Hardware Integration Manual

MTi 1-series

Revision	Date	By	Changes
A	05 Apr 2018	RGI	Initial release
B	11 Jan 2019	AKO	Added hand soldering info
2019.A	Dec 2019	AKO	Xsens brand update

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1 General information

This document provides hardware design instructions for the MTi 1-series module. The MTi 1-series module is a fully functional, self-contained module that is easy to design-in with limited external hardware components to be added. The MTi 1-series module can be connected to a host through I^{2}C, SPI or UART interfaces.

Section 2 shows recommendations for power supplies for the 1-series. Section 3 provides information about the different communication protocols that can be used, and section 4 describes some general layout considerations. The last two sections provide information about packaging and handling.

The following symbols are used in this document to highlight important information:

⚠️ **A warning symbol indicates actions that could damage the module.**

This document applies to the following products:

Table 1: MTi 1-series latest generation

Product name	Type number	Hardware version[1]	PCB number[2]
MTi-1	MTi-1T/R	≥ 2.0	≥ SM171223
MTi-2	MTi-2T/R	≥ 2.0	≥ SM171223
MTi-3	MTi-3T/R	≥ 2.0	≥ SM171223
MTi-7	MTi-7T/R	≥ 2.0	≥ SM171223

This document also applies for previous generations, unless noted otherwise.

Table 2: MTi 1-series previous generation

Product name	Type number	Hardware version	PCB number
MTi-1-8A7G6	MTi-1-8A7G6T/R	≤ 1.1	≤ SM141111
MTi-2-8A7G6	MTi-2-8A7G6T/R	≤ 1.1	≤ SM141111
MTi-3-8A7G6	MTi-3-8A7G6T/R	≤ 1.1	≤ SM141111

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[1] This number can be found on the packaging label (see Sections 5.1 and 5.2).
[2] This number can be found on the bottom side of the MTi 1-series module (see Section 5.3).

2 Power supply

The MTi 1-series module has two supply pins: VDDA and VDDIO. They can be supplied independently or tied together to adapt various concepts, depending on the intended application. The different supply voltages are explained in the following subsections.

2.1 Main supply voltage (VDDIO)

The VDDIO pin is the main supply of the MTi 1-series module. This pin is connected to all the digital IO's, and powers the processor on the MTi 1-series module. Section 2.4 shows the acceptable range of VDDIO. For the most power efficient implementation, the VDDIO pin should be connected to a 1.8 V power supply.

2.2 Analog supply voltage (VDDA)

The VDDA pin of the MTi 1-series module is connected to all the power supply pins of the sensing elements that are on the MTi 1-series module. There is no low-dropout regulator (LDO) on the MTi 1-series. Section 2.4 shows the acceptable range of VDDA. To get the best sensor performance, it is important that the VDDA pin is supplied by a power supply with a maximum ripple of 50 mVpp.

2.3 Single power supply configuration

The MTi 1-series VDDA and VDDIO supply pins can be connected to the same power supply. When the MTi 1-series is supplied with a single power supply source, it is strongly recommended to decouple the VDDA and VDDIO supply pins, for example with a resistor, for the best sensor performance (see Figure 1). This way the digital circuitry will not influence the analogue sensing part. Considering the minimum operating voltage for VDDA, the single supply voltage VDD should be at least 2.2 V, due to the voltage drop over R1.
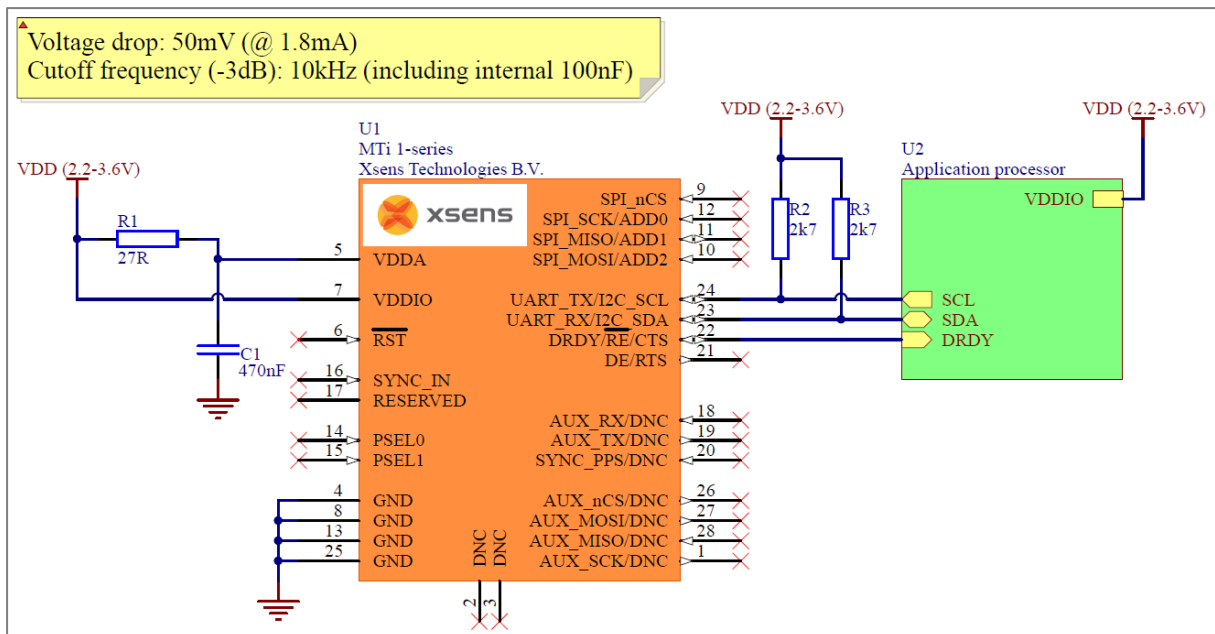
Figure 1: External components single supply (I²C interface)

2.4 Power supply specifications

Table 3 shows the maximum operating voltage ratings of the MTi 1-series. Exposure to any voltage beyond maximum operating voltage rating condition for extended periods may affect device reliability and lifetime.

