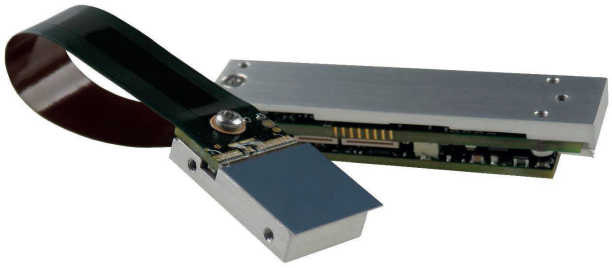
Mini*PIX* TPX3 Flex
Miniaturized and low power radiation camera with particle tracking



Key features	
Readout chip type	Timepix3
Pixel size	55 x 55 µm
Sensor resolution	256 x 256 pixels
Dynamic range in frame mode[2]..	1022 events count
Dark current	none
Interface	USB 2.0 (High-Speed)
Maximum frame rate	16 fps (full frames)
Maximum hit rate	2.35 x 10^6 pixels/s
Weight	22 g (CdTe sensor, no cover)

The MINIPIX$_{TPX3F}$ is miniaturized and low power radiation camera with particle tracking and imaging detector Timepix3 (256 x 256 square pixels with pitch of 55 µm). TheMINIPIX$_{TPX3F}$ is miniaturized and low power radiation camera wit chip is equipped with sensor according to customer preference (standardly 300 µm thick silicon).

The Timepix3 detector is position, energy and time sensitive: For each ionizing particle (e.g. X-ray photon) it digitally registers its position, energy, time of arrival and track shape - basically all information you can want. The other measures can be often calculated from the track shape (particle type, direction of flight, LET, charge ...).

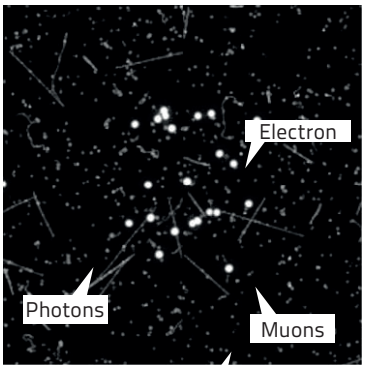


Illustration of particle tracking capability of Timepix3 device: The tracks of different particles of radiation were recorded during 10 minutes in normal office space in Prague. Brightness corresponds to energy. No noise (clean zero) is seen in dark regions. All basic particle track types are seen nicely: muons = straight lines, alpha particles = bright balls, electrons = curving lines, gamma and X-rays = dots and blobs.

The information on each detected particle is either read-out immediately (pixel mode) at maximal rate of 2.3 million hit pixels per second or accumulated in pair of images (frame mode) and read-out later at maximal speed of 16 frames per second.

The typical and intended applications of MINIPIX$_{TPX3F}$

- Spectral X-ray imaging: X-ray fluorescence imaging, X-ray radiography (low flux)
- 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)!
- Spectral gamma ray imaging: scintigraphy or SPECT, radiography with isotopes.
- Radiation monitor1: particle type sorting, spectroscopy, directional sensitivity ...
- Gamma camera: special shielded box and collimators available.
- Compton camera: special software module available for image reconstruction.

The MINIPIX$_{TPX3F}$ device is controlled via USB2.0 interface with standard µUSB connector. All major operating systems are supported (MS Windows, Mac OS and LINUX). The complex software PIXET PRO used for detector operation is provided for free. The extra software modules are available for special functions (e.g. coded aperture image reconstruction, Compton camera image and spectrum reconstruction, radiation field decomposition, networking of many devices ...).

[1] MINIPIXT^{PX3F} is not certified dosimetric device. 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 of MINIPIX$_{TPX3F}$.
[2] Dynamic range of final picture is theoretically unlimited; the only limiting factor is exposure time..

