ADVACAM
Imaging the Unseen

AdvaPIX
MAGIC Quad

Model No.: A3QxHx-Xxx220308

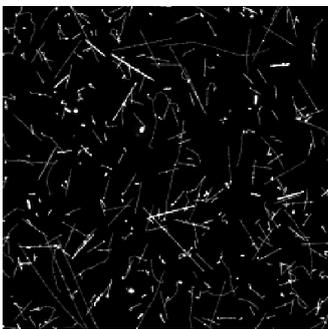**ADVACAM**
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General features

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.

The AdvaPIX MAGIC Quad modules were designed with special emphasis on performance and versatility which is often required in scientific experimental work. They contain a CERN detector Timepix3 for particle tracking and imaging with Si or CdTe sensor. The AdvaPIX MAGIC Quad modules can be used in different configurations: telescope of several layers for better particle tracking and/or side-by-side for larger area coverage. Each module contains one Timepix3 device with fast data readout of more than 47 Mhits per second. A separate USB 3.0 channel for each module ensures fast read-out of the whole modular system. The sensor type and thickness is of customer's choice. The typical and intended applications of AdvaPIX MAGIC Quad are:

- Spectral X-ray imaging: X-ray fluorescence imaging, X-ray radiography (low flux), scintigraphy or SPECT, radiography with isotopes.
- Energy dispersive XRD, SAXS or WAXS: Monochromatic X-ray source is NOT needed! Even high energy for thick samples is possible (e.g. 100 keV)!
- Particle tracking and ion beam monitoring: detectors can be used for tracking and tagging of primary particles (e.g. ions) as well as secondary radiation (spallation, fragmentation, recoiled, bremsstrahlung, prompt/delayed decays, neutrons[1] ...).
- Neutron imaging: The sensors can be adapted for neutron imaging by deposition of converter layers[2].

Recording shapes of individual hits together with advanced data processing allows increasing the spatial resolution in some applications to units of microns or even sub-micrometric level (for ions).

Main Features

- Readout chip type Timepix3
- Pixel size[3] .... 55 x 55 μm^2
- Sensor resolution[4] .... 256 x 256 or 512 x 512 pixels
- Time resolution .... 1,6 ns
- Power .... External 5V
- Sensor material.. 100, 300, 500 μm Si, 1000 **μm CdTe**
- Dark current .... none
- Interface .... USB 3.0 (Super-Speed)
- Maximum readout speed.......................... 47 million pixels / s
- Dimensions .... 210 x 94 x 38 mm
- Weight... 905 g

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[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$_4$C 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] 256 x 256 pixels per chip, i.e. 256 x 512 pixels for a 2-chip version, 512x512 pixels for a 4-chip version

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.

Vacuum operation

ADVACAM detectors can be vacuum compatible on request. Contact support@advacam.cz for more information.

- Intended for dust free indoor use.
- In case of vacuum operation, operate only with air pressure lower than 10^{-3} Pa.
- Make sure to disconnect the device from power during pumping down or venting the vacuum chamber!
- The device will automatically shut down after chip or CPU temperature exceeds 55 °C.

External temperature stabilization

Temperature stabilization of the device required. Connect the water cooler hoses to the device connectors. The temperature should be set to 22 °C.

Electrical specification

T_{dev} = 25 °C, USB voltage V_{CC} = 4,8 V

Symbol	Parameter	Min	Typ	Max	Units	Comment
V_{CC}	Supply Voltage		12±10 %		V	
I_{CC}	Supply Current		0,9-1,1	2,4		
P1	Power Dissipation		10-12	25	W	
I/O Conn. Input LVDS[2]						
V_{IN}	Voltage Range	0		2,5	V	
V_{INDIFF}	Differential Voltage	250		600	mA	
I/O Conn. +5 V (pin 2)						
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

Performance characteristics of Timepix3

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
F_{1x2_DEF}	Hit-rate, 1x2 version, default settings[1]			42	MPixels/s	with USB 3.0 cable
	Data rate		2,4		Gbit/s	with USB 3.0 cable
T_{READ}	Frame Readout Time[2]		33		ms	with USB 3.0 cable
dT	Time resolution		1,56		ns	

[1] With PIXet Pro 1.8.3 and later
[2] During Readout time (or Dead time), no signal is collected from the sensor.

