MTi 1-series User Manual

User Manual

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Datasheet

General Information

This document provides information on the contents and usage of the MTi 1-series modules. The MTi 1-series module (MTi 1-s) is a fully functional, self-contained module that is easy to design-in. The MTi 1 s can be connected to a host through I^2C, SPI or UART interfaces.

The *Hardware Integration Manual* supplements this document. It contains notes on typical application scenarios, recommended external components, printed circuit board (PCB) layout, origin of measurements, stress related considerations, reference designs and handling information.

The *MT Low Level Communication Protocol Document* provides a complete reference for the protocol to communicate with Xsens Motion Trackers. For a better understanding of the Synchronous Serial Protocol (discussed in Functional Description) for use with the MTi 1-s, the advice is to read the communication protocol reference in the *MT Low Level Communication Protocol Document* first. This document also describes the synchronization messages and settings in detail.

Ordering information

⚠ Due to obsolescence management and continuous improvement, the MTi 1-series is subject to hardware changes, resulting in different hardware versions (v1.x, v2.x and v3.x). The tables below list the ordering part numbers for the hardware versions that are currently available (v2.x and v3.x). For an overview of differences between these hardware versions we refer to the migration articles on BASE.

Ordering information for MTi 1-series modules **v2.x**

Part Number	Output	Package	Packing Method
MTi-1T	IMU; inertial data	PCB, JEDEC-PLCC-28 compatible	Tray of 20

Part Number	Output	Package	Packing Method
MTi-2T	VRU; inertial data, roll/pitch (referenced), yaw (unreferenced)	PCB, JEDEC-PLCC-28 compatible	Tray of 20
MTi-3T	AHRS; inertial data, roll/pitch/yaw	PCB, JEDEC-PLCC-28 compatible	Tray of 20
MTi-7T	GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Tray of 20
MTi-1C	IMU; inertial data	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-2C	VRU; inertial data, roll/pitch (referenced), yaw (unreferenced)	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-3C	AHRS; inertial data, roll/pitch/yaw	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-7C	GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-1R	IMU; inertial data	PCB, JEDEC-PLCC-28 compatible	Reel of 250
MTi-2R	VRU; inertial data, roll/pitch (referenced), yaw (unreferenced)	PCB, JEDEC-PLCC-28 compatible	Reel of 250
MTi-3R	AHRS; inertial data, roll/pitch/yaw	PCB, JEDEC-PLCC-28 compatible	Reel of 250
MTi-7R	GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Reel of 250

Ordering information for MTi 1-series modules v3.x

Note: "0" is a number (zero), "I" is a character (capital i).

Part Number	Output	Package	Packing Method
MTi-1-0I-T	IMU; inertial data	PCB, JEDEC-PLCC-28 compatible	Tray of 20
MTi-2-0I-T	VRU; inertial data, roll/pitch (referenced), yaw (unreferenced)	PCB, JEDEC-PLCC-28 compatible	Tray of 20

Part Number	Output	Package	Packing Method
MTi-3-0I-T	AHRS; inertial data, roll/pitch/yaw	PCB, JEDEC-PLCC-28 compatible	Tray of 20
MTi-7-0I-T	GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Tray of 20
MTi-8-0I-T	RTK GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Tray of 20
MTi-1-0I-C	IMU; inertial data	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-2-0I-C	VRU; inertial data, roll/pitch (referenced), yaw (unreferenced)	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-3-0I-C	AHRS; inertial data, roll/pitch/yaw	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-7-0I-C	GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-8-0I-C	RTK GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Tray of 100
MTi-1-0I-R	IMU; inertial data	PCB, JEDEC-PLCC-28 compatible	Reel of 250
MTi-2-0I-R	VRU; inertial data, roll/pitch (referenced), yaw (unreferenced)	PCB, JEDEC-PLCC-28 compatible	Reel of 250
MTi-3-0I-R	AHRS; inertial data, roll/pitch/yaw	PCB, JEDEC-PLCC-28 compatible	Reel of 250
MTi-7-0I-R	GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Reel of 250
MTi-8-0I-R	RTK GNSS/INS; inertial data, roll/pitch/yaw, velocity, position	PCB, JEDEC-PLCC-28 compatible	Reel of 250

Identifying device functionality using the unique Device Identifier

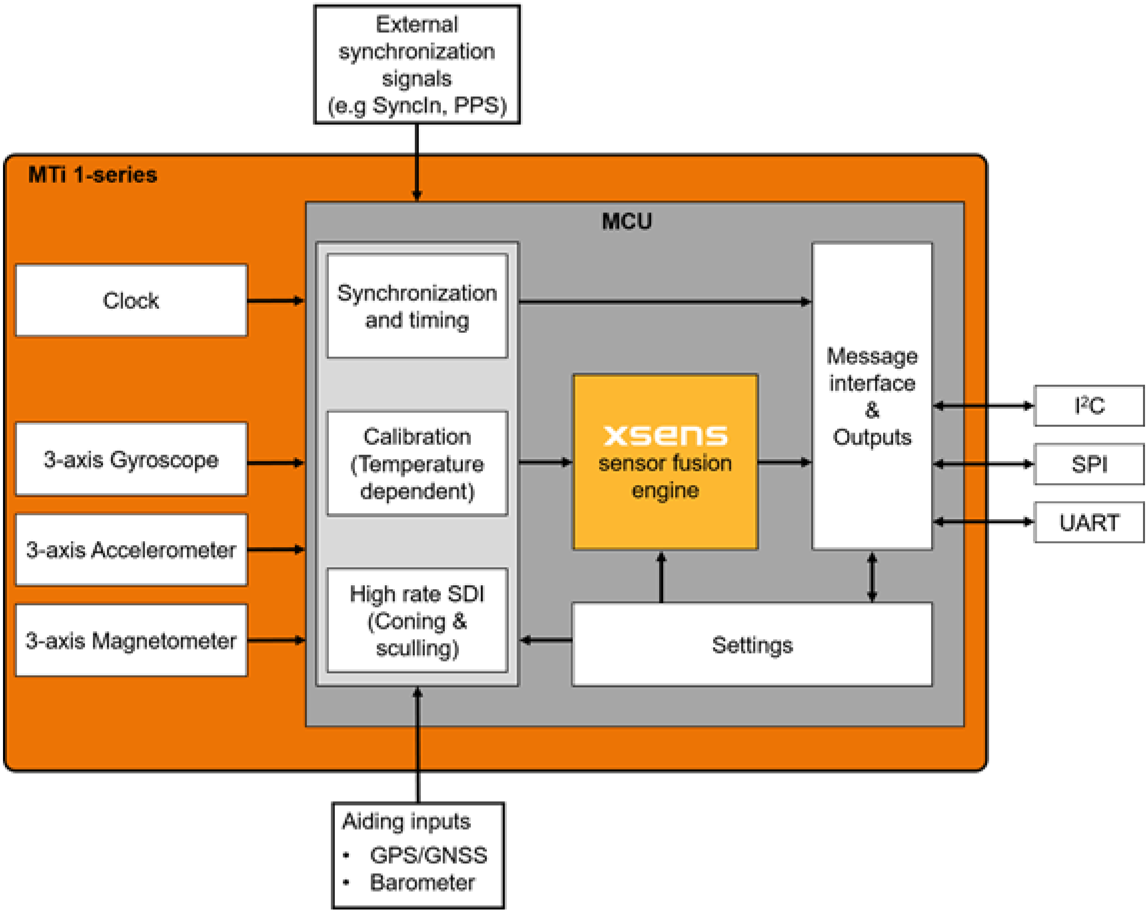
Each Xsens product is marked with a unique serial device identifier referred to as the Device ID. The Device ID is categorized per MTi product configuration in order to make it possible to recognize the MTi by reviewing the Device ID. The second digit of the Device ID denotes the functionality (e.g. ‘1’ for all IMU products, such as MTi-1, MTi-10 and MTi-100), the third digit denotes the product series (6 for MTi 10-series, 7 for MTi 100-series, 8 for MTi 1-series) and the fourth digit denotes the interface (always 8 for the MTi 1-series). The last four digits are unique for each device; these four digits have a hexadecimal format.
Below is a list of the MTi 1-series product types with their associated Device IDs.

Device ID's for MTi 1-series

<table>
<tr><th>Product (MTi 1-series)</th><th>Device ID</th><th>HW version</th></tr>
<tr><td>MTi-1 IMU</td><td>0188xxxx</td><td rowspan="3">Check component layout (Design and Packaging), MT Manager Device Settings or send the ReqHardwareVersion low-level (Xbus) command.</td></tr>
<tr><td>MTi-2 VRU</td><td>0288xxxx</td></tr>
<tr><td>MTi-3 AHRS</td><td>0388xxxx</td></tr>
<tr><td>MTi-7 GNSS/INS</td><td>0788xxxx</td><td>≥ 2.0 only. Check component layout (Design and Packaging), MT Manager Device Settings or send the ReqHardwareVersion low-level (Xbus) command.</td></tr>
<tr><td>MTi-8 RTK GNSS/INS</td><td>0888xxxx</td><td>≥ 3.1 only. Check component layout (Design and Packaging), MT Manager Device Settings or send the ReqHardwareVersion low-level (Xbus) command.</td></tr>
</table>

The rest of this document only caters to MTi 1-series with HW version ≥ 2.0. Refer to the MTi 1-series Datasheet version 1.x if you have an MTi with HW version < 2.0.

Block diagram



MTi 1-series module diagram

The above diagram shows a simplified organization of the MTi 1-series module (MTi 1-s). The MTi 1-s contains a 3-axis gyroscope, a 3-axis accelerometer, a 3-axis magnetometer, a high-accuracy crystal and a low-power microcontroller unit (MCU). The MTi-7/8 module can also accept the signals from an external GNSS receiver and/or barometer. The MCU coordinates the timing and synchronization of the various sensors. The module offers the possibility to use external signals in order to accurately synchronize the Mti 1-s with any user application. The MCU applies calibration models (unique to each sensor and including orientation, gain and bias offsets, plus more advanced relationships such as non-linear temperature effects and other higher order terms) and runs the Xsens optimized strapdown algorithm, which performs high-rate dead-reckoning calculations at 800 Hz, allowing accurate capture of high frequency motions and coning & sculling compensation. The Xsens sensor fusion engine combines all sensor inputs and optimally estimates the orientation, position and velocity at an output data rate of up to 100 Hz. The MTi 1-s is easily configurable for the outputs and, depending on the application's needs, can be set to use one of the filter profiles available within the Xsens sensor fusion engine. In this way, the MTi 1-s limits the load and the power consumption on the user application processor. The user can communicate with the module by means of three different communication interfaces. They are I^2C, SPI and UART.

Sensor Specifications

- MTi 1-series performance specifications
- Sensor specifications

This section presents the performance and the sensor component specifications for the calibrated MTi 1-s module. Each module goes through the Xsens calibration process individually. The calibration procedure calibrates for many parameters, including bias (offset), alignment of the sensors with respect to the module PCB and each other and gain (scale factor). All calibration values are temperature dependent and temperature calibrated. The calibration values are stored in non-volatile memory of the module.

MTi 1-series performance specifications

Orientation performance specifications

Parameter		MTi-1 IMU	MTi-2 VRU	MTi-3 AHRS	MTi-7 GNSS/INS	MTi-8 RTK GNSS/INS
Roll/Pitch	Static [RMS]	N/A	0.5º	0.5º	0.5º	0.5º
	Dynamic (car, 25m/s) [RMS]	N/A	0.8º	0.8º	0.5º	0.5º
Yaw	[RMS]	N/A	Unreferenced	2º	1.5º	1.0º

Position and velocity performance MTi-7 GNSS/INS (with MTi-7-DK)

Parameter		Specification
Position	Horizontal (CEP)	1.0 m
	Vertical (CEP)	2.0 m
Velocity	(1σ RMS)	0.05 m/s

Position and velocity performance MTi-8 RTK GNSS/INS (with MTi-8-DK and RTK correction signals provided)

Parameter		Specification
Position	Horizontal (CEP)	0.01 m

Parameter		Specification
	Vertical (CEP)	0.1 m
Velocity	(1σ RMS)	0.05 m/s

All the above specifications are based on typical application scenarios, and with MTi-x-DK reference designs.

Sensor specifications

Gyroscope specifications#1

Gyroscope specification	Unit	MTi 1-series v2.x	MTi 1-series v3.x
Standard full range	[°/s]	±2000	±2000
In-run bias stability	[°/h]	10	6
Bandwidth (-3dB)	[Hz]	255	230
Noise density	[°/s/√Hz]	0.007	0.003
g-sensitivity (calibrated)	[°/s/g]	0.001	0.001
Non-linearity	[%FS]	0.1	0.1
Sensitivity variation	[%]	0.05	0.05

Accelerometer specifications#1

Accelerometer	Unit	MTi 1-series v2.x	MTi 1-series v3.x
Standard full range	[g]	±16	±16
In-run bias stability	[mg]	0.03	0.04
Bandwidth (-3dB)	[Hz]	324 (Z: 262)	230
Noise density	[µg/√Hz]	120	70
Non-linearity	[%FS]	0.5	0.5

Magnetometer specifications#1

Magnetometer	Unit	MTi 1-series v2.x/v3.x
Standard full range	[G]	8
Non-linearity	[%]	0.2
Total RMS noise	[mG]	0.5
Resolution	[mG]	0.25

Alignment specifications#1

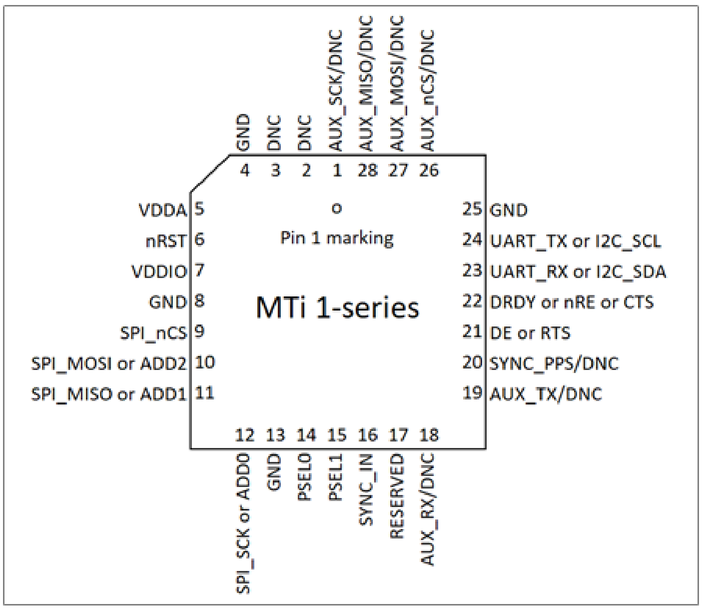
Parameter	Unit	MTi 1-series v2.x/v3.x
Non-orthogonality (accelerometer)	[°]	0.05
Non-orthogonality (gyroscope)	[°]	0.05
Non-orthogonality (magnetometer)	[°]	0.05
Alignment (gyr to acc)	[°]	0.05
Alignment (mag to acc)	[°]	0.1
Alignment of acc to the module board	[°]	0.2

[1] As Xsens continues to update the sensors on the module, these specifications may change in the future.

Functional Description

This chapter describes the MTi 1-s pinout and gives details about the supported communication interfaces.

Pin configuration



Pin configuration of the MTi 1-series module (top view)

Pin map

The pin map depends on the peripheral selection, as can be seen in the table below. Configuring the peripheral is explained in #Peripheral interface selection.

Pin mapping for peripheral selection

	PSEL: I^2C	PSEL: SPI	PSEL: UART half duplex	PSEL: UART full duplex
1#1	AUX_SCK/DNC	AUX_SCK/DNC	AUX_SCK/DNC	AUX_SCK/DNC
2	DNC	DNC	DNC	DNC
3	DNC	DNC	DNC	DNC
4	GND	GND	GND	GND
5	VDDA	VDDA	VDDA	VDDA
6	nRST	nRST	nRST	nRST
7	VDDIO	VDDIO	VDDIO	VDDIO
8	GND	GND	GND	GND
9	DNC	SPI_nCS	DNC	DNC
10	ADD2#2	SPI_MOSI	DNC	DNC
11	ADD1#2	SPI_MISO	DNC	DNC
12	ADD0	SPI_SCK	DNC	DNC
13	GND	GND	GND	GND
14	PSEL0	PSEL0	PSEL0	PSEL0
15	PSEL1	PSEL1	PSEL1	PSEL1
16	SYNC_IN	SYNC_IN	SYNC_IN	SYNC_IN
17	RESERVED	RESERVED	RESERVED	RESERVED
18#1	AUX_RX/DNC	AUX_RX/DNC	AUX_RX/DNC	AUX_RX/DNC

19#1	AUX_TX/DNC	AUX_TX/DNC	AUX_TX/DNC	AUX_TX/DNC
20#1	SYNC_PPS/DNC	SYNC_PPS/DNC	SYNC_PPS/DNC	SYNC_PPS/DNC
21	DNC	DNC	DE	RTS
22	DRDY	DRDY	nRE	CTS#3
23	I2C_SDA	DNC	UART_RX	UART_RX
24	I2C_SCL	DNC	UART_TX	UART_TX
25	GND	GND	GND	GND
26#1	AUX_nCS/DNC	AUX_nCS/DNC	AUX_nCS/DNC	AUX_nCS/DNC
27#1	AUX_MOSI/DNC	AUX_MOSI/DNC	AUX_MOSI/DNC	AUX_MOSI/DNC
28#1	AUX_MISO/DNC	AUX_MISO/DNC	AUX_MISO/DNC	AUX_MISO/DNC

[1] AUX and SYNC_PPS pins are only available on MTi-7

[2] I^2C addresses, see #List of I2C addresses.

[3] CTS cannot be left unconnected if the interface is set to UART full duplex. If HW flow control is not used, connect to GND.

Pin descriptions

Pin description MTi 1-series module

Name	Type	Description
Power Interface		
VDDA	Power	Analog power supply voltage for sensing elements
VDDIO	Power	Digital supply voltage. Also used as I/O reference.
Controls		

Name	Type	Description
PSEL0	Selection pins	These pins determine the signal interface. See #Peripheral interface selection. Note that when the PSEL0/PSEL1 is not connected, its value is 1. When PSEL0/PSEL1 is connected to GND, its value is 0.
PSEL1		
nRST		Active low reset pin. Only drive with an open drain output or momentary (tactile) switch to GND. During normal operation this pin must be left floating, because this line is also used for internal resets. This pin has an internal weak pull-up to VDDIO.
ADD2	Selection pins	I^2C address selection lines. See #List of I2C addresses.
ADD1		
ADD0		
Signal Interface		
I2C_SDA	I^2C interface	I^2C serial data input/output
I2C_SCL		I^2C serial clock input
SPI_nCS	SPI interface	SPI chip select input (active low)
SPI_MOSI		SPI serial data input (slave)
SPI_MISO		SPI serial data output (slave)
SPI_SCK		SPI serial clock input
RTS	UART interface	Hardware flow control output in UART full duplex mode (Ready-to-Send)
CTS		Hardware flow control input in UART full duplex mode (Clear-to-Send). If flow control is not used, connect to GND
nRE		Receiver control signal output in UART half duplex mode
DE		Transmitter control signal output in UART half duplex mode
UART_RX		Receiver data input
UART_TX		Transmitter data output
SYNC_IN	Sync interface	Accepts a trigger input to request the latest available data message
DRDY	Data ready	Data ready output indicates that data is available (SPI / I^2C)

Name	Type	Description
Auxiliary interface (MTi-7 only)		
AUX_RX	Auxiliary GNSS interface	Receiver data input from GNSS module
AUX_TX		Transmitter data output to GNSS module
SYNC_PPS		Pulse per second input from GNSS module
AUX_nCS	Auxiliary SPI interface	SPI chip select output
AUX_MOSI		SPI serial data output (master)
AUX_MISO		SPI serial data input (master)
AUX_SCK		SPI serial clock output

Peripheral interface selection

The MTi 1-series module supports UART, I^2C, and SPI interfaces for host communication. The host can select the active interface through the peripheral selection pins PSEL0 and PSEL1. The module reads the state of these pins at start-up, and configures its peripheral interface according to the Table below. To change the selected interfaces, the host must first set the desired state of the PSEL0 and PSEL1 pins, and then reset the module. The module has internal pull-ups on the PSEL0 and PSEL1 pins. If these pins are left unconnected, the peripheral interface selection defaults to I^2C (PSEL0 = 1, and PSEL1 = 1).

