



Document MT0512P, Revision 2019.A, Dec 2019

**xsens**

# MTi 1-series Datasheet

IMU, VRU, AHRS and GNSS/INS module

| Revision | Date        | By       | Changes  |
|----------|-------------|----------|--|
| A        | 8 Jul 2015  | MHA      | Initial release  |
| F        | 1 July 2018 | AVY      | Added MTi-2 VRU and MTi-3 AHRS performance specifications.<br>Updated MTi-7 performance specifications.  |
| G        | 11 Jan 2019 | MCR, AKO | Added information on Device ID/functionality.<br>Updated documentation on AHS.<br>Added EU and FCC declaration of conformity.<br>Updated gyroscope specifications. |
| H        | 26 Mar 2019 | MCR      | Updated EU and FCC declaration of conformity for hardware v2.0.  |
| I        | 3 June 2019 | AKO      | Added information on MTi-#-C packaging   |
| 2019.A   | Dec 2019    | AKO      | Xsens brand update   |

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## 1 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<sup>2</sup>C, SPI or UART interfaces.

The *Hardware Integration Manual: MTi 1-series* (MT1503) supplements this document. Notes on typical application scenarios, recommended external components, printed circuit board (PCB) layout, origin of measurements, stress related considerations, reference designs and handling information could be found in the hardware integration manual.

The *MT Low Level Communication Protocol* (MT0101P) document provides a complete reference for the protocol to communicate with Xsens Motion Trackers. For a better understanding of the Synchronous Serial Protocol (Section 3.4.3) 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. The communication protocol document also describes the synchronization messages and settings in detail.

Links to the latest available documentation can be found in your MT Software Suite installation folder or via the following link: <https://xsens.com/xsens-mti-documentation>

### 1.1 Ordering information

Table 1: Ordering information for MTi 1-series modules

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

### 1.2 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.

Table 2: Device ID's for MTi 1-series

| Product (MTi 1-series) | Device ID | HW version                           |
|------------------------|-----------|--------------------------------------|
| MTi-1 IMU              | 0188xxxx  | Check component layout (Section 6.4) |
| MTi-2 VRU              | 0288xxxx  |                                      |
| MTi-3 AHRS             | 0388xxxx  | ≥ 2.0 only                           |
| MTi-7 GNSS/INS         | 0788xxxx  |                                      |

The rest of this document only caters to MTi 1-series with HW version  $\geq 2.0$ . Refer to version MTi 1-series Datasheet rev D (5 Dec 2016) when you have an MTi with HW version  $< 2.0$ .

### 1.3 Block diagram



Figure 1: MTi 1-series module diagram

The diagram in Figure 1 shows a simplified organization of the MTi 1-series module (MTi 1-s). The MTi 1-s contains a 3-axis gyroscope, 3-axis accelerometer, 3-axis magnetometer, a high-accuracy crystal and a low-power micro controller unit (MCU). The MTi-7 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 I2C, SPI and UART.

## 2 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.

### 2.1 MTi 1-series performance specifications

Table 3: Orientation performance specifications

| Parameter  |         | MTi-1 IMU | MTi-2 VRU    | MTi-3 AHRS | MTi-7 GNSS/INS |
|------------|---------|-----------|--------------|------------|----------------|
| Roll/Pitch | Static  | N/A       | 0.5°         | 0.5°       | 0.5°           |
|            | Dynamic | N/A       | 0.8°         | 0.8°       | 0.5°           |
| Yaw        | Dynamic | N/A       | Unreferenced | 2°         | 1.5°           |

Table 4: Position and velocity performance specifications (with MTi-7-DK)

| Parameter | Specification         |                           |
|-----------|-----------------------|---------------------------|
| Position  | Horizontal (SBAS)     | 1.0 m (1 $\sigma$ STD)    |
|           | Vertical (SBAS, baro) | 2.0 m (1 $\sigma$ STD)    |
| Velocity  |                       | 0.05 m/s (1 $\sigma$ RMS) |

All above specifications are based on typical application scenarios. The specifications mentioned in Table 3 and Table 4 are with MTi-3-DK and MTi-7-DK reference designs.

### 2.2 Sensors specifications

Table 5: Gyroscope specifications

| Gyroscope specification <sup>1</sup> | Unit      | MTi 1-series                     |
|--------------------------------------|-----------|----------------------------------|
| Standard full range                  | [°/s]     | ±2000                            |
| In-run bias stability                | [°/h]     | 10                               |
| Bandwidth (-3dB)                     | [Hz]      | 255                              |
| Noise density                        | [°/s/√Hz] | 0.007                            |
| g-sensitivity (calibrated)           | [°/s/g]   | 0.001                            |
| Non-linearity                        | [%FS]     | 0.1                              |
| Scale Factor variation               | [%]       | 0.5 (typical)<br>1.5 (over life) |
|                                      |           |                                  |

<sup>1</sup> As Xsens continues to update the sensors on the module, these specifications may change

Table 6: Accelerometer specifications

| Accelerometer <sup>2</sup> | Unit     | MTi 1-series |
|----------------------------|----------|--------------|
| Standard full range        | [g]      | ±16          |
| In-run bias stability      | [mg]     | 0.03         |
| Bandwidth (-3dB)           | [Hz]     | 324 (Z: 262) |
| Noise density              | [µg/√Hz] | 120          |
| Non-linearity              | [%FS]    | 0.5          |
|                            |          |              |