Table 3: Maximum operating voltage ratings

	Min	Max	Unit
VDDA	2.16	3.6[3]	V
VDDA ripple		50	mVpp
VDDIO	1.8	VDDA + 0.1	V

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[3] Previous generation version ≤1.1, VDDA max: 3.45V

3 Interfaces

3.1 Pin Configuration

Figure 2 shows the pin configuration of the MTi 1-series module. Pin 18, 19 and 20 are only used on the MTi-7, for MTi-1/2/3 these pins need not be connected (DNC).
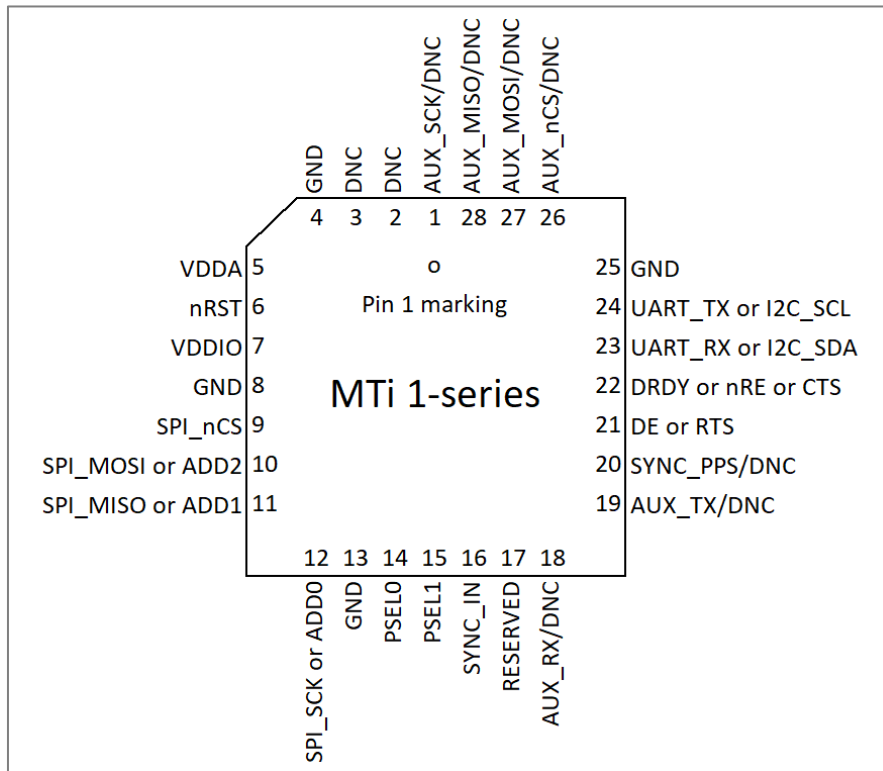
Figure 2: Pin configuration of the MTi 1-series module (top view)

3.2 Communication to host

The MTi 1-series modules are designed to be used as peripheral devices in embedded systems. The MTi 1-series modules support inter-integrated circuit (I^2C), serial peripheral interface (SPI) and universal asynchronous receiver/transmitter (UART) protocols for the communication between the MTi 1-series module and host CPU. The I^2C and SPI protocols are well suited for communication between integrated circuits and on-board peripherals. To select the correct communication interface, PSEL1 and PSEL0 should be configured accordingly (see section 3.2.1). For interface specifications, see Table 4.

Table 4: Host communication interfaces specifications

Interface		Min	Typ	Max	Units
I^2C	Host I^2C Interface Speed			400	kHz
SPI	Host SPI Interface Speed			2	MHz
	Clock Duty Cycle	30	50	70	%

UART	Baud Rates		921.6	4000	kbps

3.2.1 PSEL serial host communication interface selection

The MTi 1-series modules has four modes of peripheral interfacing. Only one mode can be used at a time and this is determined by the state of peripheral selection pins PSEL0 and PSEL1 at start up. Table 5 specifies how the PSEL lines select the peripheral interface. Note that the module has internal pull-ups (30 kΩ – 50 kΩ). Not connecting PSEL results in a value of 1, connecting PSEL to GND results in a value of 0.

Table 5: Serial host interface selection

Interface	PSEL1	PSEL0
I^{2}C	1	1
SPI	1	0
UART half-duplex	0	1
UART full-duplex	0	0

