MTi User Manual

MTi 10-series and MTi 100-series 5th generation

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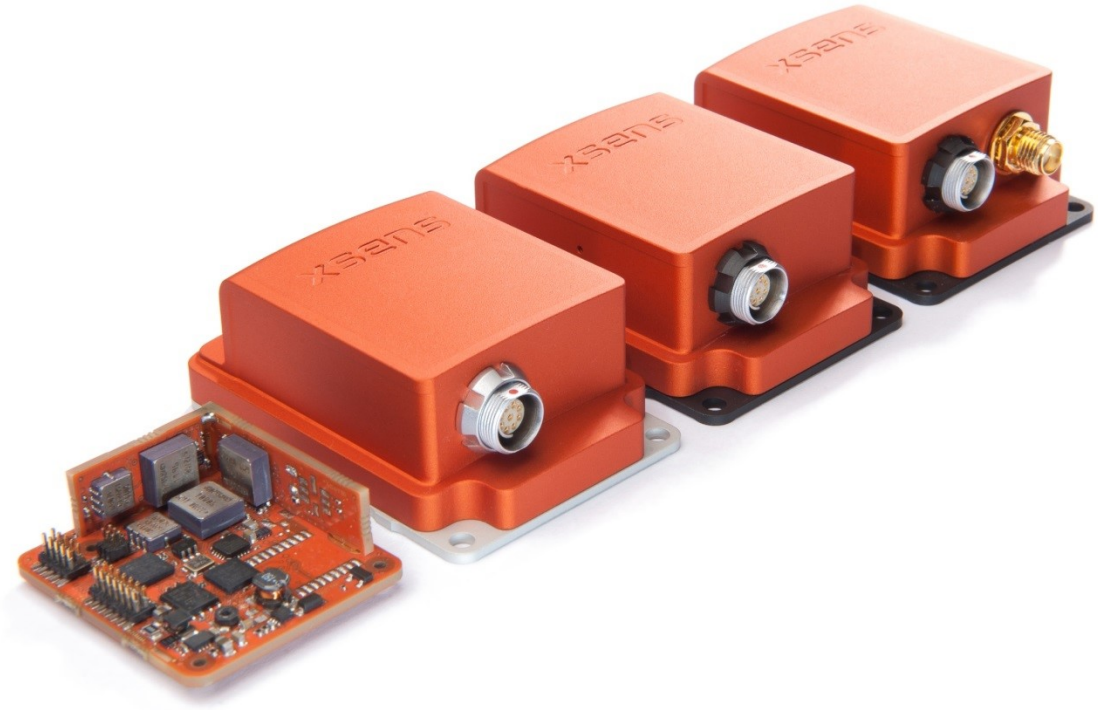

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Revisions

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A	26 Sep 2012	MHA	Initial release
…	….		…
I	20 Dec 2016	MHA	Holonomic constraints now mention correctly y-axis Redirected antenna information to BASE Redirected Sync chapter to BASE Added AHS boolean Added ICC Added NMEA strings (GPZDA and XSVEL) Added HighPerformanceEDR to the filter profiles
J	14 August 2017	MHA	New version for 5th generation (sensor specifications, hardware connections) Removed MTw from product history Grouped legacy products in product history Corrected number of stop bits Added 1 PPS specifications Removed legacy USB converter specifications
J1	4 October 2017	MHA	Typo in Table 2 header Reference in 3.2.6 missing Added power consumption table Removed 1-series references
J2	14 December 2017	MHA	Added links to other documents, clean-up
2018.A	28 February 2018	AVY	Updated Section 5.2.3 with heading definition, revised mounting considerations for MTi-G-710 for use with Automotive filter profile.

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1 References

Reference id	Document description
[LLCP]	“MT Low-Level Communication Protocol Documentation.pdf”, document ID MT0101P
[MTM]	“MT Manager User Manual.pdf”, document ID MT0216P
[XDA_DOC]	XDA doxygen HTML documentation. Found in Xsens folder structure
[MTI_1]	“MTi 1-series Datasheet.pdf”, document ID MT0512P

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2 Xsens Help Center and User Community

Xsens has an extensive help center, a place where users of Xsens and Xsens employees (support, field application engineers, sales and R&D engineers) meet. The knowledge base contains tips and tricks, guidance and answers to frequently asked questions. News is also shared at the knowledge base and it is possible to ask additional questions (registration required).

The user community is the place to ask questions. Answers may be given by other users or by Xsens employees. The response time in the user community is significantly shorter than the response time at Xsens support.

The knowledge base and user community are searchable simultaneously. A search query thus shows results irrespective of the source.

Please visit https://base.xsens.com to complete your 1 minute registration.

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3 Introduction

This manual gives an overview of the 5th generation products and its usage. For previous generations, refer to User Manual revision I (20 December 2016). Refer to section 3.2.5 to identify the generation of your MTi. The MTi product portfolio from Xsens currently has 10 family members ranging in functionality from inertial measurement units (IMU's) to a fully integrated GNSS/INS solution. All products contain a 3D inertial sensor assembly (ISA: gyroscopes and accelerometers) and 3D magnetometers, with optionally a barometer and GNSS receiver.

The MTi product range is divided in three series, the MTi 1-series, the MTi 10-series and the MTi 100-series. The MTi 10-series is Xsens' entry level model with robust accuracy and a limited range of IO options. The 100-series is a new class of MEMS IMU's, orientation and position sensor modules offering unprecedented accuracies and a wide array of IO interfaces. The MTi 1-series is a low-cost module for SMD assembly. Refer to [MTI_1] for more information on the MTi 1-series.

All MTi's have a powerful multi-processor core. It processes IMU, magnetometer and barometer signals with extremely low latencies, and gives several outputs: calibrated 3D linear acceleration, rate of turn (gyroscope data), (earth) magnetic field and atmospheric pressure (100-series only) data along with sensor fusion estimates of roll, pitch and yaw. The MTi-G-710 GNSS/INS also offers 3D position and 3D velocity. Over 50 various output formats can be retrieved directly from the MTi. Refer to [LLCP] for more information on the available outputs per device.

This documentation describes the use, basic communication interfaces and specifications of all the 7 MTi's in the MTi 10-series and MTi 100-series. Where they differ is clearly indicated. All products are designed to be interchangeable from a mechanical and software interface point of view.

3.1 MTi 10-series

The MTi 10-series is the basic product range of the MTi product portfolio, offering inertial and orientation data at an affordable price. The MTi 10-series consists of 3 products that have various integration levels.

The MTi-10 series can easily be recognized by the silver base plate. There are no visual differences among the MTi-10 IMU, MTi-20 VRU and MTi-30 AHRS devices, other than their label marking

Figure 1: MTi 10-series

3.1.1 MTi-30 AHRS

The MTi-30 AHRS is a full gyro-enhanced Attitude and Heading Reference System (AHRS). It give various outputs: drift-free roll, pitch and true/magnetic North referenced yaw, plus sensor measurements: 3D acceleration, 3D rate of turn and 3D earth-magnetic field data. All products of the MTi 10-series can also give processed data output from the strapdown integration algorithm (orientation and velocity increments Δq and Δv).

3.1.2 MTi-20 VRU

The MTi-20 VRU is a 3D vertical reference unit (VRU), which means that it gives the same data as the MTi-30, except for the referenced yaw. The yaw is unreferenced, though still superior to just gyroscope integration, when using the gyro bias estimation techniques available.

3.1.3 MTi-10 IMU

The MTi-10 IMU is a 3D inertial measurement unit (IMU) that gives 3D acceleration, 3D rate of turn and 3D earth-magnetic field data, so it does not process data to orientation. The MTi-10-IMU can be set to a data output generated by the strapdown integration algorithm (orientation increments Δq and velocity increments Δv).

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3.2 MTi 100-series

The MTi-100 series is the high-performance product range of the MTi product portfolio, with accuracies surpassing conventional MEMS AHRS's, because of the use of superior gyroscopes and a new optimization filter, going beyond (Extended) Kalman Filter implementations. In addition, the factory calibration is more accurate repeatable and robust.