Table 7: Magnetometer specifications

| Magnetometer <sup>2</sup> | Unit | MTi 1-series |
|---------------------------|------|--------------|
| Standard full range       | [G]  | 8            |
| Non-linearity             | [%]  | 0.2          |
| Total RMS noise           | [mG] | 0.5          |
| Resolution                | [mG] | 0.25         |
|                           |      |              |

Table 8: Alignment specifications

| Parameter <sup>2</sup>               | Unit | MTi 1-series |
|--------------------------------------|------|--------------|
| 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          |
|                                      |      |              |

<sup>2</sup> As Xsens continues to update the sensors on the module, these specifications may change

### 3 Functional description

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

#### 3.1 Pin configuration



Figure 2: Pin configuration of the MTi 1-series module (top view)

### 3.2 Pin map

The pin map depends on the peripheral selection. See Section 3.4 on how to set the peripherals.

Table 9: Pin mapping for peripheral selection

|    | PSEL:<br>I <sup>2</sup> C | PSEL:<br>SPI | PSEL:<br>UART half duplex | PSEL:<br>UART full duplex |
|----|---------------------------|--------------|---------------------------|---------------------------|
| 1  | AUX_SCK/DNC <sup>3</sup>  | 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 <sup>4</sup>         | SPI_MOSI     | DNC                       | DNC                       |
| 11 | ADD1                      | 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 | AUX_RX/DNC                | AUX_RX/DNC   | AUX_RX/DNC                | AUX_RX/DNC                |
| 19 | AUX_TX/DNC                | AUX_TX/DNC   | AUX_TX/DNC                | AUX_TX/DNC                |
| 20 | SYNC_PPS/DNC              | SYNC_PPS/DNC | SYNC_PPS/DNC              | SYNC_PPS/DNC              |
| 21 | DNC                       | DNC          | DE                        | RTS                       |
| 22 | DRDY                      | DRDY         | nRE                       | CTS <sup>5</sup>          |
| 23 | I2C_SDA                   | DNC          | UART_RX                   | UART_RX                   |
| 24 | I2C_SCL                   | DNC          | UART_TX                   | UART_TX                   |
| 25 | GND                       | GND          | GND                       | GND                       |
| 26 | AUX_nCS/DNC               | AUX_nCS/DNC  | AUX_nCS/DNC               | AUX_nCS/DNC               |
| 27 | AUX_MOSI/DNC              | AUX_MOSI/DNC | AUX_MOSI/DNC              | AUX_MOSI/DNC              |
| 28 | AUX_MISO/DNC              | AUX_MISO/DNC | AUX_MISO/DNC              | AUX_MISO/DNC              |

### 3.3 Pin descriptions

Table 10: Pin description MTi 1-series module

| Name                   | Type           | Description   |
|------------------------|----------------|---|
| <b>Power Interface</b> |                |   |
| VDDA                   | Power          | Analog power supply voltage for sensing elements  |
| VDDIO                  | Power          | Digital supply voltage. Also used as I/O reference.   |
| <b>Controls</b>        |                |   |
| PSEL0                  | Selection pins | These pins determine the signal interface. See Table 11. 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           |

<sup>3</sup> AUX and SYNC\_PPS pins are only available on MTi-7

<sup>4</sup> I<sup>2</sup>C addresses, see Table 13.

<sup>5</sup> CTS cannot be left unconnected if the interface is set to UART full duplex. If HW flow control is not used, connect o GND.

|   |                            |  |
|---|----------------------------|--|
|   |                            | line is also used for internal resets. This pin has an internal weak pull-up to VDDIO.                           |
| ADD2                                    | Selection pins             | I <sup>2</sup> C address selection lines. See Table 13 for list of I <sup>2</sup> C addresses.                   |
| ADD1                                    |                            |  |
| ADD0                                    |                            |  |
| <b>Signal Interface</b>                 |                            |  |
| I2C_SDA                                 | I <sup>2</sup> C interface | I <sup>2</sup> C serial data input/output  |
| I2C_SCL                                 |                            | I <sup>2</sup> C 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 <sup>2</sup> C)                                      |
| <b>Auxiliary interface (MTi-7 only)</b> |                            |  |
| 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  |

### 3.4 Peripheral interface selection

The MTi 1-series module supports UART, I<sup>2</sup>C, 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 Table 11. 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<sup>2</sup>C (PSEL0 = 1, and PSEL1 = 1).

Table 11: Peripheral interface selection

| Interface        | PSEL1 | PSEL0 |
|------------------|-------|-------|
| I <sup>2</sup> C | 1     | 1     |
| SPI              | 1     | 0     |
| UART half-duplex | 0     | 1     |
| UART full-duplex | 0     | 0     |

#### 3.4.1 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<sup>2</sup>C and SPI interfaces. The I<sup>2</sup>C and SPI interfaces differ from UART in that they are synchronous, and have a master-slave relation 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<sup>2</sup>C and SPI interfaces. Figure 3 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<sup>2</sup>C and SPI, the MTSSP layer translates these messages, while for the UART connection, the module transports the messages as-is.