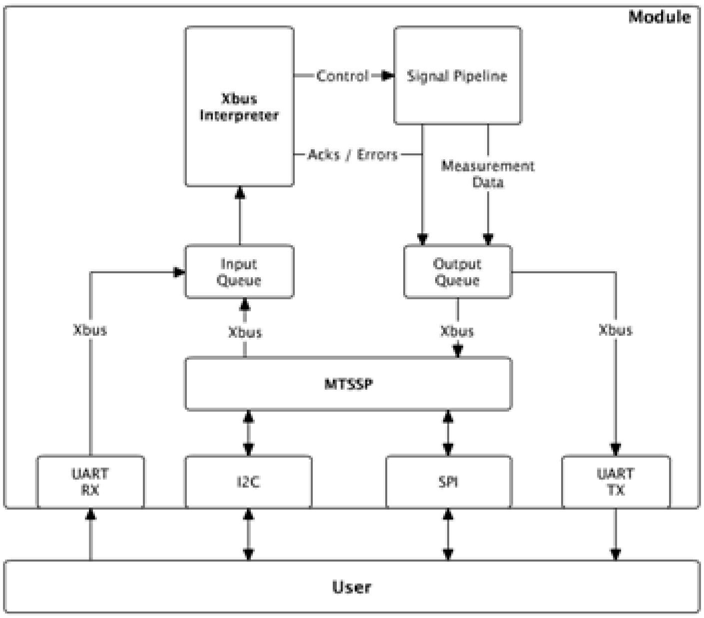
Peripheral interface selection

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

Peripheral interface architecture

At its core, the module uses the Xsens-proprietary Xbus protocol which is compatible with all Xsens Motion Tracker products. This protocol is available on all interfaces; UART (asynchronous serial port interfaces), I^2C and SPI interfaces. The I^2C and SPI interfaces differ from UART in that they are synchronous, and have a master-slave relationship in which the slave cannot send data by itself. This makes the Xbus protocol not directly transferable to these interfaces. For this purpose, the module introduces the MTi Synchronous Serial Protocol (MTSSP) protocol, a protocol for exchanging standard Xbus protocol messages over the I^2C and SPI interfaces. The below figure shows how MTSSP fits in the module's (simplified) communication architecture. The module has generic Input- and Output-Queues for Xbus protocol messages. For I^2C and SPI, the MTSSP layer translates these messages, while for the UART connection, the module transports the messages as-is.

Note: The MTi 1-series offers access to the module via the UART, SPI and I²C interfaces, as well as an additional USB interface when using the Development Shield. Please note that the graphical software tools, such as MT Manager and the Magnetic Field Mapper, as well as a large part of the MT SDK are only supported when using serial (UART/USB) communication. For I²C or SPI communication, dedicated "embedded example codes" are available as part of the MT SDK.



Communication architecture of MTi 1-series module (simplified)

Xbus Protocol

The Xbus protocol is Xsens' proprietary protocol for interfacing with the MTi 1-series. The *MT Low Level Communication Protocol Documentation* is a complete reference for the protocol. For a better understanding of the MTSSP explanation, the advice is to read the protocol reference first.

MTSSP Synchronous Serial Protocol

This Section specifies the MTi Synchronous Serial Protocol (MTSSP). The MTi 1-series module uses MTSSP as the communication protocol for both the I^2C and SPI interfaces. The embedded example codes, which can be found in the MT SDK folder of the MT Software Suite, provide a reference implementation for the host side of the protocol.

Data flow

MTSSP communication happens according to the master-slave model. The MTi 1-series module will always fulfill the slave-role while the user/integrator/host of the module is always the Master. The Master always initiates and drives communication. The Master either writes a message to the module, or reads a message from the module.

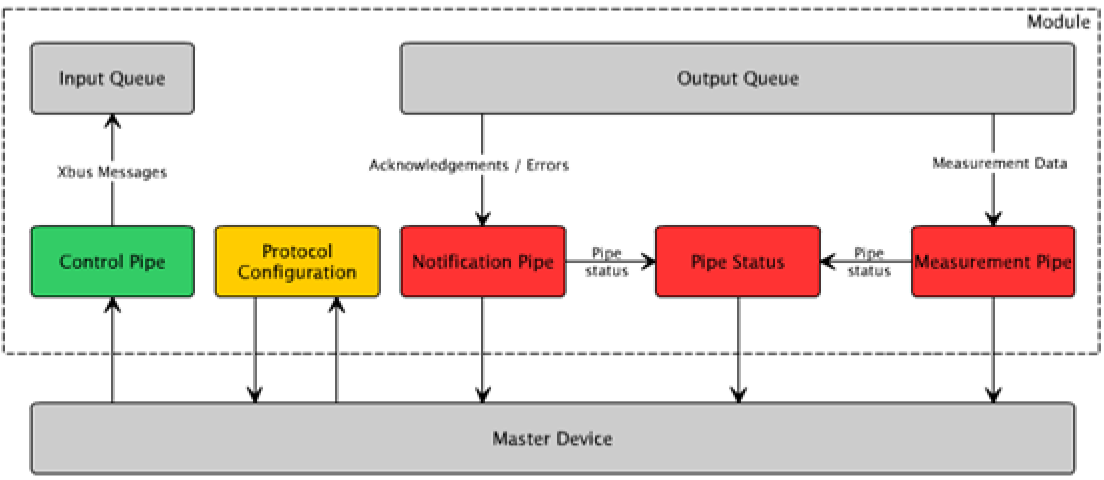
The figure below shows the data flow between the host (Master Device), and the MTi 1-s (Slave). The Master can control the Module by sending Xbus messages to the Control Pipe. The Module considers the bytes received in a single bus transfer to be exactly one Xbus message. The MTi 1-s places the received message in the Input Queue for further handling. The Xbus Interpreter handles the messages in the Input Queue, and places the response messages in the Output Queue. The Master Device can read these response messages from the Notification Pipe.

The Master can switch the Module between configuration and measurement mode by sending the usual GotoConfig and GotoMeasurement (reduced Xbus) messages to the Control Pipe. When placed in Measurement mode, the module will place the generated measurement data (MTData2) in the Measurement Pipe. The Master Device has to read the Measurement Pipe to receive measurement data.

For the Master to know the size of the messages in the Notification and Measurement pipes, it can read the Pipe Status. The Pipe Status contains the size in bytes of the (single) next message in both the Notification and Measurement pipes. The Master can tweak the behavior of the protocol by writing the Protocol Configuration. The Master can also read the Protocol Configuration to check current behavior, and get protocol information.

Note: Both the Measurement Pipe and the Notification Pipe have limited sizes and can therefore only contain a limited number of (reduced) Xbus messages. The amount of messages that can be contained in the pipes depends on the size of the individual messages. Both pipes act as a First-In-First-Out (FIFO) buffer: When reading from either pipe, the oldest message in the pipe will be read first. Once the pipe is full, a newly produced message will be discarded by the MTi 1-s and a (reduced Xbus) error message (data overflow, 0x42 0x01 0x29 0x95) will be added to the Notification Pipe. It is therefore important for the host to read out new messages in time, such that the pipe will not fill up, resulting in lost measurement data or notifications.

For best practices for I^2C and SPI communication, please see BASE: Best practices I^2C and SPI for MTi 1-series



Data flows within MTSSP

Data ready signal

The Data Ready Signal (DRDY) is a notification line driven by the module. Its default behavior is to indicate the availability of new data in either the Notification or the Measurement pipe. By default, the line is low when both pipes are empty, and will go high when either pipe contains an item. As soon as the Master has read all pending messages, the DRDY line will go low again. The Master can change the behaviour of the DRDY signal using the Procotol Configuration. Please refer to the description of the ConfigureProtocol opcode (#List of defined opcodes) for more information.

Opcodes

The Master starts each transfer with an opcode. The opcode determines the type of the transfer. The defined opcodes are as listed in the table below. Following the opcode, and depending on whether it is a read or write transfer, the Master either reads or writes one or more data bytes. The specific transfer format depends on the underlying bus protocol (I^2C or SPI).

For some opcodes, the MTSSP uses reduced Xbus messages. A reduced Xbus message is a regular Xbus message with the preamble and busID fields removed to save bandwidth. These fields correspond to the first two bytes of a regular Xbus message. The calculation of the checksum for a reduced Xbus message still includes the busID and assumes its value to be 0xFF. For an overview of available Xbus messages, refer to the *MT Low Level Communication Protocol Documentation*.

List of defined opcodes

Opcode	Name	Read/Write	Data format	Description
0x01	ProtocolInfo	Read	Opcode defined	Status of the protocol behaviour, protocol version
0x02	ConfigureProtocol	Write	Opcode defined	Tweak the Protocol, e.g. the behaviour of the DRDY pin, behaviour of the pipes
0x03	ControlPipe	Write	Reduced Xbus	Used to send control messages to the module
0x04	PipeStatus	Read	Opcode defined	Provides status information for the read pipes
0x05	NotificationPipe	Read	Reduced Xbus	Used to read non-measurement data: errors, acknowledgements and other notifications from the module
0x06	MeasurementPipe	Read	Reduced Xbus	All measurement data (Xbus: MTData2) generated by the module will be available in the measurement pipe

ProtocolInfo (0x01)

The ProtocolInfo opcode allows the Master to read the active protocol configuration. The format of the message is as follows (All data is little endian, byte aligned):

```
struct MtsspInfo
{
uint8_t m_version;
uint8_t m_drdyConfig;
};
```

`m_version:`

7	6	5	4	3	2	1	0
VERSION [7:0]							

`m_drdyConfig:`

Bits 7:4	Reserved for future use
Bit 3	**MEVENT**: Measurement pipe DRDY event enable 0 : Generation of DRDY event is disabled 1 : Generation of DRDY event is enabled (default)
Bit 2	**NEVENT**: Notification pipe DRDY event enable 0 : Generation of DRDY event is disabled 1 : Generation of DRDY event is enabled (default)
Bit 1	**OTYPE**: Output type of DRDY pin 0: Push/pull (default) 1: Open drain
Bit 0	**POL**: Polarity of DRDY signal 0: Idle low (default) 1: Idle high

ConfigureProtocol (0x02)

The ProtocolInfo opcode allows the Master to change the active protocol configuration. The format of the message is as follows (All data is little endian, byte aligned):

```
struct MtsspConfiguration
{
uint8_t m_drdyConfig;
};
```

`m_drdyConfig:`

Bits 7:4	Reserved for future use
Bit 3	**MEVENT**: Measurement pipe DRDY event enable 0 : Generation of DRDY event is disabled 1 : Generation of DRDY event is enabled (default)
Bit 2	**NEVENT**: Notification pipe DRDY event enable 0 : Generation of DRDY event is disabled 1 : Generation of DRDY event is enabled (default)
Bit 1	**OTYPE**: Output type of DRDY pin 0: Push/pull (default) 1: Open drain
Bit 0	**POL**: Polarity of DRDY signal 0: Idle low (default) 1: Idle high

Note: Changes made to the DRDY configuration are volatile, e.g. they are lost during a power cycle. Non-default settings should therefore be re-applied after each power-up.

ControlPipe (0x03)

The ControlPipe opcode allows the Master to write messages to the Control Pipe. The bytes following the opcode represent a single (reduced) Xbus message.

PipeStatus (0x04)

The PipeStatus opcode allows the Master to retrieve the status of the module's Notification- and Measurement pipes. The format of the message is as follows (All data is little endian, byte aligned):

```
struct MtsspConfiguration
{
uint16_t m_notificationMessageSize;
uint16_t m_measurementMessageSize;
};
```

NotificationPipe (0x05)

The Master uses the NotificationPipe opcode to read from the Notification Pipe. The read data is a single reduced Xbus message.

MeasurementPipe (0x06)

The Master uses the MeasurementPipe opcode to read from the Measurement Pipe. The read data is a single reduced Xbus message (MTData2).

I^2C

The MTi 1-series module acts as an I^2C Slave. The User of the MTi 1-series module is the I^2C Master.

The user can configure the I^2C slave address through the ADD0, ADD1 and ADD2 pins. The module reads the state of these pins at start-up, and configures the slave address according to the table below. The ADD0, ADD1 and ADD2 pins are pulled-up internally, so when left unconnected, the address selection defaults to 0x6B (ADD = 111).

List of I^2C 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

Implemented I^2C bus protocol features

Feature	Slave Requirement	MTi 1-series
7-bit slave address	Mandatory	Yes
10-bit slave address	Optional	No
Acknowledge	Mandatory	Yes
Arbitration	N/A	N/A
Clock stretching	Optional	Yes#4
Device ID	Optional	No
General Call address	Optional	No
Software Reset	Optional	No
START byte	N/A	N/A
START condition	Mandatory	Yes
STOP condition	Mandatory	Yes
Synchronization	N/A	N/A

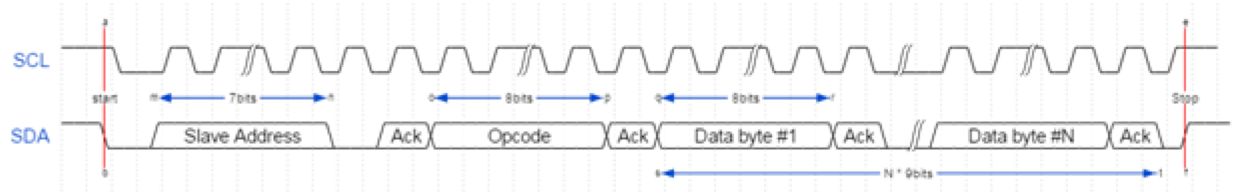
[4] The MTi-1 module relies on the I^2C clock stretching feature to overcome fluctuations in processing time. The Master is required to support this feature.

Writing to the MTi 1-s

Write operations consists of a single I^2C write transfer. The Master addresses the module and the first byte it sends is the opcode. The bytes that follow are the data bytes. The interpretation of these data bytes depends on the opcode, as described in #MTSSP.

The maximum message size a module can receive is 512 bytes. If the Master sends more than 512 bytes, the module will reset its receive-buffer, which reduces the received message to consist only of the excess bytes.

The below figure shows the I^2C transfer of a write message operation:



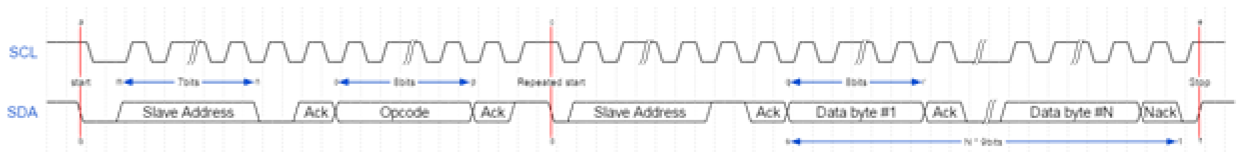
I^2C write message operation

Reading from the module

To read from the module, the Master first does an I^2C write transfer to transmit the opcode. The opcode tells the module what data the Master wants to read. The module then prepares the requested data for transmission. The Master then does an I^2C read transfer to retrieve the data. The figure below shows the I^2C transfers for the described read method.

Read message operation with full write transfer and full read transfer (I^2C)

Alternatively, the user can perform the read operation using an I^2C transfer with a repeated start condition. The below figure depicts this read method.



Read message transfer using a repeated start condition (I^2C)

The Master controls how many data bytes it reads. For reading the Notification- and Measurement Pipes, the number of bytes the Master must read depends on the size of the pending message. In order to determine the correct number of bytes, the Master should first read the Pipe Status to obtain the sizes of the pending messages.

If the Master reads more bytes than necessary, the module will restart sending the requested data from the beginning.

SPI

The MTi 1-series module acts as an SPI Slave. The User of the MTi 1-series module is the SPI Master.

SPI Configuration

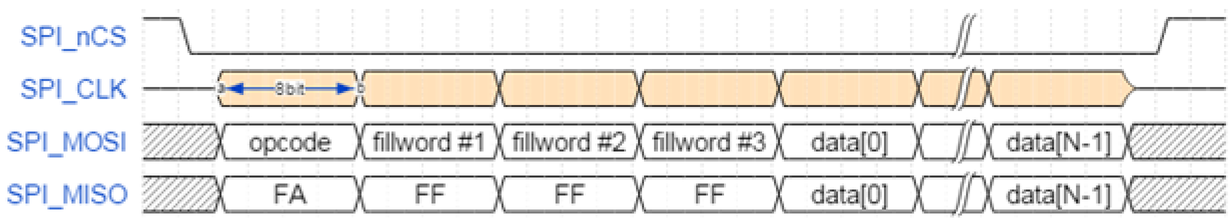
The MTi 1-series supports 4-wire mode SPI. The four lines used are:

- Chip Select (SPI_nCS)
- Serial Clock (SPI_SCK)
- Master data in, slave data out (SPI_MISO)
- Master data out, slave data in (SPI_MOSI)

The module uses SPI mode 3: It captures data on the rising clock edge, and it latches/propagates data on the falling clock edge. (CPOL=1 and CPHA=1). Data is clocked-out MSB first. The module uses an 8-bit data format.

Data transfer

The module uses a single type of SPI transfer for all communications. The below figure depicts this basic transfer.



SPI basic transfer

The Master starts a transfer by pulling the SPI_nCS low, in order to select the Slave. The Master must keep the SPI_nCS line low for the duration of the transfer. The Slave will interpret the rising edge of the SPI_nCS line as the end of the transfer. The Master places the data it needs to transmit on the SPI_MOSI line. The Slave will place its data on the SPI_MISO line.

The Master first transmits the opcode. The opcode determines what kind of data the Master transmits, and what kind of data the Master wants to read from the Slave (see #MTSSP). The second-to-fourth byte the Master transmits are the fill words. These fill words are needed to give the Slave time to select the data it must send for the remainder of the transfer. Both Master and Slave are free to choose the value of the fill words, and the receiving end should ignore their value. However, the first 4 bytes transmitted by the MTi 1-series module (Slave) are always 0xFA, 0xFF, 0xFF, 0xFF.

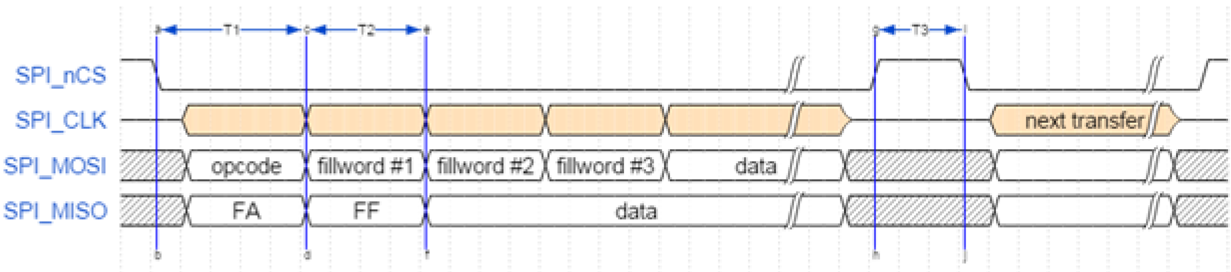
Following the first four words are the actual data of the transfer. It is the responsibility of the Master to determine how many bytes it must transfer. For reading the Notification- and Measurement Pipes, the number of bytes the Master must read depends on the size of the pending message. In order to determine the correct number of bytes, the Master should first read the Pipe Status to obtain the sizes of the pending messages.

Timing

The table below and figure specify the timing constraints that apply to the SPI transport layer. The Master must adhere to these constraints.

SPI timing

Symbol	Parameter	Unit	Min	Max
T1	Slave select to first complete word delay	µs	4	
T2	Byte time	µs	4	
T3	Consecutive SPI transfer guard time	µs	3	
	Max SPI bitrate	Mbit		2



SPI timing

UART half-duplex

The user can configure the MTi 1-series module to communicate over UART in half-duplex mode. The UART frame configuration is 8 data bits, no parity and 1 stop bit (8N1). In addition to the RX and TX pins, the modules use control lines nRE and DE. The modules use these control outputs to drive the TX signal on a shared medium and to drive the signal of the shared medium on the RX signal.