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.
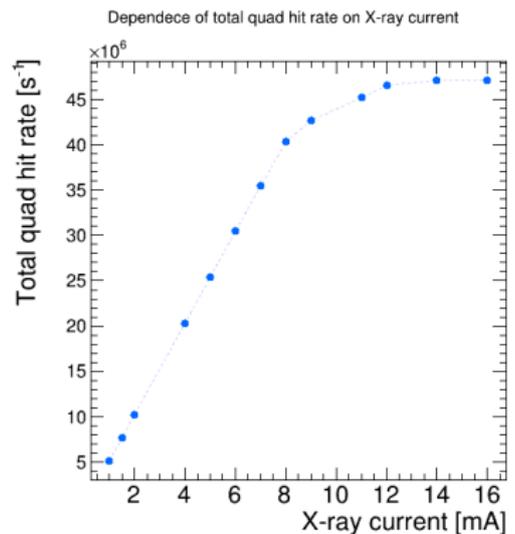

If you need to adjust the high-hit rate settings or have any questions, please do not hesitate to contact our technical support at support@advacam.cz

Basic principles, measurement types
Sensor parameters
and operational modes

Sensor parameters

$T_{dev} = 25\ °C$

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	5 to 60			5 to 500	keV	See chart below
	Pixel size[1]	55 x 55			55	μm²	

[1] 55 x 110 μm at the edges and 110 x 110 μm at the corners

Detection efficiency
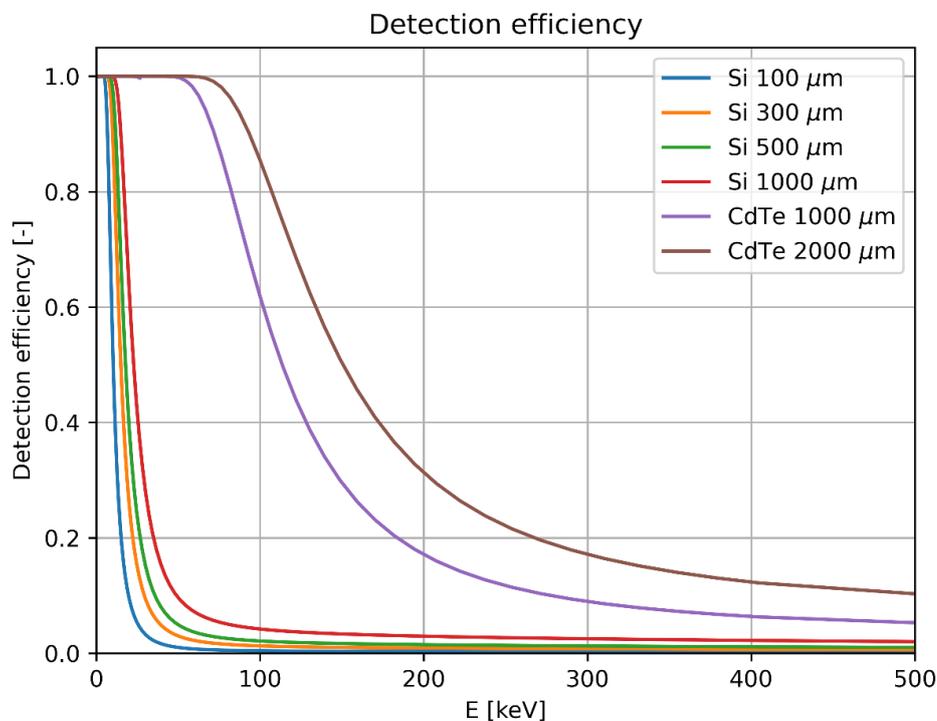
Basic principles, measurement types and operational modes

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-over-Threshold (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-of-Arrival (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-Time-of-Arrival (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:

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

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_p 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.

