ADVACAM
Imaging the Unseen

MINIPIX TPX3F

Datasheet

Model No.: MNXT3F-Xxx190731
MT3Fxx-Xxx190925
MT3F10-Xxx211214
MT3F10-Xxx220422

General features

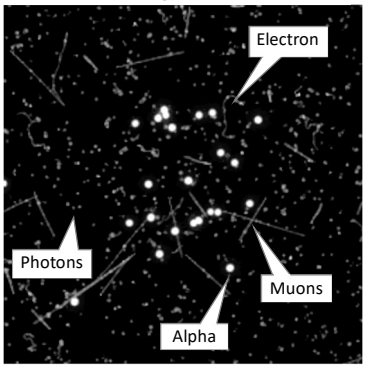


Illustration of particle tracking capability of Timepix3 device: The tracks of different particles of radiation were recorded during 10 minutes in normal office space in Prague. Brightness corresponds to energy. No noise (clean zero) is seen in dark regions. All basic particle track types are seen nicely: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

The **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). The **MINIPIX TPX3F** chip is equipped with sensor according to customer preference (usually 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 …). 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 monitor[1]:** 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 USB 2.0 interface with standard µUSB connector. All major operating systems are supported (MS Windows, Mac OS and LINUX). Complex PIXet Pro software 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 …).

Main Features

- Readout chip type Timepix3
- Pixel size[2] ..... 55 x 55 µm
- Sensor resolution ..... 256 x 256 pixels
- Time resolution ..... 1,6 ns
- Dynamic range in one frame[3] 1022
- Sensor material ..... 100, 300, 500 µm Si, 1000 µm CdTe
- Dark current ..... none
- Interface ..... USB 2.0 (High-Speed)
- Maximum readout speed ..... 2,35 million pixels / s
- Dimensions ..... see p. 8-11
- Weight ..... 22 g (CdTe sensor, no cover)

[1] **MINIPIX TPX3F** 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] 55 x 110 µm at the edges and 110 x 110 µm at the corners

[3] i.e., counter depth. Dynamic range of integrated picture is theoretically unlimited.

Device parameters

Operating conditions

Symbol	Parameter	Value	Units	Comment
T_a	Operating ambient temperature range [1]	0-50	°C	
Φ	Humidity	< 85	%	Not condensing
IP	IP rating with cover	IP20		For transport purposes
IP	IP rating without cover	IP00		

[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.

- In case of vacuum operation, operate only with air pressure lower than 10^{-3} Pa. Intended for dust free indoor use.
- 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.
- A direct connection to the host device is required for maximum performance. Connecting via a USB hub may negatively affect the performance and stability of the device.

External temperature stabilization

Temperature stabilization of the device required. Attach the back of the device to a water-cooled plate or to a Peltier module. The temperature should be set to 22 °C.

Electrical Specification

T_{dev} = 22°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_{CC}	Supply Current		300	500	mA	Comply with USB 2.0, Mode dependent
P1	Power Dissipation			2,5	W	

Typical bias voltage source for sensor diode	Si				CdTe		Units
Thickness	100	300	500	1000[1]	1000	2000[1]	µm
V_{BIAS} [2]	50	150	150	200	-300 to -500	-500	V

[1] Customized product

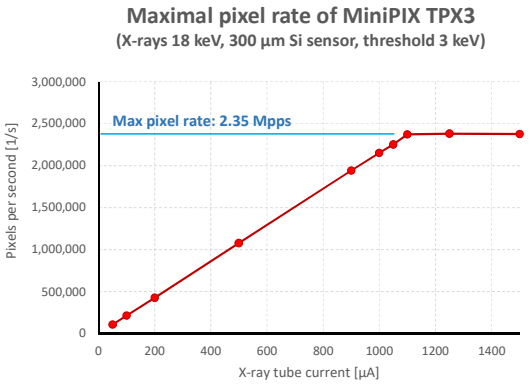
[2] Positive for Si sensors, negative for CdTe. Typical values

Performance characteristics

Symbol	Parameter	Min	Typ.	Max	Units	Comment
f_f	Frame-rate			16	fps	with USB 2.0 Host
T_{FREAD}	Frame Readout Time	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

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.