3.2.2 I²C

I²C is the default interface (when PSEL1 and PSEL0 pins are floating or connected to VDDIO). The I²C SCL and SDA pins are open drain and therefore they need pull-up resistors to VDDIO (R2 and R3 in Figure 3; typical value: 2.7 kΩ).
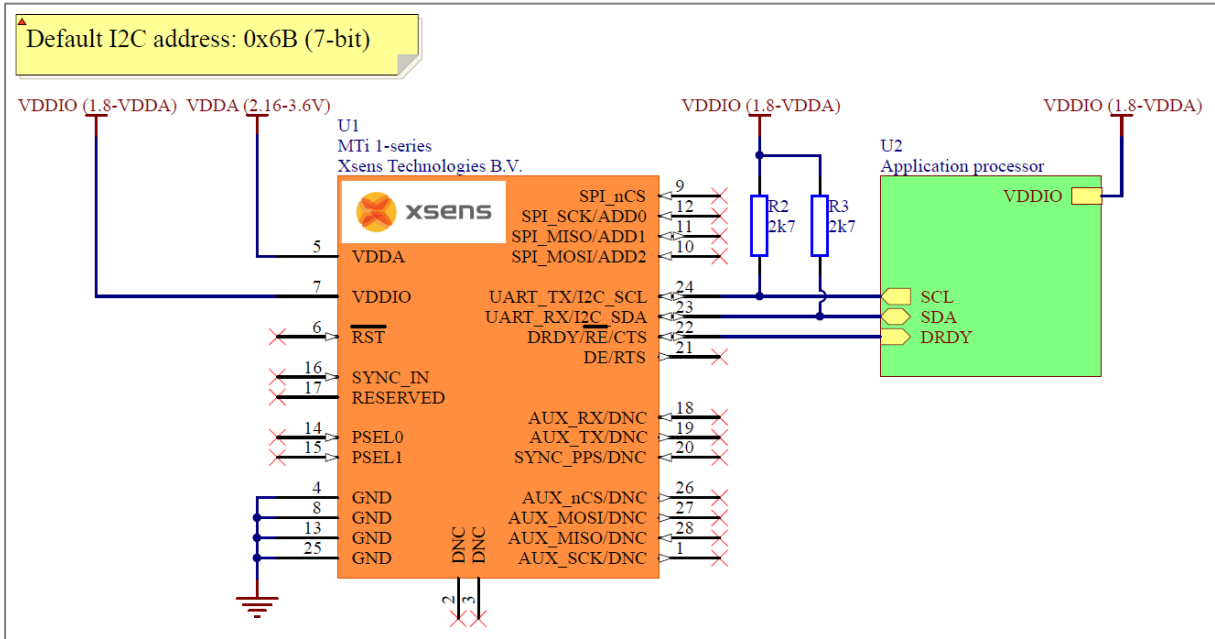
Figure 3: External components (I²C interface)

The MTi 1-series module acts as an I²C Slave. The I²C slave address is determined by the ADD0, ADD1 and ADD2 pins. These pins are pulled-up internally so when left unconnected the address selection defaults to ADD[0..2] = 111. Table 6 shows a list of all possible I²C addresses.

Table 6: List of I²C addresses

I²C address	ADD2	ADD1	ADD0
0x1D	0	0	0
0x1E	0	0	1
0x28	0	1	0
0x29	0	1	1
0x68	1	0	0
0x69	1	0	1
0x6A	1	1	0
0x6B *(default)*	1	1	1

3.2.3 SPI

For the SPI interface, PSEL1 can be left floating or pulled-up to VDDIO and PSEL0 pin needs to be connected to GND, as shown in Figure 4.
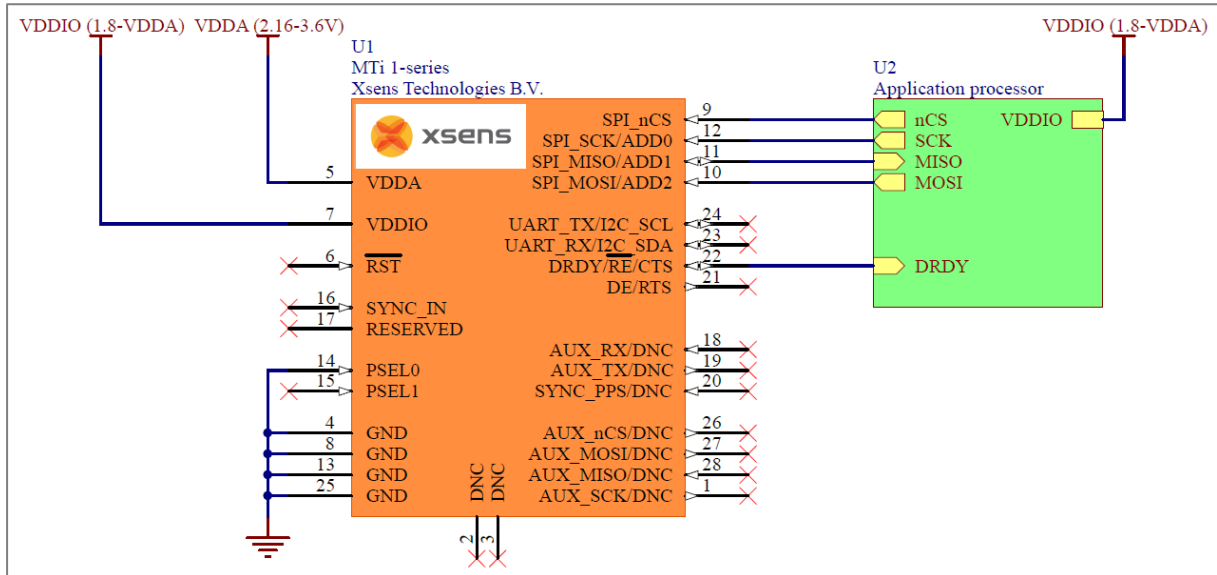
Figure 4: Connections (SPI interface)

3.2.4 UART

For the UART full-duplex interface, PSEL1 and PSEL0 pins needs to be connected to GND, as shown in Figure 5. The UART full-duplex communications mode can be used without hardware flow control. In this case the CTS line needs to be tied low (GND) to make the MTi 1-series transmit. For UART half-duplex interface, PSEL1 needs to be connected to GND and PSEL0 pin must be left floating (see Table 5).

