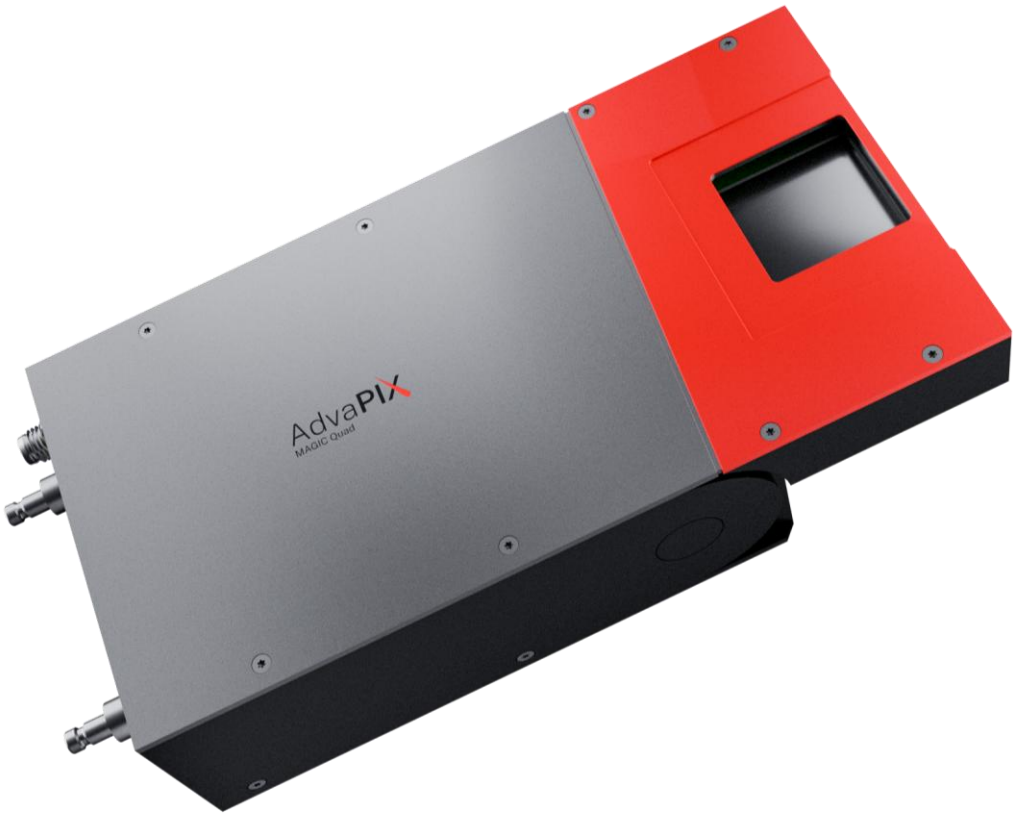
ADVACAM
Imaging the Unseen

AdvaPIX
MAGIC Quad

Model No.: A3QxHx-Xxx220308



Datasheet

General features

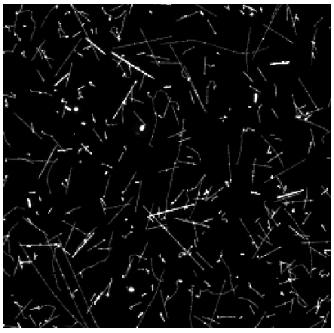


Illustration of single particle sensitivity of Timepix3 detector. The tracks of different particles of radiation background (mostly muons and few protons) were recorded in 5 minutes on board of an airplane. No noise (clean zero) is seen in the dark regions.

A precise and fast particle-tracking detector with four CERN Timepix3 chips, the **AdvaPIX MAGIC Quad** delivers superior spatial resolution, timing performance, and ionizing-radiation detection capabilities. The matrix has **512 × 512 pixels** and can also be modify with a central hole for a direct high-energy primary X-ray beam. The mechanical design of the housing and internal electronics allows safe operation even with intense high-energy X-ray beams without damaging the device

The four Timepix3 chips together provide a fast, combined data throughput of more than **47 Mhits/s** in continuous data-driven mode. Recording the shapes of individual hits, combined with advanced data-processing methods, makes it possible to reach spatial resolutions of a few micrometers and even sub-micrometer precision for ions. Sensor material **Si** or **CdTe** and thickness are selectable according to application needs. USB 3.0 channel ensures fast read-out of the whole system. Typical and intended applications include:

- **Spectral X-ray imaging:** XRF imaging, low-flux radiography, scintigraphy/SPECT, and isotope-based radiography.
- **Energy-dispersive XRD, SAXS, WAXS:** No monochromatic X-ray source required; suitable for high-energy measurements up to ~100 keV for thick samples.
- **Particle tracking and ion-beam monitoring:** For tracking primary particles (e.g., ions) and secondary radiation such as fragments, recoils, bremsstrahlung, prompt/delayed decays, and neutrons. [1]
- **Neutron imaging:** The sensors can be adapted for neutron imaging by deposition of converter layers. [2]

Main Features

- Readout chip type..... Timepix3
- Pixel size[3]..... 55 x 55 µm^2
- Sensor resolution[4] ..... 512 x 512 pixels
- Time resolution..... 1,6 ns
- Power..... External 12 V
- Sensor material..... 100, 300, 500 µm Si, 1000 µm CdTe
- Dark current..... none
- Interface ..... USB 3.0 (SuperSpeed)
- Maximum readout speed..... 47 million pixels/s
- Dimensions ..... 210 x 94 x 38 mm
- Weight..... 905 g

[1] The device is not certified dosimeter. It serves as the first level indicator and monitor of radiation fields allowing identification of a radiation type. Radiation protection of people cannot be based on measurements with this device.

[2] Convertors based on ^{6}LiF or $^{10}B_4C$ for slow neutrons (efficiency up to 4%) or PE for fast neutrons.

[3] 55 x 110 µm^2 at the edges and 110 x 110 µm^2 at the corners.

[4] variant without the hole

Device parameters

Operation conditions

Symbol	Parameter	Value	Units	Comment
T_a	Operating ambient temperature range[1]	0-50	°C	
Φ	Humidity	< 80	%	Not condensing
IP	IP rating with cover	IP40		
IP	IP rating without cover	IP10		

[1] With temperature stabilization – see the paragraph below.

Water cooling interface

Temperature stabilization of the device is required when in operation. The temperature should be set to 22 °C. **AdvaPIX MAGIC** uses water connectors that allow for quick disconnection/reconnection. Mating connector is included as standard accessories and must be attached to 4x6 mm plastic hose.

Temperature of the cooling water must be within range 22 ± 4 °C.
Max. pressure in the water-cooling system: 1,2 bar.
The device will automatically shut down after chip or CPU temperature exceeds 55 °C.
Intended for dust free indoor use.

Electrical specification

T_a = 22 °C

Symbol	Parameter	Min	Typ	Max	Units	Comment
V_{CC}	Supply Voltage	11	12	13	V	
I_{CC}	Supply Current		1	2,4	A	
P1	Power Dissipation		12	25	W	
I/O Conn. Input LVDS[2]						
V_{IN}	Voltage Range	0		2,5	V	
V_{INDIFF}	Differential Voltage	250		600	mV	
I/O Conn. +5 V (pin 8)						
I_{MAX}	Maximum current	0		0,05	A	
V_{+5V}	Pin Voltage	4,5	5		V	
Bias Voltage Source for Sensor Diode						
V_{BIAS}	Bias Voltage	0		-450 to +150	V	Polarity is sensor dependent

[2] With mandatory external terminator

Chip parameters

T_{dev} = 22 °C

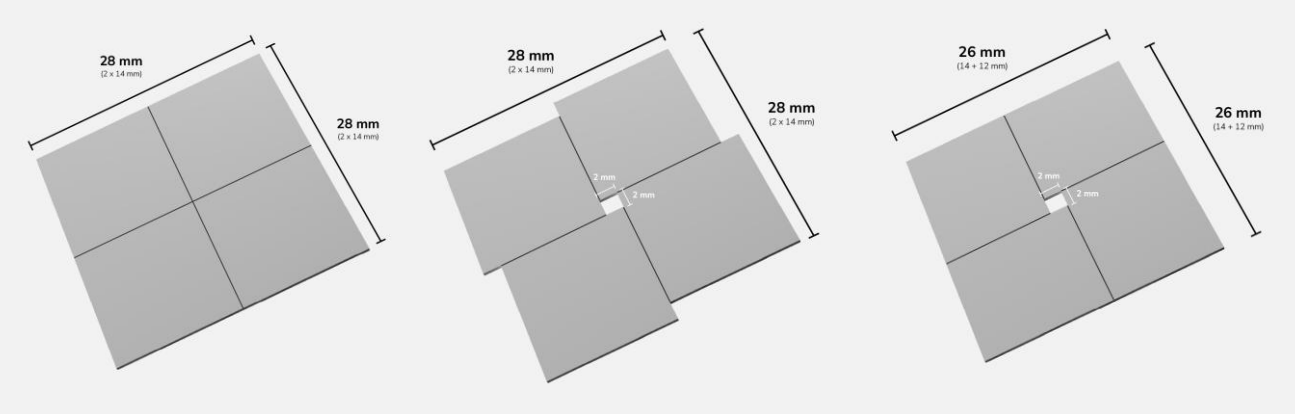
Symbol	Parameter	AdvaPIX MAGIC Quad	AdvaPIX MAGIC Quad with hole CdTe	AdvaPIX MAGIC Quad with hole Si	Units	Comment
	Pixel size	55 × 55	55 × 55	55 × 55	μm²	
	Detector resolution	512 × 512	512 × 512	477 × 477[1]	Pixels	
A	Sensitive area	28,2 × 28,2	28,2× 28,2	26,2 × 26,2[1]	mm²	