Sensor parameters

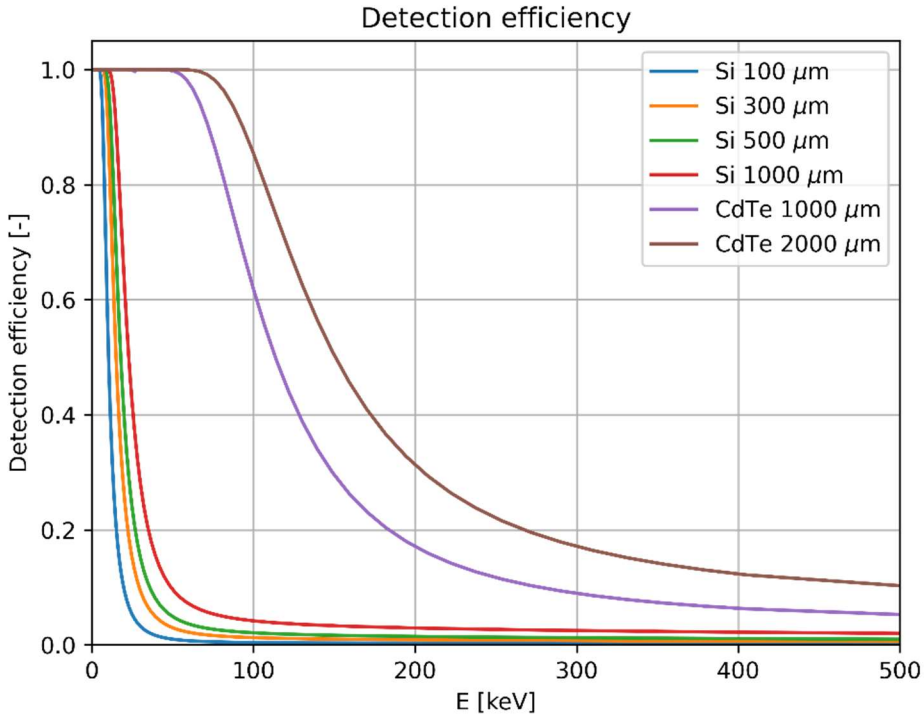
T_{dev} = 22°C

Parameter	Si				CdTe		Units	Comment
Thickness	100	300	500	1000[1]	1000	2000[1]	µm	
Calibrated energy threshold[2]	3,0	3,0	3,0	3,0	5,0	5,0	keV	
Energy resolution in ToT mode (σ @ 60 keV)	1,2 - 2,6	1,3 - 2,7	1,4 - 3,5	1,7 - 3,6	2,8 - 5,4	2,9 - 8,3	keV	Valid for the standard calibration
Energy resolution in ToT mode (σ @ 122 keV)					3,4 - 6,0	4,5 - 9,9	keV	Valid for the standard calibration
Typical detectable energy range for X-rays	3,0 - 60				5,0 - 500		keV	See chart below
Good pixels	> 99,5%				> 99,5%			
Pixel size[3]	55 x 55						µm	

[1]Customized product

[2] Premium calibration and/or chip class can achieve even better performance. For more information, please contact support@advacam.cz

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



Basic principles, measurement types and 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 basic values which can be measured and stored in counters of each pixel.

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). **T**ime-**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:

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

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 into ***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 by software automatically. For Pixel type measurement, if saved as a .t3pa file, ToA and FToA are stored as separate items.