Figure 2: MTi 100-series including the MTi-G-710

The MTi 100-series can be recognized by the dark-grey base plate and the holes on one side of the casing. These holes are used for the adaptation of the inside air pressure to atmospheric pressure, required for a proper functioning of the barometer. Note that the electronics inside are protected with a vent that keeps the casing IP67 rated. There are no visual differences among the MTi-100 IMU, MTi-200 VRU and MTi-300 AHRS, other than their label markings. The MTi-G-710 has an extra SMA connector to allow a GPS/GNSS antenna to be attached.

3.2.1 MTi-G-710 GNSS/INS

The flagship of the MTi product portfolio is the MTi-G-710 GNSS/INS, a fully integrated solution that includes an onboard GNSS receiver (GPS, GLONASS, BeiDou, Galileo and QZSS). The MTi-G-710-GNSS/INS can thus not only give GNSS-enhanced 3D orientation output; it also gives AHRS-augmented 3D position and velocity outputs. Furthermore, it provides 3D sensors data, such as acceleration, rate of turn, magnetic field, the PVT (position, velocity, time) data of the GNSS receiver and static pressure. Data generated from the strapdown integration algorithm (orientation and velocity increments Δq and Δv) are available, as along with other processed data, at 400 Hz.

3.2.2 MTi-300 AHRS

The MTi-300 AHRS is a full gyro-enhanced Attitude and Heading Reference System (AHRS). It gives drift-free roll, pitch and true/magnetic North referenced yaw outputs. It also gives sensors data and processed data from the strapdown integration algorithm as well as described in section 3.2.1.

3.2.3 MTi-200 VRU

The MTi-200 VRU is a 3D vertical reference unit (VRU) and this unit runs the Xsens sensor fusion algorithm from the MTi-300 as well. The difference between the data of the MTi-300 and MTi-200 is that yaw is unreferenced, though the yaw is still much better than just integrating rate of turn when using the gyro bias estimation techniques available. The MTi-200 also comes with Active Heading Stabilization.

3.2.4 MTi-100 IMU

The MTi-100 IMU is a 3D inertial measurement unit (IMU) that gives 3D acceleration, 3D rate of turn and 3D earth-magnetic field data. The MTi-100-IMU can also be configured that it gives data generated by the strapdown integration algorithm (orientation increments Δq and velocity increments Δv).

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3.2.5 Identifying device functionality using the unique Device Identifier

Each Xsens product is marked with a unique serial device identifier referred to as the DeviceID. The DeviceID is categorized per MTi product configuration in order to make it possible to recognize the MTi (and thus its functionality and interface) by reviewing the DeviceID. The second digit of the DeviceID denotes the functionality (e.g. '1' for MTi-10 and MTi-100), the third digit denotes the product series (6 for MTi 10-series, 7 for MTi 100-series) and the fourth digit denotes the interface (e.g. '0' for RS232+USB). The last four digits are unique for each device; these four digits have a hexadecimal format.

Below is a list of the product types with their associated DeviceIDs.

Table 1: Device ID's 4th generation MTi

Refer to version MTi User Manual rev I (20 Dec 2016) when you have an MTi with one of these DeviceIDs

Product (MTi MkIV)	Multi-protocol	RS232+USB	RS422	RS485+USB
MTi-10 IMU		0160xxxx	0161xxxx	0163xxxx
MTi-20 VRU		0260xxxx	0261xxxx	0263xxxx
MTi-30 AHRS		0360xxxx	0361xxxx	0363xxxx
MTi-100 IMU		0170xxxx	0171xxxx	0173xxxx
MTi-200 VRU		0270xxxx	0271xxxx	0273xxxx
MTi-300 AHRS		0370xxxx	0371xxxx	0373xxxx
MTi-G-700 GPS/INS		0770xxxx <07701000	0771xxxx <07711000	0773xxxx <07731000
MTi-G-710 GNSS/INS		0770xxxx >07701000	0771xxxx >07711000	0773xxxx >07731000

Table 2: Device ID's 5th generation MTi (HW 3.x last 4 digits start from 2000)

Product (MTi Mk5)	Multi-protocol	RS232+USB	RS422	RS485+USB
MTi-10 IMU		0168xxxx	0169xxxx	016Bxxxx
MTi-20 VRU		0268xxxx	0269xxxx	026Bxxxx
MTi-30 AHRS		0368xxxx	0369xxxx	036Bxxxx
MTi-100 IMU		0178xxxx	0179xxxx	017Bxxxx
MTi-200 VRU		0278xxxx	0279xxxx	027Bxxxx
MTi-300 AHRS		0378xxxx	0379xxxx	037Bxxxx
MTi-G-710 GNSS/INS		0778xxxx	0779xxxx	077Bxxxx

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3.2.6 Product code

The product code of the MTi Mk5 consists of a number of characters that represent the product type, full ranges of the inertial sensors, the interface and the casing option. Figure 3 shows the product code build-up, e.g. MTi-10-4A8G4 is an IMU with RS485 interface, 20g full range on the accelerometers and 450 deg/s full range for the gyroscopes.

Note that not every combination is available.

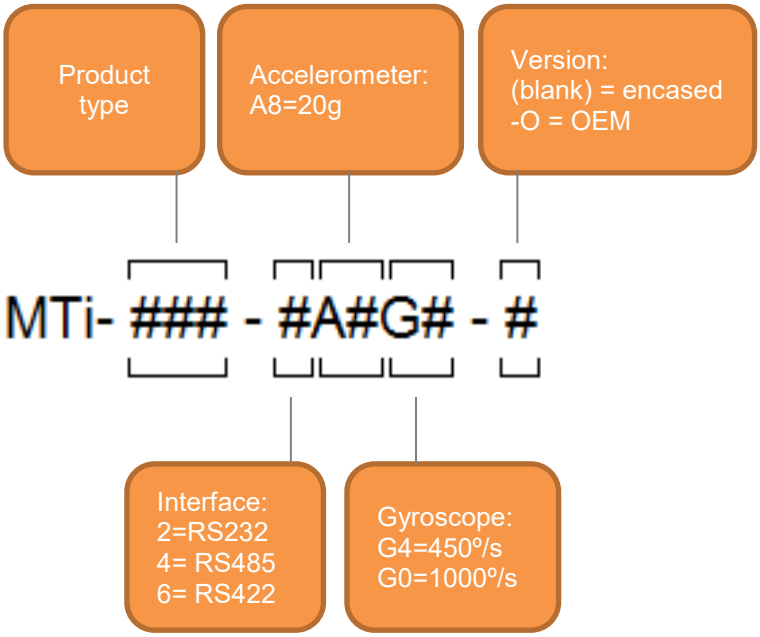

Figure 3: Product codes of MTi devices

Figure 4: Example of a label showing the SN (DeviceID) and the product code

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3.3 Evolution of MTi products

The MTi 10-series and MTi 100-series are described in detail in section 3.1 and 3.2, for completeness they are listed below as well.

Table 3: Evolution of MTi products

Product name	Description	Availability	Product photo
MTi 10-series, MTi 100-series (including MTi-G-700/710) and OEM	The 4th generation addition to the Motion Trackers of Xsens (MkIV). See section 3.1 and 3.2 for more information. The OEM board is orange. This manual focuses on these products. Product codes are in the form of e.g. MTi-30-2A5G4	Introduced: 2012	
MTi 1-series	The MTi 1-series is a full range (IMU, VRU, AHRS) in a module form-factor for SMD use. The MTi 1-series is not described in this manual. For MTi 1-series, see [MTI_1].	Introduced: 2015	
MTi 10-series, MTi 100-series (including MTi-G-710) and OEM	The new 5th generation of the MTi series. The product will replace the 4th generation MTi and has significantly higher specifications in e.g. acceleration and MTBF.	Introduced: 2017	

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3.4 Overview MTi Development Kit

The MTi development kit is a very easy to use starter's kit that allows for fast and easy integration of the MTi in any user scenario. On the right, the Development Kit is shown, containing an MTi and cable. All software and installation instructions are available online.

Figure 5: MTi Development Kit

The full content of the MTi DK is described below.