A typical use case for this mode is to control an RS485 transceiver where the shared medium is the RS485 signal, and the nRE and DE lines control the buffers inside the transceiver.

When the module is transmitting data on its TX pin it will raise both the nRE and DE lines, else it will pull these lines low. The below figure depicts the behaviour of the involved signals.

Behaviour of the nRE and DE lines

Note that in this mode the UART of the MTi 1-s itself is still operating full duplex.

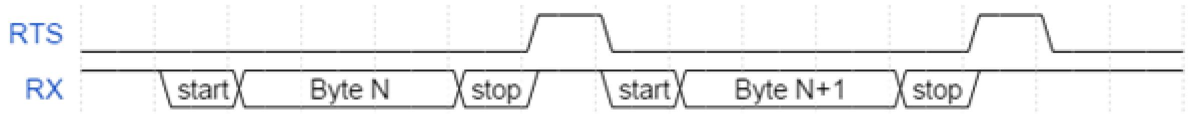
UART full duplex with RTS/CTS flow control

The user can configure the MTi 1-s module to communicate over UART in full duplex mode with RTS/CTS flow control. The UART frame configuration is 8 data bits, no parity and 1 stop bit (8N1). In addition to the RX and TX signals for data communication, the module uses the RTS and CTS signals for hardware flow control.

The CTS signal is an input for the module. The module checks the state of the CTS line at the start of every byte it transmits. If CTS is low, the module transmits the byte. Otherwise, it postpones transmission until CTS is lowered. When, during the transmission of a byte, the user raises the CTS signal, then the module completes transmission of that byte before postponing further output. The module will not retransmit this byte. The figure below shows the behaviour of the TX and CTS lines.

Data transmit behaviour under CTS

The RTS signal is an output for the module. If the RTS line is high, the module is busy and unable to receive new data. Otherwise, the module's UART is idle and ready to receive. After receiving a byte, the direct memory access (DMA) controller of the module will transfer the byte to its receive first in first out (FIFO) buffer. The module will raise the RTS signal during this transfer. Therefore, with every byte received, the module raises the RTS line quickly. The figure below shows this behaviour.



RTS behaviour under data reception

The user can use this communication mode without hardware flow control. In this case, the user must tie the CTS line low (GND) to make the module transmit.

MTi 1-series architecture

This section discusses the MTi 1-s module architecture including the various configurations available and the signal processing pipeline.

MTi 1-series configurations

The MTi 1-s module is a fully tested self-contained module available as an Inertial Measurement

Unit (IMU), Vertical Reference Unit (VRU), Attitude and Heading Reference System (AHRS) and GNSS aided Inertial Navigation System (GNSS/INS). It can output 3D orientation data (Euler angles, rotation matrix or quaternions), orientation and velocity increments (Δq and Δv), position and velocity quantities and calibrated sensor data (acceleration, rate of turn, magnetic field). Depending on the product, output options may be limited to sensor data and/or unreferenced yaw.

The MTi 1-s module features a 3D accelerometer, a 3D gyroscope, a magnetometer, a high-accuracy crystal and a low-power MCU. The MCU coordinates the timing and synchronization of the various sensors, applies calibration models (e.g. temperature models) and runs the sensor fusion algorithm. The MCU also generates output messages according to the proprietary XBus communication protocol. The data output is fully configurable, so that the MTi 1-s limits the load, and thus power consumption, on the user application processor.

MTi-1 IMU

The MTi-1 module is an IMU that outputs calibrated 3D rate of turn, 3D acceleration and 3D magnetic field. The MTi-1 also outputs coning and sculling compensated orientation increments and velocity increments (Δq and Δv). Advantages over a gyroscope-accelerometer combo-sensor are the inclusion of synchronized magnetic field data, on-board signal processing and the easy-to-use synchronization and communication protocol. Moreover, the testing and calibration over temperature performed by Xsens result in a robust and reliable sensor module that can be integrated within a short time frame. The signal processing pipeline and the suite of output options allow access to the highest possible accuracy at any output data rate, limiting the load on the user application processor.

MTi-2 VRU

The MTi-2 is a 3D VRU. Its algorithm computes 3D orientation data with respect to a gravity referenced frame: drift-free roll, pitch and unreferenced yaw. Although the yaw is unreferenced, it is superior to gyroscope integration. In addition, it outputs calibrated sensor data: 3D acceleration, 3D rate of turn and 3D magnetic field data. All modules of the MTi 1-series output data generated by the strapdown integration algorithm (orientation and velocity increments - Δq and Δv). The 3D acceleration is also available as so-called free acceleration, which has the local-gravity subtracted. The drift in unreferenced heading can be limited using the #Active Heading Stabilization feature.

MTi-3 AHRS

The MTi-3 supports all features of the MTi-1 and MTi-2, and, in addition, is a full magnetometer-enhanced AHRS. In addition to the roll and pitch, it outputs a true magnetic North referenced yaw and calibrated sensor data: 3D acceleration, 3D rate of turn, 3D orientation and velocity increments (Δq and Δv) and 3D earth-magnetic field data. Free acceleration is also computed by the MTi-3 AHRS.

MTi-7 GNSS/INS

The MTi-7 provides a GNSS/INS solution offering a position and velocity output in addition to orientation output. The MTi-7 uses advanced sensor fusion algorithms developed by Xsens to synchronize the inputs from the module's on-board accelerometer, gyroscope and magnetometer with the data from an external GNSS receiver and/or barometer. The raw sensor signals are combined and processed at a high data rate of 800 Hz to produce a real-time data stream with the device's 3D position, velocity and orientation (roll, pitch and yaw).

MTi-8 RTK GNSS/INS

The MTi-8 is an improved version of the MTi-7, designed to be used with high precision GNSS receivers. Using RTK (Real-Time Kinematics) functionality, GNSS receivers can determine global position at centimeter-level accuracy. The MTi-8 features more advanced sensor fusion algorithms and signal processing pipelines that allow it to process these data without loss of accuracy/precision. The MTi-8 also takes into account timing errors and the distance between the GNSS antenna and the MTi itself.

GNSS input

The MTi-7 and MTi-8 require data from an external GNSS receiver to provide a full GNSS/INS solution. This can be achieved by connecting a GNSS receiver that communicates with one of the following supported protocols:

- u-blox' UBX protocol
- NMEA sentences (officially supported with firmware version 1.10.0 and up)
- Septentrio's SBF protocol (beta support with firmware version 1.18.0 and up)
- Trimble's GSOF protocol (beta support with firmware version 1.18.0 and up)

The use of each of these supported protocols is discussed in more detail in the paragraphs below.

u-blox (UBX) input

When connecting to a u-blox receiver (e.g. u-blox MAX-M8), the MTi will configure it correctly on start-up. No prior configuration of the u-blox receiver is required. It is, however, recommended to inform the MTi of what type of u-blox receiver is connected. This can be done using the Device Settings window in MT Manager (version 2021.4 and later), or using an Xbus message called SetGnssReceiverSettings, described in the *MT Low Level Communication Protocol Documentation*. The user can select one of the officially supported u-blox receiver series: MAX-M8 (default), NEO-M8 or ZED-F9.

NMEA input

Almost all GNSS receivers support the output of NMEA messages, which means that this functionality enables the use of virtually any external GNSS receiver. It is important to note that both the GNSS receiver and the MTi must be configured prior to connecting both systems to each other. The NMEA input mode can be enabled using the Device Settings window in MT Manager (version 2021.4 and later), or using an Xbus message called SetGnssReceiverSettings, described in the *MT Low Level Communication Protocol Documentation*.

The table below summarizes the settings needed to configure the MTi-7/8 to use the NMEA input mode. This will enable the MTi to use the GNSS data and provide the user with a full GNSS/INS solution. The MTi will also synchronize its internal clock with the UTC time that is present in the sentences.

Settings required to enable the NMEA input mode for the MTi-7/8

Setting	Description
Baudrate	Minimum 115200 bps
GNSS Message frequency	4 Hz recommended/default, 10 Hz maximum
Talker ID	GN, GP or GL
Required messages	GGA, GSA, GST and RMC High precision coordinate formats such as GGALONG are also supported.

An example of how to setup an external GNSS receiver using the NMEA protocol can be found on BASE.

Septentrio (SBF) input

Please note that both the GNSS receiver and the MTi must be configured prior to connecting both systems to each other. The Septentrio input mode can be enabled using the Device Settings window in MT Manager (version 2021.4 and later), or using an Xbus message called SetGnssReceiverSettings, described in the *MT Low Level Communication Protocol Documentation*.

The table below summarizes the settings needed to configure the MTi-7/8 to use the Septentrio input mode. This will enable the MTi to use the GNSS data and provide the user with a full GNSS/INS solution. The MTi will also synchronize its internal clock with the UTC time that is present in the sentences.

Settings required to enable the Septentrio input mode for the MTi-7/8

Setting	Description
Baudrate	Minimum 230400 bps
GNSS Message frequency	5 Hz recommended/default, 10 Hz maximum
Required messages	ReceiverTime, PVTGeodetic, PosCovGeodetic, VelCovGeodetic, DOP, MeasEpoch, ChannelStatus

An example of how to setup an external GNSS receiver using the SBF protocol can be found on BASE.

Trimble (GSOF) input

Please note that both the GNSS receiver and the MTi must be configured prior to connecting both systems to each other. The Trimble input mode can be enabled using the Device Settings window in MT Manager (version 2021.4 and later), or using an Xbus message called SetGnssReceiverSettings, described in the *MT Low Level Communication Protocol Documentation*.

The table below summarizes the settings needed to configure the MTi-7/8 to use the Trimble input mode. This will enable the MTi to use the GNSS data and provide the user with a full GNSS/INS solution. The MTi will also synchronize its internal clock with the UTC time that is present in the sentences.

Settings required to enable the Trimble input mode for the MTi-7/8

Setting	Description
Baudrate	Minimum 115200 bps
GNSS Message frequency	5 Hz recommended/default, 10 Hz maximum
Required messages	Position Time [#01], Lat,Long,Ht [#02], Velocity [#08], DOP Info [#09], Position Sigma [#12], Current Time UTC [#16], Detail All SV [#34]

An example of how to setup an external GNSS receiver using the GSOF protocol can be found on BASE.

Signal processing pipeline

The MTi 1-series is a self-contained module, so all calculations and processes such as sampling, coning & sculling compensation and the Xsens sensor fusion algorithm run on board.

Strapdown integration

The Xsens optimized strapdown algorithm performs high-rate dead-reckoning calculations at 800 Hz, allowing accurate capture of high frequency motions. This approach ensures a high bandwidth. Orientation and velocity increments are calculated with full coning & sculling compensation. These orientation and velocity increments are suitable for any 3D motion tracking algorithm. Increments are internally time-synchronized with other sensors. The output data rate can be configured with different frequencies up to 100 Hz. The inherent design of the signal pipeline with the computation of orientation and velocity increments ensures there is absolutely no loss of information at any output data rate. This makes the MTi 1-series attractive for systems with limited communication bandwidth.

Xsens sensor fusion algorithm for VRU and AHRS product types

The Xsens sensor fusion algorithm optimally estimates the orientation with respect to an Earth fixed frame utilizing the 3D inertial sensor data (orientation and velocity increments) and 3D magnetometer.

The user can set the sensor fusion algorithm with different filter profiles in order to get the best performance based on the application scenario (see table below). These filter profiles contain predefined filter parameter settings suitable for different user application scenarios.

In addition, all filter profiles can be used with the #Active Heading Stabilization setting, which significantly reduces heading drift during magnetic disturbances. The #In-run Compass Calibration setting can be used to compensate for magnetic distortions that are caused by every object the MTi is attached to.

Filter profiles for VRU and AHRS

Name	Number	Product	Description
General	50	MTi-3	Suitable for most applications.
High_mag_dep	51	MTi-3	Heading corrections strongly rely on the magnetic field. This filter profile should be used when the magnetic field is homogeneous.
Dynamic	52	MTi-3	Assumes that the motion is highly dynamic.
North_referenced	53	MTi-3	Assumes a good magnetic calibration and a homogeneous magnetic field. Given stable initialization procedures and observability of the gyro bias, after dynamics, this filter profile will trust more on the gyro solution and the heading will slowly converge to the disturbed mag field over the course of time.
VRU_general	54	MTi-2 MTi-3	Magnetometers are not used to determine heading. Consider using VRU_general in environments that have a heavily disturbed magnetic field or when the application only requires unreferenced heading.

Xsens sensor fusion algorithm for GNSS/INS product types

The Xsens sensor fusion algorithm in the MTi-7 and MTi-8 has several advanced features. The algorithm adds robustness to the orientation and position estimates by combining measurements and estimates from the inertial sensors and GNSS receiver in order to compensate for transient accelerations and magnetic disturbances.

When the MTi-7/8 has limited/mediocre GNSS reception or even no GNSS reception at all (outage), the sensor fusion algorithm seamlessly adjusts the filter settings in such a way that the highest possible accuracy is maintained. The GNSS status is continuously monitored and the filter accepts GNSS data when available and sufficiently trustworthy. The sensor will continue to output position, velocity and orientation estimates, although the accuracy is likely to degrade over time as the filters will have to rely on dead-reckoning. If the GNSS outage lasts longer than 45 seconds, the MTi-7/8 stops output of the position and velocity estimates and begins sending these outputs once the GNSS data becomes acceptable again.

The table below reports the different filter profiles the user can set based on the application scenario. Every application is different, and results may vary from setup to setup. It is recommended to reprocess recorded data with different filter profiles in MT Manager to determine the best results in your specific application.

Filter profiles for MTi-7/8 (GNSS/INS)

Name	GNSS#1	Barometer#1	Magnetometer	Description
General / General_RTK	●	●		This filter profile is the default setting. Yaw is North referenced (when GNSS is available). Altitude (height) is determined by combining static pressure, GNSS altitude and accelerometers. The barometric baseline is referenced by GNSS, so during GNSS outages, accuracy of height measurements is maintained.
GeneralNoBaro / GeneralNoBaro_RTK	●			This filter profile is very similar to the general filter profile except for the use of the barometer.
GeneralMag / GeneralMag_RTK #2	●	●	●	This filter profile bases its yaw estimate mainly on magnetic heading and GNSS measurements. A homogenous or magnetic field calibration is essential for good performance.

[1] External aiding sensors for the MTi-7/8
[2] This filter profile can be used even when the barometer is not part of the design.

Magnetic interference

Magnetic interference can be a major source of error for the heading accuracy of any AHRS. As an AHRS uses the magnetic field to reference the dead-reckoned orientation on the horizontal plane with respect to the (magnetic) north, a severe and prolonged distortion in that magnetic field will cause the magnetic reference to be inaccurate. The MTi 1-series module has several ways to cope with these distortions to minimize the effect on the estimated orientation.

Magnetic Field Mapping

When the distortion moves with the MTi (i.e. when a ferromagnetic object solidly moves with the MTi module), the MTi can be calibrated for this distortion. Examples are the cases where the MTi is attached to a car, aircraft, ship or other platforms that can distort the magnetic field. It also handles situations in which the sensor has become magnetized. These types of errors are usually referred to as soft and hard iron distortions. The Magnetic Field Mapping procedure compensates for both hard iron and soft iron distortions.

The magnetic field mapping (calibration) is performed by moving the MTi together with the object/platform that is causing the distortion. The results are processed on an external computer (Windows or Linux), and the updated magnetic field calibration values are written to the non-volatile memory of the MTi 1-series module. The magnetic field mapping procedure is extensively documented in the *Magnetic Calibration Manual*.

In-run Compass Calibration (ICC)

In-run Compass Calibration is a way to calibrate for magnetic distortions present in the sensor operation environment using an onboard algorithm. The ICC is an alternative to the offline MFM (Magnetic Field Mapper). It results in a solution that can run embedded on different industrial platforms (leaving out the need for a host processor like a PC) and relies less on specific user input. The MFM tool, which does require a host processor, is, however, still recommended over or in addition to the ICC. The ICC is aimed at applications for which the MFM solution cannot be used (e.g. MTi 1-s that is not able to be connected to a PC), when MFM is not sufficient (e.g. applications that move outside of the plane of motion used during the calibration), or when the user uses the same MFM result performed for one sensor to calibrate different sensors (typical for large volume applications).

It should be noted that magnetic distortions present in the environment of the motion tracker that move independently or change over time are not compensated by the ICC unless they are changing very slowly. Such distortions do not affect the parameter estimation; they are simply not compensated for. This also means that (ferromagnetic) objects should not be attached to or detached from the sensor while ICC is running.

If the user is able to perform a calibration motion in a homogeneous magnetic field or environment that is representative of the application, then it is possible (and recommended) to use the "Representative Motion" feature (RepMo). RepMo is available in MT Manager, XDA and Low-Level Communication Protocol (Xbus protocol).

Additional details are available on BASE.

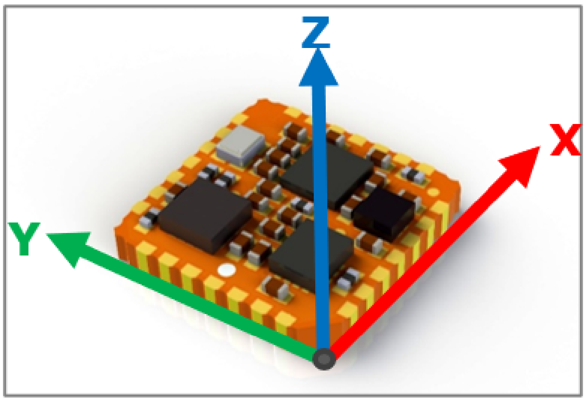
Active Heading Stabilization (AHS)

The Active Heading Stabilization (AHS) is not a magnetic calibration procedure, but a software component within the sensor fusion engine designed to give low-drift unreferenced heading solution in a disturbed magnetic environment. AHS is not tuned for nor intended to be used with GNSS/INS devices. Therefore, Xsens discourages the use of this feature for GNSS/INS devices, including the MTi-7/8.

For more information on the activation and use of AHS, refer to BASE**.**

Frames of reference

The MTi 1-series module uses a right-handed coordinate system and the default sensor frame is defined as shown in **the figure below.** For a more exact location of the sensor frame origin, refer to the *Hardware Integration Manual*. Some of the commonly used data outputs with their output reference coordinate system are listed in **the table below.**



Default sensor fixed coordinate system for the MTi 1-series module

Data outputs and their corresponding reference coordinate system

Data	Reference coordinate system
Acceleration	Sensor-fixed or object frame
Rate of turn	Sensor-fixed or object frame
Magnetic field	Sensor-fixed or object frame
Velocity increment	Sensor-fixed or object frame
Orientation increment	Sensor-fixed or object frame

Data	Reference coordinate system
Free acceleration	Local Tangent Plane (LTP), default ENU
Orientation	Local Tangent Plane (LTP), default ENU
Velocity	Local Tangent Plane (LTP), default ENU
Position	Local Tangent Plane (LTP), default ENU

The default local reference coordinate system is East-North-Up (ENU). In addition, the MTi 1-s module has predefined output options for North-East-Down (NED) and North-West-Up (NWU). Orientation resets have an effect on all outputs that are by default output with an ENU reference coordinate system.

For the MTi-7/8, the Local Tangent Plane (LTP) is a local linearization of the Ellipsoidal Coordinates (Latitude, Longitude, Altitude) in the WGS-84 Ellipsoid. Velocity data calculated by the sensor fusion algorithm is provided in the same coordinate system as the orientation data, and thus adopts orientation resets as well. For the MTi-3, the Latitude, Longitude and Altitude can be stored in the non-volatile memory of the MTi. Refer to the *MT Low-level Communication Protocol Document* for more information. The default location stored in memory is that of the calibration setup in Enschede, the Netherlands.