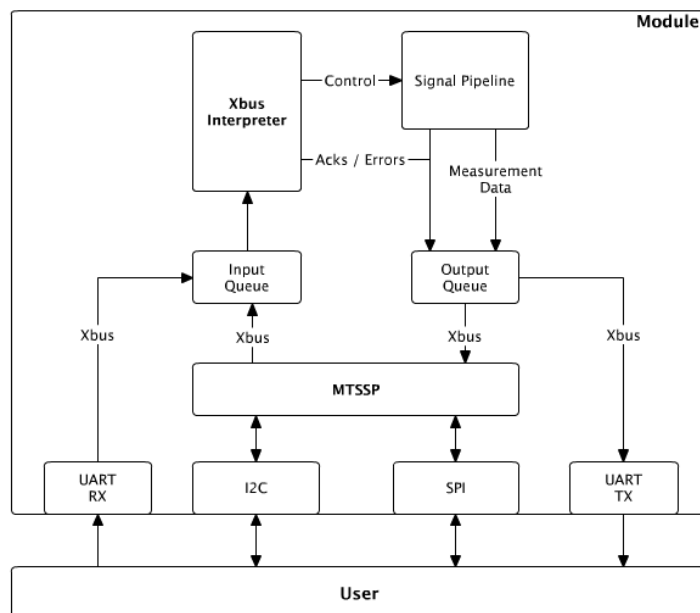


Figure 3: Communication architecture of MTi 1-series module (simplified)

### 3.4.2 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.

### 3.4.3 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<sup>2</sup>C and SPI interfaces. The ARM® mbed™ example program (see <https://developer.mbed.org/teams/Xsens>), provides 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.

Figure 4 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 module 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 messages to the Control Pipe. When placed in Measurement mode, the module will place the generated measurement data 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 next message in both the Notification- and Measurement pipe. 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.

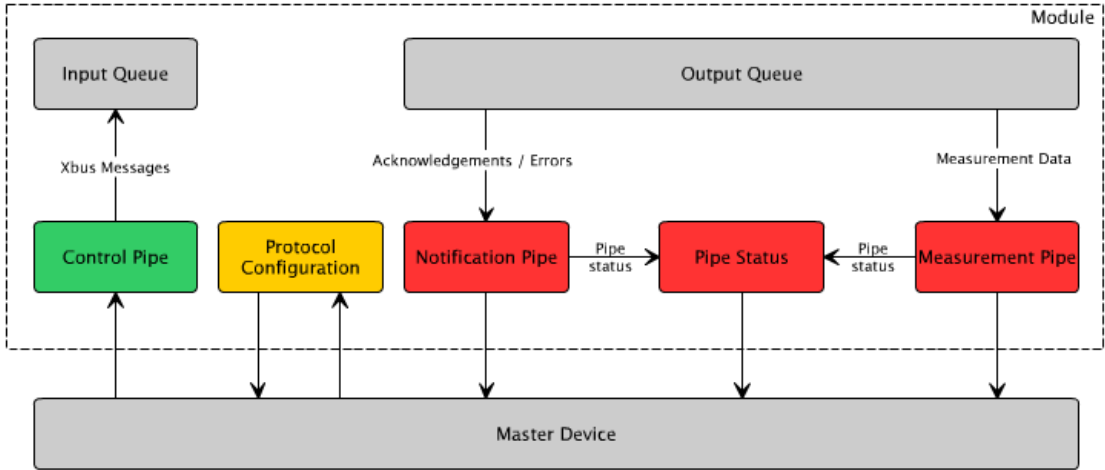


Figure 4: Data flows within MTSSP

**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 Protocol Configuration. Please refer to the description of the ConfigureProtocol opcode (Table 12) 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 Table 12. 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 is dependent of the underlying bus protocol (I<sup>2</sup>C or SPI), and is specified in Sections 3.4.4 and 3.4.5.

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.

Table 12: 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 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:



m\_drdyConfig:

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

#### 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

### 3.4.4 I<sup>2</sup>C

The MTi 1-series supports the I<sup>2</sup>C transport layer as of firmware 1.0.6. Note, it is not possible to upgrade devices with firmware revision 1.0.3 or earlier, to support this protocol. The MTi 1-series module acts as an I<sup>2</sup>C Slave. The User of the MTi 1-series module is the I<sup>2</sup>C Master.

The User can configure the I<sup>2</sup>C 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 Table 13. The ADD0, ADD1 and ADD2 pins are pulled-up internally so when left unconnected the address selection defaults to 0x6B (ADD = 111).

Table 13: List of I<sup>2</sup>C 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<br>(default) | 1    | 1    | 1    |

Table 14: Implemented I<sup>2</sup>C 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 <sup>6</sup> |
| 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              |

### Writing to the MTi 1-s

Write operations consists of a single I<sup>2</sup>C 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 Section 3.4.3.

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.

Figure 5 shows the I<sup>2</sup>C transfer of a write message operation:



Figure 5: I<sup>2</sup>C write message operation

### Reading from the module

To read from the module, the Master first does an I<sup>2</sup>C write transfer to transmit the opcode. The opcode tells the module what data the Master want to read. The module then prepares the requested data for transmission. The Master then does an I<sup>2</sup>C read transfer to retrieve the data. Figure 6 shows the I<sup>2</sup>C transfers for the described read method.

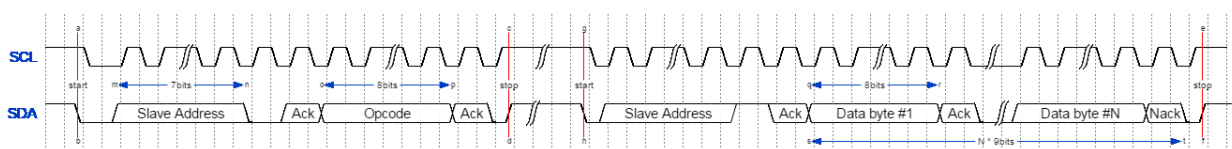


Figure 6: Read message operation with full write transfer and full read transfer (I<sup>2</sup>C)

<sup>6</sup> The MTi-1 module relies on the I<sup>2</sup>C clock stretching feature to overcome fluctuations in processing time, the Master is required to support this feature

Alternatively, the User can perform the read operation using a I<sup>2</sup>C transfer with a repeated start condition. Figure 7 depicts this read method.