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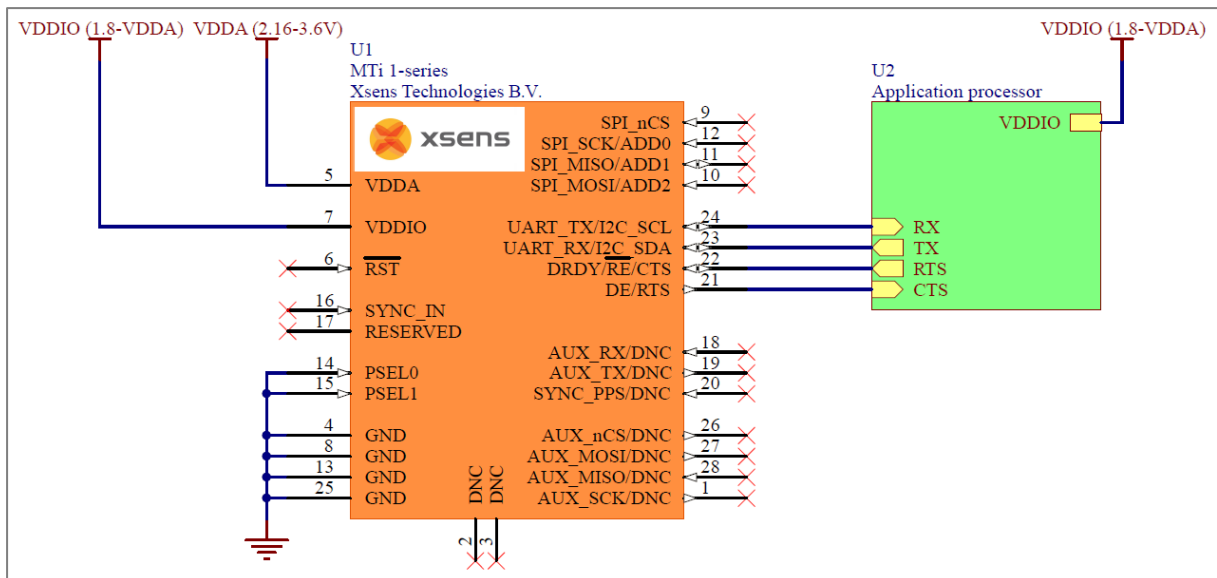
Figure 5: Connections (UART interface full-duplex)

3.3 GNSS receiver and barometer interface

The MTi-7 variant of the MTi 1- series module family supports external inputs from a GNSS receiver like the uBlox MAX-M8. For the GNSS receiver, the UART communication and PPS/TIMEPULSE pins of the receiver need to be connected to the AUX_TX, AUX_RX and SYNC_PPS pins of the MTi-7 module. See Figure 6 for schematic details and Table 7 for interface specifications.

Table 7: GNSS receiver interface specifications

Interface		Typ	Max	Units
UART	Baud Rates	115.2	2000	kbps

Besides the GNSS receiver, the MTi-7 also supports an external barometer like the BMP280. For the barometer, the SPI pins need to be connected to the AUX_nCS, AUX_MOSI, AUX_MISO and AUX_SCK pins of the MTi-7 module. See Figure 6 for schematic details.

Figure 6: Connections (GNSS interface)

3.4 I/O pins

The I/O interface specifications are listed in Table 8.

Table 8: I/O interface specifications

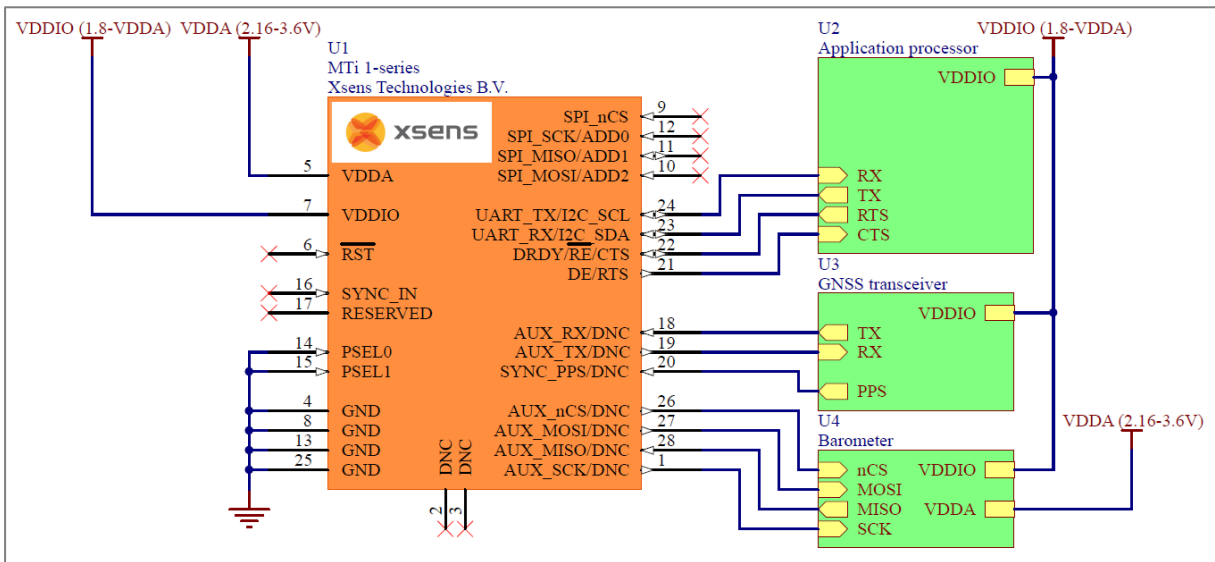| I/O interface	Symbol	Min	Max	Unit	Description
SYNC_IN	V_{IL}		$0.3 \cdot VDDIO$	V	Input low voltage
	V_{IH}	$0.45 \cdot VDDIO + 0.3$		V	Input high voltage
	V_{HYS}	$0.45 \cdot VDDIO + 0.3$		V	Threshold hysteresis voltage
nRST	V_{IL}		$0.3 \cdot VDDIO$	V	Only drive momentarily
	R_{PU}	30	50	kΩ	Pull-up resistor
	T_P	20		µs	Generated reset pulse duration

3.4.1 Reset

The reset pin is active low. Drive this pin with an open drain output or momentary (tactile) switch to GND. During normal operation, this pin should be left floating, as this line is also used for internal resets. This pin has an internal weak pull-up to VDDIO.