Triggering and Synchronization

The MTi 1-series supports a limited set of synchronization options. Please refer to BASE for more information: Synchronization with the MTi

System and Electrical Specifications

Interface specifications

Communication interfaces

Interface		Min	Typ	Max	Unit	Description
I^2C	f_{I2C}			400	kHz	Host I^2C interface Clock speed
SPI	f_{SPI}			2	MHz	Host SPI Interface Clock Speed
	DC_{SCK}	30	50	70	%	SPI Clock Duty Cycle
UART	f_{UART}		921.6	4000	kbps	Host UART Interface Baud Rate

Auxiliary interfaces

Interface	Symbol	Min	Typ	Max	Unit	Description
SYNC_IN	V_{IL}			0.3 · VDDIO	V	Input low voltage
	V_{IH}	0.45 · VDDIO + 0.3			V	Input high voltage
	V_{HYS}	0.45 · VDDIO + 0.3			V	Threshold hysteresis voltage

Interface	Symbol	Min	Typ	Max	Unit	Description
nRST	V_{IL}			0.3 · VDDIO	V	Only drive momentarily
	R_{PU}	30		50	kΩ	Pull-up resistor
	T_P	20			µs	Generated reset pulse duration
AUX_UART	f_{UART}		115.2	2000	kbps	UART baud rate
AUX_SPI	f_{SPI}		1	8	MHz	SPI serial clock speed

System specifications

System specifications

Interface		Min	Typ	Max	Unit	Comments
Size	Width/Length	12.0	12.1	12.2	mm	PLCC-28 compatible
	Height	2.5	2.6	2.7	mm	
Weight			0.6		gram	
Temperature	Operating temperature	-40		+85	ºC	Ambient temperature, non-condensing
Power consumption				150	mW	VDDA 3.0V; VDDIO 1.8V
Timing accuracy			10		ppm	#1
MTBF	Ground Benign	640,000			hours	MIL-HDBK-217F; 30 °C; VDDA 3.3V; VDDIO 3.3V
	Ground Mobile	130,000				
Output data rate				800	Hz	RateOfTurnHR and AccelerationHR DataID only

[1] Output clock accuracy of 1 ppm can be achieved with the MTi-7/8-DK reference design.

Electrical specifications

Electrical specifications

	Min	Max	Unit	Description
VDDA	2.8	3.6#2	V	Analog supply voltage
VDDA ripple		50	mVpp	Analog supply ripple
VDDIO	2.8	VDDA + 0.1	V	Digital supply voltage
V_{IL}		0.3 · VDDIO	V	Input low voltage
V_{IH}	0.45 · VDDIO + 0.3		V	Input high voltage
V_{HYS}	0.45 · VDDIO + 0.3		V	Threshold hysteresis voltage
V_{OL}		0.4	V	Output low voltage
V_{OH}	VDDIO – 0.4		V	Output high voltage

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

Absolute maximum ratings

Absolute maximum ratings for the MTi 1-series module

	Min	Max	Unit	Comments
Storage temperature	-40	+90	ºC	

	Min	Max	Unit	Comments
Operating temperature	-40	+85	ºC	
VDDA	0.3	4.0	V	With respect to GND
VDDIO	0.3	VDDA + 0.5	V	With respect to GND
SYNC_IN		5	V	With respect to GND
Acceleration#3		10,000	g	Any axis, unpowered, for 0.2 ms
ESD protection#4		±2000	V	Human body model

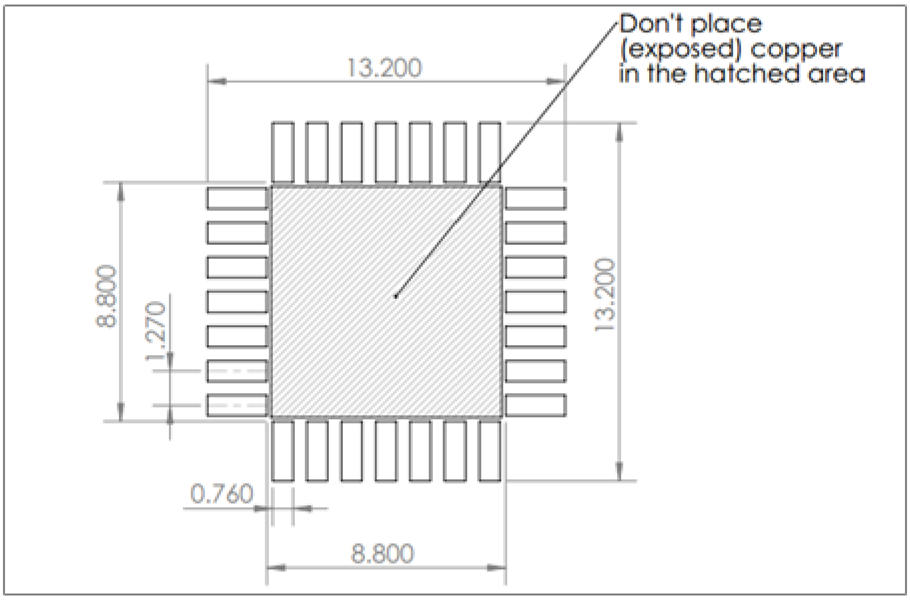
[3] This is a mechanical shock (g) sensitive device. Proper handling is required to prevent damage to the part.

[4] This is an ESD-sensitive device. Proper handling is required to prevent damage to the part.

Design and Packaging

Footprint

The footprint of the MTi 1-s module is similar to a 28-lead Plastic Leaded Chip Carrier package (JEDEC MO-047). Although it is recommended to solder the MTi 1-s module directly onto a PCB, it can also be mounted in a compatible PLCC socket (e.g. 8428-21B1-RK of M3, 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 shown under #Package drawing (note the tolerance of ± 0.1 mm).

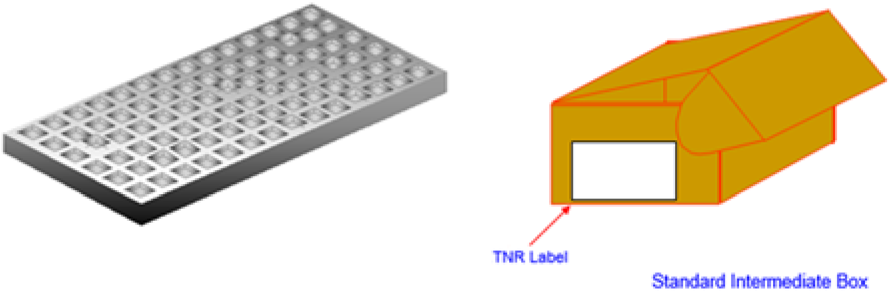


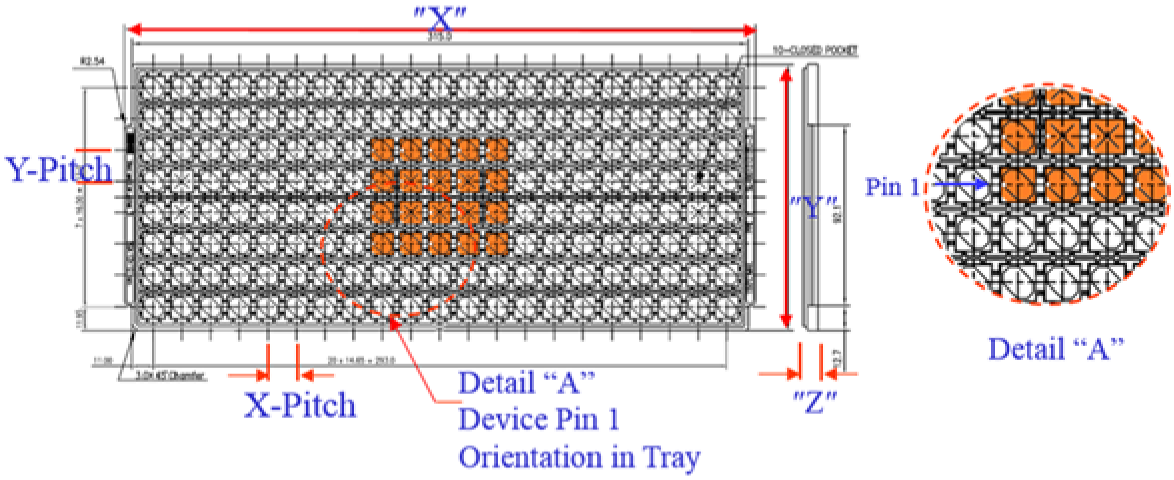
Recommended MTi 1-series module footprint

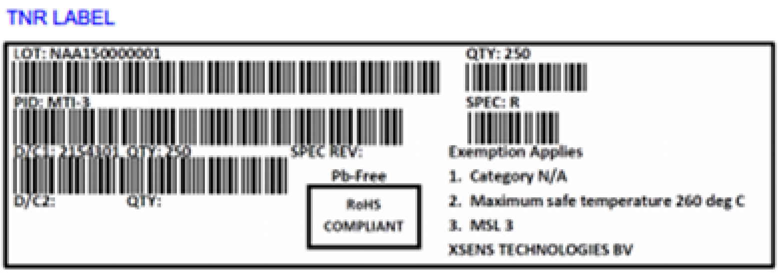
The MTi 1-s module is shipped in trays with 20 or 100 modules or in reels with 250 modules.

Tray packaging information

Tray of 20 pcs (MTi-#-T or MTi-#-0I-T)







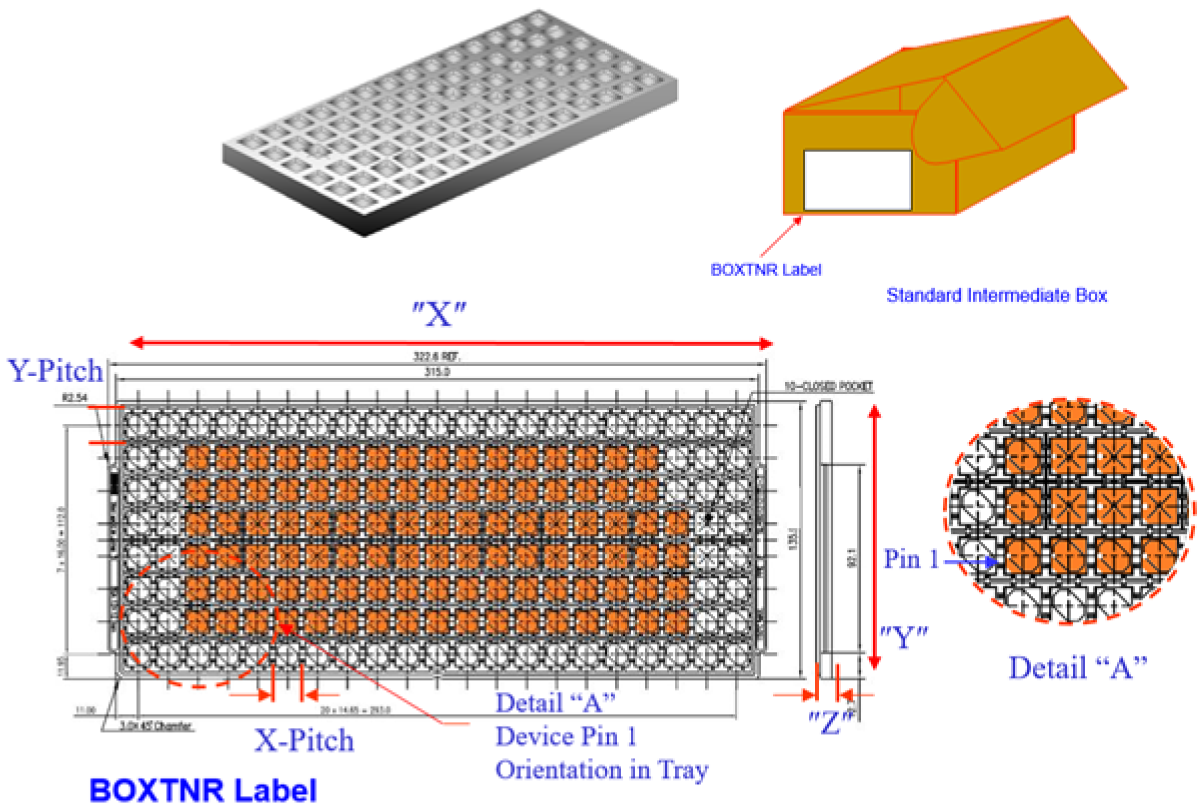
Tray Dimensions (mm)						Tray packaging information		Pin 1
Length "X"	Width "Y"	Height "Z"	Pocket X-Pitch	Pocket Y-Pitch	Pocket X-Y Array	Qty/Tray	Qty/Box	
322.60	135.90	7.62	14.65	16.00	12 x 12	20 units	20 units	Detail "A" Marking

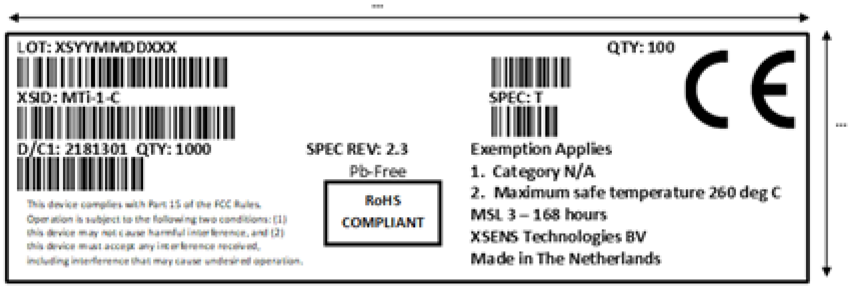
NOTES:

- 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.

Tray of 100 pcs (MTi-#-C or MTi-#-0I-C)



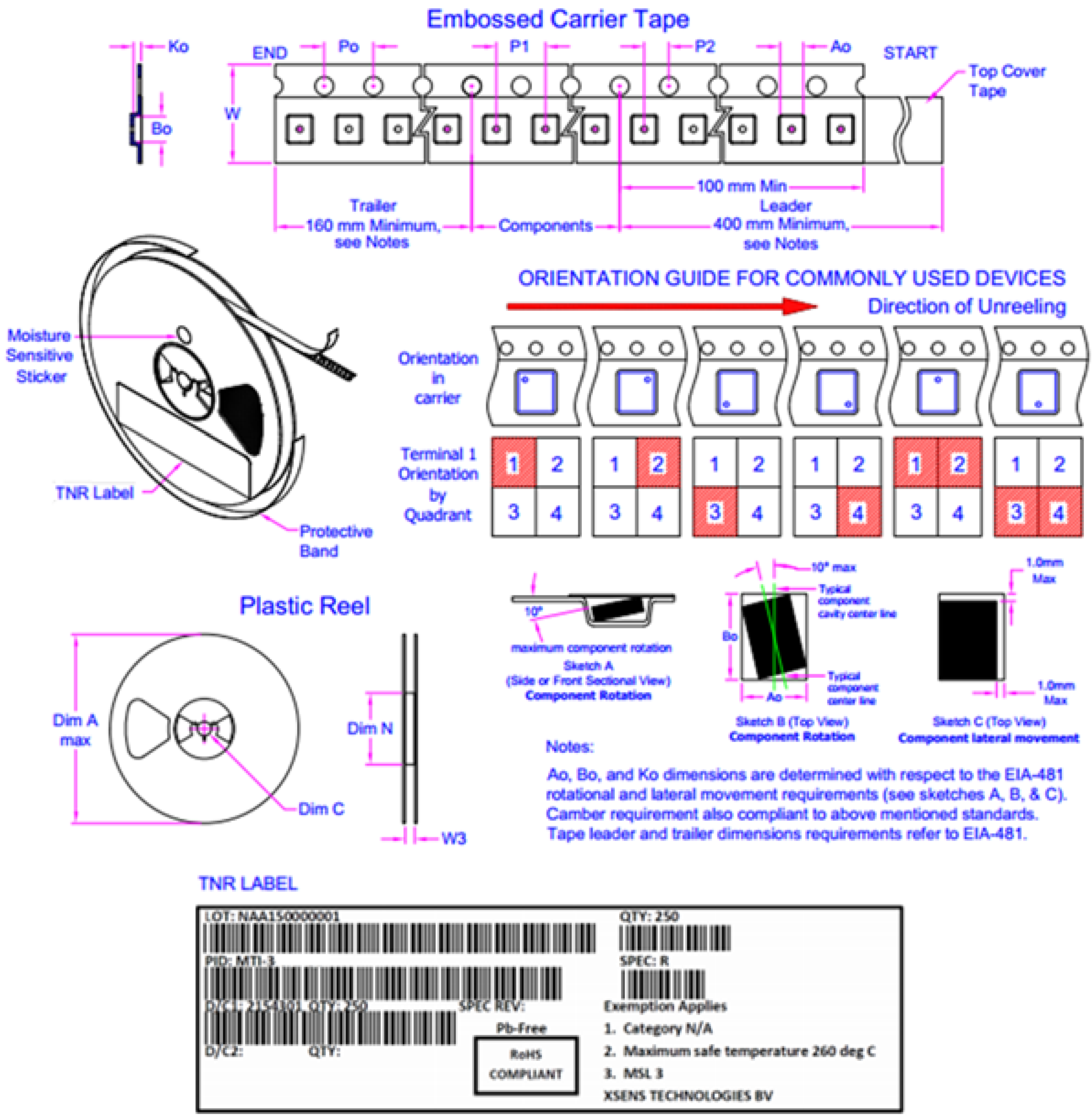


MOD	Tray Dimensions (mm)						Tray Packaging Information		Pin 1
	Length "X"	Width "Y"	Height "Z"	Pocket X-Pitch	Pocket Y-Pitch	Pocket X-Y Array	Qty/Tray	Qty/Box	Device Orientation
MKT-MTI-1-C	322.60	135.90	7.62	14.65	16.00	12 x 12	100 units	100 units	Detail "A" Marking

NOTES:

- ALL DIMENSION ARE IN MILLIMETERS UNLESS OTHERWISE SPECIFIED
- DRAWING FILE NAME : PKG-MTI-1-TRAYREV1
- PICTURED TRAY REPRESENTATIVE ONLY, ACTUAL TRAY MAY LOOK DIFFERENT

Reel packaging information (MTi-#-R or MTi-#-0I-R)



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

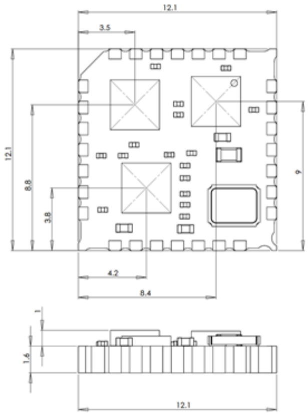
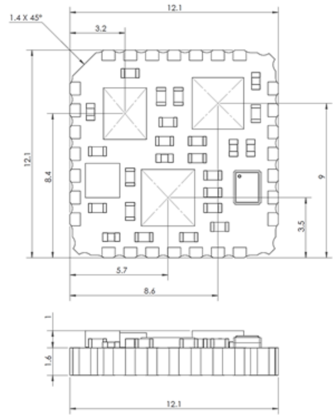
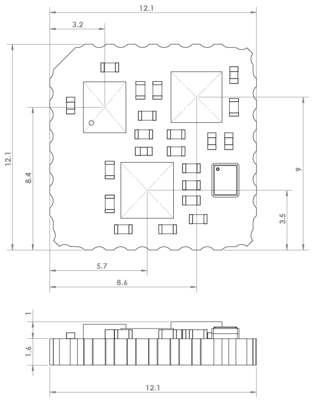
NOTES:

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

Package drawing

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

MTi 1-series module generations

Version 1.x (PCB no. SM141111)	Version 2.x (PCB no. ≥ SM171223)	Version 3.x (PCB no. ≥ SM210527)
 MTi 1-series v1.x dimensions and sensor locations	 MTi 1-series v2.x dimensions and sensor locations	 MTi 1-series v3.x dimensions and sensor locations
• All dimensions are in mm. • General tolerances are ± 0.1 mm		

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

Declaration of conformity

EU Declaration of Conformity

EU Declaration of Conformity

Applicable objects:

MTi-1-#[1]
MTi-2-#[1]
MTi-3-#[1]
MTi-7-#[1]
MTi-#-DK

Manufacturer:

Xsens Technologies B.V.
Pantheon 6a
7521 PR ENSCHEDE
THE NETHERLANDS

This declaration of conformity is issued under the sole responsibility of the manufacturer.