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

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.
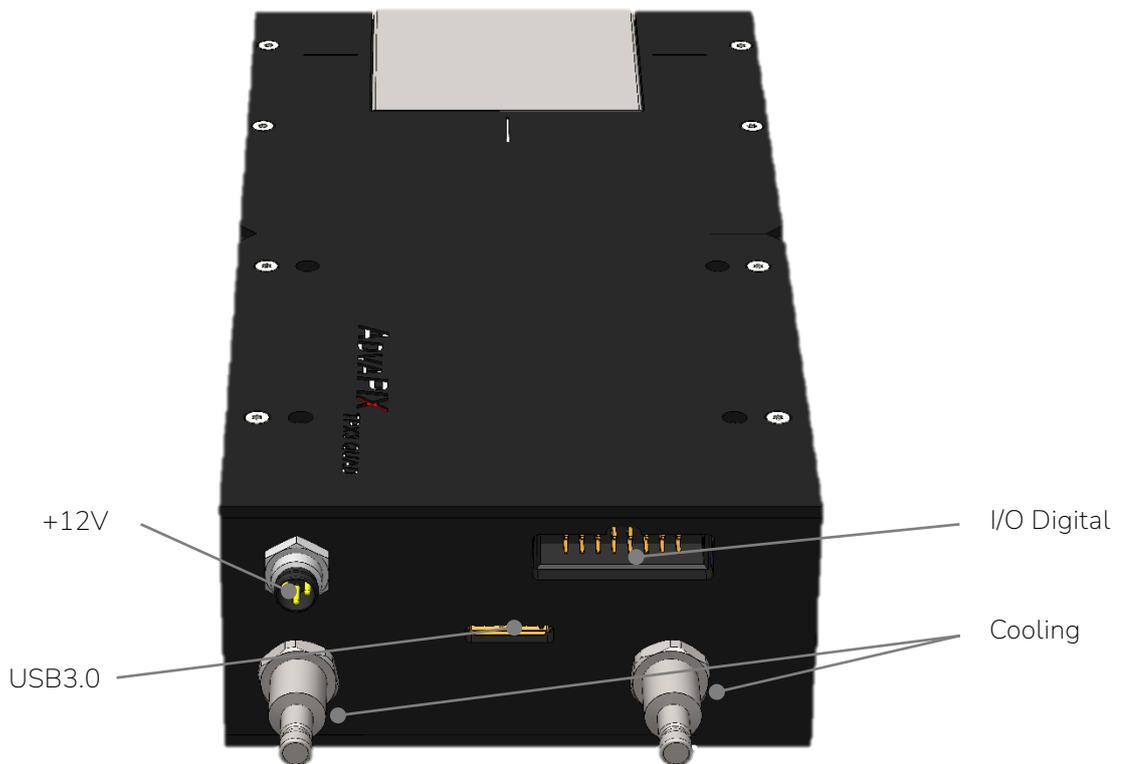

+12 V DC connector

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.