3.4.1 Contents

- Your MTi
- USB cable (CA-USB-MTi); multi-purpose cable (CA-MP2-MTI) on request
- Test and Calibration certificate
- MT Software Suite available via www.xsens.com/setup
    - Xsens MTi USB driver
    - MT Manager GUI for Linux and Windows
    - **MT Software Development Kit (MT SDK) for multiple OS**
        - **XsensDeviceApi.DLL, 32-bit and 64-bit (Windows)**
            - DLL C and C++ interface
            - COM interface
        - **XDA public source files (C, C++ wrapper ; any OS)**
        - **Example source code and examples (Windows)**
            - MATLAB: DLL example supported from MATLAB 2010b
            - C: DLL example
            - C++: public source example and DLL example
        - **Example source code and examples (Linux)**
            - C-example
            - C++-public source example
    - Magnetic Field Mapper – MFM (Windows and Linux)
        - MFM SDK (Windows and Linux)
    - Documentation
        - MTi User Manual [MT0506P]
        - MTi 1-series Data sheet [MT0512P]
        - MTi-3 DK User Manual [MT0513P]
        - MT Low Level Communication Documentation [MT0101P]
        - MT Magnetic Field Mapper Documentation [MT0202P]
        - XDA doxygen HTML API documentation
        - MTi Whitepaper
        - Firmware Updater User Manual [FU0100P]
    - Firmware Updater (Windows)

NOTE: the most recent version of the software, source code and documentation can always be downloaded on www.xsens.com/mt-software-suite. Links to documentation can be found on BASE: https://base.xsens.com/hc/en-us/articles/207003759

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3.5 Installation

3.5.1 Transient accelerations

The 3D linear accelerometers in the MTi are primarily used to estimate the direction of gravity to obtain a reference for attitude (pitch/roll). During long periods (more than tens of seconds) of transient “free” accelerations (i.e. 2nd derivative of position) the observation of gravity cannot be made. The sensor fusion algorithms can mitigate these effects to a certain extent, but nonetheless it is impossible to estimate true vertical without additional information.

The impact of transient accelerations can be minimized when you take into account a few things when positioning the device when installing it in the object you want to track/navigate/stabilize or control.

If you want to use the MTi to measure the dynamics of a moving vehicle/craft it is best to position the measurement device at a position close to the centre of gravity (CG) of the vehicle/craft. Any rotations around the centre of gravity translate into centripetal accelerations at any point outside the point of rotation. For the MTi-G-710 with a valid GNSS-fix, the detrimental effect of transient accelerations on orientation estimates is overcome by integrating with GNSS measurements in the sensor fusion engine.

The MTi 100-series copes better with transient “free” accelerations because of the higher-class gyroscopes in the MTi 100-series. Next to the better hardware, the algorithm in the MTi 100-series is superior in detecting and coping with challenging conditions, such as transient accelerations.

3.5.2 Vibrations

The MTi samples IMU signals at 10kHz per channel, processing them using a strapdown integration algorithm with coning/sculling compensation. Proper coning/sculling compensation already mitigates errors that poorly designed signal processing pipelines introduce when the device is under vibration. For best results however, it is recommended that the MTi be mechanically isolated from vibrations as much as possible: since vibrations are measured directly by the accelerometers, the following two conditions can make the readings from the accelerometers invalid;

1. The magnitude of the vibration is larger than the measurement range of the accelerometer. This will cause the accelerometer to saturate, which may be observed as a “drift” in the zero-level of the accelerometer. This will show up as an erroneous roll/pitch.
2. The frequency of the vibration is higher than the bandwidth of the accelerometer. In theory, such vibrations are rejected, but in practice they can still give rise to aliasing, especially if close to the bandwidth limit. This can be observed as a low frequency oscillation. Further, high frequency vibrations often tend to have large acceleration amplitudes (see item 1).

There is an effect on the gyroscopes as well and especially when the vibrations include high-frequent coning motion, the gyroscope readings may become invalid. The MTi 100-series features mechanical vibration rejecting gyroscopes, designed to better cope with these specific conditions.

Note that the moving part on the Fischer connector can move to enable mating and unmating of the cable with the MTi. The ring behind the moving part must be locked to prevent vibrations of the moving parts of the connector to be transferred to the casing of the MTi.

Xsens has tested a set of vibration dampeners on the MTi. Vibration dampeners are low-profile rubber cylinders that allow the MTi to be mounted on an object without a direct metal to metal connection that transduces vibrations from the object to the MTi. The vibration dampeners have been tested with frequencies up to 1200 Hz that caused aliasing when the MTi was mounted directly on the vibration table had no effect with the vibration dampeners fitted. The dampeners tested are manufactured by Norelem and have part number 26102-00800855, www.norelem.com

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3.5.3 Magnetic materials and magnets

When an MTi is placed close to or on an object that is either magnetic or contains ferromagnetic materials, the measured magnetic field is distorted (warped) and causes an error in the computed yaw. The earth magnetic field is altered by the presence of ferromagnetic materials, permanent magnets or power lines with strong currents (several amperes) in the vicinity of the device. The distance to the object and the amount of ferromagnetic material determines the magnitude of disturbance introduced. Errors in estimated yaw due to such distortions can be quite large, since the earth magnetic field is very weak in comparison to the magnitude of the sources of distortion.

For more information on how to mitigate the detrimental effects of magnetic distortion, refer to this BASE article: https://base.xsens.com/hc/en-us/articles/115004479409

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3.6 Typical User Scenarios

This section is intended to help you find the right software component and corresponding documentation for the way you want to use your MTi.

3.6.1 MT Software Suite

The MT Software Suite is a set of software components that can be used to communicate with the MTi and to perform more high-level routines, such as logging, exporting, a magnetic field calibration and updating of the firmware. Depicted below is a flow chart based on the software platform and the preferred interface level.

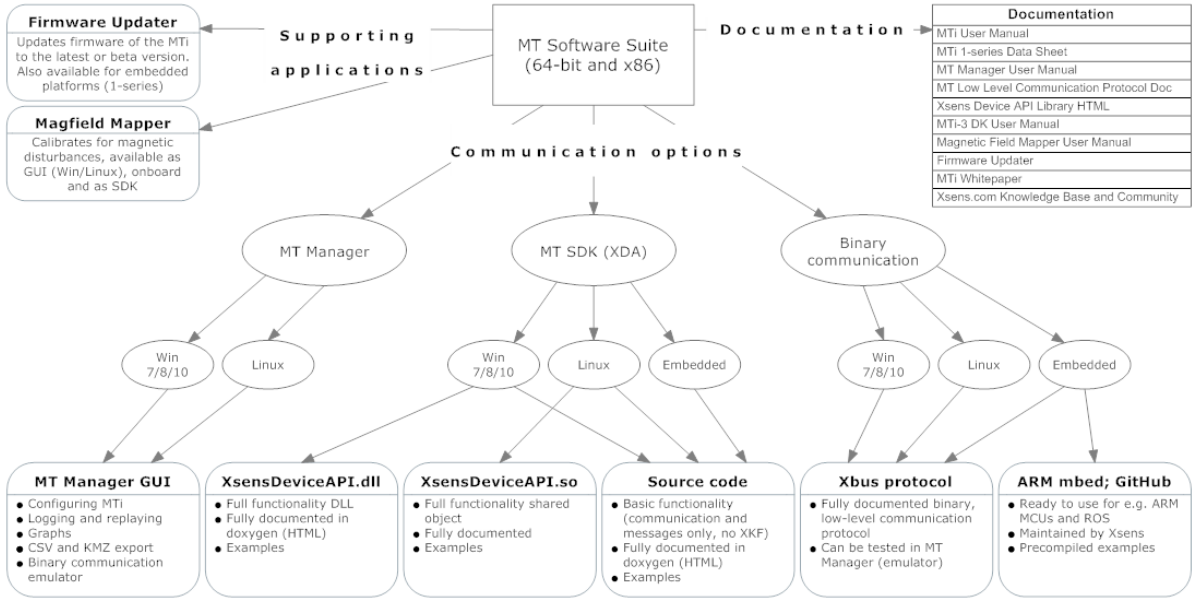

Figure 6: Structure of the MT Software Suite

On the left, three programs with GUIs are shown (Firmware Updater, Magnetic Field Mapper and MT Manager). These programs offer the possibility to configure the MTi in a very easy way. The MT Manager can also be used to communicate with the MTi. The MagField Mapper is also available as an SDK for integration into another application.

The MT SDK contains all the developer code, such as a DLL, a shared object and basic functionality in source code for embedded systems. Of course, it is possible to use lower level communication options, down to the Xbus Low Level protocol; most of the functionality however can be found in the DLL and shared object.

The Xbus low-level protocol is described in high detail in the Low Level Communication Protocol: [LLCP].