The objects of the declaration described above are in conformity with the relevant Union harmonization legislation, based on the tested mode of operation(s), the applicable performance criteria, and specified acceptance criteria:

Short name	Directive
Electromagnetic compatibility (EMC)	2014/30/EU
Restriction of the use of certain hazardous substances (RoHS)	2011/65/EU

Relevant harmonized standards used:

Standard description	Standard	Result
Emission	EN 61326-1 (2013), class B	Passed
Immunity	EN 61326-1 (2013), Industrial	Passed
Radiated emission up to 1 GHz (SAC)	EN 55011 (2009) + A1 (2010)	Passed
Radiated immunity	EN-IEC 61000-4-3 (2006) + A1 (2008) + A2 (2010)	Passed
Power Frequency Magnetic field	EN-IEC 61000-4-8 (2010)	Passed

Signed for and on behalf of:

Enschede 2019 January, 15

Giovanni Bellusci, CTO

[1] When pre-mounted on the MTi-#-DK

FCC Declaration of Conformity

FCC Declaration of Conformity

Applicable objects:

MTi-1-#[1]
MTi-2-#[1]
MTi-3-#[1]
MTi-7-#[1]
MTi-#-DK

Manufacturer:
Xsens Technologies B.V.
Pantheon 6a
7521 PR ENSCHEDE
THE NETHERLANDS

The objects of the declaration described above is in conformity with the relevant FCC regulations, based on the tested mode of operation(s), the applicable performance criteria, and specified acceptance criteria

Object classification	Directive
Computers and other digital devices, unintentional radiator	47 CFR 15

Relevant standards used:

Test description	Standard	Result
Emission	47 CFR 15 & ICES-003 (Issue 6), class B	Passed
Radiated emission up to 1 GHz (SAC)	ANSI C63.4 (2014)	Passed

Operation is subject to the following two conditions:

(1) this device may not cause harmful interference, and
(2) this device must accept any interference received, including interference that may cause undesired operation.

The following test report is subject to this declaration:

Test report number: 18C00845RPT02.pdf
Issue date: 2019 January, 15

The following manufacturer/importer/entity is responsible for this declaration:

Company name: Xsens Technologies B.V.
Name Title: Giovanni Bellusci, CTO
Address: Pantheon 6a, 7521 PR ENSCHEDE, THE NETHERLANDS
Phone: +31 (0)889736700
Fax: +31 (0)889736701

[1] When pre-mounted on the MTi-#-DK

Reach Declaration

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T +31 88 973 67 00
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E info@xsens.com

Pantheon 6A
P.O. Box 559
7500 AN Enschede
The Netherlands

www.xsens.com

REACH Declaration

Date: August 2020

According to the definition in Article (3) of the REACH Regulation, Xsens is a producer of articles and consequently a downstream user. Therefore, we are not subject to the obligation to register chemicals.

Xsens affirms that it follows the REACH-Regulation updates and it compares these updates with the substance information on hand. The expansion of the Candidate List and the inclusion of substances in the Annex XIV of REACH receives special attention.

We hereby confirm that the products manufactured by Xsens do not contain substances listed in Annex XIV in concentrations exceeding the permitted limiting value of 0.1%. *

This statement is based on our current knowledge. We cannot issue a warranty or assume liability for factors that lie outside the state of our knowledge and control.

Xsens Technologies B.V.

Xsens Technologies B.V.

Jeroen Weijts

Sr. Operations Manager

* this excludes substances exempt under ROHS regulations

DK User Manual

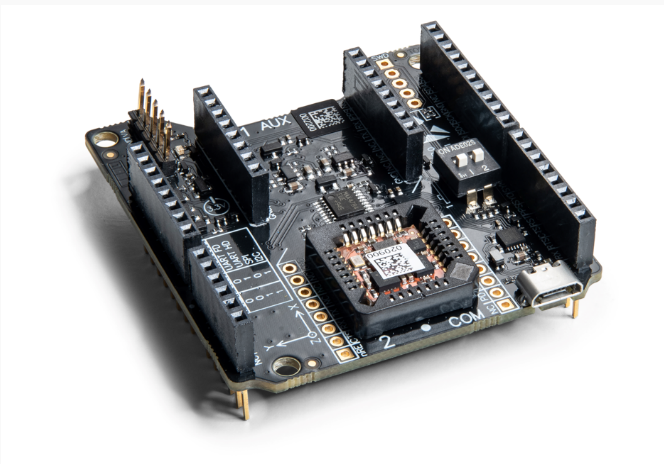
General Information

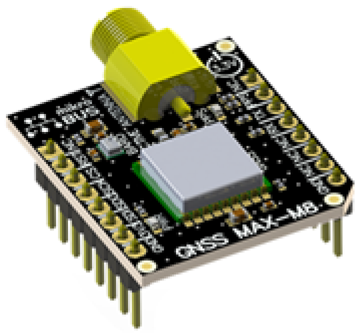
This document provides information on the contents and usage of the MTi 1-series Development Kits. The MTi 1-series module (MTi 1-s) is a fully functional, self-contained module that is easy to design-in. The MTi 1-s can be connected to a host through I2C, SPI or UART interfaces. The MTi-3 Development Kit (MTi-3-DK) enables users to evaluate features for the MTi-3 (AHRS), MTi-2 (VRU) and MTi-1 (IMU) modules. The MTi-7 Development Kit (MTi-7-DK) enables users to evaluate features of the MTi-7 (external GNSS/INS), and the MTi-8 Development Kit (MTi-8-DK) enables users to evaluate features of the MTi-8 (external GNSS/INS). In addition to the MTi 1-s interfaces, both Development Kits include a USB interface.

⚠ **The MTi 1-series module consists of components that are sensitive to stress. As a result, sensor characteristics may change when forces are applied to the module. As each module is calibrated individually, Xsens cannot guarantee performance after improper handling. It is therefore recommended not to remove the module from the socket, and to use the Development Kit for prototyping and evaluation purposes only. For more information on proper handling, refer to the MTi 1-series Hardware Integration manual (see chapter Software and documentation).**

Package information

Package contents for MTi 1-series Development Kits

Component	Name
	Shield board, including MTi 1-series module (MTi 1-s)

 	GNSS daughter card[1] u-blox MAX-M8Q GNSS receiver (default) or GNSS RTK daughter card[1] u-blox ZED-F9P GNSS receiver (default)
 or 	GNSS antenna[1]
	USB cable

Ordering information

⚠ Due to obsolescence management and continuous improvement, the MTi 1-series is subject to hardware changes, resulting in different hardware versions (v1.x, v2.x and v3.x). The table below lists the ordering part numbers for the hardware versions that are currently available (v2.x and v3.x). For an overview of differences between these hardware versions we refer to the migration articles on BASE.

Ordering information for MTi 1-series Development Kits

Kit	Description	Package contents	Packing Method

MTi-8-0I-DK (v3.x)	Development kit for MTi-8 (external-RTK-GNSS/INS)	• Shield board • MTi-8 module (in the socket) • GNSS daughter card • GNSS antenna • USB cable	Single unit
MTi-7-DK (v2.x) MTi-7-0I-DK (v3.x)	Development kit for MTi-7 (external-GNSS/INS)	• Shield board • MTi-7 module (in the socket) • GNSS daughter card • GNSS antenna • USB cable	Single unit
MTi-3-DK (v2.x) MTi-3-0I-DK (v3.x)	Development kit for MTi-1 (IMU), MTi-2 (VRU) and MTi-3 (AHRS)	• Shield board • MTi-3 module (in the socket) • USB cable	Single unit

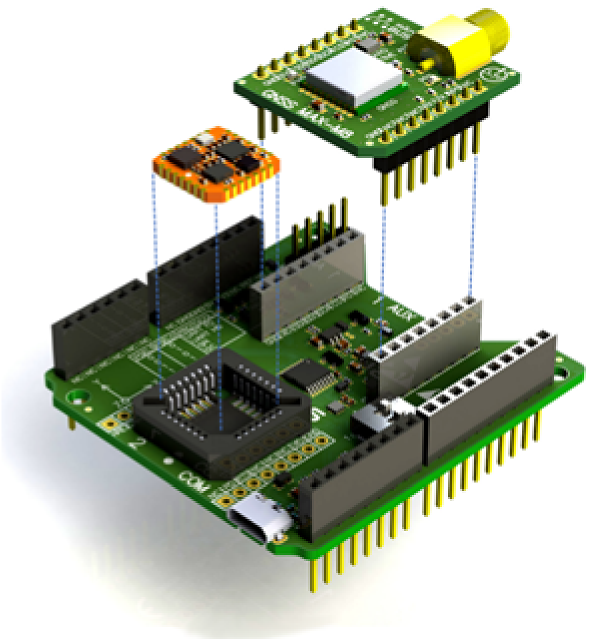
[1] Only with MTi-7-DK, MTi-7-0I-DK (daughter card with u-blox MAX-M8Q) or MTi-8-0I-DK (daughter card with u-blox ZED-F9P).

Introduction

Kit contents and features

The MTi 1-series Development Kit contains

- Shield board
- MTi-3, MTi-7 or MTi-8 mounted in the socket
- GNSS daughter card (only with MTi-7/8-DK)
- GNSS antenna (only with MTi-7/8-DK)
- USB cable



Exploded view of the MTi 1-series Shield board

The Shield Board, the MTi 1-s (orange module) and the GNSS daughter card (with the SMA connector) are shown in figure
Exploded view of the MTi 1-series Shield board. The features of the Shield Board include:

- 3.3 V compatible I/O
- Power indicator LEDs
- Arduino-compatible headers
- External power pin header
- Manual peripheral selection switch for MTi 1-series
- Switching between UART and I^2C on Arduino-compatible headers based on PSEL switch

setting

- USB to UART converter
- Auxiliary extension socket
- Optional socket connections for mikroBUS™ RS232/RS485 click boards™ (see BASE for more info)

See Chapter Shield board for more details.

Software and Documentation

The MTi 1-series Development Kit is supported by the MT Software Suite, which includes the following software components:

- MT Manager
- Magnetic Field Mapper
- MT SDK with documentation

Additionally, the latest firmware for the MTi module can be downloaded and updated using the Firmware Updater that is also available on our website.

The software components can be downloaded from the Xsens website.

> Note: The MTi 1-series Development Kit offers access to the module via the UART, SPI and I²C interfaces, as well as an additional USB interface. Please note that the graphical software tools, such as MT Manager and the Magnetic Field Mapper, as well as a large part of the MT SDK are only supported when using serial (UART/USB) communication. For I²C or SPI communication, dedicated "embedded example codes" are available.

Along with the SDK documentation that is part of the MT Software Suite installer package, the MTi 1 series Development Kit is supported by the following additional documents:

- Hardware Integration Manual: MTi 1-series
- Datasheet: MTi 1-series
- MT Low Level Communication Protocol Document
- MT Manager User Manual

- MT Magnetic Calibration Manual
- Product Change Notices and Release Notes

Embedded examples

There are embedded examples available for the MTi 1-series Development Kit that make use of the SPI and I^2C interfaces. The examples and corresponding documentation can be found in the MT Software Suite installation folder at:

C:Program FilesXsensMT Software Suite **x.x.x**MT SDKExamplesembedded_examples

The examples target the STM32F401 Nucleo board. They allow for a quick start in receiving measurement data from the MTi, and evaluating the low-level communication protocol.

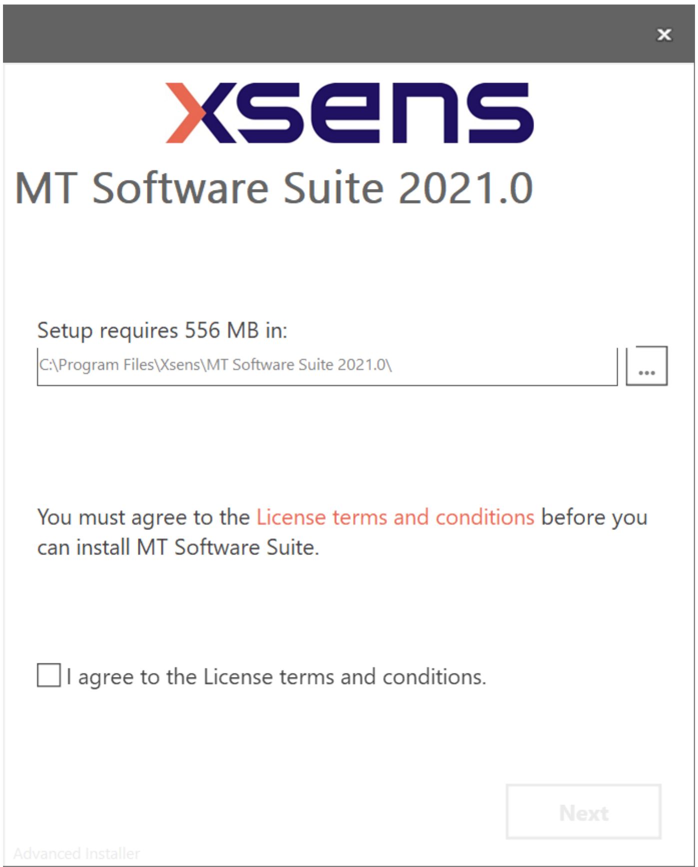
It is easy to extend the program with commands from the Xsens Low Level Communication Protocol (LLCP). This protocol is documented in detail in the *Low Level Communication Protocol Documentation*.

Getting Started

Installing MT Software Suite

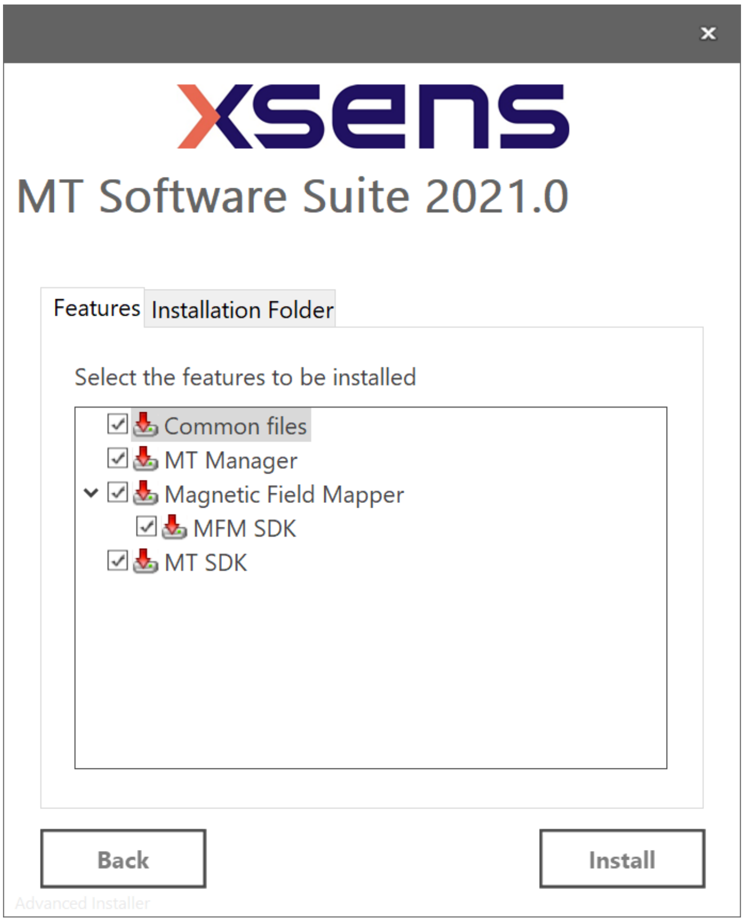
The MT Software Suite is available from the Xsens website (www.xsens.com/software-downloads).

The installation procedure consists of a set of several installers and starts with the following GUI:



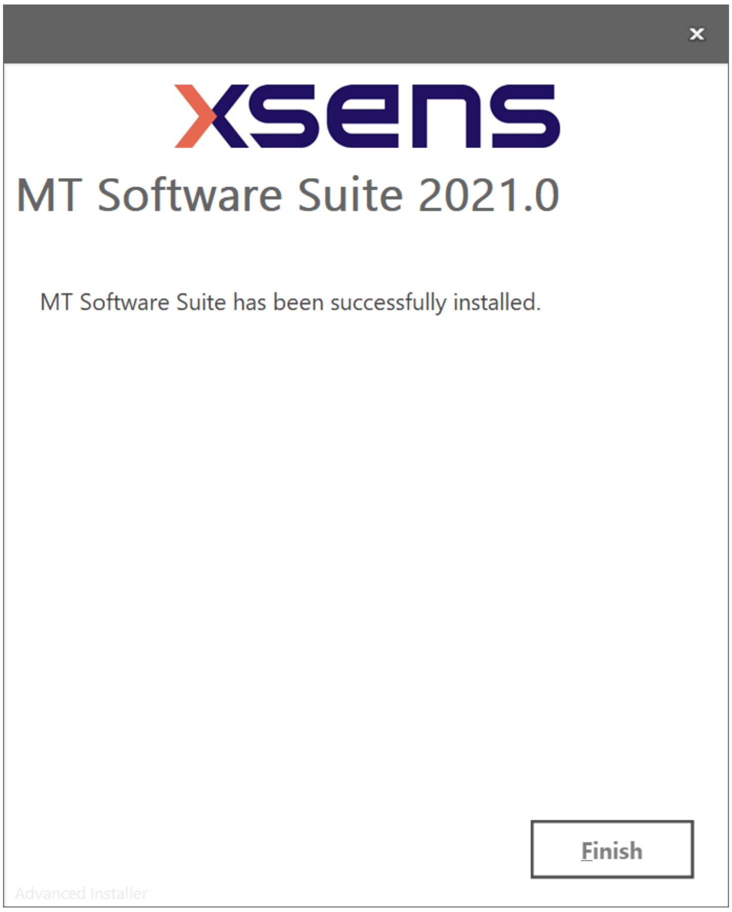
Start up screen for MT Software Suite installer

It is possible to choose the components that you need to install:



Software components installation

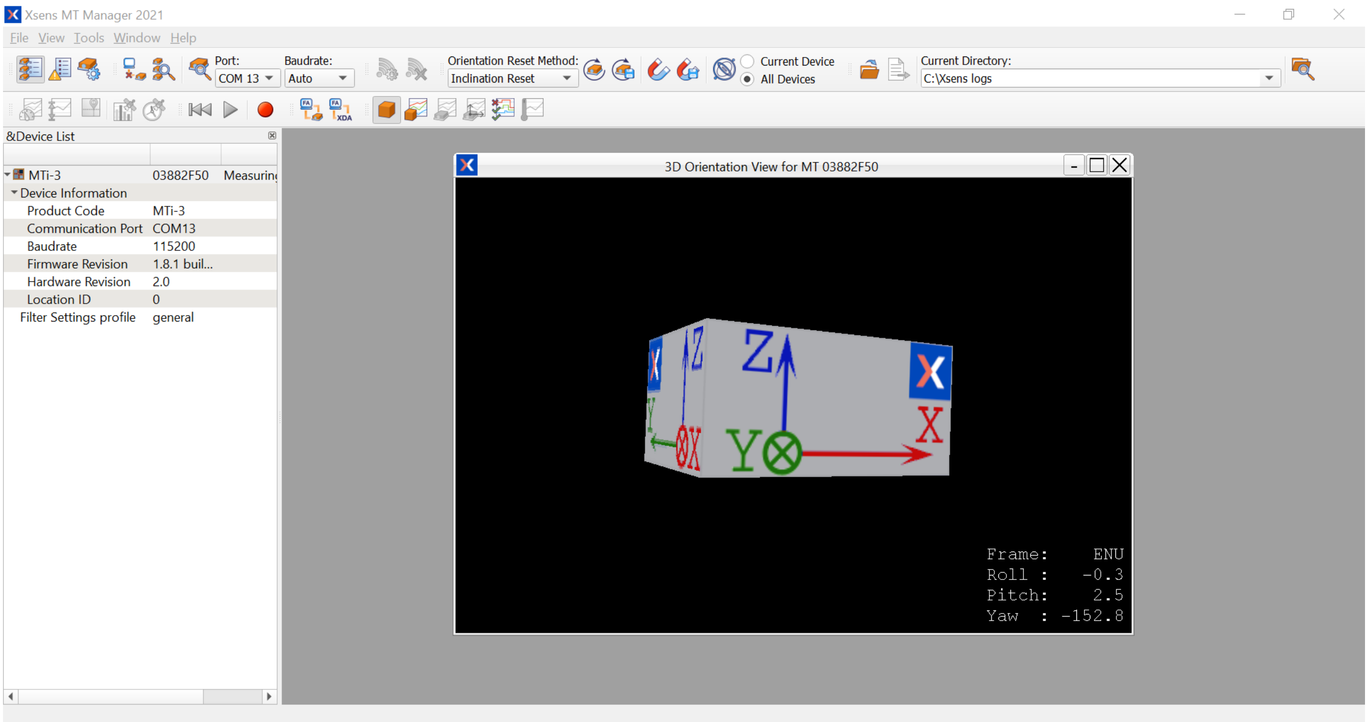
When you cancel the installation of a particular component, the installer will continue with the next component. Make sure to accept the End-User License agreement and Software License Agreements, and then wait for the successful installation screen to appear:



Successful installation screen

Displaying data in MT Manager

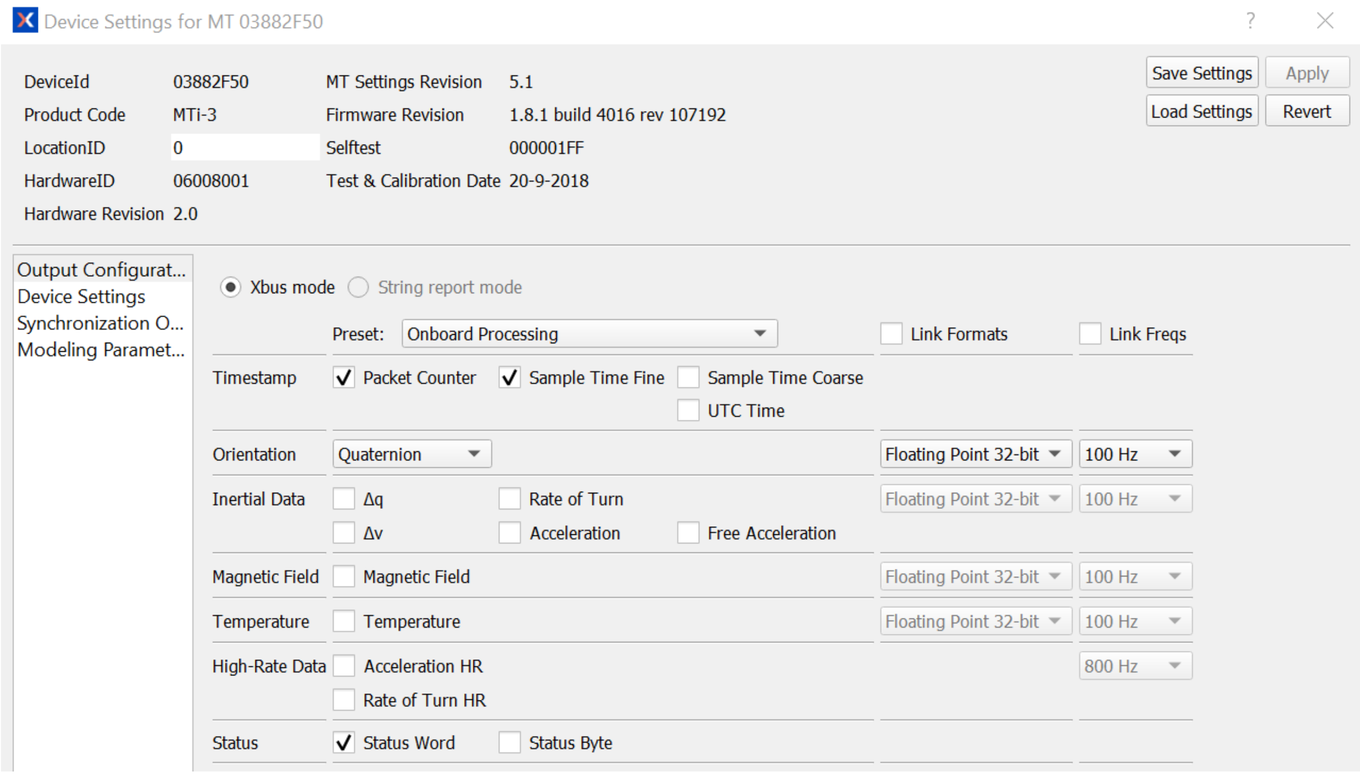
When the MTi 1-series Shield Board is connected in MT Manager, the device description is shown in the "Device List" (MT Manager overview). To see a real time 3D orientation of the MTi, click the 3D View icon . The inertial data , orientation data in Euler angles and the status data can be visualized by clicking their respective icons in the figure MT Manager overview.



MT Manager overview

Configuring the MTi 1-series

The MTi 1-series can be directly configured by means of MT Manager. Click the Device Settings button  to open the Output Configuration dialog:



Output configuration dialog in MT Manager using an MTi-3-DK

By default, the output of the MTi-2, -3, -7 and -8 is set to the ‘Onboard Processing’ preset, whereas the MTi-1 module is set to the ‘XDA processing’ preset. Click “Inertial Data” (Δq/Δv or Rate of Turn/Acceleration) and “Magnetic Field” to be able to show this data in MT Manager.

With MT Manager, it is possible to record data and export that data for use in other programs, set alignment matrices, configure synchronization options and to review the test and calibration report. More information on the functions and features can be found in the *MT Manager User Manual*.

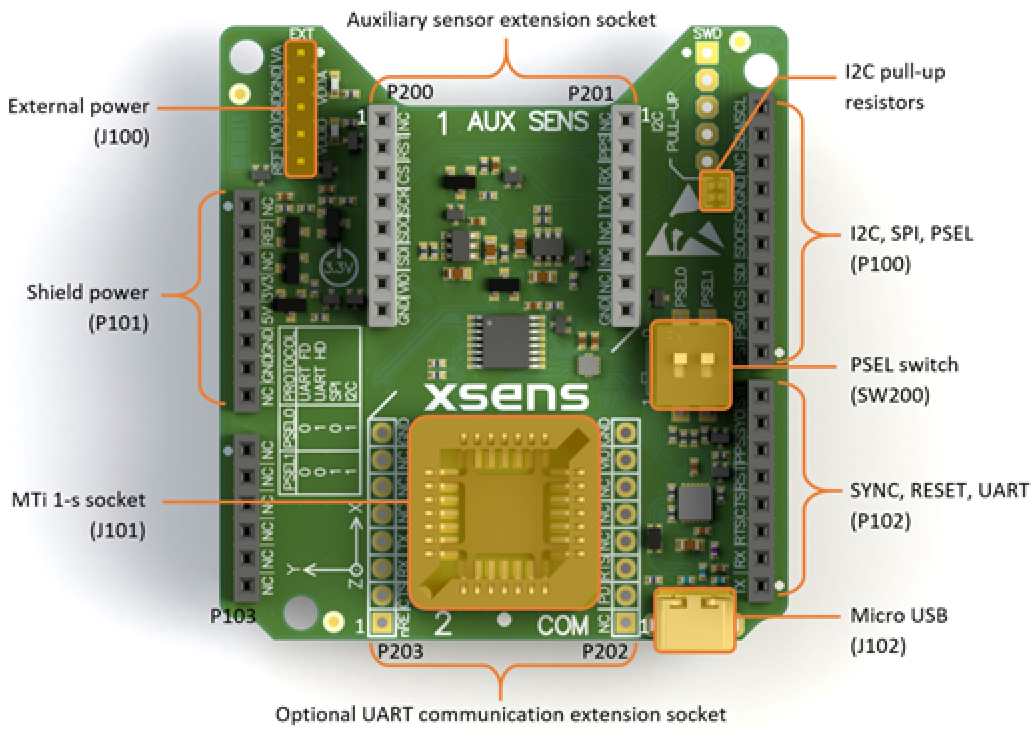
Shield board

The MTi 1-s modules are available with a development kit. An MTi-3 AHRS or an MTi-7/8 external-GNSS/INS is mounted in a PLCC-28 socket and connected to USB, UART, I^2C and SPI. The Shield Board exposes the pins of the MTi 1-s module, making it easier for the user to test all the features and the peripherals offered by the MTi 1-s. This chapter discusses in more detail the connections and peripherals available on the MTi 1-s Shield Board.

Connections and peripheral switch

The MTi 1-series Shield Board has the following connections as shown in the figure below: MTi 1-series Shield Board with connector designators:

- External power pin header (J100)
- Arduino-compatible headers (P100, P101, P102 and P103)
- UART communication extension socket, not placed by default (P202 and P203)
- Micro USB (J102)
- Peripheral selection switch (SW200)
- Auxiliary sensor extension socket (P200 and P201) used for GNSS daughter card
- MTi 1-series module placed in J101



MTi 1-series Shield Board with connector designators

⚠ **Shield boards from version 2.4 (PCB number: SD180624) and higher have 2.7 kΩ pull-up resistors on the I²C pins on the Arduino-compatible header (P100-9 and P100-10). These resistors pull the I²C lines to VDDIO. The figure above shows the position of the resistors. The version number of the board can be derived from the last two digits of the PCB number, located at the bottom side of the board (in the solder mask). For shield boards of version 2.3 or lower, the pull-up resistors need to be added externally, if the I²C protocol is used.**

The *External power pin header* J100 can be used to directly supply the VDDIO and/or VDDA supplies for the MTi 1-s module (Table Connections on external power header). The IOREF pin on this connector can be used to override the default 3.3 V VDDIO by placing a jumper from this pin to the adjacent VDDIO pin.

Connections on external power header (J100 in Figure MTi 1-series Shield Board)

Pin	Description
1	VDDA

2	GND
3	GND
4	VDDIO
5	IOREF

The connections for *Arduino-compatible headers* with a pitch of 2.54 mm (0.1 inch) are shown in the table below. The MTi 1-series Shield Board does not support Arduino-compatible boards with an IOREF of 5V as the maximum VDDIO is 3.6V for the MTi 1-s module. Therefore, the VDDIO is by default set to 3.3V. This default VDDIO voltage can be overruled by placing a jumper on the external power header, but only for voltages within the operational VDDIO range of the MTi 1-s module. For information on the connections, refer to the pin description in Section Pin Descriptions Refer to the table Connections on Arduino-compatible header on how to enable the various interfaces on the Shield Board.

Connections on Arduino-compatible headers (P100, P101, P102 and P103 in Figure MTi 1-series Shield Board)

Pin	Arduino	Shield Board	Pin	Arduino	Shield Board
			P100-10	SCL/D15	SCL
			P100-9	SDA/D14	SDA
			P100-8	AVDD	NC
P101-1	NC	NC	P100-7	GND	GND
P101-2	IOREF	IOREF	P100-6	SCK/D13	SCK/ADD0
P101-3	NRST	NC	P100-5	MISO/D12	MISO/ADD1
P101-4	3V3	3V3	P100-4	MOSI/D11	MOSI/ADD2
P101-5	5V	5V	P100-3	CS/D10	nCS
P101-6	GND	GND	P100-2	D9	PSEL0
P101-7	GND	GND	P100-1	D8	PSEL1

P101-8	VIN	NC	P102-8	D7	SYNC_IN
			P102-7	D6	SYNC_OUT
P103-1	A0	NC	P102-6	D5	SYNC_PPS
P103-2	A1	NC	P102-5	D4	RESET
P103-3	A2	NC	P102-4	D3	DRDY/CTS/nRE
P103-4	A3	NC	P102-3	D2	RTS/DE
P103-5	A4	NC	P102-2	TX/D1	RxD
P103-6	A5	NC	P102-1	RX/D0	TxD

The *UART communication extension socket* is not placed by default. When the socket is placed, it can be used to directly plug an UART transceiver module of MikroElektronika like the 'RS232 click' or 'RS485 click 3.3V'. This UART communication extension socket uses (only) the 3.3V supply pin, which is connected to VDDIO. We recommend to place low profile sockets (like the *CES-108-01-T-S*) to make sure that the MTi 1-s module is still easily accessible. The pin description of these headers is shown in the table Connections on UART communication extension sockets.

Connections on UART communication extension sockets (P202 and P203 in Figure MTi 1-series Shield Board)

Pin	Mikro BUS	MTi 1-s	Pin	Mikro BUS	MTi 1-s
P202-1	AN	NC	P203-1	PWM	DRDY/CTS/nRE
P202-2	RST	Pull-down	P203-2	INT	DRDY/CTS/nRE
P202-3	CS	RTS/DE	P203-3	TX	RxD
P202-4	SCK	NC	P203-4	RX	TxD
P202-5	MISO	NC	P203-5	SCL	NC
P202-6	MOSI	NC	P203-6	SDA	NC

P202-7	3.3V	VDDIO	P203-7	5V	NC
P202-8	GND	GND	P203-8	GND	GND

The MTi 1-series Shield Board has a *Micro USB* connection that can be connected directly to a USB port on a PC or laptop. **Note**: Make sure to disconnect any other power supply, as this will overrule the USB connection.

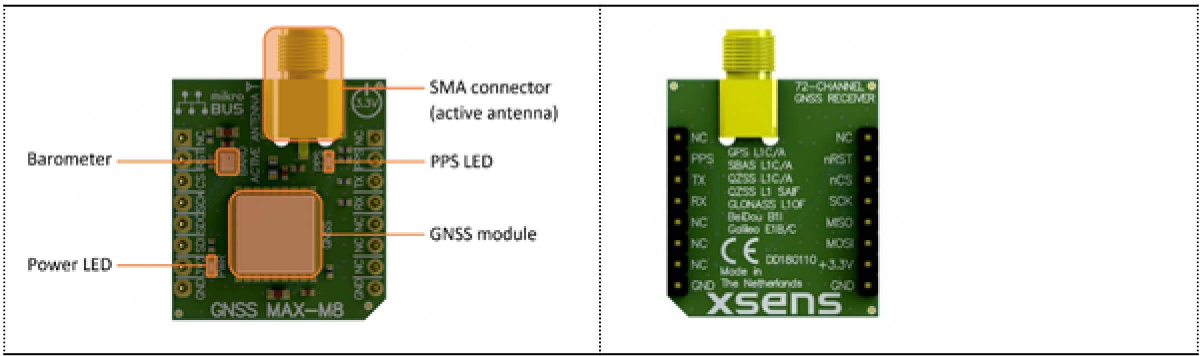
The *Peripheral selection switch* sets the interface configuration of the MTi 1-s module in the socket. The switch connects the PSEL lines (Table Switch positions to enable interfaces on Shield Board) to GND with a 5 kΩ pull-down when set to ON. Otherwise, the PSEL lines are pulled-up with a 100 kΩ resistor. The PSEL pins on the Arduino-compatible headers can be used to overrule these lines.

Switch positions to enable interfaces on Shield Board (SW200 in MTi 1-series Shield Board)

PSEL1	PSEL0	Interface	Comments
0	0	UART full-duplex	This interface uses the flow control lines RTS and CTS. 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 device transmit.
0	1	UART half-duplex	The UART itself is still full duplex but the DE and nRE lines are used to control a half-duplex transceiver
1	0	SPI	
1	1	I^2C	When the I^2C interface is selected, it is required to set the address on the Arduino-compatible headers (see MTi 1-series Data Sheet for the I^2C-addresses table)

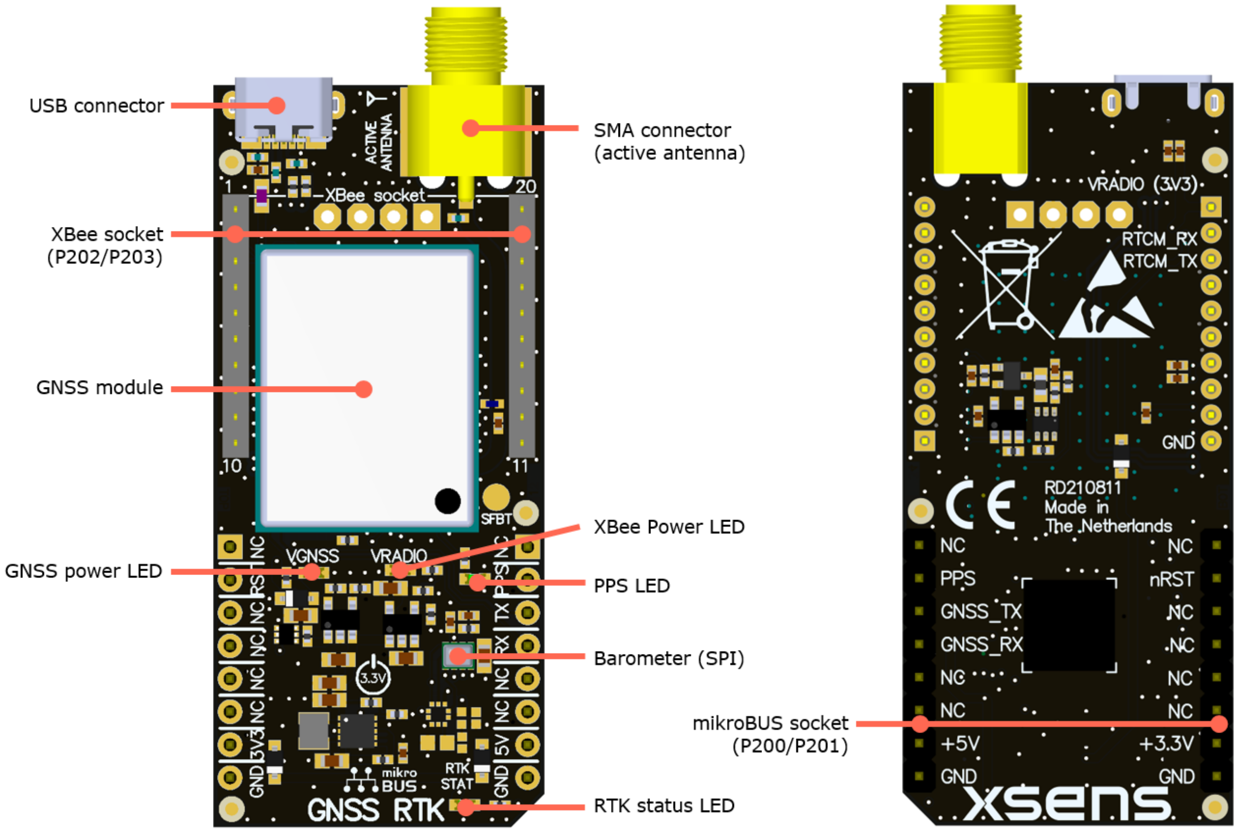
GNSS extension socket

The MTi-7-DK and MTi-8-DK come with a GNSS daughter card installed in the *auxiliary sensor extension sockets* (P200 and P201). As shown in the figure below, the MTi-7-DK GNSS daughter card consists of a GNSS and a barometer sensor component. The LEDs (Power and PPS) give an indication of the proper functioning of the GNSS daughter card. The supplied GNSS antenna can be connected to the SMA connector.



Top view (left) and the bottom view (right) of the MTi-7-DK GNSS daughter card

The MTi-8-DK comes with an RTK GNSS daughter card. As shown in the figures below, the RTK GNSS daughter card consists of an RTK GNSS receiver, a barometer sensor component, an Xbee socket and a USB connector. The LEDs (Power, PPS, Xbee and RTK status) give an indication of proper functioning of the RTK GNSS daughter card and Xbee power. The supplied GNSS antenna can be connected to the SMA connector.



Top view (left) and the bottom view (right) of the MTi-8-DK RTK GNSS daughter card

⚠ **The power consumption of the MTi-8-DK RTK GNSS daughter card (MTi-DK-RTK) is higher than the MTi-7-DK GNSS daughter card. Use only with MTi 1-s DEV Hardware Revision 2.7 and higher!**

The RTK GNSS daughter card is equipped with an XBee module socket. XBee modules are embedded solutions providing wireless end-point connectivity to devices. The XBee socket can be used to feed RTCM correction messages to the MTi-8-DK RTK GNSS receiver or to connect to an XBee wireless module.

XBee socket pinning

Pin	GNSS board
P202-1	VRADIO (3V3, max. 300 mA)
P202-2	RTCM_RxD
P202-3	RTCM_TxD
P202-[4..9]	NC

P202-10	GND
P203-[11..20]	NC

The RTK GNSS daughter card (MTI-DK-RTK) also features a Safeboot pin which can be used in case communication issues with the GNSS module on the daughter card arise. Please refer to BASE for instructions on how to use this pin and how to retrieve communication.