⚠️ **Do not connect the reset pin directly to VDDIO!**

3.4.2 SYNC_IN

SYNC_IN pin accepts an external trigger, on which the MTi 1-series sends out the latest available data message. The SYNC_IN pin is 5V tolerant and can be connected directly to an external device. Please make sure that the MTi 1-series and the external device are connected to or have the same common GND. Table 8 shows the electrical specifications.

3.5 DNC/RESERVED pins

These pins are reserved for future use.

⚠️ **Do not connect, leave pins floating!**

4 Design

4.1 PCB layout

To prevent current flows that can influence the performance of the MTi 1-series, it is recommended to remove all copper (planes) underneath the MTi 1-series as shown in Figure 7.
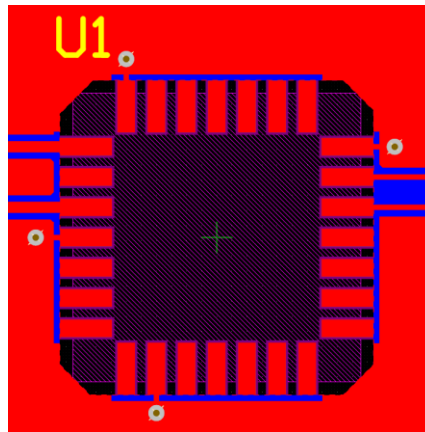

Figure 7: Layout example

4.1.1 Frames of reference used in MTi 1-series

The MTi 1-series module uses a right-handed coordinate system as the basis of the sensor frame.
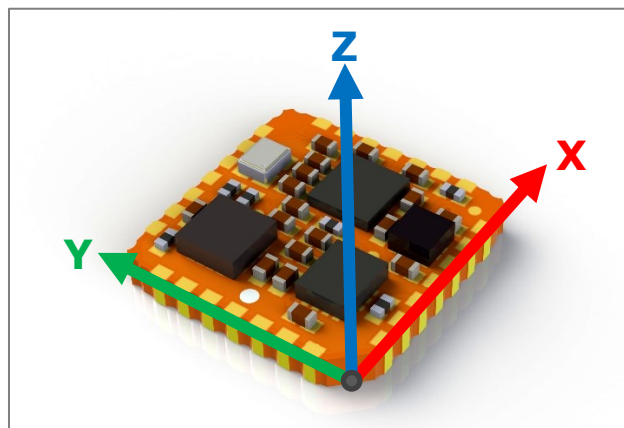
Figure 8: Default sensor fixed coordinate system for the MTi 1-series module

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4.1.2 Origin of measurements

The accelerometer determines the origin of measurements. Figure 9 shows the location of the accelerometer of the MTi 1-series.
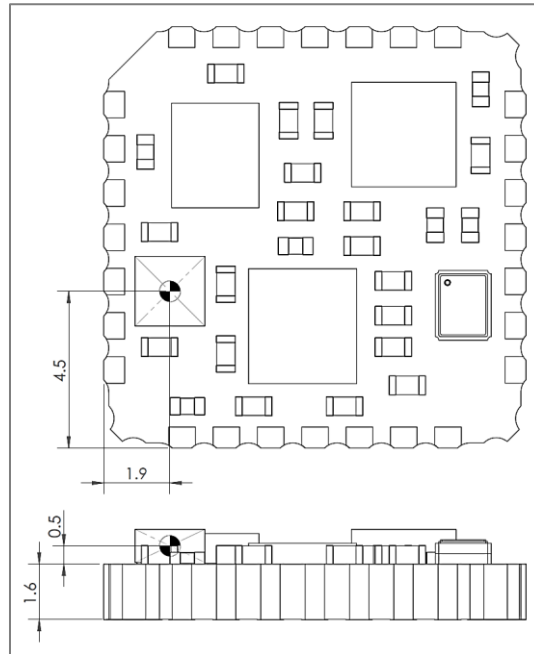
Figure 9: Location origin of measurements

4.2 Mechanical stress

In general, it is recommended to place the MTi 1-series module in an area on the PCB with minimal mechanical stress. The following paragraphs show causes of mechanical stress and ways to reduce it.

4.2.1 Pushbutton contacts

Pushbuttons induce mechanical stress when used. Therefore, it is recommended to keep a reasonable distance between a pushbutton and the MTi 1-series module.

4.2.2 Anchor points

Anchor points are usually a cause of mechanical torsional stress. The MTi 1-series module should not be placed near an anchor point. Furthermore, since a plane is uniquely determined by three points, it is recommended to affix the PCB with no more than three anchor points. More than three anchor points over define the PCB plane and therefore induce mechanical stress. Figure 10 shows an example of a PCB with four anchor points that gives a maximum stress in the centre of the diagonal crossover. Avoid placing the MTi 1-series module in such an area.
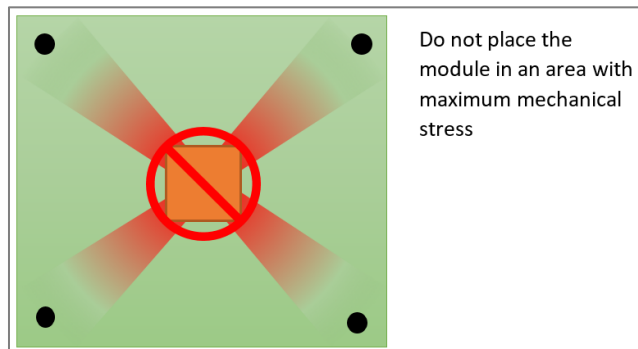
Figure 10: High mechanical stress in diagonal crossover between anchor points

The best way to deal with the problem shown in Figure 10 is to remove one of the anchor points as shown in Figure 11. This will reduce the overall stress in the PCB. If more anchor points are required (e.g. in case of a large PCB) the MTi 1-series module should be moved to an area with minimal mechanical stress, as shown in Figure 12.