[1] number include central hole 35 × 35 px, that is 2 × 2 mm²

Chip layout

The detector is assembled from 14,1 × 14,1 mm² readout chips that are bump-bonded to the sensor layer.
Silicon sensor: A monolithic sensor that is fully sensitive across the entire active area. At chip boundaries, the pixels have increased dimensions: 55 × 110 along the inner edges and 110 × 110 μm² in the corner regions.
CdTe sensor: Constructed from four tiles, with an inter-tile gap corresponding to 20-30 μm between the sensors. As with silicon, pixels adjacent to tile edges have enlarged dimensions of 55 × 110 μm², and pixels in the corners measure 110 × 110 μm².

Without hole **With hole**



AdvaPIX MAGIC Quad

AdvaPIX MAGIC Quad with hole CdTe

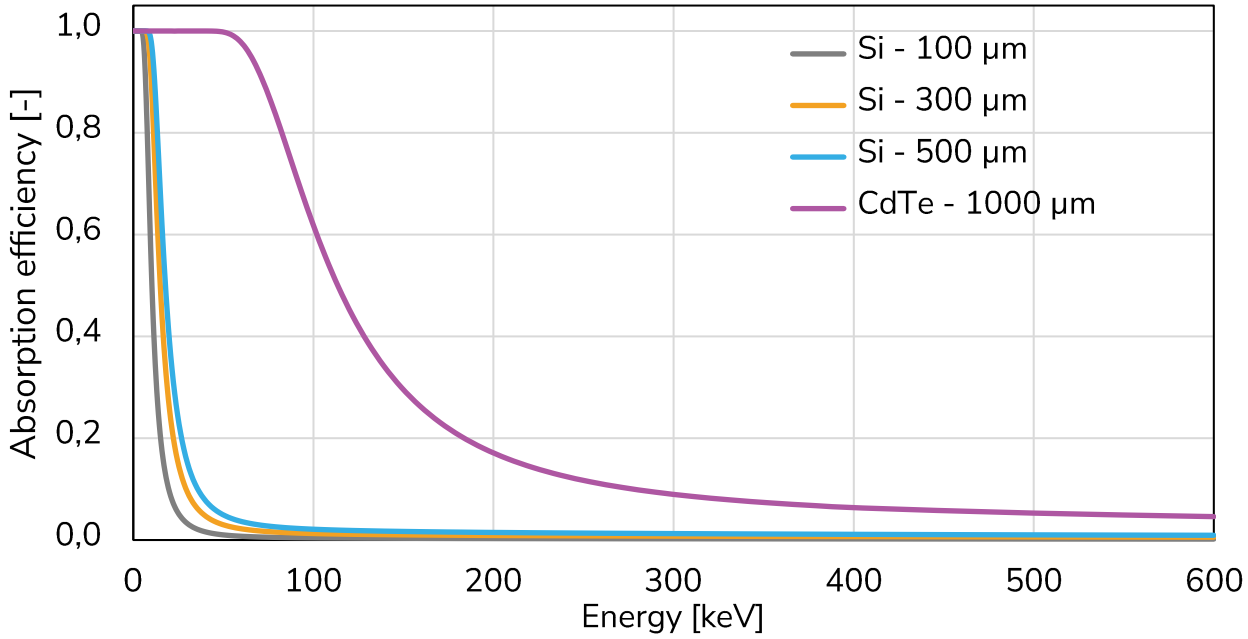
AdvaPIX MAGIC Quad with hole Si

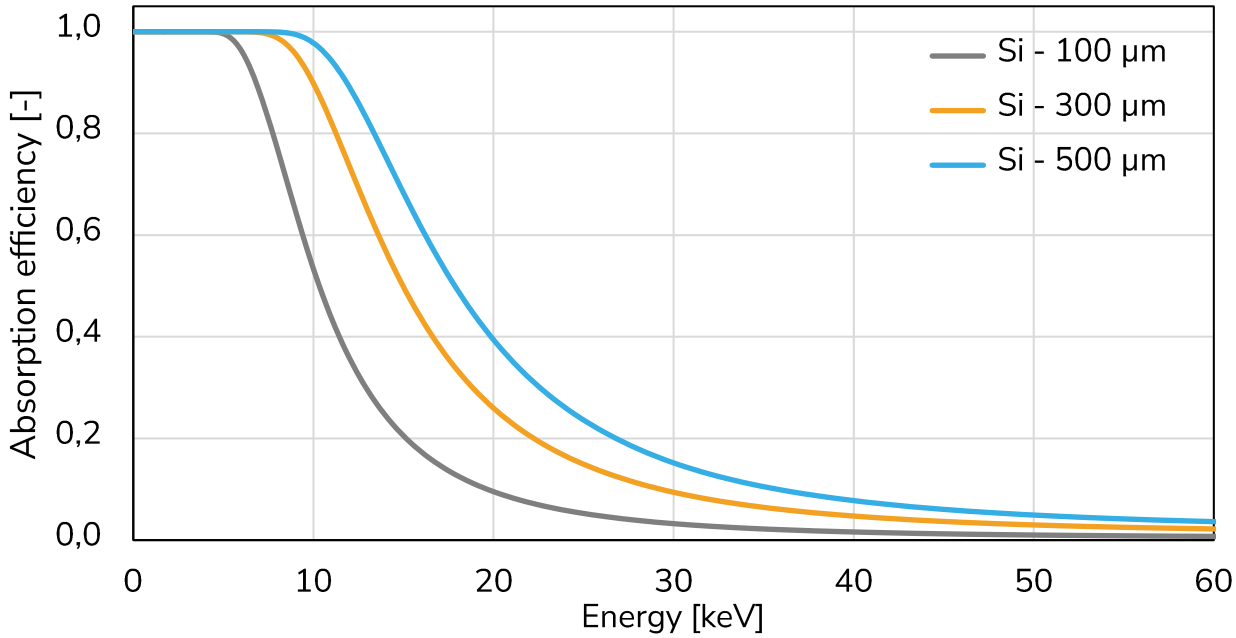
Sensor parameters

T_{dev} = 22 °C

Symbol	Parameter	Si			CdTe	Units	Comment
	Thickness	100	300	500	1000	μm	
σ	Energy resolution in full spectral mode (σ @ 60 keV)	1,2 – 2,6	1,3 – 2,7	1,4 – 3,5	2,8 – 5,4	keV	
	Typical detectable energy range for X-rays	3 to 60			5 to 500	keV	See chart below

Detector efficiency





Basic principles, measurement types and operational modes

The ionizing radiation particle interacts with the sensor material creating an electric charge. This charge is collected by electric field and brought to pixel preamplifier where it is amplified and shaped forming triangular voltage pulse. The amplitude and duration of this pulse is proportional to energy deposited by particle within the pixel. The situation when the voltage pulse amplitude in particular pixel exceeds preselected threshold value is called “event” or “hit”.