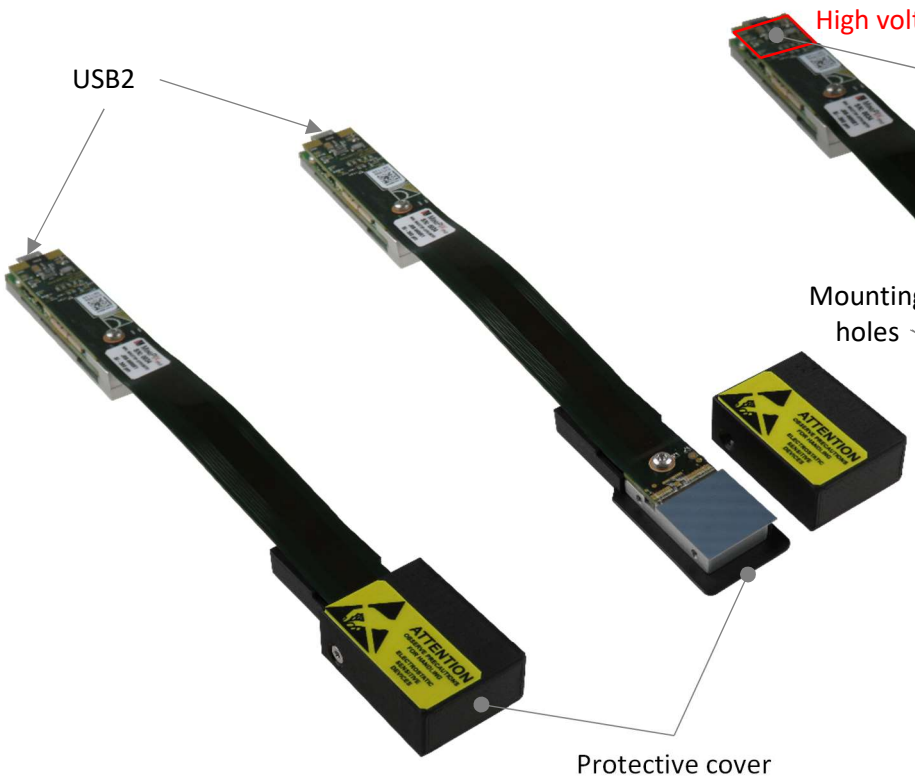
Device description

The device is supplied with USB flash disk containing installer of PIXet Pro software, unique device configuration and calibration file and protocol on quality tests. The device is delivered with protective plastic box covering the sensitive detector part. The protective cover is used for transport only.
The communication and powering is provided by USB Micro-B connector and cable.

- Protective cover must be removed before use to avoid sensor damage from overheating. Remove the cover with extreme care, avoid any contact with the sensor chip or wire-bonds.
- High voltage - Sensor chip is supplied with high voltage up to ±500 V. To avoid sparks or unwanted discharge follow EN 61010-1 (chapter 6.7, Insulation requirements. Fig. 4, Tab. 6, Annex C).