Figure 11: Reducing anchor points to reduce overall stress in the PCB

Figure 12: Keeping the MTi 1-series module away from high mechanical stress areas

4.2.3 Vibrations

The MTi 1-series features an industry-leading signal processing pipeline (AttitudeEngine™) which rejects vibrations. For best results however, it is recommended that the MTi 1-series is mechanically isolated fro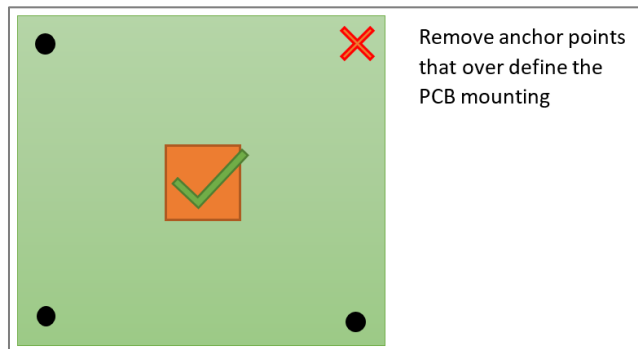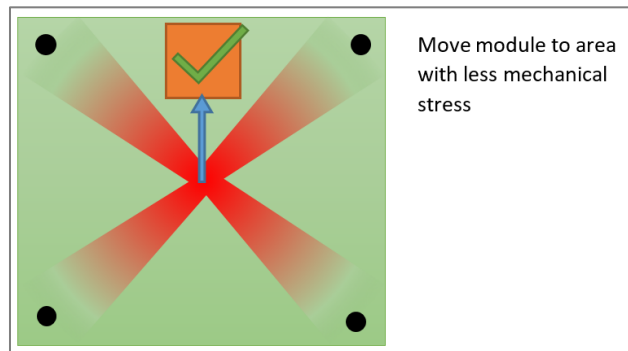m vibrations as much as possible. Especially in applications where vibrations are likely to occur, the anchor points of the PCB that holds the MTi 1-series module should be dampened. The required type of dampening varies from application to application.

4.2.4 Heat

Keep the MTi 1-series module away from heat sources. Thermal gradients can cause mechanical stress, which can affect the sensor performance of the MTi 1-series.

4.2.5 Sockets

For best performance, it is best to solder the module directly onto a PCB by a solder reflow process. When placed in a socket, the module may be subjected to mechanical stress by the springs in the socket, which might result in deteriorated performance.

4.2.6 Hand soldering

⚠️ **It is not recommended to solder the module by hand onto a PCB, as may introduce unwanted stress on the module, which might result in deteriorated performance.**

4.3 Magnetometer

The MTi 1-series uses a 3D magnetometer for measuring the geomagnetic field. This part is sensitive to magnetic disturbances.

4.3.1 Ferromagnetic materials

Ferromagnetic materials can be magnetized and the magnetic behaviour can change during operation. This behaviour will influence the measurements of the 3D magnetometer of the MTi 1-series.
Therefore, keep these ferromagnetic materials away from the MTi 1-series.

4.3.2 High currents

High current power lines on the PCB will introduce magnetic fields that will influence the measurements of the 3D magnetometer of the MTi 1-series. Place high current power lines away from the MTi 1-series.

Example: a power line with a current of 100 mA at a distance of 10 mm, will introduce an error of 2 μT.

4.4 Footprint

The footprint of the MTi 1-series module is similar to a 28-lead Plastic Leaded Chip Carrier package (JEDEC MO-047). Although it is recommended to solder the MTi 1-series module directly onto a PCB, it can also be mounted in a compatible PLCC socket (e.g. 8428-21B1-RK of 3M, as used on the MTi 1-series Development Kit). When using a socket, make sure that it supports the maximum dimensions of the MTi 1-series module as given in Section 5.3 (note the tolerance of ± 0.1 mm).
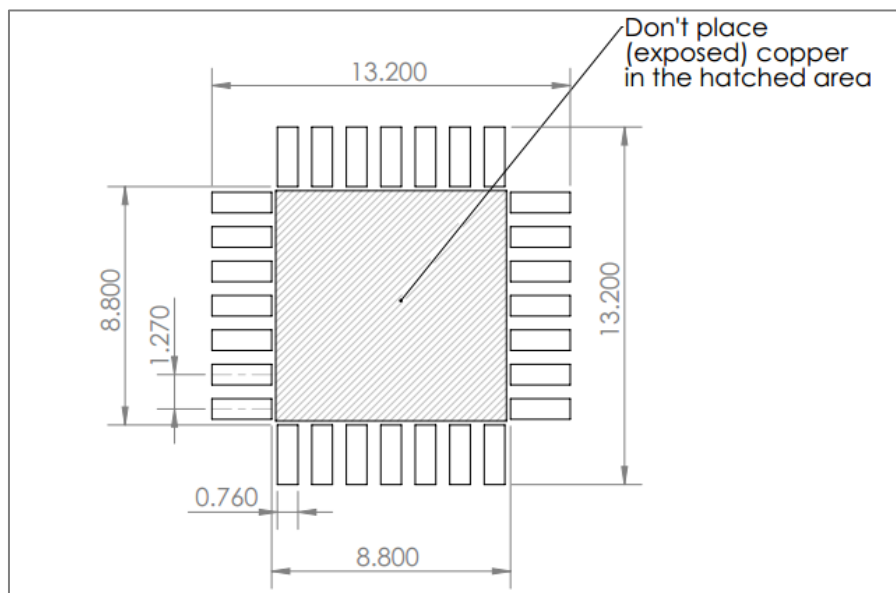

Figure 13: Recommended MTi 1-series module footprint

5 Packaging

The MTi 1-series module is shipped in trays with 20 modules or in reels with 250 modules.