Each pixel contains three digital counters (10, 14 and 4 bits). These counters are used differently according to measurement type and mode. There are four different quantities which can be measured and stored in counters of each pixel – these are selected by operational modes.

Operational modes

Number of events	= number of events (hits) in the pixel during exposure time (this mode is suitable mainly for frame type readout).
Time-**o**ver-**T**hreshold (ToT)	= number of periods of 40 MHz clock signal (25 ns step) when amplifier output signal stays over the energy threshold. The ToT can be transformed to energy in keV using per-pixel-calibration function. The coefficients for per-pixel-calibration are unique for each pixel, and they are stored in configuration file delivered with the device. The energy calibration is valid only for given values of other detector parameters as delivered in configuration file (especially threshold)
Time-**o**f-**A**rrival (ToA)	= number of periods of 40 MHz clock signal (25 ns step) from start of exposure till the event is registered by pixel (i.e. pulse in pixel crosses the threshold). The range is 409,6 µs. Additional 16 bits are added in FPGA in readout electronics so that the total range is 26,8 seconds. An additional counter has also been added to perform scans beyond 26,8 seconds.
Fast-**T**ime-**o**f-**A**rrival (FToA)	= time difference between event detection and next clock signal measured with step of 1,5625 ns. Range is 4 bits. The combination of ToA and FToA gives precise time of event detection in nanoseconds using following formula:

$$\text{Time [ns]} = \text{ToA}*25 - \text{FToA}*1{,}5625$$

Combinations of operation modes and measurement types (rarely used cases are shown with gray background):