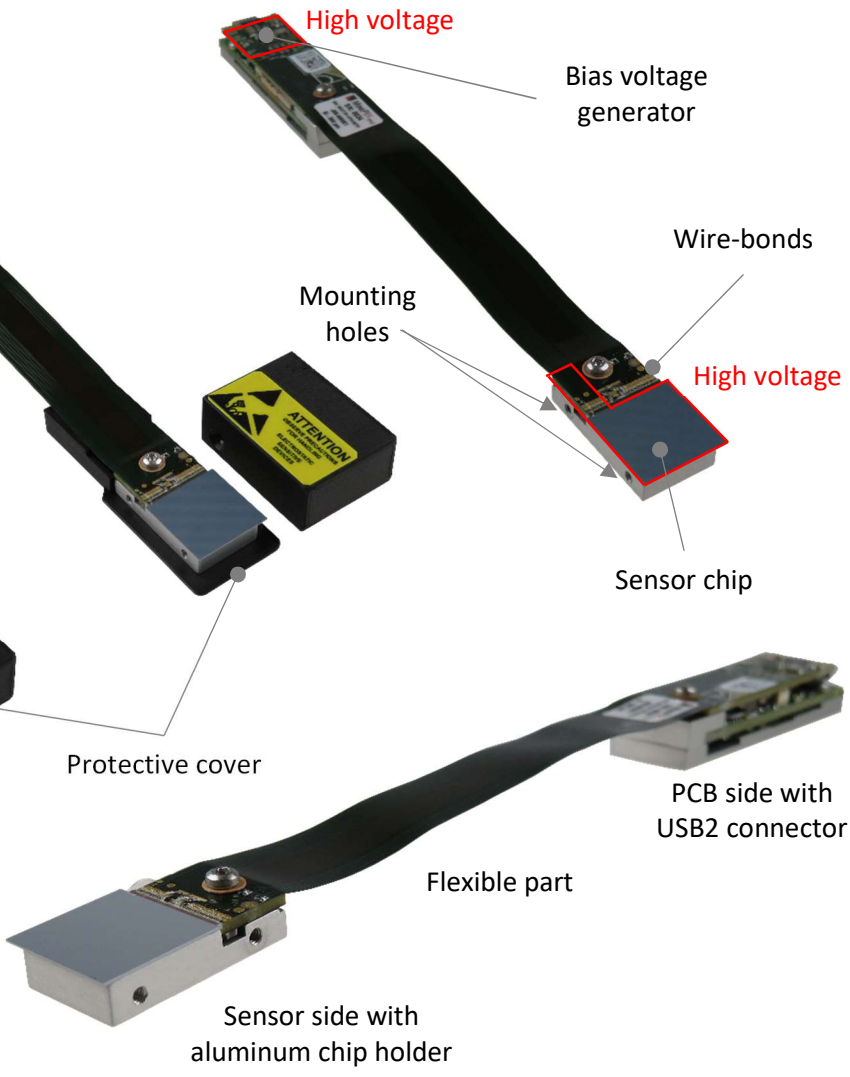
Device with protective plastic cover

(Left: as delivered, right: opened)



Plastic cover removed

(Before installation)