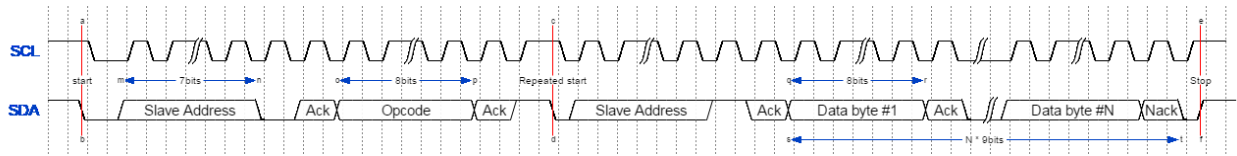


Figure 7: Read message transfer using a repeated start condition (I<sup>2</sup>C)

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.

### 3.4.5 SPI

The MTi 1-series supports the SPI transport layer as of firmware 1.0.6. Note, that it is not possible to upgrade devices with firmware revision 1.0.3 or earlier, to support this protocol.

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. Figure 8 depicts this basic transfer.

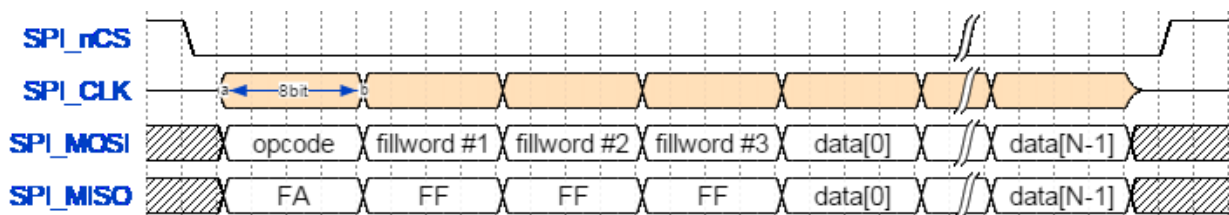


Figure 8: SPI basic transfer

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 Section 3.4.3). 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 in 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**

Table 15 and Figure 9 specify the timing constraints that apply to the SPI transport layer. The Master must adhere to these constraints.

Table 15: SPI timing

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

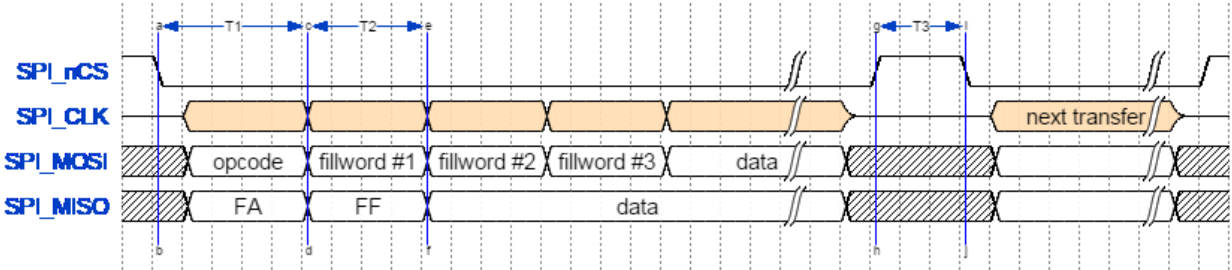


Figure 9: SPI timing

**3.4.6 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 uses control lines nRE and DE. The

modules uses 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. Figure 10 depicts the behaviour of the involved signals.



Figure 10: 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.

### 3.4.7 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. Figure 11 shows the behaviour of the TX and CTS lines.



Figure 11: 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 shortly. Figure 12 shows this behaviour.



Figure 12: RTS behaviour under data reception

This 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.



## 4 MTi 1-series architecture

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

### 4.1 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 ( $\Delta q$  and  $\Delta v$ ), position and velocity quantities and calibrated sensors data (acceleration, rate of turn, magnetic field). Depending on the product, output options may be limited to sensors 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 are fully configurable, so that the MTi 1-s limits the load, and thus power consumption, on the user application processor.

#### 4.1.1 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 ( $\Delta q$  and  $\Delta v$ ). 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.

#### 4.1.2 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 -  $\Delta q$  and  $\Delta v$ ). 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 (AHS) feature, see Section 4.3.3 for more details.

#### 4.1.3 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 sensors data: 3D acceleration, 3D rate of turn, 3D orientation and velocity increments ( $\Delta q$  and  $\Delta v$ ) and 3D earth-magnetic field data. Free acceleration is also computed by the MTi-3 AHRS.

#### 4.1.4 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 device's 3D position, velocity and orientation (roll, pitch and yaw).

## 4.2 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.

### 4.2.1 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 sensor. 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 ensure there is absolute no loss of information at any output data rate. This makes the MTi 1-series attractive for systems with limited communication bandwidth.

