiable for economic reasons, the Supplier shall have the right to rescind the contract. The same applies if required export permits are not granted or cannot be used. If the Supplier intends to exercise its right to rescind the contract, it shall notify the Purchaser thereof without undue delay after having realized the repercussions of the event; this shall also apply even where an extension of the delivery period has previously been agreed with the Purchaser.

Article XII: Other Claims for Damages

1. Unless otherwise provided for in the present GL, the Purchaser has no claim for damages based on whatever legal reason, including infringement of duties arising in connection with the contract or tort.

2. This does not apply if liability is based on:

- (a) the German Product Liability Act ("Produkthaftungsgesetz");
- (b) intent;
- (c) gross negligence on the part of the owners, legal representatives or executives;
- (d) fraud;
- (e) failure to comply with a guarantee granted;
- (f) negligent injury to life, limb or health; or
- (g) negligent breach of a fundamental condition of contract ("wesentliche Vertragspflichten").

However, claims for damages arising from a breach of a fundamental condition of contract shall be limited to the foreseeable damage which is intrinsic to the contract, provided that no other of the above case applies.

3. The above provision does not imply a change in the burden of proof to the detriment of the Purchaser.

Artikel XIII: Venue and Applicable law

1. If the Purchaser is a businessman, sole venue for all disputes arising directly or indirectly out of the contract shall be the Supplier's place of business. However, the Supplier may also bring an action at the Purchaser's place of business.

2. This contract and its interpretation shall be governed by German law, to the exclusion of the United Nations Convention on contracts for the International Sale of Goods (CISG).

Article XIV: Severability Clause

The legal invalidity of one or more provisions of this Agreement in no way affects the validity of the remaining provisions. This shall not apply if it would be unreasonably onerous for one of the parties to be obligated to continue the contract.

6.8. Copyright

All texts, pictures and graphics are protected by copyright and other laws protecting intellectual property. It is not permitted to copy or modify them for trade use or transfer, nor may they be used on websites.

6.9. Revision History

Version	Date	Notes
1.00	07/26/2013	Initial version
1.20	05/05/2015	Corrected wrong information, added IO signaling
1.21	10/10/2015	Minor changes in specification
1.22	12/01/2016	Corrected typos
1.23	01/25/2017	Corrected typos
1.24	03/28/2017	Updated specification
1.25	04/18/2017	Software chapter review
1.26	08/31/2017	Added chapter 3.5 Heat Dissipation
1.27	08/21/2018	Added accessories ADPT-MU9P-USB2-UB-V
1.28	09/06/2019	IO naming changed (removed RX/TX names) - UART is not supported Corrected operating conditions.
2.01	08/13/2020	Added USB3.1 Gen1 camera family
2.10	06/02/2021	Corrected: MU9 scope of delivery. Chapter 6.7 (T&C) Replaced with latest version Part-number MU9 lens adapters corrected

7. Glossary

Term /Abbreviation	Definition
ADC	Analog to Digital Converter
API	Application Programming Interface
AR (coating)	Anti-Reflex
B/W or B&W	Black and White
CCD	Charge-Coupled Device
CDS	Correlated double sampling
CMOS	Complementary Metal Oxide Semiconductor
DNC	Do not connect
DSNU	Dark Signal non-Uniformity
DR	Dynamic Range
EMC	Electro Magnetic Compatibility
ERS	Electronic rolling shutter
FPN	Fixed pattern noise
FPS	Frame per second
FWC	Full Well Capacity
GR	Global reset
GS	Global shutter
IR	Infra-Red
JTAG	Joint Test Action Group
LSB	Least Significant Bit
MIMR	Multiple integration multiple ROI
MSB	Most significant bit
MSL	Moisture sensitivity level
NA	Not Available
PCB	Printed Circuit Board (same as PWB)
PGA	Programmable gain amplifier
PRNU	Photo response non-uniformity
PWB	Printed Wiring Board (same as PCB)
RGB	Red Green Blue
ROI	Region of interest
Sat	Saturation value
SDK	Software Development Kit
SIMR	Single integration multiple ROI
SNR	Signal To Noise (ratio)
SPI	Serial peripheral interface
SW	Software
T _{int}	Integration time

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