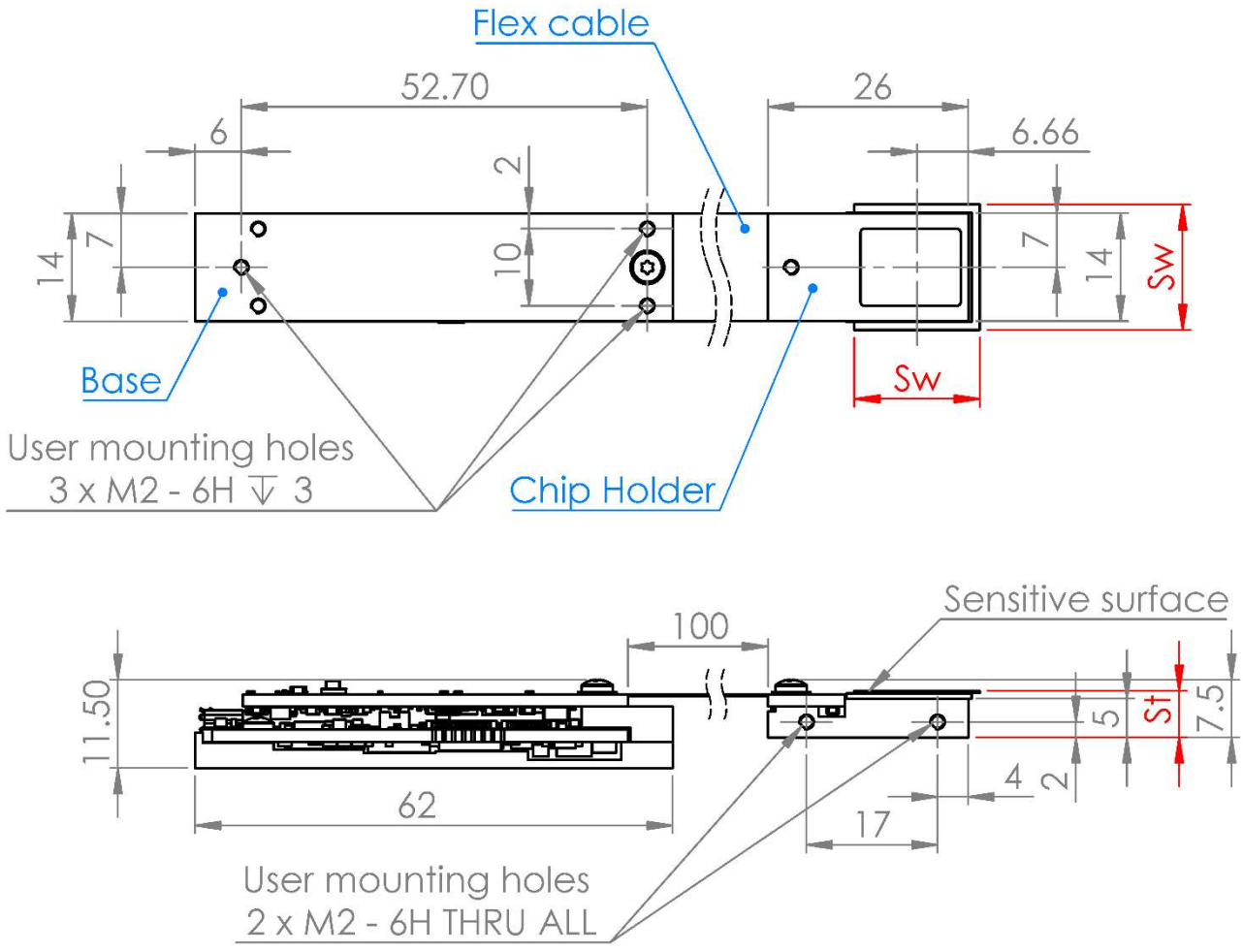


USB connector

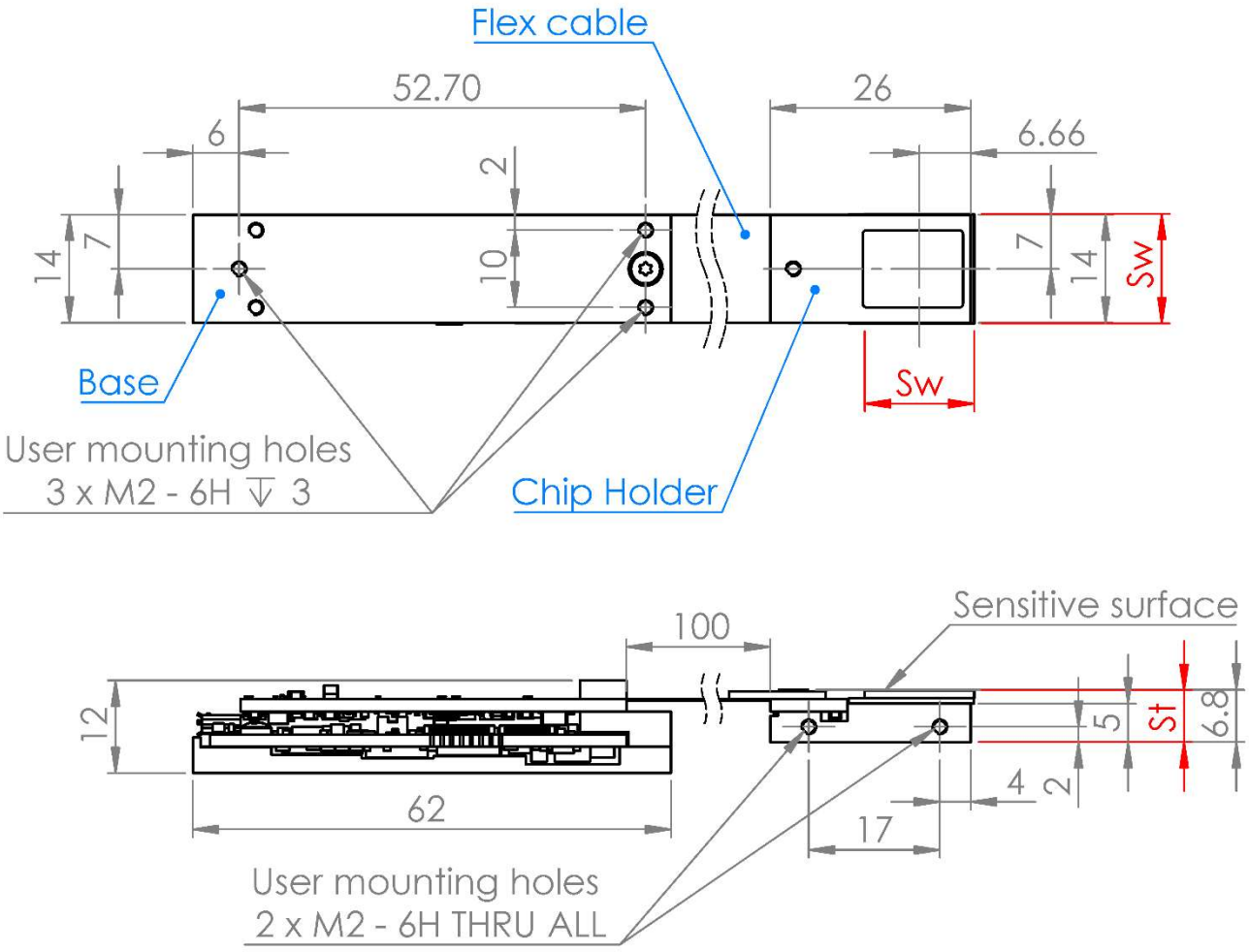
USB type Micro-B, Standard USB 2.0 High-Speed. The USB cable length should be less than 2m. For longer connections, a repeater or active cable is suggested.