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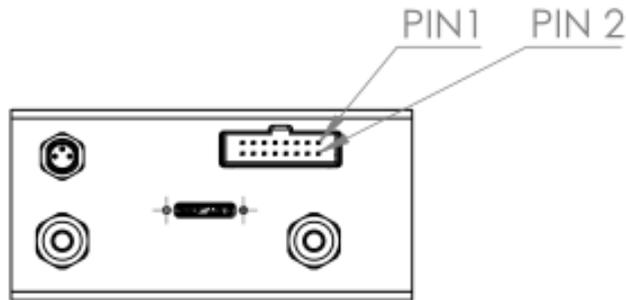
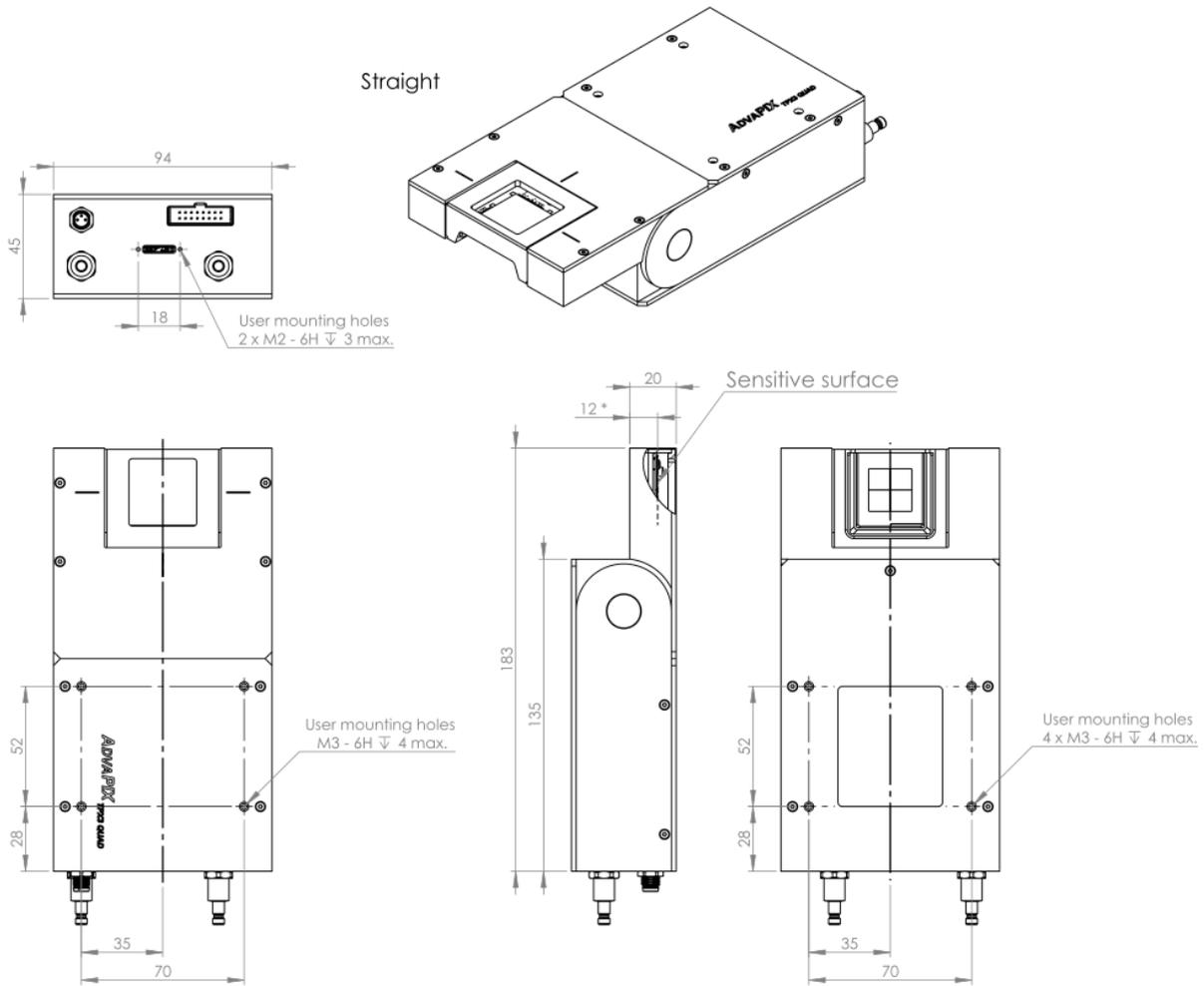| Pin	Name	Signal type	Pin	Name	Signal type
1	Reserved	M-LVDS	2	Reserved	LVDS
3	Reserved	M-LVDS	4	Reserved	CMOS (2,5V)
5	Reserved	CMOS	6	Reserved	CMOS
7	GND		8	+5V	
9	Master Disable	CMOS 0-2,5V/5V	10	CLK n	LVDS (2,5V)
11	CLK p	M-LVDS (2,5V)	12	T0/Sh-sel	CMOS 0-2,5V
13	Th/Sh p	M-LVDS (2,5V)	14	Th/Sh n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

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

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Mechanical dimensions

Without protection cover. Do not operate without protection cover!