### 4.2.2 Xsens sensor fusion algorithm for VRU and AHRS product types

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 16). 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 (AHS) setting, which significantly reduces heading drift during magnetic disturbances. The In-run Compass Calibration (ICC) setting can be used to compensate for magnetic distortions that are caused by every object the MTi is attached to. See Section 4.3 for more details.

Table 16: 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 measured and should be used when magnetic field is homogeneous.  |
| Dynamic          | 52     | MTi-3          | Assumes that the motion is highly dynamic.   |
| North_referenced | 53     | MTi-3          | Assumes a good Magnetic Field Mapping (MFM) 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<br>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 (see also Section 4.3.3).  |

#### 4.2.3 Xsens sensor fusion algorithm for GNSS/INS product

The Xsens sensor fusion algorithm in the MTi-7 has several advanced features. The MTi-7 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 has limited/mediocre GNSS reception or even no GNSS reception at all (outage), the MTi-7 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 stops output of the position and velocity estimates, and begins sending these outputs once the GNSS data becomes acceptable again.

Table 17 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.

Table 17: Filter profiles for MTi-7 (GNSS/INS)

| Name                    | Number | GNSS <sup>7</sup> | Barometer <sup>7</sup> | Magnetometer | Description   |
|-------------------------|--------|-------------------|------------------------|--------------|---|
| General                 | 11     | ●                 | ●                      |              | 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           | 12     | ●                 |                        |              | This filter profile is very similar to the general filter profile except for the use of barometer.  |
| GeneralMag <sup>8</sup> | 13     | ●                 | ●                      | ●            | 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.  |

### 4.3 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.

#### 4.3.1 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

<sup>7</sup> External aiding sensors for the MTi-7

<sup>8</sup> This filter profile can be used even when the barometer is not part of the design.

the magnetic field. It also handles situations in which the sensor has become magnetized. These type 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 Field Mapper User Manual (MT0202P), available in the MT Software Suite.

#### 4.3.2 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 for 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 for the application, then it is possible to use "Representative Motion" feature (RepMo). RepMo is available in MT Manager, XDA and Low-Level Communication Protocol (Xbus protocol).

Additional examples are available in BASE: <https://base.xsens.com/hc/en-us/articles/213588029>.

#### 4.3.3 Active Heading Stabilization (AHS)

The Active Heading Stabilization (AHS) is 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.

For more information on the activation and use of AHS, refer to the BASE article: <https://base.xsens.com/hc/en-us/articles/211809465>.

## 4.4 Frames of reference

The MTi 1-series module uses a right-handed coordinate system and the default sensor frame is defined as shown in Figure 13. 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 Table 18.



Figure 13: Default sensor fixed coordinate system for the MTi 1-series module

Table 18: Data output with 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           |
| 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 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 effect on all outputs that are by default output with an ENU reference coordinate system.

For MTi-7, 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.

## 5 System and electrical specifications

### 5.1 Interface specifications

Table 19: Communication interfaces

| Interface        |                   | Min | Typ   | Max  | Unit | Description                                 |
|------------------|-------------------|-----|-------|------|------|---|
| I <sup>2</sup> C | f <sub>I2C</sub>  |     |       | 400  | kHz  | Host I <sup>2</sup> C interface Clock speed |
| SPI              | f <sub>SPI</sub>  |     |       | 2    | MHz  | Host SPI Interface Clock Speed              |
|                  | DC <sub>SCK</sub> | 30  | 50    | 70   | %    | SPI Clock Duty Cycle                        |
| UART             | f <sub>UART</sub> |     | 921.6 | 4000 | kbps | Host UART Interface Baud Rate               |

Table 20: Auxiliary interfaces

| Interface | Symbol            | Min                | Typ   | Max         | Unit | Description                    |
|-----------|-------------------|--------------------|-------|-------------|------|--------------------------------|
| SYNC_IN   | V <sub>IL</sub>   |                    |       | 0.3 · VDDIO | V    | Input low voltage              |
|           | V <sub>IH</sub>   | 0.45 · VDDIO + 0.3 |       |             | V    | Input high voltage             |
|           | V <sub>HYS</sub>  | 0.45 · VDDIO + 0.3 |       |             | V    | Threshold hysteresis voltage   |
| nRST      | V <sub>IL</sub>   |                    |       | 0.3 · VDDIO | V    | Only drive momentarily         |
|           | R <sub>PU</sub>   | 30                 |       | 50          | kΩ   | Pull-up resistor               |
|           | T <sub>P</sub>    | 20                 |       |             | μs   | Generated reset pulse duration |
| AUX_UART  | f <sub>UART</sub> |                    | 115.2 | 2000        | kbps | UART baud rate                 |
| AUX_SPI   | f <sub>SPI</sub>  |                    | 1     | 8           | MHz  | SPI serial clock speed         |

## 5.2 System specifications

Table 21: 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  | °C    | Ambient temperature, non-condensing         |
| Power consumption |                       |         |                 | 100  | mW    | VDDA 3.0V; VDDIO 1.8V                       |
| Timing accuracy   |                       |         | 10 <sup>9</sup> |      | ppm   |   |
| MTBF              |                       | 225,000 |                 |      | hours |   |
| Output data rate  |                       |         |                 | 800  | Hz    | RateOfTurnHR and ArcelerationHR DataID only |