Quantum Design
1 avenue de l'Atlantique
Bâtiment Fuji-Yama
91940 Les Ulis - France

Tél. : +33 1 69 19 49 49
france@qd-europe.com
www.qd-europe.com

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Device parameters

Operating conditions						
Symbol	**Parameter**	**Min**	**Typ**	**Max**	**Units**	**Comment**
TA	Ambient Temperature Range	0	50	70	°C	
Φ	Humidity	0	55	60	%	Not condensing
	Altitude (55 x 110 µm at the edges and 110 x 110 µm at the corners)		<2000		m	Above sea level
Warning: Disconnect the device from power during pumping down or venting the vacuum chamber!						

Electrical specification

T_A = 25 °C, USB voltage V_{CC} = 4.8 V

Symbol	Parameter	Min	Typ	Max	Units	Comment
V_{CC}	Supply Voltage	4.0	5.0	5.5	V	Comply with USB 2.0
I_{CC2}	Supply Current		300	500	mA	Comply with USB 2.0 Mode dependent
P1	Power Dissipation			2.5	W	

Bias voltage source for sensor diode							
Symbol	**Parameter**		**Min**	**Typ**	**Max**	**Units**	**Comment**
V_{BIAS}	Bias Voltage	Si 100 µm	3	50	50	V	
		Si 300 µm	3	200	200		
		Si 500 µm	3	200	200		
		CdTe 1000 µm	-500	-300	-4		
		CdTe 2000 µm	-500	-500	-4		

Performance characteristics						
Symbol	**Parameter**	**Min**	**Typ**	**Max**	**Units**	**Comment**
f_r	Frame rate			16	fpr	with USB 2.0 Host
T_{FREAD}	Frame readout time[3]	62			ms	
f_p	Pixel type hit-rate in ToT+ToA mode (pixels per second)			2.35 x 10^6	pps	with USB 2.0 Host
[3] During readout time (or dead time), no signal is collected from the sensor.						

Sensor parameters T_A = 25 °C									
Symbol	**Parameter**	**Si**				**Cd**		**Units**	**Comment**
	Thickness	100	300	500	1000	1000	2000	µm	
	Minimum energy threshold	2.0 - 2.7	2.0 - 2.7	2.0 -3.0	2.0 -3.0	2.5 - 4.5	3.0 - 5.0	keV	
$\sigma_{Thl@60}$	Energy resolution in ToT mode (σ @ 60 keV)	1.2 - 2.6	1.3 - 2.7	1.3 - 2.7	1.3 - 2.7	2.8 - 5.4	2.8 - 5.4	keV	
$\sigma_{Thl@122}$	Energy resolution in ToT mode (σ @ 122 keV)					3.4 - 6.0	4.5 - 9.9	keV	
	Typical detectable energy range for X-rays	2.0 - 60				2.5 - 500		keV	see chart on next page
	Pixel size	55						keV	

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Pixel mode hit-rate measurement
The whole detector is exposed to homogenous 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" all other parameters are set to factory defaults (as stored in configuration file delivered with device). 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.

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".

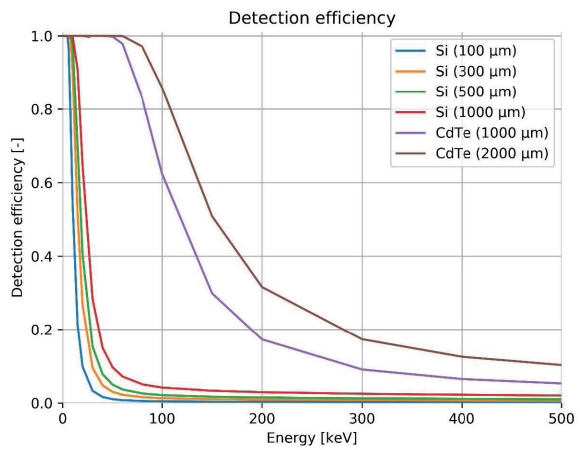
Each pixel contains three digital counters (10, 14 and 4 bits). These counters are used differently according to measurement type and mode. There are four different quantities which can be measured and stored in counters of each pixel – these are selected by operational modes.