Mechanical dimensions

MiniPIX versions: MNXT3F-Xxx190731; MT3Fxx-Xxx190925; MT3F10-Xxx211214
Mechanical dimensions for Si sensor.
Drawing of the device with aluminum base supporting the PCB side:

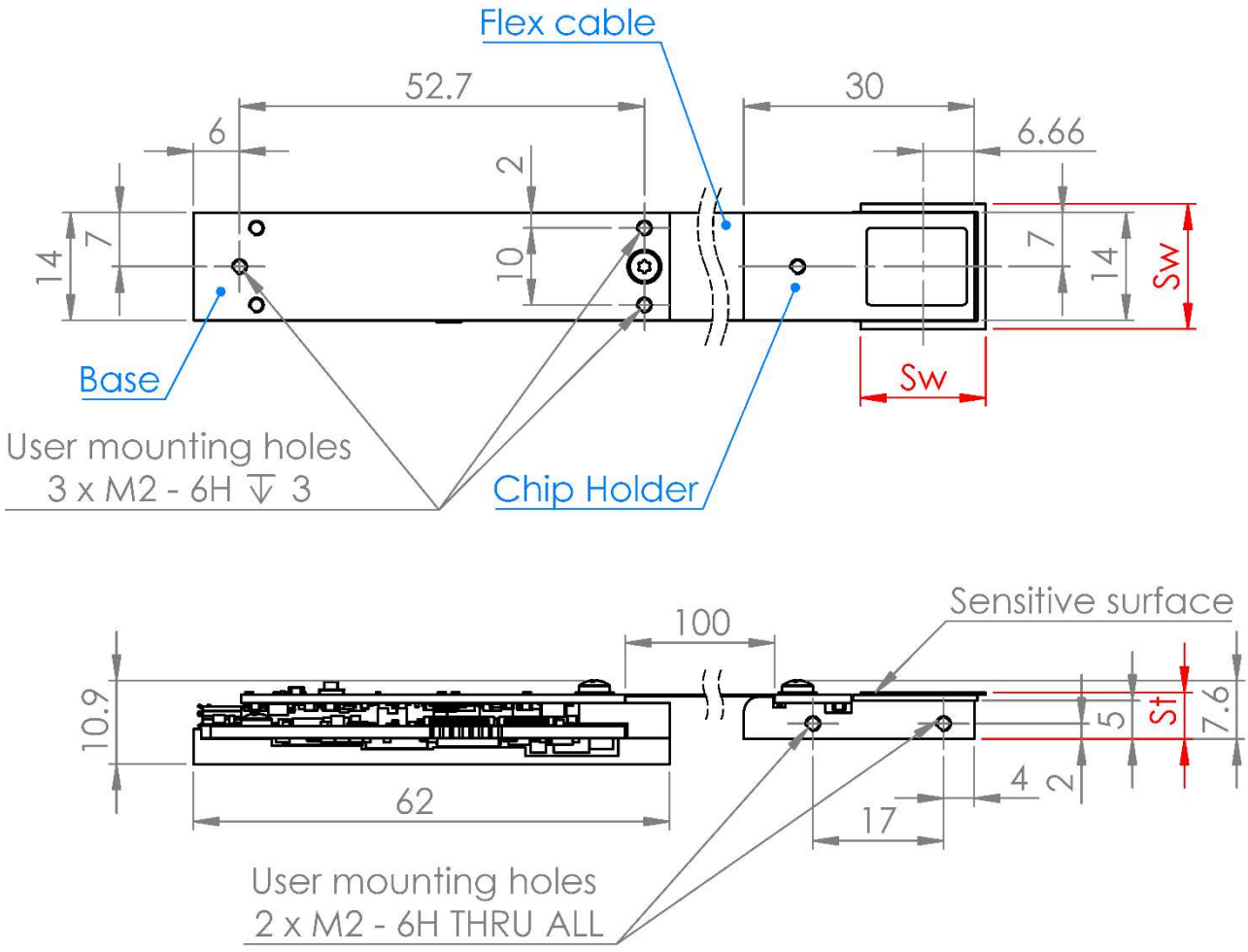


MiniPIX versions: MNXT3F-Xxx190731; MT3Fxx-Xxx190925; MT3F10-Xxx211214