Straight

94

45

18

User mounting holes
2 x M2 - 6H ▽ 3 max.

20

12 *

Sensitive surface

183

135

52

28

User mounting holes
M3 - 6H ▽ 4 max.

35

70

52

28

User mounting holes
4 x M3 - 6H ▽ 4 max.

35

70

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

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Angled

94

93

45

18

User mounting holes
2 x M2 - 6H ↧ 3 max.

Sensitive surface

20

12 *

135

User mounting holes
M3 - 6H ↧ 4 max.

52

28

35

70

User mounting holes
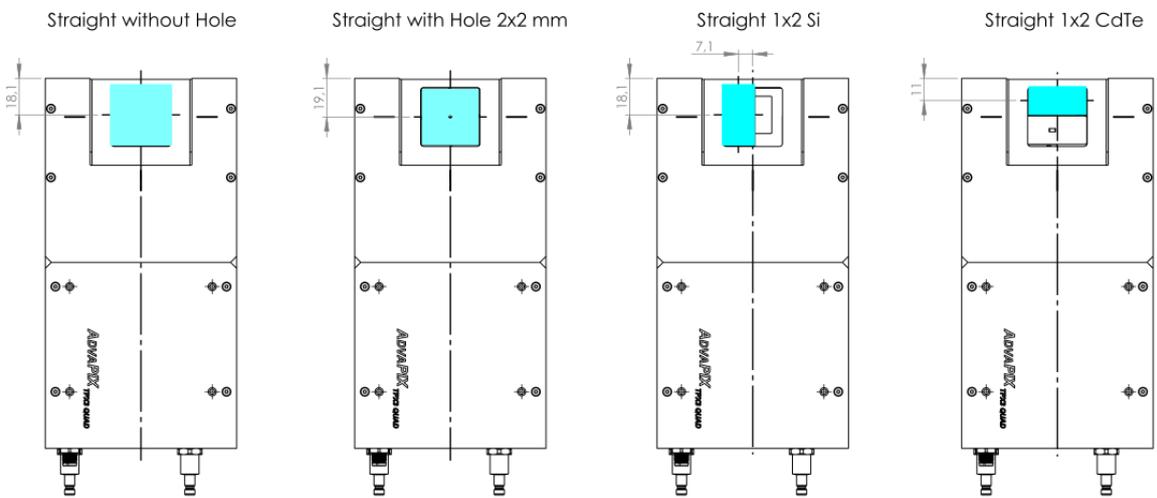4 x M3 - 6H ↧ 4 max.

52

28

35

70

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

Straight without Hole	Straight with Hole 2x2 mm	Straight 1x2 Si	Straight 1x2 CdTe