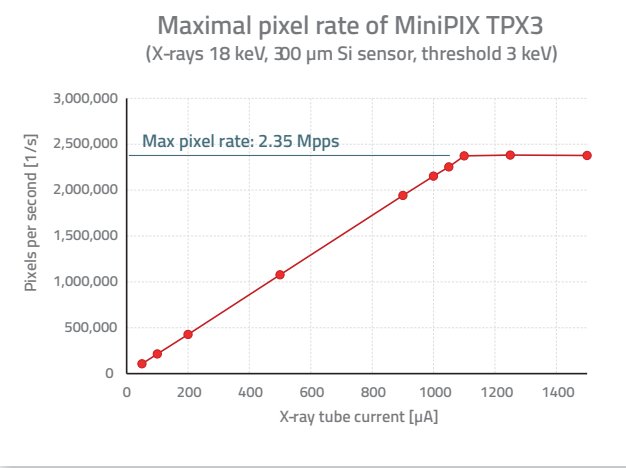
Operational modes

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) = measured as 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 detector pixel and they are stored in configuration file delivered with 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.





The additional bits are usable only if the pixel hit rate is below maximal value (see fp in table of Performance characteristics). 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:

Time [ns] = ToA*25 - FToA*1.5625

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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 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.

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 fp in table of Performance characteristics) then there is virtually no dead-time.

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

Type	Mode	Range	Description
Frame (reading all pixels after end of exposure)	Event+ iToT	10 bit + 14 bit	2 output frames per exposure: 1st Events = Number of events in pixel, 2nd iToT = total time over threshold for all events in pixel.
	iToT	14 bit	1output frame: iToT = total time over threshold for all events in pixel.
	ToA	18 bit	1 output frame: ToA+FToA[1] = Time of Arrival of first event in pixel.
Pixel (reading only hit pixels continuously during exposure)	ToT+ ToA	10 bit + 18 bit	4 numbers per pixel per event: Position, ToT, ToA and FToA[1].
	ToA	18 bit	3 numbers per pixel per event: Position, ToA and FToA[1].
	Only ToT	10 bit	2 number per pixel per event: Position and ToT.

[1] ToA and FToA are combined together by software automatically. If saved, ToA and FToA are stored as separate items (for Pixel type measurement).

Vacuum Operation

Advacam detectors are vacuum compatible out of the box. Operate only with air pressure lower than 10-3Pa. Intended for dust free indoor use.

Make sure to disconnect the device from power during pumping down or venting the vacuum chamber.

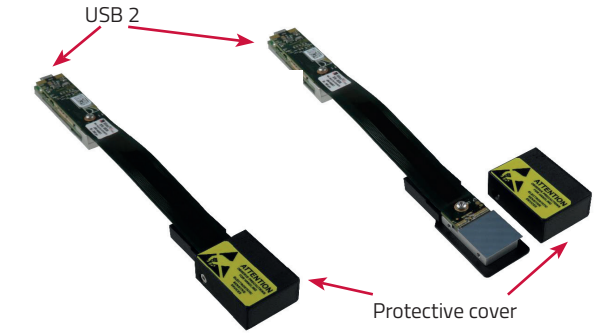
Device description

The device is supplied with USB flash disk containing installer of PiXet-Pro software, unique device configuration and calibration file and protocol on quality tests. The communication and powering is provided by USB Micro-B connector and cable.

The device is delivered with protective plastic box covering the sensitive detector part. The protective box is used only for transportation. Protective cover has to be removed before use to avoid sensor damage from overheating. The removing has to be performed with extreme care avoiding any touches to the sensor chip or wire-bonds.

High voltage - Sensor chip is supplied with high voltage up to ±500V. To avoid sparks or unwanted discharge follow EN 61010-1 (chapter 6.7, Insulation requirements. Fig. 4, Tab. 6, Annex C).