Mechanical dimensions for CdTe sensor.
Drawing of the device with aluminum base supporting the PCB side:



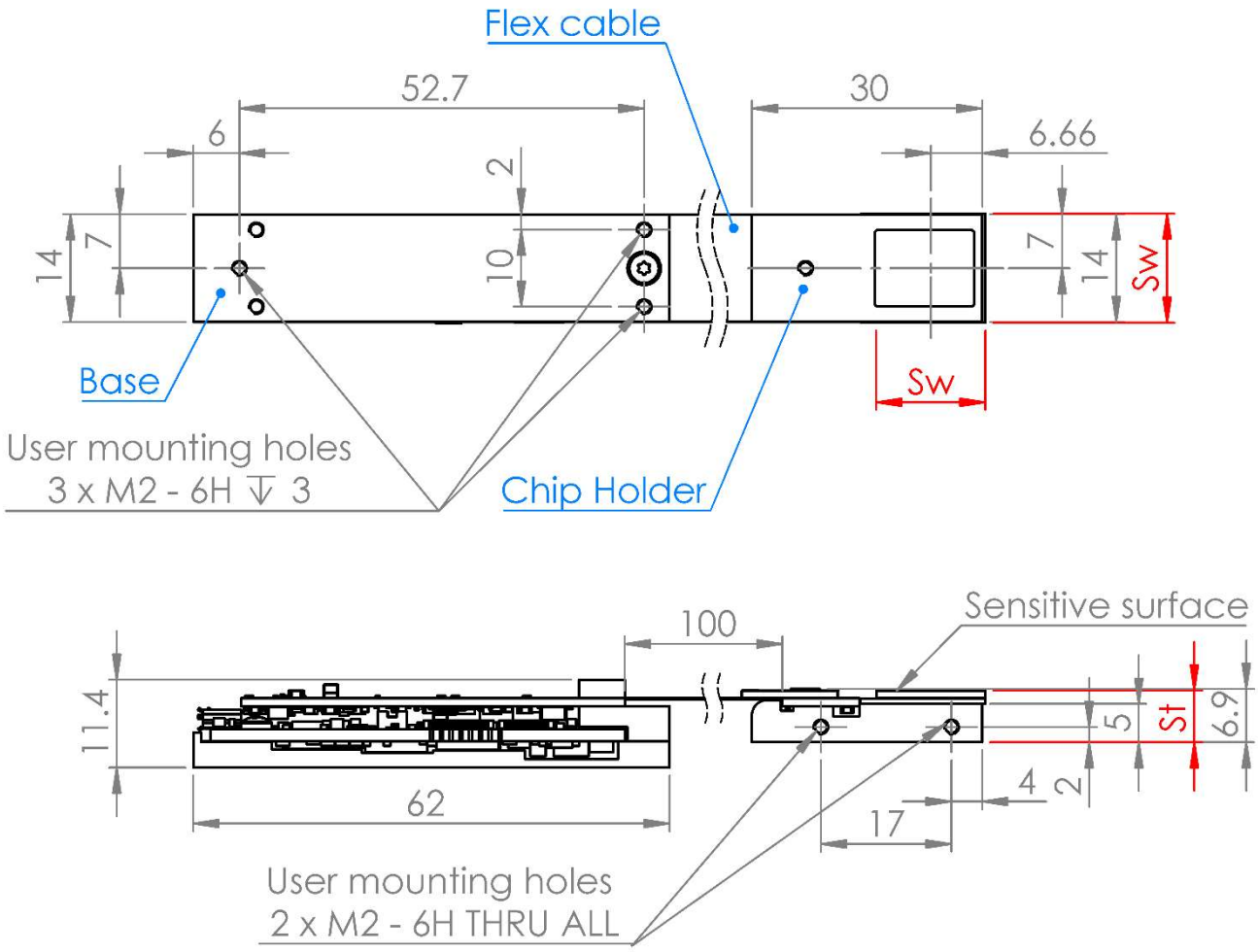
All dimensions are in mm. The sensor specific dimensions s_t and s_w (shown in red) are listed in the following table.