The hardware driver of the USB interface for Linux can be found on https://github.com/xsens/xsens_mt. The driver is also included in Linux kernel 3.9 and higher.

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3.6.2 Getting Started with the MT Manager

The easiest way to get started with your MTi is to use the **MT Manager** software for Windows 7, Windows 8 and Windows 10.
This easy to use software with a Windows user interface allows you to:

- record data and playback/review data
- view orientation, position and velocity in real-time (if available)
- view inertial and magnetic sensor data in real time
- view low-level communication and XDA communication via message terminals
- export log files to ASCII and KMZ
- change and view various device settings and properties
- reprocess pre-recorded data, e.g. with different settings

The MT Manager is therefore an easy way to get to know and to demonstrate the capabilities of the MTi and to configure the device easily to suit your needs.

With the MT Manager, it is possible to apply a configuration profile to multiple MTi's. This allows system integrators to configure MTi's correctly with a quick turn-around time.

Please refer to the **MT Manager User Manual** [MTM] for more information on this topic

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3.6.3 Using the Software Development Kit (SDK)

This chapter gives an introduction to the Xsens Device API (XDA). It serves as a starting point for system integrators interested in assessing the basis of the SDK and knowing about the background considerations. The main objective of the SDK is to facilitate easy development of user-specific host applications based on Xsens motion trackers.

The MT SDK 4.x (and the MT Software Suite) is designed for the MTi 1-series, MTi 10-series and MTi 100-series.

3.6.3.1 Using the Source code and Dynamic Library

The MT SDK consists of Source code and a Dynamic Library. Source code is made available in C, since this language can be handled by many other programming languages, such as C++, Java and Python. Since C++ is a more convenient language to use for first-time users of the MT SDK (lower risk of making mistakes, easier to handle complex functions), Xsens also supplies a C++ wrapper around the C-compiled library. Refer to the MT SDK documentation in the Xsens installation folder to find schematic overview of the Xsens Device API. The host application developer can choose to use a COM, C, C# or C++ interface. However, only the C interface is delivered as a compiled dynamic library. For the C# and C++ interface the source code of the wrapper classes are supplied as part of the SDK. The interfaces are discussed in more detail in the following sections.

Note that conceptually XDA makes no distinction between the cases of real-time data stream from a device or a recorded file data stream.

Using the Xsens Xbus low-level communication protocol is discussed in section 3.6.4.

Device management and global control functions are grouped in the XsControl object. To access functionality for a specific device the XsDevice object is available. Typical steps are:

1. Scan for Xsens devices with XsScanner::scanPorts
2. Open port with XsControl::openPort and get device object with XsControl::device
3. Configure device with XsDevice functions
4. Start measuring

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C-interface libraries

XDA is implemented in two C-interface libraries that are supplied for Windows and Linux, consisting of two parts:

- XDA that contains the access to functionality as implemented in devices, e.g. configuring the Motion Trackers, requesting data etc
- XsTypes that contains generic types (vectors, matrices, quaternions, etc.) and some basic operations on those types, e.g. converting quaternions coming from the MTi into Euler angles.

The C API exposes all possible functions that could be supported by an Xsens device. As such, a certain functionality implemented in devices is accessible by a function call that takes at least an XsDevice Object as a parameter. Not every Xsens device supports all functionality, e.g. an MTi-30 does not support getting a position estimate whereas the MTi-G-710 does. This means that whether the function returns a meaningful result depends on the type of connected device. The DeviceID indicates the MTi product with associated functionality: a list of DeviceIDs can be found in section 3.2.5. Exposing all the possible functionalities has the advantage that when changing the MTi in the application to a device with other functionalities, the majority of the code can remain unchanged.

Internally the Xsens host software is implemented using an object oriented approach in which the functionality is only implemented in subclasses, see schematic below.

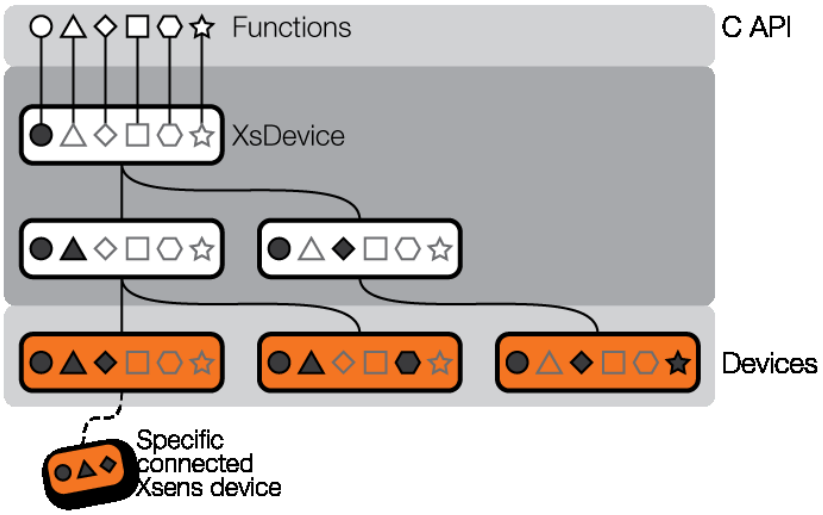

Figure 7: Functionality implementation for specific products

It is important for the developer to use only functions supported by the connected device. During run time, calling an unsupported function will generate an error status in line with the normal error handling framework.

C++ interface

To offer the convenience of object-lifetime management to developers, the XDA is also offered as a C++ interface which basically implements a convenience wrapper around the C API. This means that the developer does not have to deal with memory management (i.e. easy object-lifetime management) as the class implementation takes care of this. This means that for example functions named `XsDevice_<function name>` in the C interface are available in the C++ interface as the `<function name>` method of the `XsDevice` class.

COM interface

For MS Windows environments, all the functionality is also available via a COM interface.

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3.6.4 Direct low-level communication with MTi

The MTi features a powerful embedded multi-processor core. As the MTi has an on-board non-volatile memory that can store all settings, the MTi can conveniently be used without using a host computer.

The low-level communication protocol (named Xbus protocol) offers full control and functionality, however without the convenience advantages that the Xsens Device API offers, such as threading, object-oriented programming and error handling. Low-level communication is essential on platforms that do not support the Xsens Device API, such as custom embedded computers.

The low-level communication is extensively described in the Low-Level Communication Protocol Documentation. Next to that, source code is delivered to make driver development and Xbus message parsing for the MTi as easy and quick as possible.

3.6.5 Terms of use of MT Software Suite

The installer of the MT Software Suite can install 4 components of the MT Software Suite: the MT Manager, the MT SDK, the Magnetic Field Mapper and the MFM SDK. The Firmware Updater is a separate installer. The MT Software Suite has a Restricted License Agreement that you need to accept. In the following table, the guidelines for use of each component are described.

Table 4: Guidelines for the use of the MT Software Suite

Component	Guidelines
MT Manager	For use with Xsens products only Not allowed to re-distribute Not allowed to reverse engineer Not allowed to modify
MT SDK	For use with Xsens products only Allowed to re-distribute “as is” or embed in programs Not allowed to reverse engineer Allowed to execute, reproduce, modify and compile (modified) source code to use with Xsens products only Not allowed to modify DLL Include License Agreement with distribution
MFM	For use with Xsens products only Allowed to re-distribute “as is” Not allowed to reverse engineer Not allowed to modify Include License Agreement with distribution
MFM SDK	For use with Xsens products only Allowed to re-distribute “as is” or embed in programs Not allowed to reverse engineer Allowed to execute, reproduce, modify and compile (modified) source code to use with Xsens products only Not allowed to modify DLL Include License Agreement with distribution
FWU	For use with Xsens products only Allowed to re-distribute “as is” Not allowed to reverse engineer Not allowed to modify Include License Agreement with distribution

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4 MTi System Overview

4.1 Calibration

A correct calibration of the sensor components inside the MTi is essential for an accurate output. The quality and importance of the calibration are of highest priority and so each Xsens' MTi is calibrated and tested by subjecting each product to a wide range of motions and temperatures.

The individual calibration parameters are used to convert the sensor component readout (digitized voltages) to physical quantities as accurately as possible, compensating for a wide range of deterministic errors. Additionally, the calibration values are used in Xsens sensor fusion algorithms, as discussed below.