Type	Mode	Range	Description
Frames (reading all pixels after end of exposure)	ToA+ToT	18 bit + 10 bit	2 output frames per exposure: ToA = Time of Arrival of first event in pixel, ToA and FToA[1] combined ToT = Time over Threshold, i.e. energy in keV if calibration is loaded and switched on
	ToA	18 bit	1 output frame: ToA = Time of Arrival of first event in pixel, ToA and FToA[1] combined
	Event+iToT	10 bit + 14 bit	2 output frames per exposure: Events = number of events in pixel iToT = integrated Time over Threshold, i.e. energy in keV if calibration is loaded and switched on, for all events in pixel
Pixels (reading only hit pixels continuously during exposure)	ToA+ToT	18 bit + 10 bit	Data stream contains 4 values per pixel per event: Position, ToT, ToA and FToA[1] (for data formats .t3*)
	ToA	18 bit	Data stream contains 3 values per pixel per event: Position, ToA and FToA[1] (for data formats .t3*)
	Only ToT	10 bit	Data stream contains 2 values per pixel per event: Position and ToT (for data formats .t3*)

[1] ToA and FToA are combined together by software automatically. For Pixel type measurement, if saved as a .t3pa file, ToA and FToA are stored as separate items.

Measurement types:

Frame type measurement

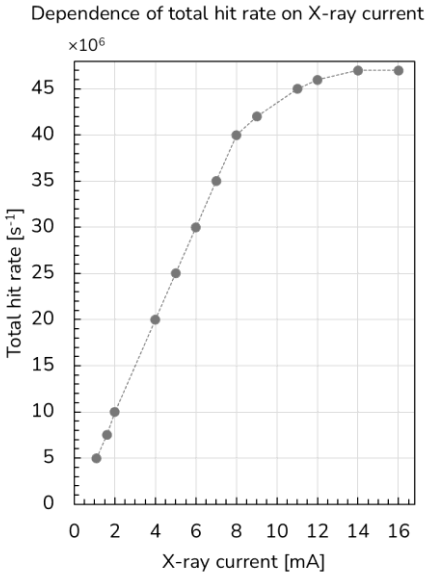
No data is sent out of device during the exposure time. All measured events are accumulated in counters of pixels. **Event counter** is incremented and ToT is integrated in to **iToT counter** for all events. The measured data is read-out after end of exposure time for all pixels with nonzero content. No measurement can be performed during readout process. Measurement types in PIXet Pro: Frames, Integral.

Pixel type measurement

Information about all hit pixels is read-out immediately and continuously during exposure time. If hit rate is below maximal value (see f in table of Performance characteristics) then there is practically no deadtime. Measurement type in PIXet Pro: Pixels. Sometimes this mode is referred to as the data-driven mode or the event-based mode.

Pixel mode hit-rate measurement

The whole detector is exposed to homogeneous perpendicular irradiation from X-ray tube operated at 18 kVp with 2 mm Aluminum filter. The measurement type is set to "**Pixels**" and mode to "**ToT+ToA**" and a special high hit-rate configuration of the device was used. The exposure time is set to 0,1 s. The "Clustering" tool of PIXet Pro is used to analyze measured data. The number of hit pixels per second is drawn as function of X-ray tube current searching for saturation. The real number of events is verified for each step using frame type measurement when all hits are accumulated in single frame. Data in the right picture measured with 4-chip configuration on a Linux OS. Maximum hit-rate on other operating systems is slightly lower.