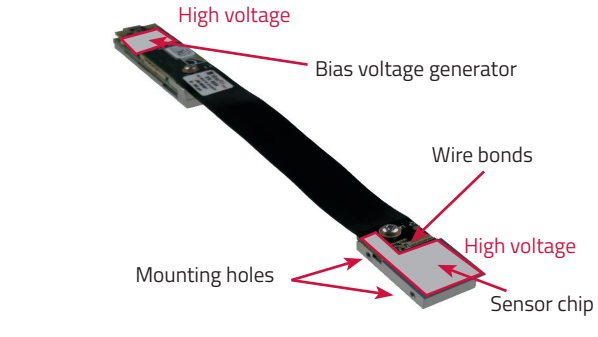
Device with protective plastic cover



Left: as delivered, right: opened

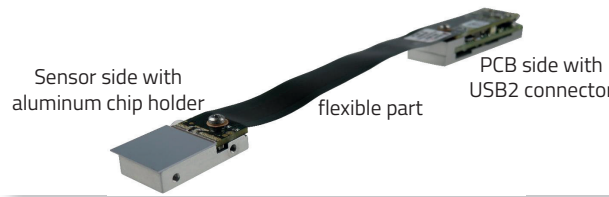
Plastic cover removed

(Before installataion)



USB connector

USB type Micro-B, standard USB 2.0 high-speed.



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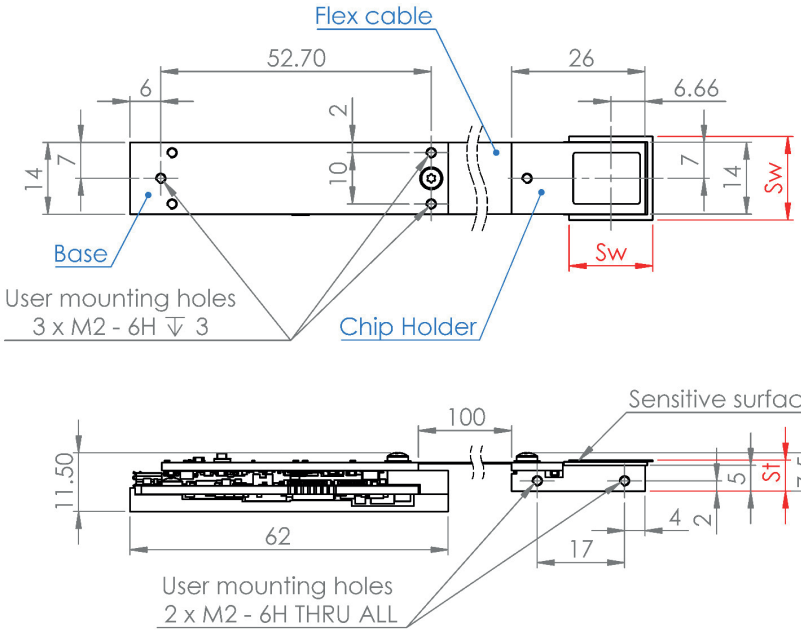
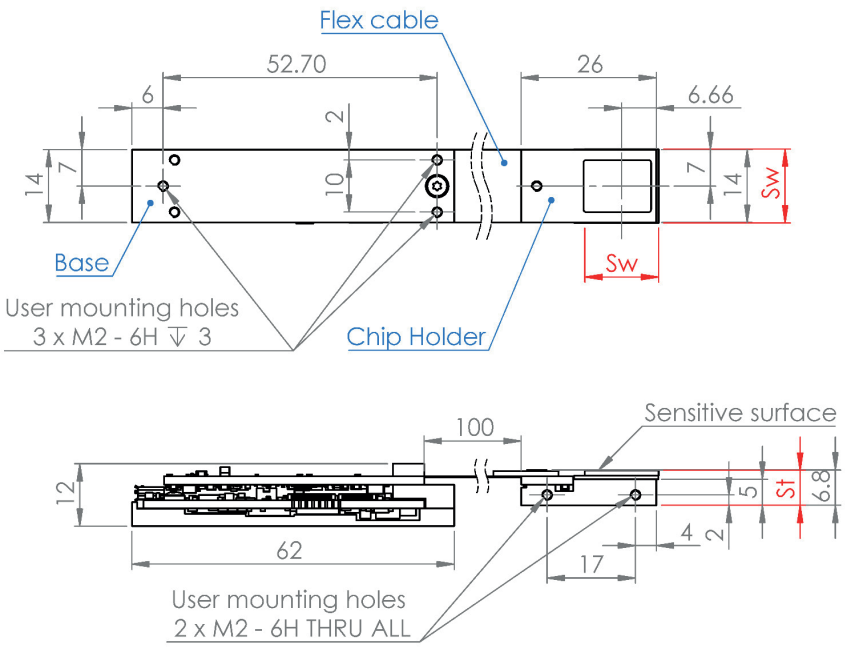
Mechanical dimensions
Mechanical dimensions for Si sensor. Drawing of the device with aluminium base supporting the PCB side:



Mechanical dimensions
Mechanical dimensions for CdTe sensor. Drawing of the device with aluminium base supporting the PCB side:



All dimensions are in mm. The sensor specific dimensions s_t and s_w (shown in red) are listed in the following table.

Extreme care must be taken when removing protecting cover and handling the $MINIPIX_{TPX3F}$ without the protective cover. Warranty does not apply to mechanical damage of the sensor and wire bonds.

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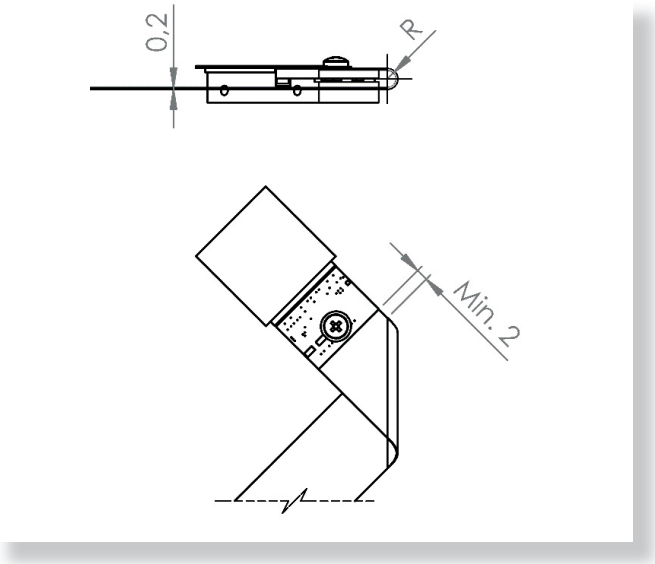
Flex cable bending parameters:



Bending radius according to IPC-2223 standard (2 layers flex PCB, 0.2 mm thick)			
Bending type	**Stable**	**Semi-Dynamic**	**Dynamic**
Min. bending radius	2 mm	4 mm	30 mm

Sensor type specific dimensions				
Sensor material	**Sensor thickness [µm]**	**Model code**	**Module thickness s_t [mm]**	**Module thickness s_w [mm]**
Si planar	100	MT3F10-X**P1**	5.84	15.45
	300	MT3F10-X**P3**	6.04	16.28
	500	MT3F10-X**P5**	6.24	16.28
CdTe	1000	MT3F10-X**CA**	6.74	14.185
	2000	MT3F10-X**CB**	7.74	14.185

Model number codes (example)

MT3	F10	X	P	3	211214
Device name MT3 – MiniPIX Timepix3	Device modification F10 – Flex cable length 100 mm		Sensor type P-Planar silicon C-CdTe	Sensor thickness 1 – 100 µm 3 – 300 µm 5 – 500 µm A – 1000 µm B – 1000 µm	YY MM DD

Remove plastic cover before use!
Attach the aluminum support to an appropriate heatsink! Do not touch sensor surface or wire bonds!
Attention an electrostatic-sensitive device!

Instructions for safe use

The MINIPIX$_{TPX3F}$ is a designed as component to be integrated into users system. It is not designed for independent use. The minimum system requirements are:

- Proper heatsink attached to an aluminum sensor support,
- Mechanical cover of the whole device,
- Electrical protection of the whole device: Avoid open access to bias voltage

To avoid malfunction or damage to your MINIPIX$_{TPX3F}$ please observe the following:

- Temperature stabilization has to be provided by user: functional parameters are not valid otherwise!
- Do not expose to water or moisture or chemicals.
- Maximum USB cable length is 3 m

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