18.1

19.1

7,1

18.1

11
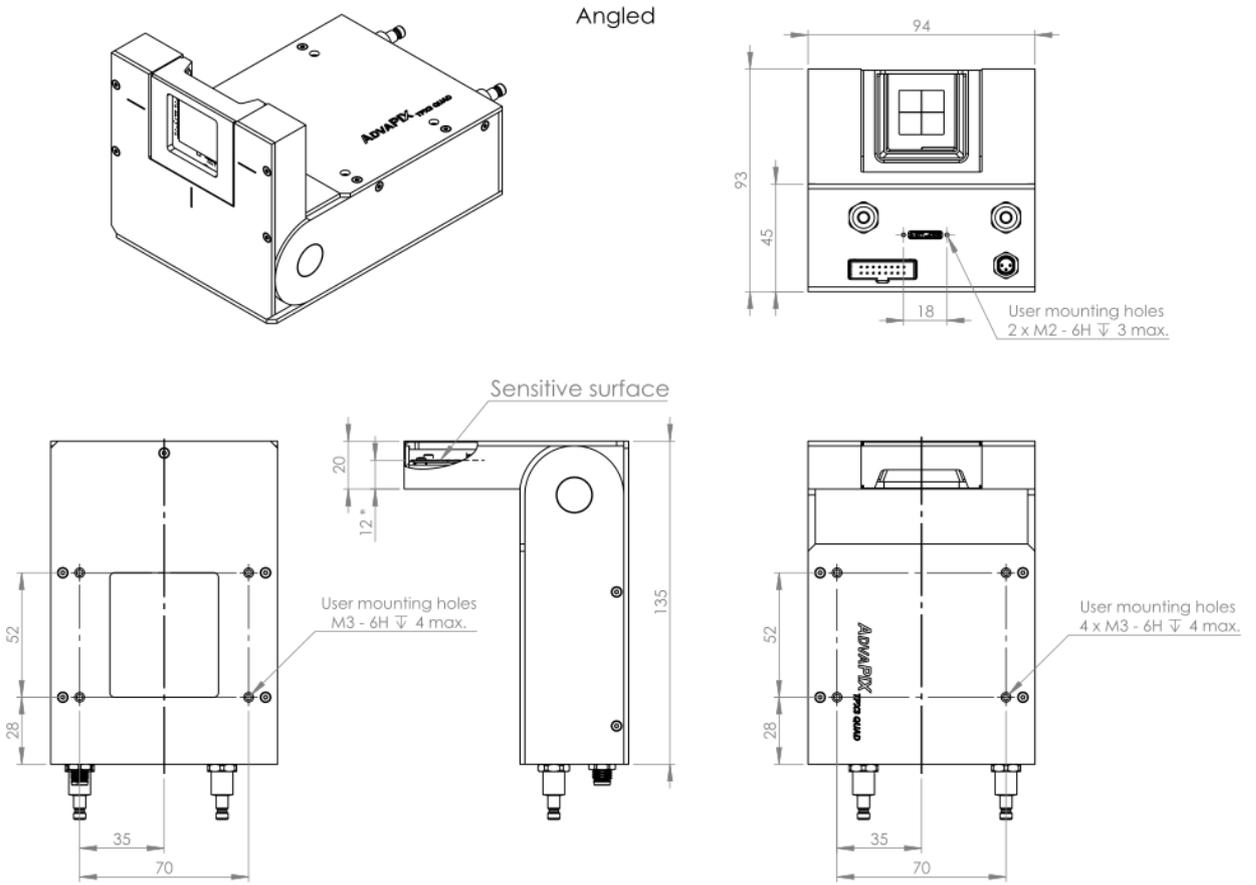
All dimensions are in mm.

Model number codes

Example: **A3Q   xHx – X   P   3   XXXXXXXX**

Device name:
APX – AdvaPIX TPX3 MAGIC Quad

Device modification:
SH0 – Straight without hole
SH2 – Straight with hole 2x2 mm
AH0 – Angled without hole
AH2 – Angled with hole 2x2 mm
S12 – Straight 1x2
A12 – Angled 1x2