Performance characteristics

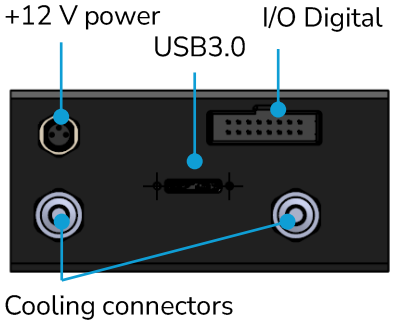
Symbol	Parameter	Min	Typ	Max	Units	Comment
f_{DEF}	Hit-rate, default settings			42	MPixels/s	with USB 3.0 cable
f_{HIGH}	Hit-rate, high hit-rate settings			47	MPixels/s	with USB 3.0 cable
	Data rate		2,4		Gbit/s	with USB 3.0 cable
T_{READ}	Frame Readout Time[1]		33		ms	with USB 3.0 cable
dT	Time resolution		1,56		ns	

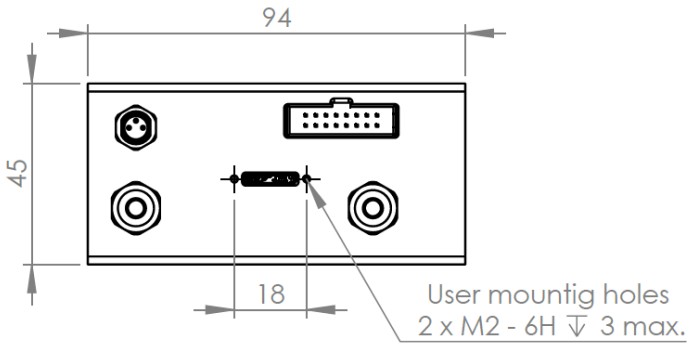
[1] Only in Frame mode - During Readout time (or Dead time), no signal is collected from the sensor.

If you need to adjust the high-hit rate settings or have any questions, please do not hesitate to contact our technical support at support@advacam.cz

Device description

The device is supplied with a USB flash disk containing an installer of PIXet Pro software, unique device configuration and calibration file, and protocol on quality tests.





Power connector +12 V DC

Main power supply (via standard M8 connector with 3 female contacts) Connect after plugging USB connector.

USB 3.0 connector

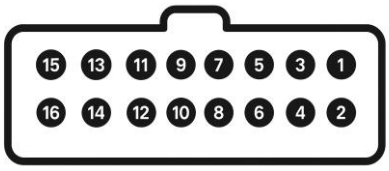
USB type micro-B, Standard USB 3.0 Super-Speed, delivered with 4,6 m cable.

The USB port shall be connected with care. Although the connector may be screw-locked, it shall not be used to support any mechanical load or weight.

I/O Digital connector

Signals on the I/O Digital connector are used for synchronization purposes. Input pins are **NOT 3V3** or **5 V** logic compatible. Pin 8 (+5 V) might be used for powering small external loads (50 mA max).