4.2 Xsens Kalman Filter for VRU and AHRS product types

The orientation of the VRU and AHRS is computed by Xsens Kalman Filter. XKF3™ is a proven sensor fusion algorithm, which can be found in various products from Xsens and partner products. The industrial applications version is XKF3i: it uses signals of the rate gyroscopes, accelerometers and magnetometers to compute a statistical optimal 3D orientation estimate of high accuracy with no drift for both static and dynamic movements.

The design of the XKF3i algorithm can be summarized as a sensor fusion algorithm where the measurement of gravity (by the 3D accelerometers) and Earth magnetic north (by the 3D magnetometers) compensate for otherwise slowly, but unlimited, increasing (drift) errors from the integration of rate of turn data (angular velocity from the rate gyros). This type of drift compensation is often called attitude and heading referencing and such a system is referred to as an Attitude and Heading Reference System (AHRS).

4.2.1 Using the acceleration of gravity to stabilize inclination (roll/pitch)

XKF3i stabilizes the inclination (i.e. roll and pitch combined) using the accelerometer signals. An accelerometer measures gravitational acceleration plus acceleration due to the movement of the object with respect to its surroundings.

XKF3i uses the assumption that on average the acceleration due to the movement is zero. Using this assumption, the direction of the gravity can be observed and used to stabilize the attitude. The orientation of the MTi in the gravity field is accounted for so that centripetal accelerations or asymmetrical movements cannot cause a degraded orientation estimate performance. The key here is the amount of time over which the acceleration must be averaged for the assumption to hold. During this time, the rate gyroscopes must be able to track the orientation to a high degree of accuracy. In practice, this limits the amount of time over which the assumption holds true.

However, for some applications this assumption does not hold. For example, an accelerating automobile may generate significant accelerations for time periods lasting longer than the maximum duration the MT's rate gyroscopes can reliably keep track of the orientation. This will degrade the accuracy of the orientation estimates with XKF3i somewhat, because the application does not match the assumptions made in the algorithm. Note however, that as soon as the movement again matches the assumptions made, XKF3i will recover and stabilize. The recovery to optimal accuracy can take some time.

NOTE: To be able to accurately measure orientations as well as position in applications which can encounter long term accelerations we offer a solution that incorporates a GNSS receiver, the MTi-G-710 GNSS/INS.

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4.2.2 Using the Earth magnetic field to stabilize yaw

By default, yaw is stabilized using the local (earth) magnetic field (only in the AHRS product types). In other words, the measured magnetic field is used as a compass. If the local Earth magnetic field is temporarily disturbed, XKF3i will track this disturbance instead of incorrectly assuming there is no disturbance. However, in case of structural magnetic disturbance (>10 to 30 s, depending on the filter setting) the computed heading will slowly converge to a solution using the 'new' local magnetic north. Note that the magnetic field has no direct effect on the inclination estimate.

In the special case the MTi is rigidly strapped to an object containing ferromagnetic materials, structural magnetic disturbances will be present. In that case, there are solutions to use the magnetometers after all. Refer to https://base.xsens.com/hc/en-us/articles/115004479409-Magnetic-distortions-and-solutions.

4.2.3 Estimating gyro bias in magnetic disturbed environments

The gyroscope bias is continuously estimated. For the rate of turn around the x-axis and the y-axis (roll and pitch axes), the gyroscope bias is estimated using gravity (accelerometers). In a homogenous magnetic field and with filter profiles using the magnetometer, the gyroscope bias around the z-axis will successfully be estimated.

In some situations, the heading cannot be referenced to the (magnetic) north. This is the case when the magnetic field is not used or when the magnetic field is not homogenous. There are several ways to mitigate the drift in heading (rotation around the z-axis):

1. The gyroscope bias can be estimated using Active Heading Stabilization (AHS). As the heading is not referenced, there is no guarantee for this performance under all circumstances. Refer to https://base.xsens.com/hc/en-us/articles/210133105-Use-of-Active-Heading-Stabilization-AHS-in-MTi
2. When the MTi has sufficient movement in roll and pitch (>30 deg for more than 10 seconds), the gyroscope bias will be estimated for the z-gyroscope. When rotating the MTi back to roll and pitch around 0, the heading will be more stable than before the roll/pitch movements.
3. When the MTi cannot or is not rotated around roll and pitch, it is possible to let the gyroscopes bias to be estimated when the MTi does not rotate (a so-called no-rotation update). Refer to https://base.xsens.com/hc/en-us/articles/203307252-Bias-repeatability-of-gyroscopes

4.2.4 Initialization

The XKF3i algorithm not only computes orientation, but also keeps track of variables such as sensor biases or properties of the local magnetic field (magnetic field: MTi-30 AHRS only). For this reason, the orientation output may need some time to stabilize once the MTi is put into measurement mode. Time to obtain optimal stable output depends on a number of factors. An important factor determining stabilizing time is determined by the time to correct for small errors on the bias of the rate gyroscopes. The bias of the rate gyroscope may slowly change due to different effect such as temperature change or exposure to impact.

4.2.5 XKF3i filter profiles

As described above, XKF3i uses assumptions about the acceleration and the magnetic field to obtain orientation. Because the characteristics of the acceleration or magnetic field differ for different applications, XKF3i makes use of filter profiles to be able to use the correct assumptions given the application. This way, XKF3i can be optimized for different types of movement. For optimal performance in a given application, the correct filter profile must be set by the user. For information on how to specify a filter profile in XKF3i, please refer to the MT Manager User manual [MTM] or the MT low-level communication protocol documentation [LLCP].

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Table 5: Filter profiles for the MTi-200/MTi-300

Number	Name	IMU	Magnetometer	Product
39	General	•	•	30/300-AHRS
40	High_mag_dep	•	•	30/300-AHRS
41	Dynamic	•	•	30/300-AHRS
42	Low_mag_dep	•	•	30/300-AHRS
43	VRU_general	•		30/300-AHRS; 20/200-VRU

The **general** filter profile is the default setting. It assumes moderate dynamics and a homogenous magnetic field. External magnetic distortions are considered relatively short (up to ~20 seconds). Typical applications include camera tracking (e.g. TV camera's), remotely operated robotic arms on ROV's etc

The **high_mag_dep** filter profile assumes homogenous magnetic field and an excellent Magnetic Field Mapping. This filter profile heavily relies on the magnetometer for heading. Dynamics of the motion are relatively slow. Typical applications are navigation of ROV's or the control of small unmanned helicopters.

The **dynamic** filter profile assumes jerky motions. However, the assumption is also made that there is no GNSS available and/or that the velocity is not very high. In these conditions a 100-series MTi may be a better choice. The dynamic filter profile uses the magnetometer for stabilization of the heading, and assumes very short magnetic distortions. Typical applications are where the MTi is mounted on persons or hand-held (e.g. HMD, sports attributes etc.).

The **low mag_dep** filter profile assumes that the dynamics is relatively low and that there are long-lasting external magnetic distortions. Also use this filter profile when it is difficult to do a very good Magnetic Field Mapping (MFM). The use of the low_mag_dep filter profile can be useful to limit drift in heading whilst not being in a homogenous magnetic field. Typical applications are large vessels and unmanned ground vehicles in buildings.

The **VRU_general** filter profile assumes moderate dynamics in a field where the magnetic field cannot be trusted at all and benefits from the Active Heading Stabilization feature. It is also possible to use this filter profile in situations where an alternative source of yaw is available. Yaw from the VRU is unreferenced; note however, that because of the working principle of the VRU, the drift in yaw will be much lower than when gyroscope signals would be integrated. Typical applications are stabilized antenna platforms mounted on cars of ships and pipeline inspection tools. This filter profile is the only one available for the MTi-20 VRU.

Every application is different and although example applications are listed above, 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.

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4.3 Xsens sensor fusion algorithm for MTi-G-710

The Xsens sensor fusion algorithm in the MTi-G-710 has several advanced features. It can handle a multitude of data channels, to incorporate GNSS and barometer data as well.

4.3.1 Transient accelerations

The MTi-G-710 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.