## 5.3 Electrical specifications

Table 22: Electrical specifications

|                  | Min                | Max               | Unit | Description                  |
|------------------|--------------------|-------------------|------|------------------------------|
| VDDA             | 2.16               | 3.6 <sup>10</sup> | V    | Analog supply voltage        |
| VDDA ripple      |                    | 50                | mVpp | Analog supply ripple         |
| VDDIO            | 1.8                | VDDA + 0.1        | V    | Digital supply voltage       |
| V <sub>IL</sub>  |                    | 0.3 · VDDIO       | V    | Input low voltage            |
| V <sub>IH</sub>  | 0.45 · VDDIO + 0.3 |                   | V    | Input high voltage           |
| V <sub>HYS</sub> | 0.45 · VDDIO + 0.3 |                   | V    | Threshold hysteresis voltage |
| V <sub>OL</sub>  |                    | 0.4               | V    | Output low voltage           |
| V <sub>OH</sub>  | VDDIO - 0.4        |                   | V    | Output high voltage          |

## 5.4 Absolute maximum ratings

Table 23: Absolute maximum ratings MTi 1-series module

|                              | Min | Max        | Unit | Comments                        |
|------------------------------|-----|------------|------|---------------------------------|
| Storage temperature          | -40 | +90        | °C   |                                 |
| Operating temperature        | -40 | +85        | °C   |                                 |
| 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 <sup>11</sup>   |     | 10,000     | g    | Any axis, unpowered, for 0.2 ms |
| ESD protection <sup>12</sup> |     | ±2000      | V    | Human body model                |

<sup>9</sup> Output clock accuracy of 1 ppm can be achieved with the MTi-7-DK reference design

<sup>10</sup> Previous generation version ≤1.1, VDDA max: 3.45V

<sup>11</sup>  $\Delta$ This is a mechanical shock (g) sensitive device. Proper handling is required to prevent damage to the part.

<sup>12</sup>  $\blacklightning$ This is an ESD-sensitive device. Proper handling is required to prevent damage to the part.



## 6 Design and packaging

### 6.1 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 given in Table 21 (note the tolerance of  $\pm 0.1$  mm).

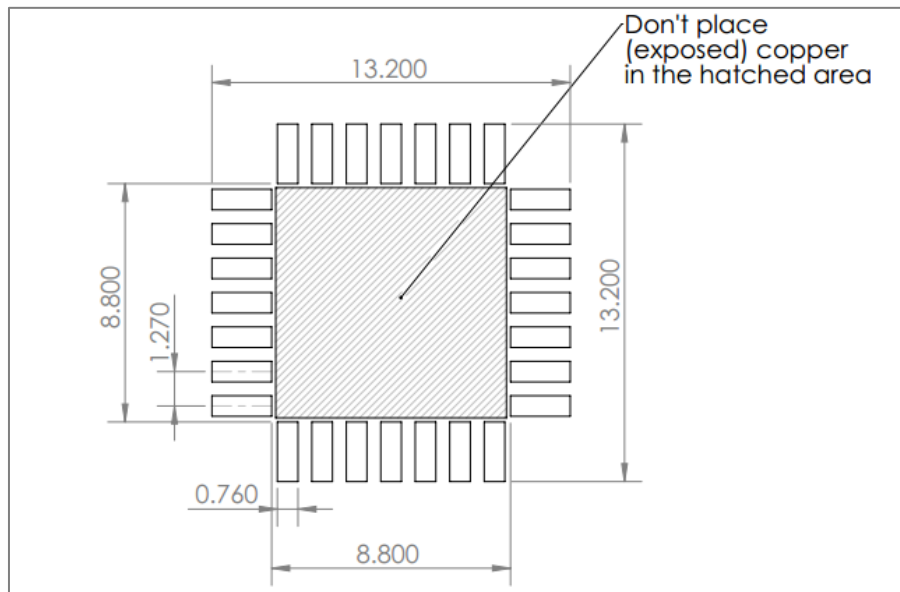
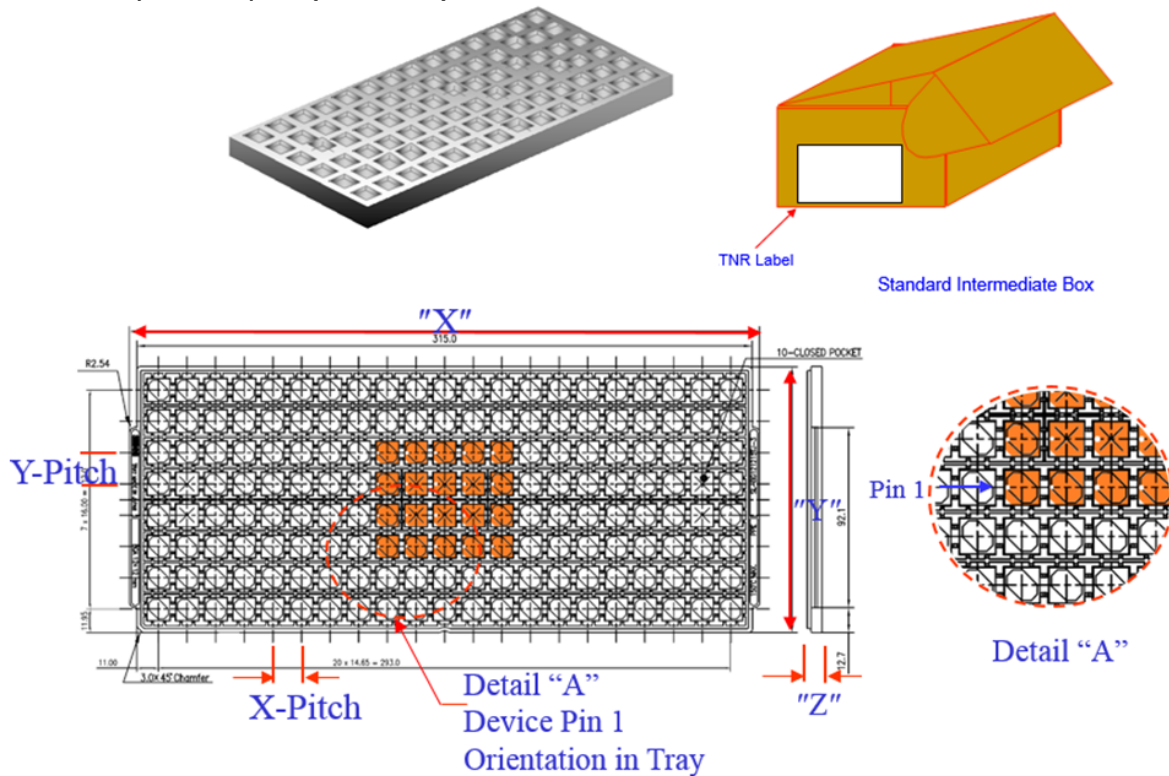