5.1 Tray packaging information

TNR Label

Standard Intermediate Box

Y-Pitch

X-Pitch

Detail "A"
Device Pin 1
Orientation in Tray
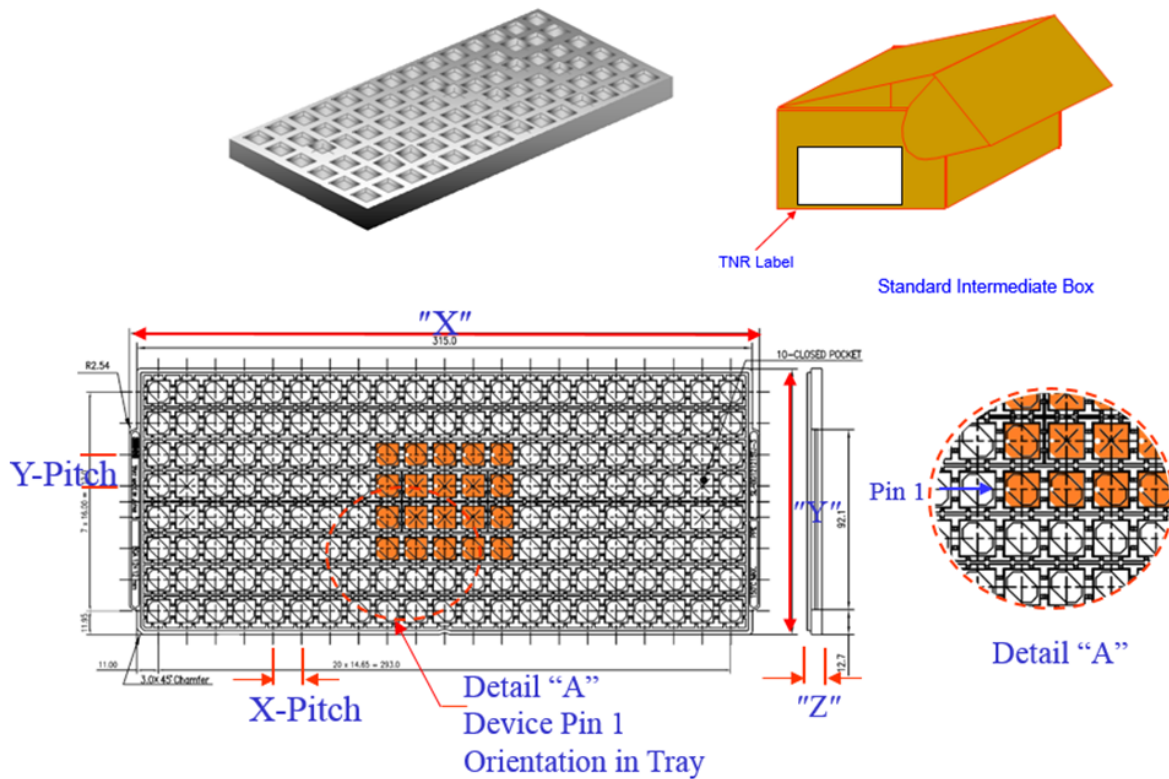
Pin 1

Detail "A"

TNR LABEL

Tray Dimensions (mm)						Tray packaging information		Pin 1
Length "X"	Width "Y"	Height "Z"	Pocket X-Pitch	Pocket Y-Pitch	Pocket X-Y Array	Qty/Tray	Qty/Box	
322.60	135.90	7.62	14.65	16.00	12 x 12	20 units	20 units	Detail "A" Marking

NOTES:
- All dimensions are in millimeters.

- Pictured tray representative only, actual tray may look different.
- The hardware version number is labeled SPEC REV on the TNR Label.

5.2 Reel packaging information
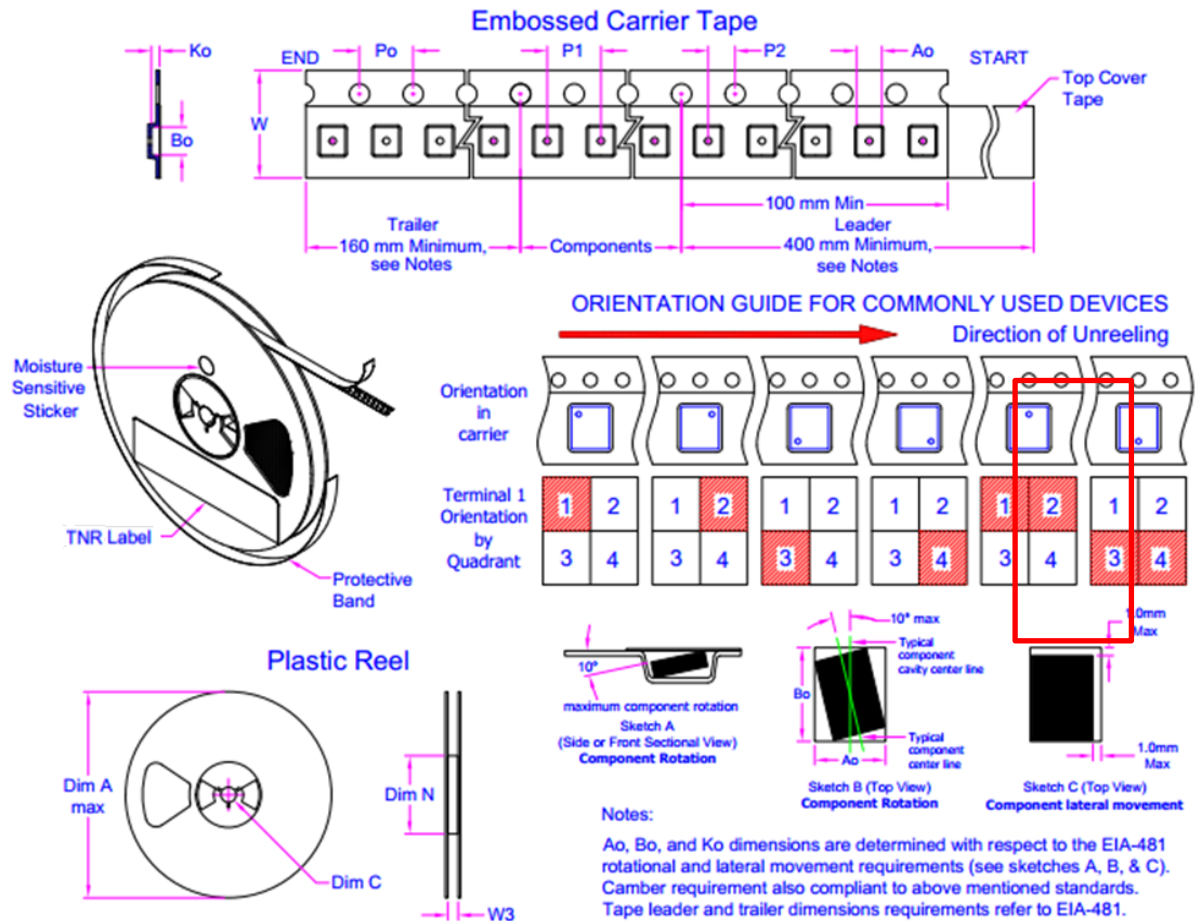
Carrier tape (mm)							Reels (mm)				Pin 1	Packing
Ao	Bo	Ko	W	Po	P1	P2	A	N	C	W3	Orientation by quadrant	QTY/ Reel