4.3.2 Magnetic disturbances

Next to the solutions described on https://base.xsens.com/hc/en-us/articles/115004479409-Magnetic-distortions-and-solutions to mitigate effects from magnetic disturbances, the MTi-G-710 sensor fusion algorithm makes use of data coming from the GNSS receiver. It is for example possible to estimate the heading based on comparison between accelerometer data and the GPS acceleration: https://base.xsens.com/hc/en-us/articles/212547829-Heading-estimation-using-GPS-acceleration

4.3.3 Loss of GNSS

When the MTi-G-710 has limited/mediocre GNSS reception or even no GNSS reception at all, the MTi-G-710 sensor fusion algorithm seamlessly adjusts the filter settings in such a way that the highest possible accuracy is maintained. The GNSS status will be monitored continuously so that the filter can take GNSS data into account when available and sufficiently trustworthy. In case loss of GNSS lasts longer than 45-60 seconds (exact time depends on the filter profile), the MTi-G-710 will go into a state where it no longer uses velocity estimates in the filter.

4.3.4 MTi-G-710 filter profiles

The filter profiles for MTi-G-710 are described below. Please note the specific cautions with each of these filter profiles.

Table 6: Filter profiles for the MTi-G-710 GNSS/INS

Nr	Name	IMU	Mag field	Static pressure	GNSS	Holonomic constraints	Product
1	General	•		•	•		710-GNSS/INS
2	GeneralNoBaro	•			•		710-GNSS/INS
3	GeneralMag	•	•	•	•		710-GNSS/INS
4	Automotive	•		•	•	•	710-GNSS/INS
5	HighPerformanceEDR	•		•	•		710-GNSS/INS

The **General** filter profile is the default setting. It makes few assumptions about movements. Yaw is referenced by comparing GNSS acceleration with the on-board accelerometers, so the more movement (when GNSS is available) will result in a better yaw. Altitude (height) is determined by combining static pressure, GNSS altitude and accelerometers. The barometric baseline is referenced by GNSS, so during GNSS outages, accurate height measurements are maintained because this barometric baseline is monitored.

The **GeneralNoBaro** filter profile is very similar to the general filter profile. However, it does not use the barometer for height estimation (it thus uses GNSS and accelerometers only). Since airflows near the venting holes in the MTi-G will lower the barometric pressure (and thus make height estimations inaccurate), you can use this filter profile when the MTi-G is mounted in such airflow.

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The **GeneralMag** filter profile bases it yaw mainly on magnetic heading, together with comparison of GNSS acceleration and the accelerometers. Although this combination makes the yaw more robust than magnetic field alone, a homogenous or calibrated-for magnetic field is essential for good-performance yaw. Other parameters are tuned the same as in the General filter profile.

The **Automotive** filter profile assumes that the yaw of the MTi-G-710 is also the GNSS course over ground (holonomic constraints). This assumption holds for most automotive/ground vehicles, except for those who experience side slip, such as racing cars, tracked vehicles, some articulated vehicles (depending on where the MTi-G-710 is mounted) and vehicles driving on rough terrain. The Automotive filter profile thus uses GNSS to determine the yaw. Note that it is essential to mount MTi-G exactly in the direction of movement in order to prevent an offset. Please refer to 5.2.3 for proper mounting. When GNSS is lost, yaw will be determined by the velocity estimation algorithm for 60 seconds, before yaw is determined by gyroscopes integration only. Should GNSS outages recur regularly or if you have bad GNSS-availability (e.g. in urban canyons), consider using HighPerformanceEDR.
In the Automotive filter profile, yaw is locked (e.g. gyro bias will be estimated and yaw will not change), when GNSS indicates that there is no movement. This is useful when standing still, as gyro bias would otherwise induce a yaw drift.

The **HighPerformanceEDR** filter profile replaces the previously available AutomotiveUrbanCanyon filter profile. This filter profile is specially designed for ground-based navigation applications where deteriorated GNSS conditions and GNSS outages (0-60s) are a regular feature. This filter profile does not use the holonomic constraints and thereby removes the need for mounting considerations. Target applications: slow moving ground vehicles and locomotive navigation. The filter profile HighPerformanceEDR automatically estimates the gyro bias when the MTi is not moving. The sensor fusion algorithm detects when the MTi is motionless. Vibrations and very slow movements may influence the accuracy of the gyro bias estimation.

Every application is different and although example applications are listed above, 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.

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4.4 Active Heading Stabilization (AHS)

One powerful feature when it comes to heading estimation is Active Heading stabilization (AHS). AHS uses the magnetometers to estimate the gyro bias, but it does not reference the heading. This way, drift in heading can be as low as 1 deg after 60 minutes for the MTi 100-series and 3 deg after 60 minutes for the MTi 10-series. When the magnetic field is disturbed, AHS will still function. The frequency though of the updates of the gyro bias will be lower, as AHS is triggered only when the magnetic field is stable.

There is one known situation where AHS will have a detrimental effect on the performance. When the magnetic field is changing very slowly (e.g. when an object is rotating slowly, less than e.g. 0.5 deg/s), AHS might estimate the gyro bias incorrectly.

When AHS is applied to a filter profile that uses the magnetic field as a reference, the magnetic field will no longer be used as a reference. Heading output will be heading tracking instead of referenced heading.

AHS is off by default from firmware version 1.4.12. To enable AHS, enable AHS via SetOptionFlags. The message for enabling AHS is “FA FF 48 08 00 00 00 10 00 00 00 00 A1” or tick the boolean in the Device Settings of MT Manager.

4.5 In-run Compass Calibration (ICC)

When it is not possible to do a Magnetic Field Mapping and when there are hard- and soft-iron effects that are moving with the MTi, it is possible to perform an 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 leaving out the need for a host processor like a PC. It estimates the hard- and soft-iron effects and provides new magnetometer calibration parameters. To expedite the estimation of magnetometer calibration parameters, there is a Representative Motion feature. Representative Motion is available in MT Manager, XDA and Low-Level Communication Protocol (Xbus protocol).

For more information, refer to the BASE-articles on ICC: https://base.xsens.com/hc/en-us/articles/213588029

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5 Output Specification

In this chapter the various output modes of the MTi are described. The MTi's have tens of various output options; it is possible to select a different output frequency and/or output format (e.g. float or double) per output or group of outputs. A full overview of outputs can be found in the [LLCP].

Performance specifications on orientation, position and sensor data can be found in section 5.3 and 5.4. Before going into these sections, it is useful to read section 5.2, which explains the various coordinate systems and position representations.

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5.1 Overview of data outputs

The MTi supports two different data protocols: the binary (hexadecimal) XBus protocol and NMEA. Refer to [LLCP] to learn how to switch between data protocols.

5.1.1 MTData2 output in XBus protocol

The [LLCP] contains a full list of all data outputs. Refer to the table in the MTData2 message description.

5.1.2 ASCII output (NMEA)

The MTi also supports a variety of strings in ASCII, amongst others messages in the NMEA protocol. The list of available ASCII strings can be found in the [LLCP], in the table in the description of the SetStringOutputType message.

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5.2 Coordinate systems

Data from the MTi is represented in various coordinate systems, which are explained below.

5.2.1 Calibrated inertial data and magnetic field data

The **sensor coordinate system (S)** is a right-handed coordinate Cartesian system that is body-fixed to the device. It is possible to rotate the sensor coordinate system to an **object coordinate system (O)** when the MTi is not exactly aligned with the axes of the object or vehicle the MTi is attached to. See section 5.10 for more information on alignment matrices.

(S) and (O, when applied) are used in the rate-of-turn (DataID 0x8020), acceleration (DataID 0x4020) and magnetic field (DataID 0xC020) outputs. The encased version of the MTi shows the coordinate system on the sticker. Depicted below is the sensor coordinate system on the encased MTi and the OEM version. Small x, y and z are used for **(S)** and the object coordinate system **(O)**. Capital X, Y and Z are *generally*, but not always, used for velocity. They stand for the local-earth fixed coordinate system **(L)**, see section 5.2.3.