Sensor type:
M – Silicon monolithic
C – CdTe

Sensor thickness:
1 – 100 μm
3 – 300 μm
5 – 500 μm
A – 1000 μm
B – 2000 μm

Device build version:
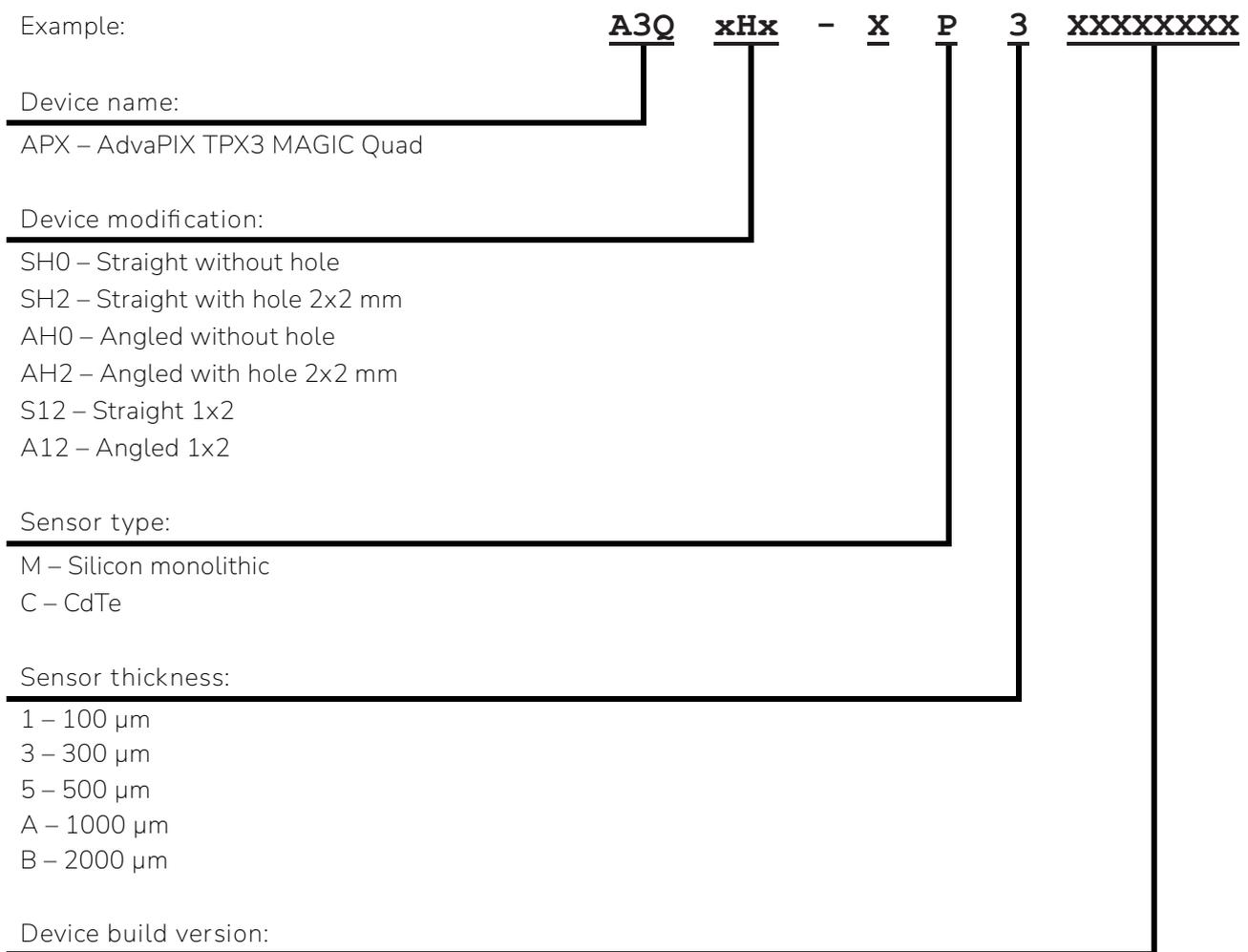
Instructions for safe use

⚠	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 connection may be irreversibly damaged.
- Do not insert any object into the sensor window.
- The maximum USB cable length is 2 m.
- Thermal stabilization of the device is necessary. Recommended temperature is 22 °C.
- Extreme care must be taken when removing the protecting cover or handling the AdvaPIX MAGIC Quad without the protecting 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 to 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	P. Bloudek

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