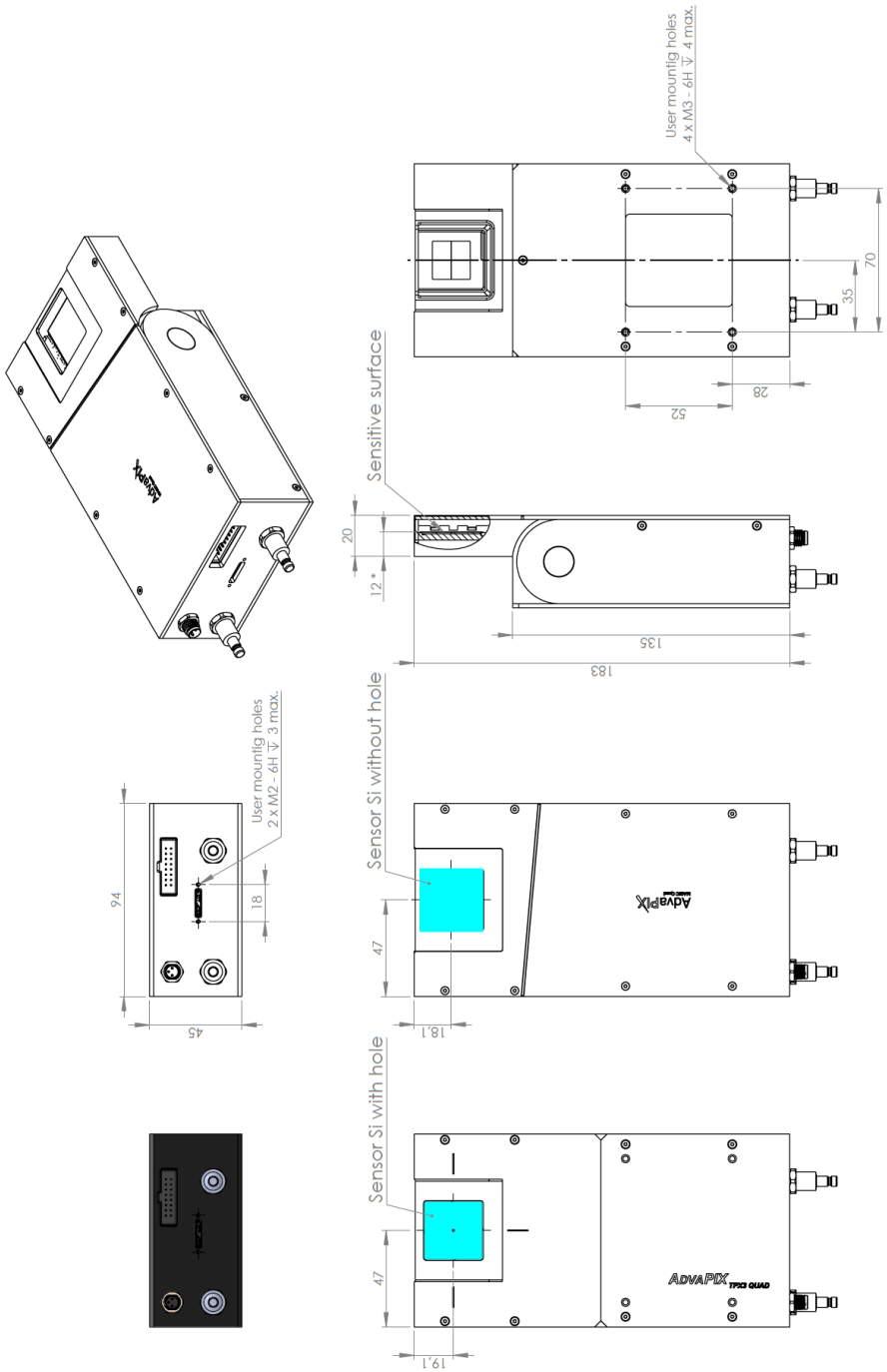
Pin	Name	Signal type	Pin	Name	Signal type
1	Reserved	M-LVDS	2	Reserved	LVDS
3	Reserved	M-LVDS	4	Reserved	CMOS (2,5V)
5	Reserved	CMOS	6	Reserved	M-LVDS
7	GND		8	+5V	
9	Master Disable	CMOS 0-2,5V/5V	10	CLK n	LVDS (2,5V)
11	CLK p	M-LVDS (2,5V)	12	T0/Sh-sel	CMOS 0-2,5V
13	Th/Sh p	M-LVDS (2,5V)	14	Th/Sh n	LVDS (2,5V)
15	Ready OUT	CMOS 0-2,5V	16	T0/Sh-CMOS	CMOS 0-2,5V



This connector is used for internal purposes. If you need to use synchronization I/O, please contact our technical support at support@advacam.cz

Mechanical dimensions

Without protection cover. Do not operate without protection cover!