The *auxiliary sensor extension socket* has mikroBUS™ compatible pinning. This enables the user to connect alternate GNSS daughter card modules with mikroBUS™ pinning to the MTi 1-series Shield board. The pinning connections for the auxiliary sensor extension socket are listed in Connections on auxiliary sensor extension sockets.

Connections on auxiliary sensor extension sockets (P200 and P201 in Figure MTi 1-series Shield Board)

Pin	Mikro BUS	MTi 1-s	Pin	Mikro BUS	MTi 1-s
P200-1	AN	NC	P201-1	PWM	NC
P200-2	RST	nRST	P201-2	INT	SYNC_PPS
P200-3	CS	AUX_nCS	P201-3	TX	AUX_RxD
P200-4	SCK	AUX_SCK	P201-4	RX	AUX_TxD
P200-5	MISO	AUX_MISO	P201-5	SCL	NC
P200-6	MOSI	AUX_MOSI	P201-6	SDA	NC
P200-7	3.3V	VDDIO	P201-7	5V	5V (Rev. 2.8 and higher)
P200-8	GND	GND	P201-8	GND	GND

Pin descriptions

Pin descriptions Shield Board

Name	Type	Description
Power Interface		
VDDA	Power	Power supply voltage for sensing elements
VDDIO	Power	Digital I/O supply voltage
Controls		
PSEL0	Selection pins	These pins determine the signal interface. Note that when the PSEL0/PSEL1 is not connected, its logic value is 1. When PSEL0/PSEL1 is connected to GND, its logic value is 0
PSEL1		
RESET		Active high reset pin, connect to GND if not used
Peripheral Interface		
SDA	I2C interface	I2C serial data
SCL		I2C serial clock
ADD[0..2]		I2C address selection pins
nCS	SPI interface	SPI chip select
MOSI		SPI serial data input (slave)
MISO		SPI serial data output (slave)
SCK		SPI serial clock
RTS	UART interface	Hardware flow control in UART full-duplex mode (Ready-to-Send)
CTS		Hardware flow control in UART full-duplex mode (Clear-to-Send)
nRE		Receiver control signal in UART half-duplex mode
DE		Transmitter control signal in UART half-duplex mode
RxD		Receiver data input
TxD		Transmitter data output
DRDY	Data ready	Data ready pin indicates that data is available (SPI / I2C)

SYNC_IN	Sync interface	Accepts a trigger input to request the latest available data message
SYNC_OUT		N/A
SYNC_PPS		Pulse Per Second output of GNSS module
AUX_RxD	Auxiliary UART interface	Auxiliary UART data input
AUX_TxD		Auxiliary UART data output
AUX_nCS	Auxiliary SPI interface	Auxiliary SPI chip select
AUX_MOSI		Auxiliary SPI serial data output (master)
AUX_MISO		Auxiliary SPI serial data input (master)
AUX_SCK		Auxiliary SPI serial clock

Power supplies

The MTi 1-series module requires two different power supplies: VDDIO (used for the MCU and all IO) and VDDA (used as an analog supply for the sensing elements).
The Shield Board has five supply inputs:

1. USB: supplies both VDDIO and VDDA at 3.3V. Forces USB mode (SPI/I2C/UART interfaces not available).
2. 5V (P101): supplies both VDDIO and VDDA at 3.3V. Forces USB mode (SPI/I2C/UART interfaces not available).
3. 3V3 (P101): supplies VDDIO directly and overrides USB mode (SPI/I2C/UART interfaces available).
4. VDDIO (J100): supplies VDDIO directly, overrides all other VDDIO supplies and overrides USB mode (SPI/I2C/UART interfaces available).
5. VDDA (J100): supplies VDDA directly.

Note: Only supplying VDDIO (through 3V3 (P101) or VDDIO (J100)) without supplying VDDA is not recommended. The only single supply options are USB and 5V (P101), but in both cases the Shield Board will be forced into USB mode.

Electrical specifications

The Shield Board has the same communication protocol as the MTi 1-s module. The table System specification Shield Board shows the electrical specifications for the Shield Board.

System specification Shield Board

		Min	Typ	Max	Unit
VDDA		2.8	3.3	3.6	V
VDDIO		2.8	3.3	3.6	V
V_{IO}	V_{IH}	0.75 * VDDIO			V
	V_{IL}			0.25 * VDDIO	V

Absolute maximum ratings

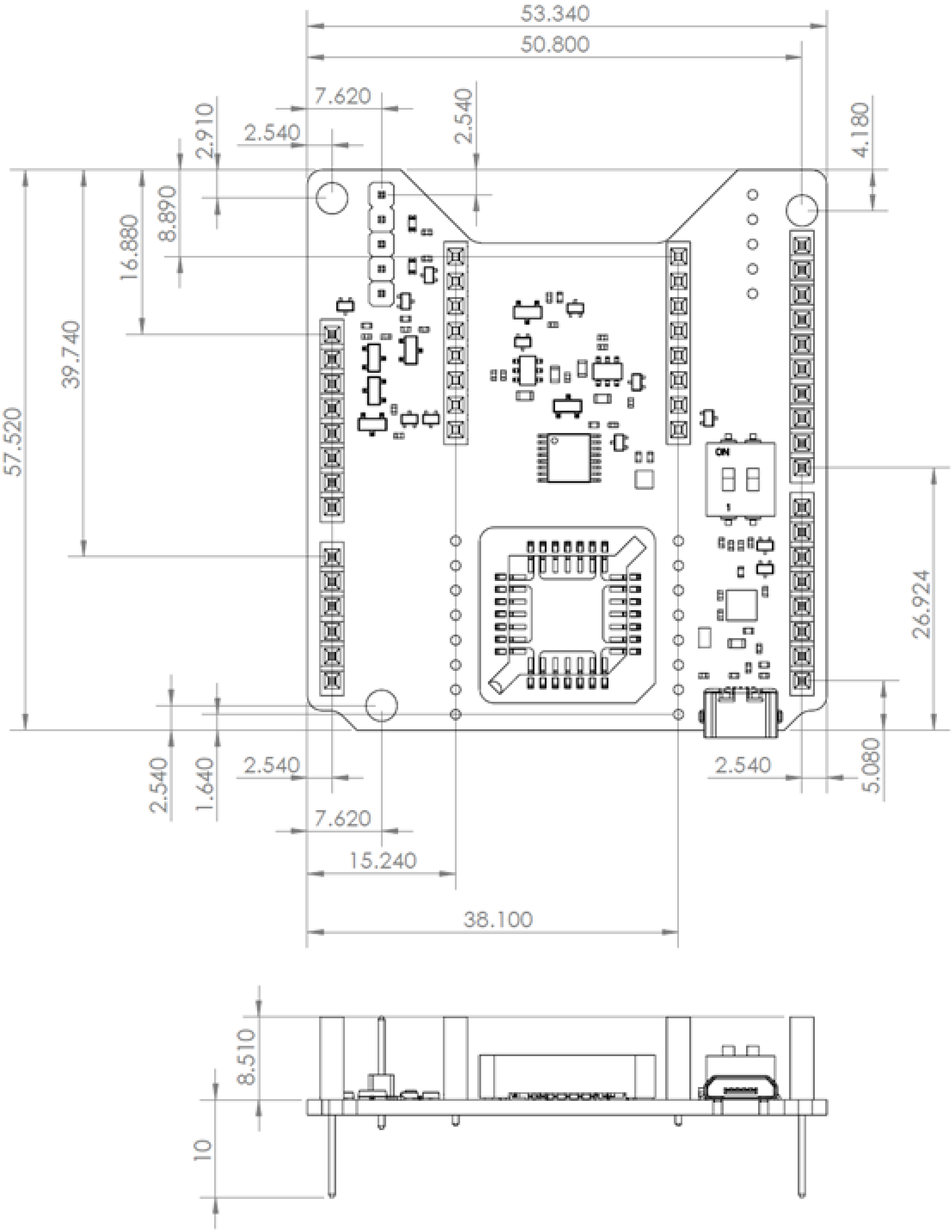
Absolute maximum ratings Shield Board

Parameter	Min	Max	Unit	Comments
Storage temperature	-50	+125	ºC	
Operating temperature	-40	+85	ºC	
VDD	-0.3	4.0	V	Specification for the external power header J100.
5V on P101 and J102	-0.3	6.0	V	Specification for the Arduino and USB.
VDDIO	-0.3	4.0	V	Specification for the external power header J100.
$V_{UART,PSEL,I^2C}$	-0.3	VDDIO + 0.3	V	

$V_{RESET,SYNC,SPI}$	-0.3	VDDIO + 4.0	V	
Acceleration [1]		10,000	g	Any axis, unpowered, for 0.2 ms
ESD protection[2]		±2000	V	Human body model

Stresses beyond those listed under “Absolute Maximum Ratings” may cause permanent damage to the device. These are stress ratings only. Functional operation of the device in these or any other conditions beyond those indicated in the operational sections of the specifications is not implied. Exposure to absolute maximum rating conditions for extended periods may affect device reliability. Make sure not to apply force on the components of the MTi 1-s module, especially when placing the MTi 1-s module in a PLCC socket.

Package drawing



MTi 1-series Shield Board package drawing (Top and Side view)

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[1] △ This is a mechanical shock (g) sensitive device. Proper handling is required to prevent damage to the part.
[2] ⚡ This is an ESD-sensitive device. Proper handling is required to prevent damage to the part.

Integration Manual

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^2C, SPI or UART interfaces.

Power supply shows recommendations for power supplies for the 1-series. Interfaces provides information about the different communication protocols that can be used, and Design describes some general layout considerations. Packaging and Handling provides 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:

MTi 1-series latest generations (v2.x and v3.x)

Product name	Type number	Hardware version[1]	PCB number[2]
MTi-1	MTi-1-T/C/R	2.x	≥ SM171223
MTi-1-0I	MTi-1-0I-T/C/R	3.x	≥ SM210527
MTi-2	MTi-2-T/C/R	2.x	≥ SM171223
MTi-2-0I	MTi-2-0I-T/C/R	3.x	≥ SM210527
MTi-3	MTi-3-T/C/R	2.x	≥ SM171223
MTi-3-0I	MTi-3-0I-T/C/R	3.x	≥ SM210527
MTi-7	MTi-7-T/C/R	2.x	≥ SM171223
MTi-7-0I	MTi-7-0I-T/C/R	3.x	≥ SM210527
MTi-8-0I	MTi-8-0I-T/C/R	3.x	≥ SM210527

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

MTi 1-series previous generation

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

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

[1] This number can be found on the packaging label (see Packaging).

[2] This number can be found on the bottom side of the MTi 1-series module (see Packaging).

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.

Main supply voltage (VDDIO)

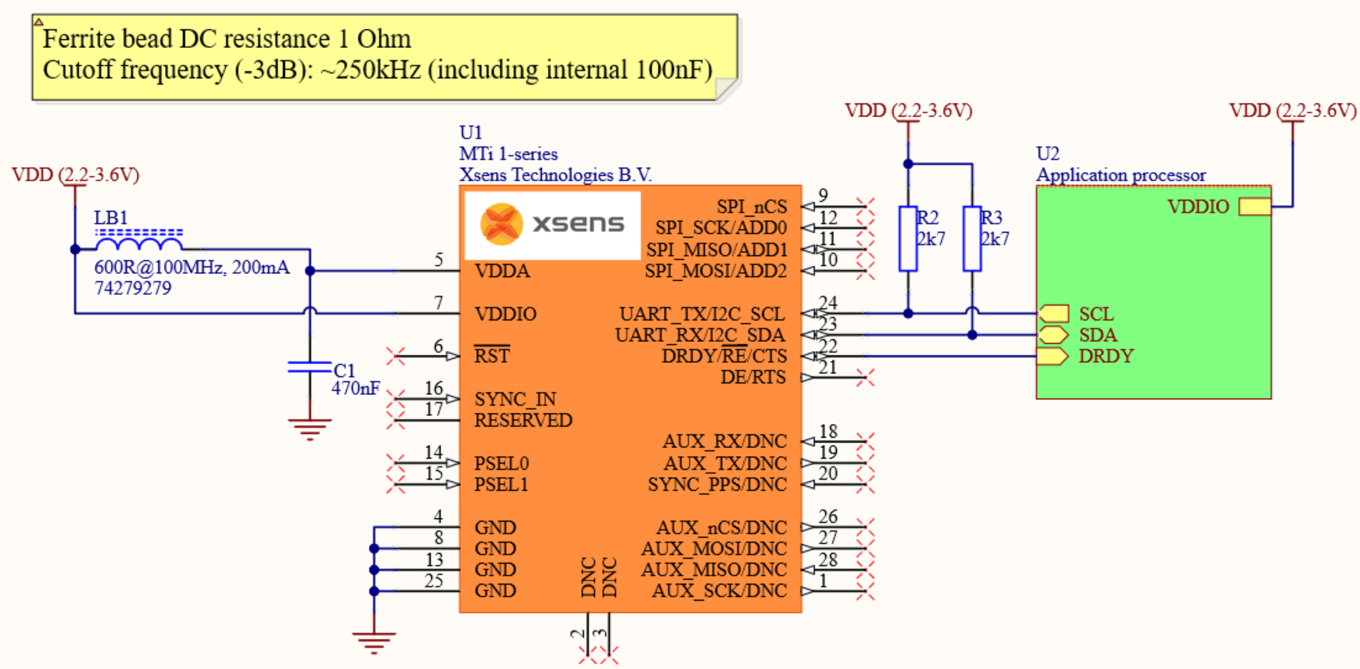
The VDDIO pin is the main supply of the MTi 1-series module. This pin is connected to all the digital IO's, and powers the processor on the MTi 1-series module. #Power supply specifications shows the acceptable range of VDDIO. For the most power efficient implementation, the VDDIO pin should be connected to a 2.8 V power supply.

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. The table below 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.

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 with a ferrite bead, for the best sensor performance. See schematic below. This way, the digital circuitry will not affect the analogue sensing part. Due to the varying current required for the VDDA, the DC resistance of the ferrite bead should not be too high. A DC resistance of maximum 1 Ω is recommended.



External components single supply (I²C interface)

Power supply specifications

The table below 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.

Maximum operating voltage ratings

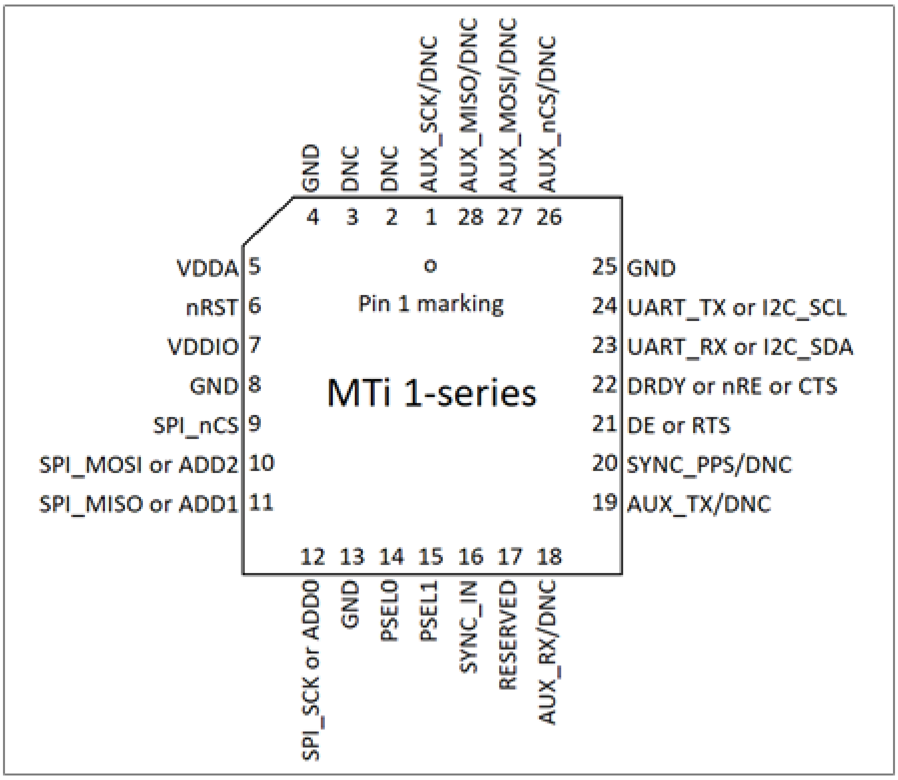
	Min	Max	Unit
VDDA	2.8	3.6[1]	V
VDDA ripple		50	mVpp
VDDIO	2.8	VDDA + 0.1	V

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

Interfaces

Pin Configuration

The figure below shows the pin configuration of the MTi 1-series module. Pins 18, 19 and 20 are only used on the MTi-7/8. For MTi-1/2/3 these pins need not be connected (DNC).



Pin configuration of the MTi 1-series module (top view)

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 #PSEL serial host communication interface selection). For interface specifications, see the table below.

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

PSEL serial host communication interface selection

The MTi 1-series modules have 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. The table below 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.

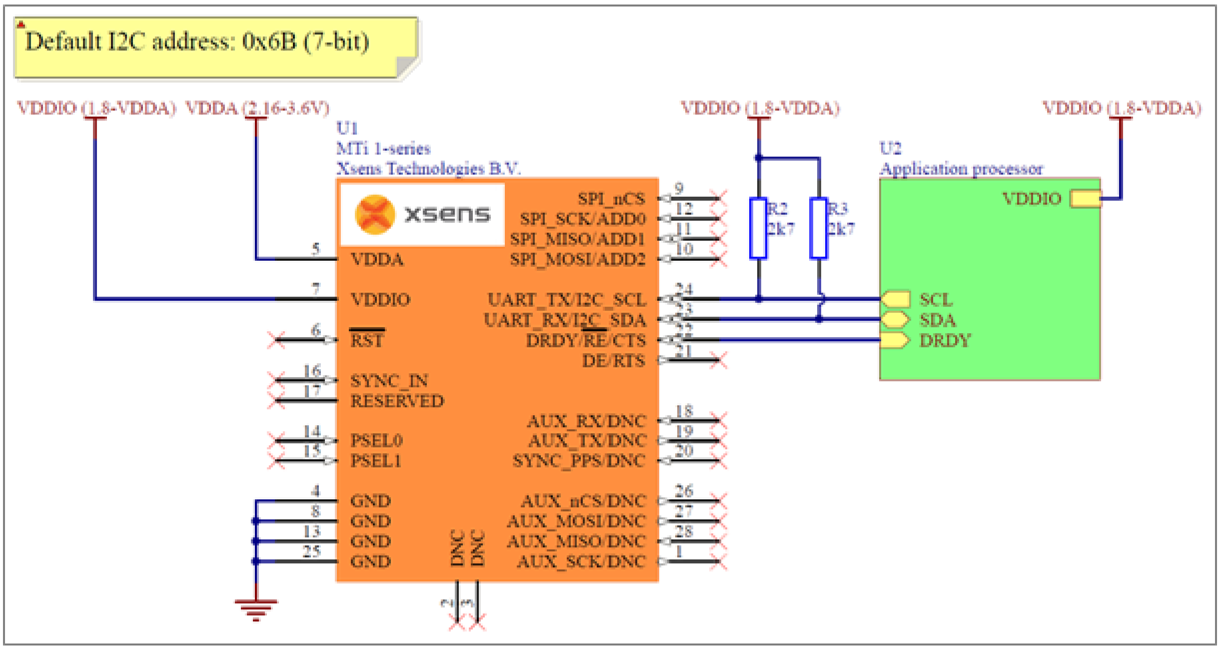
Serial host interface selection

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

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 the figure below; typical value: 2.7 kΩ).



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. The table below shows a list of all possible I²C addresses.