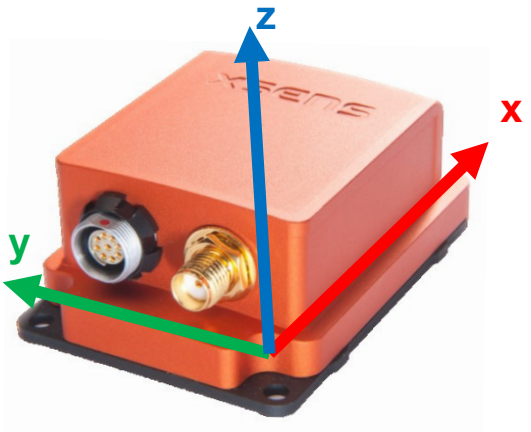

Figure 8: coordinate system of the encased MTi (Note: origin is located at the accelerometers)

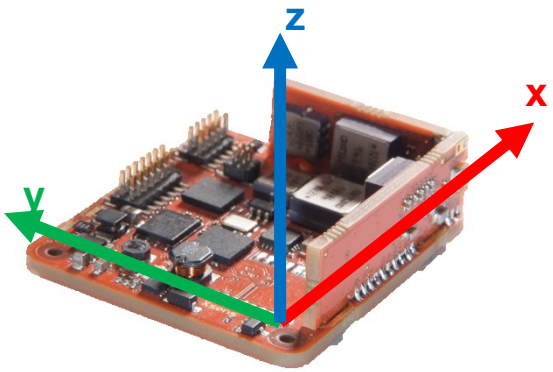

Figure 9: Coordinate system of the MTi-OEM (Note: origin is located at the accelerometers)

The aluminum base plate of the MTi is carefully aligned with the output coordinate system during the individual factory calibration. The alignment of the bottom plane and sides of the aluminum base-plate with respect to the sensor-fixed output coordinate system **(S)** is within 0.1 deg. Convenient alignment points are designed in the base plate of the MTi.

The non-orthogonality between the axes of the body-fixed co-ordinate system, **(S)**, is <0.05°. This also means that the output of 3D linear acceleration, 3D rate of turn (gyro) and 3D magnetic field data all will have orthogonal xyz readings within <0.05° as defined in the figure above.

5.2.2 Delta_angle and delta_velocity

The SDI output of the MTi contain delta_angle (dq, DataID 0x8030) and delta_velocity (dv, DataID 0x4010). These values represent the orientation change and velocity change during a certain interval. In the MTi, this interval is 2.5 ms (400 Hz) by default. The values dq and dv are always represented in the same coordinate system as calibrated inertial data and magnetic field data (see section 5.2.1), which can be **(S)** or **(O)**.

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5.2.3 Orientation data

By default the local earth-fixed reference co-ordinate system **(L)** used is defined as a right handed Cartesian co-ordinate system with:

- X positive to the East (E).
- Y positive to the North (N).
- Z positive when pointing up (U).

This coordinate system is known as ENU and is the standard in inertial navigation for aviation and geodetic applications. Note that it is possible to change the local coordinate system **(L)** using a different convention (NWU or NED), by changing the alignment matrix or applying an orientation reset.

The 3D orientation output (DataID 0x2010, 0x2020, 0x2030) is defined as the orientation between the body-fixed co-ordinate system, **(S)** or **(O)**, and the earth-fixed co-ordinate system, **(L).**

Interpretation of yaw as heading
Heading is defined as the angle between north and horizontal projection of the vehicle roll axis. Heading is positive about the local vertical axis following the right hand rule. For a local level navigation frame, yaw is the angle from a horizontal navigation axis to the projection of the longitudinal axis in the horizontal plane; positive is about the positive vertical axis following the right-hand rule[1].

With the default ENU **(L)** coordinate system, Xsens yaw output is defined as the angle between East (X) and the horizontal projection of the sensor roll axis (x), positive about the local vertical axis (Z) following the right hand rule. Table 7 shows the different yaw values corresponding to the different local coordinate systems that are available for the MTi.

Table 7: Yaw in different coordinate systems (applies only to VRU/AHRS and GNSS/INS product types). The MTi is assumed to be mounted with its roll-axis (X) aligned with the roll-axis of the vehicle (front of the vehicle).

Local coordinate system (output)	Roll-axis of the vehicle	Yaw value
East-North-Up (ENU)	Pointing North	90 deg
East-North-Up (ENU)	Pointing East	0 deg
North-West-Up (NWU)	Pointing North	0 deg
North-East-Down (NED)	Pointing North	0 deg

When using the ENU convention (default), the yaw output is 0º when the vehicle (x-axis of the MTi) is pointing East. When it is required that the yaw output is 0º when the vehicle (x-axis of the MTi) is pointing North, it is recommended to select NWU or NED as the local coordinate system. In section 5.10 the various alignment resets are described.

When using the MTi-G-710 in the Automotive filter profile, as a best practice pay proper attention to mounting of the MTi on the automotive platform/vehicle. It is recommended to always mount the MTi with the x-axis of the MTi-G-710 pointing to the front of the vehicle irrespective of the local coordinate frame used for the output data.

[1] IEEE Std 1559™-2009: IEEE Standard for Inertial Systems Terminology

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True North vs. Magnetic North
As defined above the output coordinate system of the MTi is with respect to local Magnetic North. The deviation between Magnetic North and True North (known as the magnetic declination) varies depending on the location on earth and can be roughly obtained from the World Magnetic Model (Xsens uses WMM 2010-2015) of the earth's magnetic field as a function of latitude and longitude. The MTi accepts a setting of the declination value. This is done by setting the position in the MT Manager, SDK or by direct communication with the sensor. The output will then be offset by the declination calculated internally and thus referenced to "local" True North. The MTi-G-710 GNSS/INS calculates True North automatically when GNSS-position is available.

5.2.4 Velocity data

Velocity data, calculated by sensor fusion algorithm (DataID 0xD010) is provided in the same coordinate system as the orientation data, and thus adopts orientation resets as well. It is available only in the MTi-G-710.

Velocity data from the navigation solution from the GPS receiver in the MTi-G-700 (DataID 0x8840) is represented in Earth Centered – Earth Fixed (ECEF).
Velocity data part from the PVT estimates retrieved from the GNSS receiver in the MTi-G-710 or from the GPS receiver of the MTi-G-710 in the GNSS format (DataID 0x7010) is represented in the NED reference frame.

5.2.5 Position data

Position data, calculated by the sensor fusion algorithm (DataID 0x5040) is represented in Latitude, Longitude in the WGS84 datum. It is available only in the MTi-G-710.

It is possible to retrieve position data, calculated by sensor fusion algorithm, in Earth Centered – Earth Fixed (ECEF) format. Use DataID 0x5030 to retrieve this output. Note that position in ECEF cannot be represented in Fixed Point values because of the limited range of fixed point representations. Use double or float representation instead.

Altitude is output in WGS84 datum (DataID 0x5020).

Position data (latitude and longitude) part of the PVT estimates output from the GNSS receiver in the MTi-G-710 (DataID 0x7010) is in the WGS84 datum.

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5.3 Orientation performance specification

In the MTi product portfolio, several products provide roll, pitch and (un)stabilized yaw. The table below provides an overview of the specific products and orientation performances. The 10-IMU and the 100-IMU are not listed, as they do not provide orientation.

Typical orientation errors are in 1σ RMS values; maximum errors are in degrees. For yaw, maximum errors cannot be provided, as this strongly depends on the environmental conditions.

Table 8: Orientation performance specification

		MTi-20 VRU		MTi-30 AHRS		MTi-200 VRU		MTi-300 AHRS		MTi-G-710 GNSS/INS	
		Typ	Max	Typ	Max	Typ	Max	Typ	Max	Typ	Max
Roll/Pitch	Static[2]	0.2º	0.4º	0.2º	0.4º	0.2º	0.25º	0.2º	0.25º	0.2º	0.25º
	Dynamic	0.5º	2.0º	0.5º	2.0º	0.3º	1.0º	0.3º	1.0º	0.3º	1.0º
Yaw[3]		Unref.		1.0	N/A	Unref.		1.0º	N/A	1.0º	N/A

Performance specifications highly depend on the conditions. Orientation performance of the MTi-G-700/710 is valid in an increased range of applications and motions.