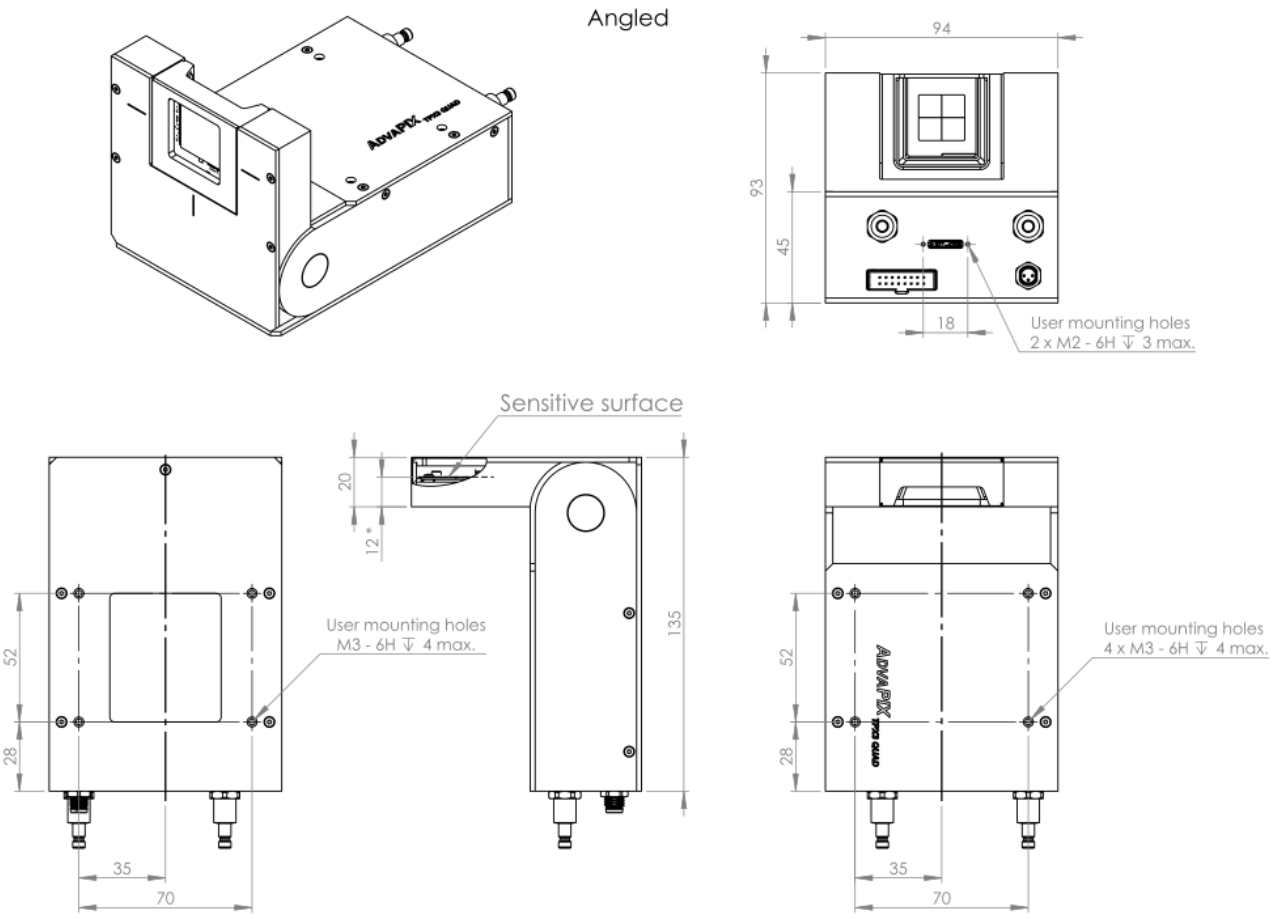
All dimensions are in mm

*Sensitive surface distance from bottom of the box is for 300 µm sensor thickness.

> The removal of the chip cover (if any) must be performed with extreme care avoiding any touches to the sensor chip or wire-bonds

L-shaped variant

The modular sensitive area supports flexible mechanical positioning and orientation, enabling configurations such as linear or L-shaped geometries. This design allows precise alignment and optimization to meet specific application and system-integration constraints.



All dimensions are in mm.
* Sensitive surface distance from bottom of the box is for 300 µm sensor thickness.

Instructions for safe use

Do not touch sensor surface!

To avoid malfunction or damage to your **AdvaPIX MAGIC Quad** please obey the following:

- Do not expose to water or moisture.
- Do not disassemble. Wire-bonding connections may be irreversibly damaged.
- Do not insert any object into the sensor window.
- Use with original cable and do not use any USB-hub.
- The USB port shall be connected with care. Although the connector may be screw-locked, it shall not be used to support any mechanical load or weight.
- Thermal stabilization of the device is necessary. Recommended temperature is 22 °C.
- Extreme care must be taken when removing the protection cover or handling the **AdvaPIX MAGIC Quad** without the protection cover. Warranty does not apply to mechanical damage of the sensor and wirebonds.
- The protection provided by this product may be impaired if it is used in a manner not described in this document.

Disposal

Do not dispose these instruments as unsorted municipal waste. Please use separate collection facility or contact the supplier from which the instrument was purchased. Please make sure discarded electrical waste is properly recycled to reduce environmental impact.

Release history

Date (YY/MM/DD)	Changes	Changed by
23/06/01	Preliminary datasheet (A3QxHx-Xxx220308)	P. Soukup; M. Koprda; M. Jakubek; J. Jakubek
24/02/12	New version added (S12/A12); drawing added	M. Kasal
24/04/26	Datasheet revision	J. Baborák
24/06/04	New graphic style of the document, hit-rate measurement details added	J. Baborák, P. Bloudek, D. Doubravová
24/07/23	Minor format changes	J. Baborák
25/01/17	Release	J. Baborák, D. Doubravová
25/04/30	CdTe version added, logo update	J. Baborák
25/05/15	Sensor resolution updated	J. Baborák
26/03/06	New graphic style of the document, rebranding, revision of parameters, chip scheme.	P. Bloudek S. Valtera
26/04/24	Updated chip scheme with hole variant	S. Valtera

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