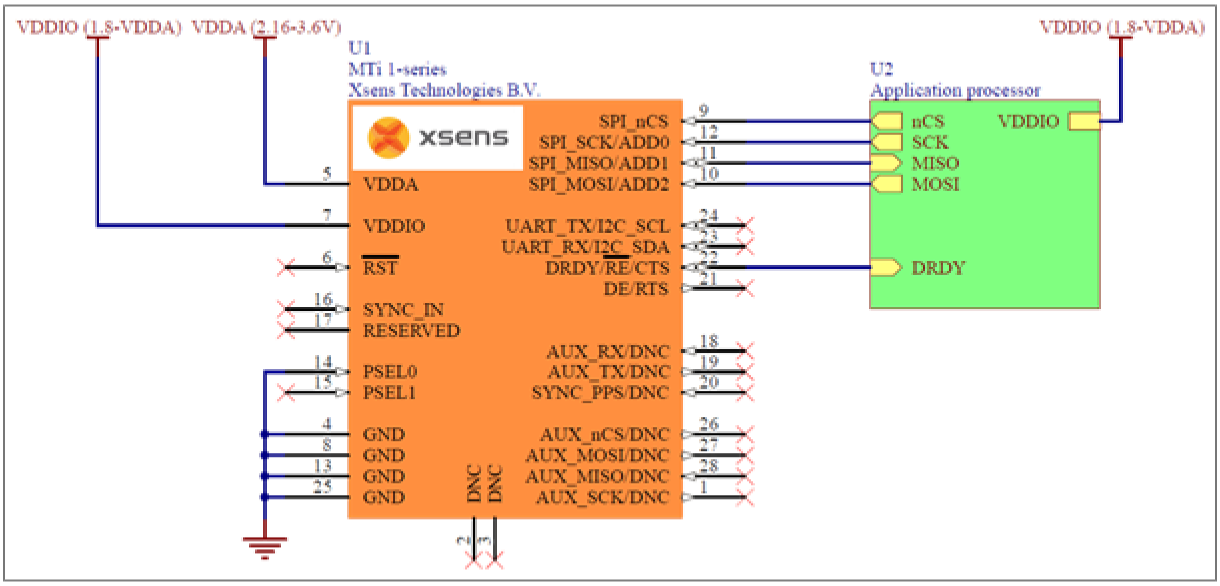
List of I2C addresses

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

I^2C address	ADD2	ADD1	ADD0
0x69	1	0	1
0x6A	1	1	0
0x6B *(default)*	1	1	1

SPI

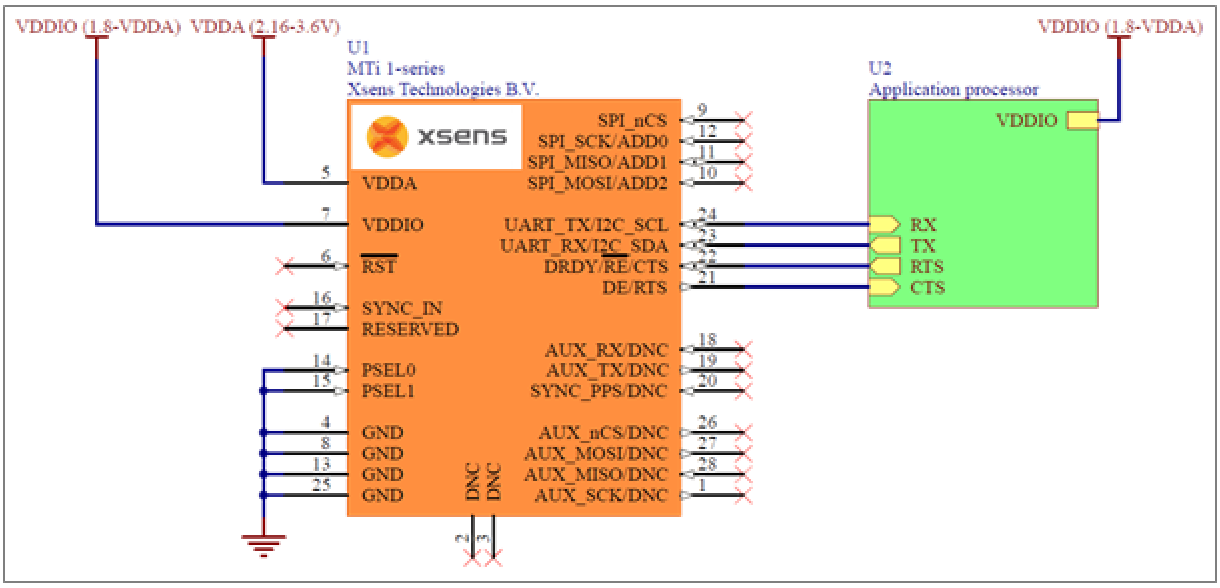
For the SPI interface, PSEL1 can be left floating or pulled-up to VDDIO and the PSEL0 pin needs to be connected to GND, as shown below.



Connections (SPI interface)

UART

For the UART full-duplex interface, the PSEL1 and PSEL0 pins need to be connected to GND, as shown below. 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 the UART half duplex interface, PSEL1 needs to be connected to GND and the PSEL0 pin must be left floating (see table above).



Connections (UART interface full-duplex)

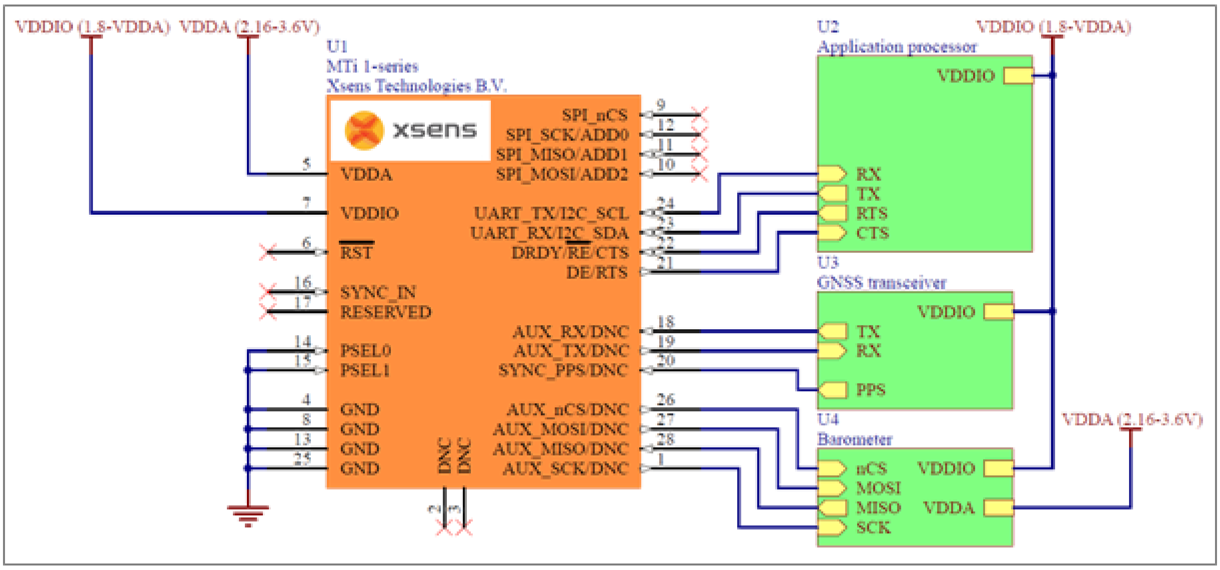
GNSS receiver and barometer interface

The MTi-7/8 variants of the MTi 1- series module family support external inputs from a GNSS receiver like the u-blox 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-7/8 module. See figure below for schematic details and table below for interface specifications.

GNSS receiver interface specifications

Interface		Typ	Max	Units
UART	Baud Rates	115.2	2000	kbps

Besides the GNSS receiver, the MTi-7/8 also supports an external barometer (the BMP280 - other models can be supported on request). 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-7/8 module. See the figure below for schematic details.



Connections (GNSS interface)

I/O pins

The I/O interface specifications are listed in the table below:

I/O interface specifications

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

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!**

SYNC_IN

The 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. The table I/O Pins shows the electrical specifications.

DNC/RESERVED pins

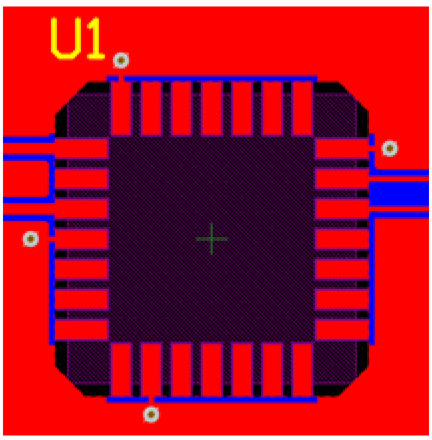
These pins are reserved for future use.

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

Design

PCB layout

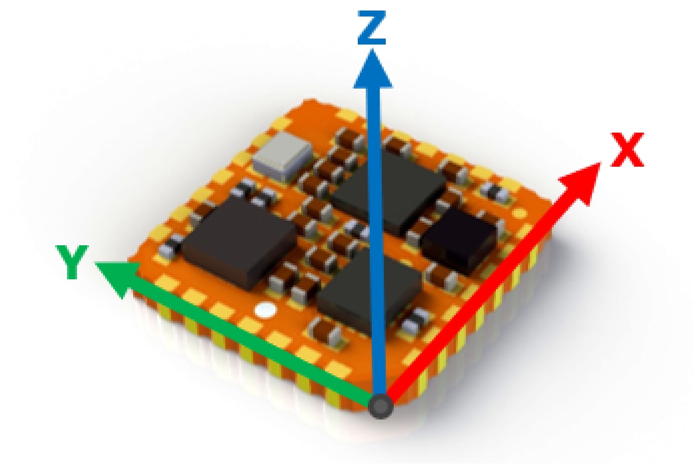
To prevent current flows that can influence the performance of the MTi 1-series, it is recommended to remove all copper (planes) underneath the MTi 1-series as shown in the image below.



Layout example

Frames of reference used in MTi 1-series

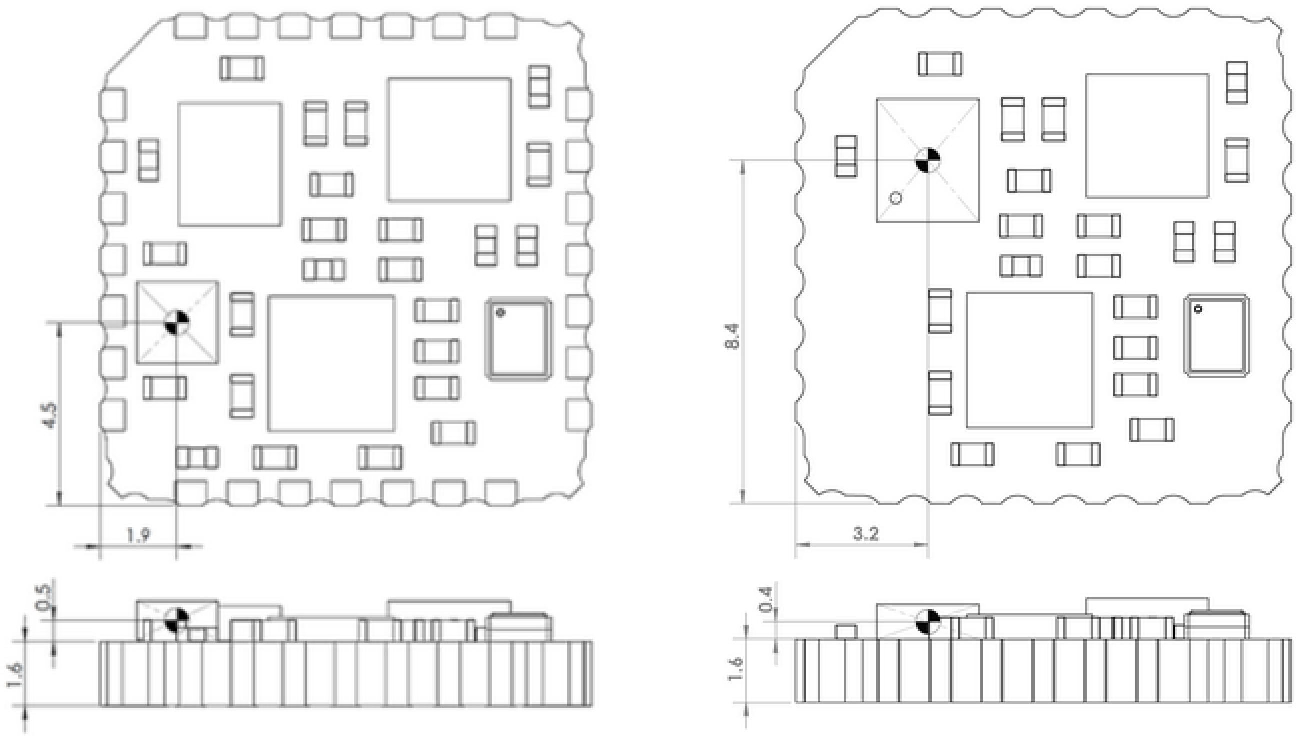
The MTi 1-series module uses a right-handed coordinate system as the basis of the sensor frame.



Default sensor fixed coordinate system for the MTi 1-series module

Origin of measurements

The accelerometer determines the origin of measurements. The images below show the location of the accelerometer of the MTi 1-series.



Location origin of measurements for HW version 2.x (left) and 3.x (right)

Mechanical stress

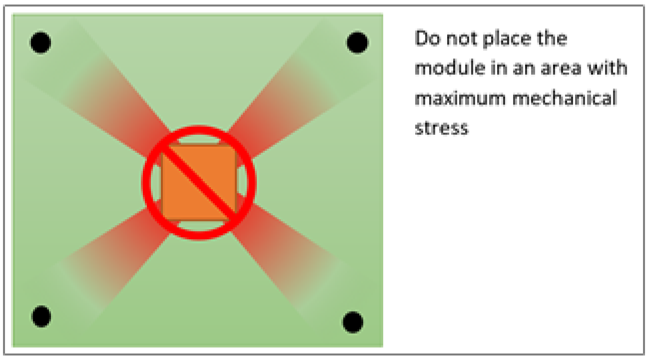
In general, it is recommended to place the MTi 1-series module in an area on the PCB with minimal mechanical stress. The following paragraphs show causes of mechanical stress and ways to reduce it.

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.

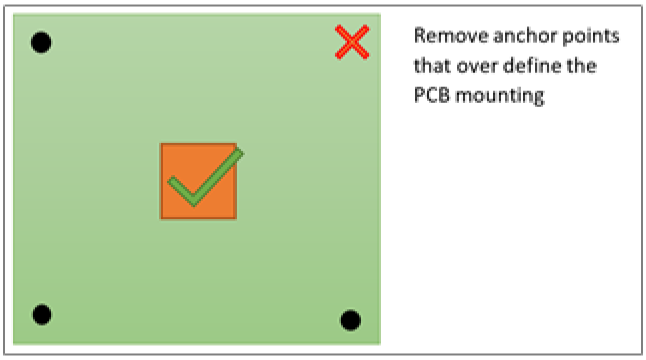
Anchor points

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. The image below 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.

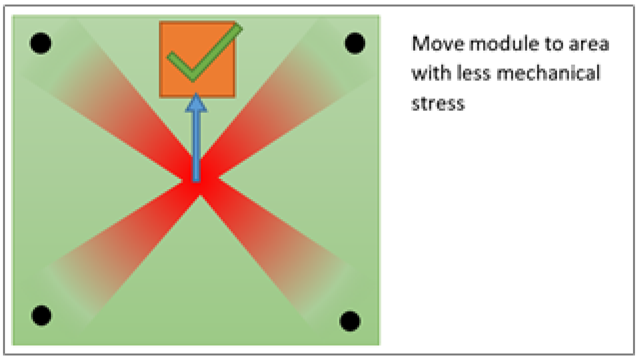


High mechanical stress in diagonal crossover between anchor points

The best way to deal with the problem shown in the image above is to remove one of the anchor points as shown in the image below. 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 the second image below.



Reducing anchor points to reduce overall stress in the PCB



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

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 from 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.

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.

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.

Hand soldering

⚠ **It is not recommended to solder the module by hand onto a PCB, as this may introduce undesired (mechanical or thermal) stress on the module, which can result in deteriorated performance.**

Magnetometer

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

Ferromagnetic materials

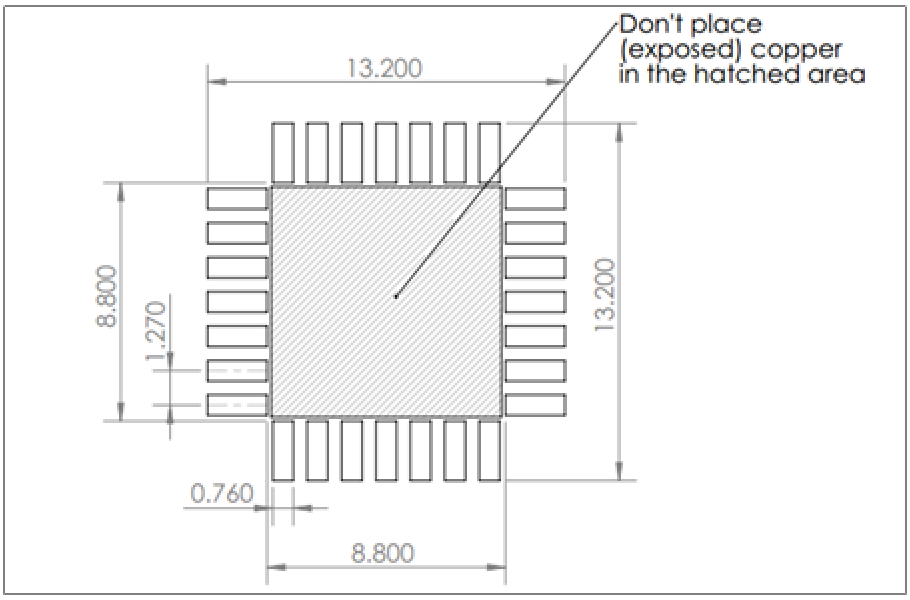
Ferromagnetic materials can be magnetized and the magnetic behaviour can change during operation. This behaviour will influence the measurements of the 3D magnetometer of the MTi 1-series. Therefore, keep these ferromagnetic materials away from the MTi 1-series.

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.

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 *Package Drawing* (note the tolerance of ± 0.1 mm).



Recommended MTi 1-series module footprint

See Design and Packaging.

Handling

⚠ For best performance, it is best to solder the module directly onto a PCB by a solder reflow process. When placed in a (PLCC28) socket, the module may be subjected to mechanical stress by the springs in the socket, which might result in deteriorated performance.

Reflow specification

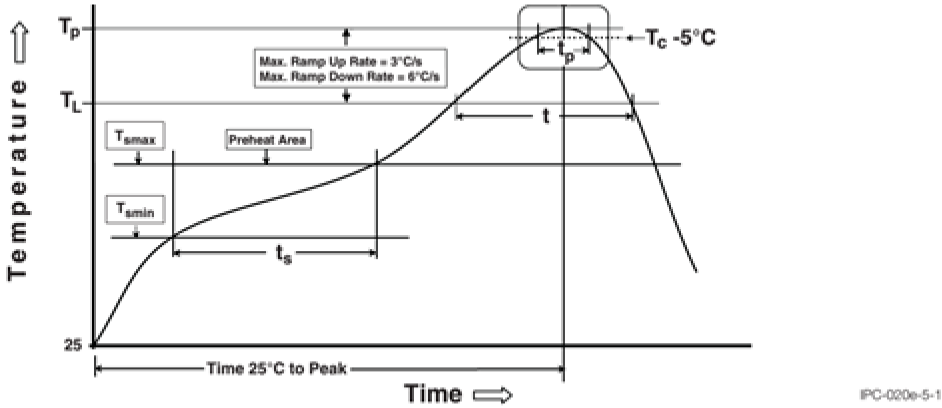
The moisture sensitivity level of the MTi 1-series modules corresponds to JEDEC MSL Level 3, see also:

- 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 should 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 Design and Packaging.



Reflow classification profile (not to scale)

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!

Conformal coating

Conformal coating can influence the performance of the MTi 1-series due to mechanical stress. Most likely this will result in small sensor biases in the output signals of the module's gyroscopes and accelerometers. Tests with conformal coating carried out at Xsens have shown negligible changes in terms of sensor fusion performance.

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.