MiniPIX version: MT3F10-Xxx220422
Mechanical dimensions for Si sensor.
Drawing of the device with aluminum 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.

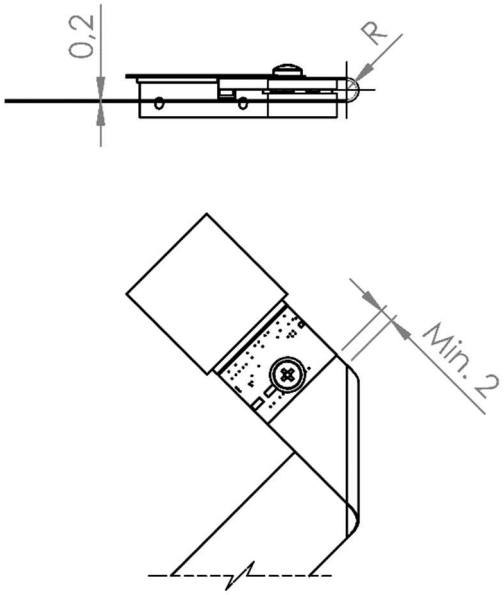
MiniPIX version: MT3F10-Xxx220422
Mechanical dimensions for CdTe sensor.
Drawing of the device with aluminum base supporting the PCB side:



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 protecting cover. Warranty does not apply to mechanical damage of the sensor and wirebonds.

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 width 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 XXXXXXXX**

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 – 2000 µm

Device build version:

Instructions for safe use

Remove plastic cover before use!

Attach the aluminum support to an appropriate heatsink!

Do not touch the sensor surface or wire bonds!

Attention! Electrostatic-sensitive device!

The **MINI*PIX* 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 **MINI*PIX* TPX3F** please observe the following:

- Do not expose to water or moisture.
- Do not disassemble. Wire-bonding connection may be irreversibly damaged.
- Do not touch the sensor surface or wire bonds!
- The maximum USB cable length is 2 m.
- Thermal stabilization of the device is necessary. Recommended temperature is 22 °C.
- A direct connection to the host device is required for maximum performance. Connecting via a USB hub may negatively affect the performance and stability of the device.
- 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 environment impact.

Release history

Date (YY/MM/DD)	Changes	Changed by
19/04/12	Preliminary datasheet	
19/07/19	Preliminary datasheet updated: Intended applications	
19/07/30	Flex version	
19/10/09	Add: Module dimensions, High Voltage standard reference	
19/11/01	Add Protective cover removal	
19/11/15	New version Mother Board	
20/04/30	Model Number Codes	
20/07/28	New version Protective Cover, add Flex cable bending parameters	
20/11/03	Mechanical dimensions	
22/03/03	New version	
22/05/03	Updated operating conditions	
21/06/06	Vacuum compatibility; Sensor parameters; ToA	
22/10/06	Mechanical dimension for new version 220422	
24/07/02	Datasheet revision, new graphic style of the document	J. Baborák P. Bloudek
24/07/23	Minor format changes	J. Baborák

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