12.6 - 12.8	12.6 - 12.8	2.9 - 3.10	23.70 - 24.30	3.90 - 4.10	15.90 - 16.10	1.90 - 2.10	177.80	55	12.80 - 13.50	23.90 - 27.40	1 & 2	250

NOTES:
- All dimensions are in millimeters, unless otherwise specified.
- The hardware version number is labeled SPEC REV on the TNR Label.

5.3 Package drawing

All the MTi 1-series module generations have the same board dimensions and footprint, but the component placement can differ between generations.

Table 9: MTi 1-series module generations

Version 1.1 (PCB no. SM141111)	Version 2.0 (PCB no. SM171223)

Figure 14: MTi 1-series v1.1 dimensions and sensor locations

Figure 15: MTi 1-series v2.0 dimensions and sensor locations

- All dimensions are in mm.
- General tolerances are ± 0.1 mm

Figure 16: Location PCB number on MTi 1-series module (bottom view)

6 Handling

6.1 Reflow specification

The moisture sensitivity level of the MTi 1-series modules corresponds to JEDEC MSL Level 3, see also:

- IPC/JEDEC J-STD-020E "Joint Industry Standard: Moisture/Reflow Sensitivity Classification for non-hermetic Solid State Surface Mount Devices"
- IPC/JEDEC J-STD-033C "Joint Industry Standard: Handling, Packing, Shipping and Use of Moisture/Reflow Sensitive Surface Mount Devices".

The sensor fulfils the lead-free soldering requirements of the above-mentioned IPC/JEDEC standard, i.e. reflow soldering with a peak temperature up to 260 °C. Recommended Preheat Area (t_s) is 80-100 sec. The minimum height of the solder after reflow shall be at least 50 µm. This is required for good mechanical decoupling between the MTi 1-series module and the printed circuit board (PCB) it is mounted on.

The number of times that MEMS components may be reflowed is limited to three times. As the IMU is already reflowed once by Xsens in order to produce the MTi 1-series module, the MTi 1-series module may only be reflowed two times when placed on the PCB board. If the MTi 1-series is designed-in a double-sided PCB, it is recommended to reflow the side with the MTi 1-series in the second run in order to prevent large offsets.

For automated pick and placement of the MTi 1-series module please be aware that the component placement on the module can differ between generations, see Table 9.
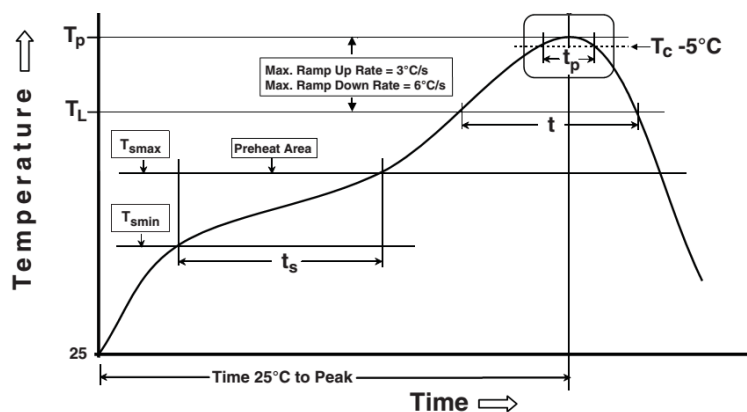
Figure 17: Reflow classification profile (not to scale)

6.2 Ultrasonic processes

The MTi 1-series is sensitive to ultrasonic waves (e.g. **ultrasonic cleaning/welding)**, which **will damage the MTi-1 series module**. Xsens will offer no warranty against damaged MTi 1-series modules caused by any ultrasonic processes.

⚠️ **Do not expose the MTi 1-series to ultrasonic processes!**

6.3 Electrostatic discharge (ESD)

Electrostatic discharge (ESD) is the sudden and momentary electric current that flows between two objects at different electrical potentials caused by direct contact or induced by an electrostatic field. The term is usually used in the electronics and other industries to describe momentary unwanted currents that may cause damage to electronic equipment.