Figure 14: Recommended MTi 1-series module footprint

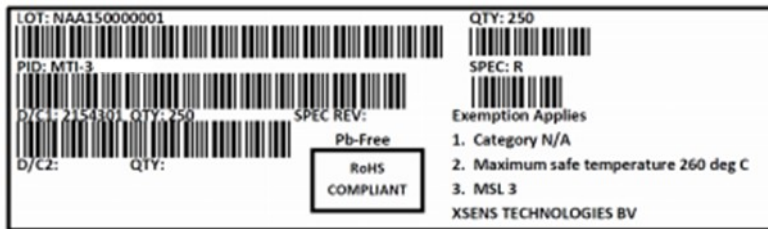
The MTi 1-s module is shipped in trays with 20 modules or in reels with 250 modules.

## 6.2 Tray packaging information

### 6.2.1 Tray of 20 pcs (MTi-#-T)



#### TNR LABEL

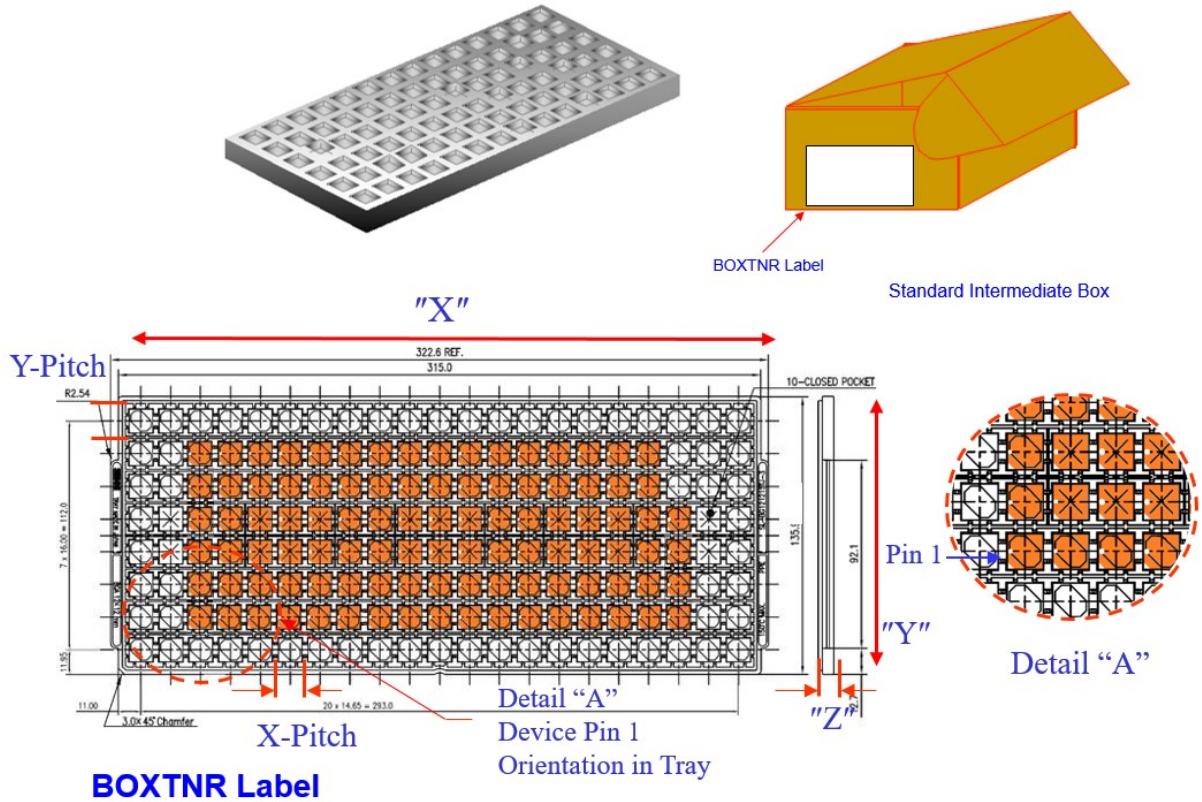


| Tray Dimensions (mm) |           |            |                |                |                  | Tray packaging information |          | Pin 1              |
|----------------------|-----------|------------|----------------|----------------|------------------|----------------------------|----------|--------------------|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

#### NOTES:

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

### 6.2.2 Tray of 100 pcs (MTi-#-C)



LOT: XSYYMMD DXXX QTY: 100

XSID: MTi-1-C

D/C1: 2181301 QTY: 1000

SPEC REV: 2.3 Pb-Free

RoHS COMPLIANT

SPEC: T

Exemption Applies

1. Category N/A
2. Maximum safe temperature 260 deg C

MSL 3 – 168 hours

XSENS Technologies BV

Made in The Netherlands

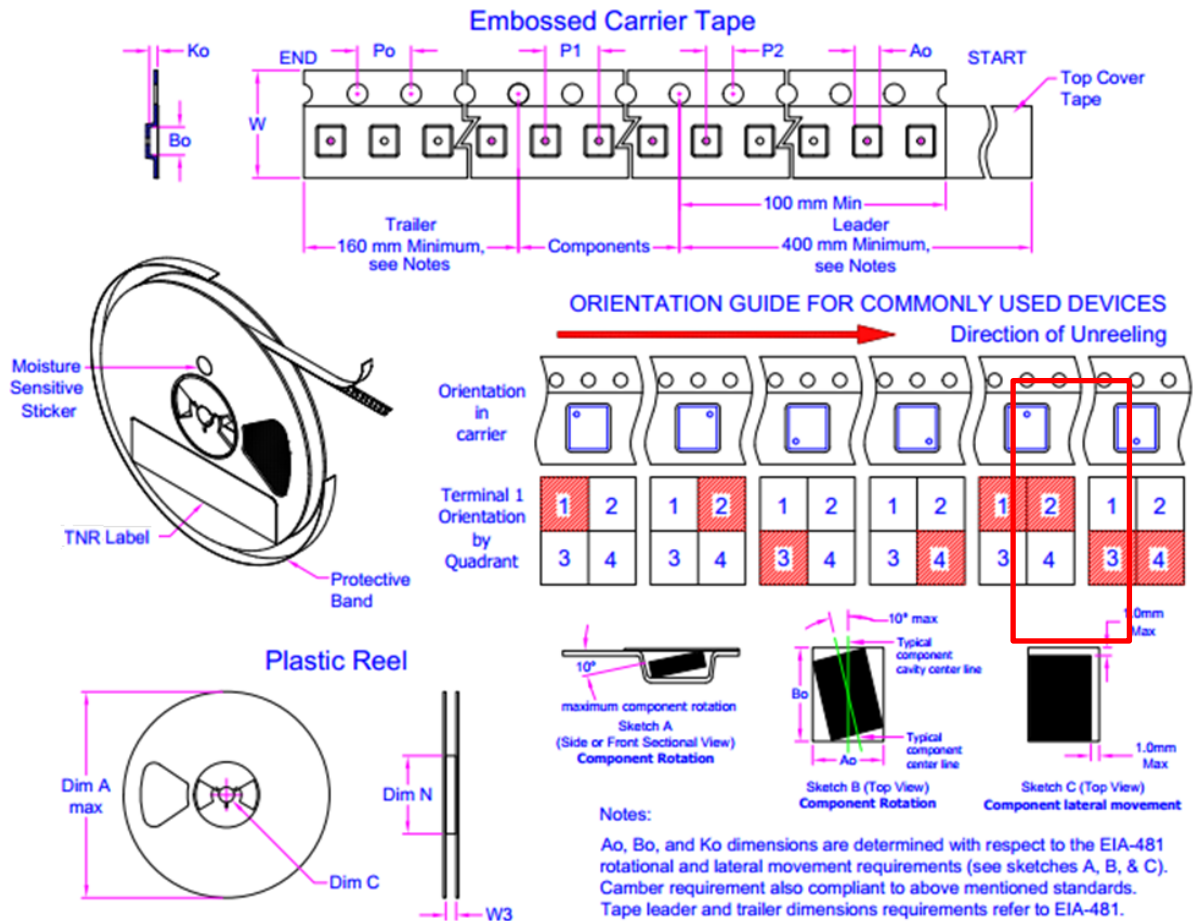
CE

This device complies with Part 15 of the FCC Rules. 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.

| 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

### 6.3 Reel packaging information



#### TNR LABEL



| 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. | 2.9 | 23.7       | 3.9 | 15.9 | 1.9 | 177.8 | 5 | 12.8    | 23.9 | 1 & 2                   | 250       |
| -                 | 6   | -   | 0          | 0   | 0    | 0   | 0     | 5 | 0       | 0    |                         |           |
| 12.8              | -   | 3.1 | -          | -   | -    | -   | -     | - | -       | -    |                         |           |
|                   | 12. | 0   | 24.3       | 4.1 | 16.1 | 2.1 |       |   | 13.5    | 27.4 |                         |           |
|                   | 8   | 0   | 0          | 0   | 0    | 0   |       |   | 0       | 0    |                         |           |

NOTES:

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

### 6.4 Package drawing

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

Table 24: MTi 1-series module generations





Figure 17: Location PCB number on MTi 1-series module (bottom view)

## 7 Declaration of conformity

### 7.1 EU Declaration of Conformity

#### EU Declaration of Conformity

Applicable objects:

MTI-1-#<sup>1</sup>  
MTI-2-#<sup>1</sup>  
MTI-3-#<sup>1</sup>  
MTI-7-#<sup>1</sup>  
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

<sup>1</sup> When pre-mounted on the MTI-#-DK