The performance specifications in this chapter are subject to the following assumptions (see also footnotes);

- **Correct filter profile:** If an unsuitable filter profile is chosen, the sensor fusion algorithm will use erroneous assumptions. Depending on the specific situation this can lead to large errors or even instability of the filter. Take care to select the correct filter profile. If you are uncertain, do not hesitate to contact Xsens or your local distributor.
- **Magnetic distortions:** In several filter profiles the on-board 3D magnetometer is used to observe the heading. It is assumed that a magnetic field mapping is performed and that the magnetometers are not distorted by nearby ferromagnetic materials in the environment.
- **Long-lasting accelerations (all, except for MTi-G-710)**: Each filter profile copes different with long-lasting accelerations. Although the MTi's are able to discard these transient accelerations, they will have an effect after a certain period of time. In the MTi 10-series, this period is shorter than in the MTi-100 series. The MTi-G-710 with a good GNSS fix can compensate for these long-lasting accelerations.
- **Settling time:** Parameters in the MTi's such as the rate gyro bias or the pressure at sea level are continuously estimated. The sensor fusion algorithms need some time to estimate such parameters. Depending on the time since last calibration of the MTi's, the chosen filter profile and the quality of the GNSS fix this can take up to 5 minutes. There is no need to have the MTi's static during the settling time, on the contrary, movement (accelerations, turns) of the MTi's will help to estimate for example the gyro bias quicker as they become observable.
- **Good GNSS fix (MTi-G-710 only):**
  - If there is no GNSS fix the position estimates based on the IMU will degrade very rapidly (in the order of a few seconds).
  - If there is no GNSS fix the MTi-G cannot calculate correct attitude and heading under all dynamic conditions due to "apparent gravity" (e.g. centripetal and linear accelerations). Based on the rate gyros the attitude and heading estimates will degrade

[2] Max error with respect to earth coordinate system
[3] MTi-20 VRU and MTi-200 VRU: unreferenced (heading is yaw rate of gyroscopes)

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slowly. Attitude accuracy will be the same as the accuracy of an MTi-300. The heading will typically drift up to a degree every minute.

- **Valid holonomic constraints (MTi-G-710 only)**: In the Automotive filter profiles of the MTi-G-710 it is assumed that the x-axis of the MTi-G is mounted in the driving direction of the vehicle. Accuracy of the heading estimate improves as the alignment error decreases and vice-versa.
- **Barometric conditions (MTi 100-series only):** In some of the filter profiles, the altitude of the MTi-G-700/710 is partly estimated by the on-board barometer. It is assumed that the pressure near the MTi-G reflects the atmospheric pressure outside of the vehicle. So, if you selected a filter profile that uses barometer data, the MTi-G cannot be used in e.g. a pressurized cabin. Furthermore, the height accuracy may reduce with very rapid changes in atmospheric pressure that could occur in e.g. severe thunderstorms.

5.4 Position and velocity performance specification (MTi-G-710)

The MTi-G-710 has the ability to give position output. The performance highly depends on the GNSS availability, placement of the GNSS antenna etc.

The table below states the position and velocity accuracy according to Xsens' reference trajectories.

Table 9: Position and velocity performance specification (MTi-G-710)

Parameter	Data source	Condition	Specification
Position			
	AHRS augmented (400 Hz GNSS/INS)	Horizontal	1.0 m STD
		Vertical	2.0 m STD
	GNSS receiver (4 Hz GNSS PVT estimates), SBAS	Horizontal	2.0 m CEP
		Vertical	5.0 m CEP
Velocity			
	AHRS augmented (400 Hz GNSS/INS)	@ 30 m/s	0.05 m/s 1σ RMS
	GNSS receiver (4 Hz GNSS PVT estimates)	@ 30 m/s	0.05 m/s 1σ RMS

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5.5 Orientation output modes

The orientation as calculated by the MTi is the orientation of the sensor-fixed co-ordinate system (***S***) with respect to a Cartesian earth-fixed co-ordinate system (***L***). The output orientation can be presented in different parameterizations:

- Unit Quaternions
- Euler angles[4]: roll, pitch, yaw (XYZ Earth fixed type, also known as Cardan or aerospace sequence)
- Rotation Matrix (directional cosine matrix)

A positive rotation is always “right-handed”, i.e. defined according to the right hand rule (corkscrew rule). This means a positive rotation is defined as clockwise in the direction of the axis of rotation.

Refer to https://base.xsens.com/hc/en-us/articles/115004491045 to find more information on how quaternions, Euler angles and the rotation matrix relate to each other.

[4] Please note that due to the definition of Euler angles there is a mathematical singularity when the sensor-fixed x-axis is pointing up or down in the earth-fixed reference frame (i.e. pitch approaches ±90°). In practice this means roll and pitch is not defined as such when pitch is close to ±90 deg. This singularity is in ***no way*** present in the quaternion or rotation matrix output mode.

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5.6 Sensor data performance specification

This section describes the specifications of the physical sensors of the MTi's. Not all MTi's feature all sensors. Per sensor, the applicable MTi's are mentioned.

5.6.1 Gyroscopes

The main difference between the MTi 10-series and the MTi 100-series is the type of gyroscopes used. The two different specifications are listed below. A full range of 1000 °/s is available upon request.

Gyroscopes in MTi 10-series: MTi-10, MTi-20, MTi-30
Gyroscopes in MTi 100-series: MTi-100, MTi-200, MTi-300, MTi-G-710

Table 10: Gyroscope specifications

Gyroscope specification		MTi 10-series	MTi 100-series
Standard full range	[deg/s]	450	450
Initial bias error	[deg/s]	0.2	0.2
In-run bias stability	[deg/h]	18	10
Bandwidth (-3dB)	[Hz]	415	415
Noise density	[deg/s/√Hz]	0.03	0.01
g-sensitivity (calibrated)	[deg/s/g]	0.006	0.003
Non-orthogonality	[deg]	0.05	0.05
Non-linearity	[%]	0.03	0.01

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5.6.2 Accelerometers and magnetometer

The MTi 10-series and MTi 100-series use the same accelerometers and magnetometer. The output of the magnetometer is in arbitrary units (a.u.), one a.u. is the magnetic field strength during calibration at Xsens' calibration lab. This is approximately 40 uT.

Accelerometers/magnetometer: all products: MTi-10, MTi-20, MTi-30, MTi-100, MTi-200, MTi-300, MTi-G-710.

Table 11: Accelerometers and magnetometers specification

Accelerometer/magnetometer specifications		MTi 10-series and 100-series
Accelerometer		
Standard full range	[m/s2]	200
Initial bias error	[m/s2]	0.05
In-run bias stability	[µg]	15
Bandwidth (-3dB)	[Hz]	375
Noise density	[µg/√Hz]	60
Non-orthogonality	[deg]	0.05
Non-linearity	[%]	0.1
Magnetometer		
Full range[5]	[Gauss]	±8
Total RMS noise	[mGauss]	0.5
Non-linearity	[%]	0.2
Resolution	mGauss	0.25

5.6.3 Barometer

The barometer features barometric (atmospheric) pressure. The MTi-100 series feature this barometer. The MTi 100-series has three holes with a protective vent in its casing in order to ensure fast adaptation inside the MTi to atmospheric pressure. Typical latency because of the vent is <10 ms.

Barometer: MTi 100-series only: MTi-100, MTi-200, MTi-300, MTi-G-710

Table 12: Barometer specification

Barometer specification		
Full range	[hpa]	300-1100
Total RMS Noise	[Pa]	3.6
Resolution at sea level, 15ºC	[m]	0.08

[5] For reliability reasons, not the entire full range is used in the filter.

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5.6.4 GPS/GNSS receiver

The MTi-G-710 is the only MTi that features a GNSS receiver. It requires an active antenna, which is delivered with the Development Kit and can be ordered separately from Xsens as well. It is possible to use a different antenna that better suits your application.

Table 13: GNSS receiver specification

GNSS Receiver specification	MTi-G-710 GNSS
Receiver Type:	72 channels, GPS/QZSS L1 C/A, GLONASS L10F, BeiDou B1
Datum, reference frame	WGS84
GNSS Update Rate:	4 Hz
Horizontal Accuracy Position SPS:	2.5 m CEP
SBAS:	2.0 m CEP
Vertical Accuracy Position SPS:	5 m
Velocity accuracy	0.05 m/s (50% @ 30 m/s)
Heading (Course-over-Ground)	0.3º (50% @ 30 m/s)
Start-up Time Cold start:	26 s (GPS+GLONASS)
Re-acquisition:	<1 s
Tracking Sensitivity:	-167 dBm (GPS+GLONASS)
Timing Accuracy:	30 ns RMS
Maximum Altitude:	50 km
Maximum Velocity:	500 m/s
Max dynamics GNSS:	4g

Note that when you are not using the default GNSS antenna, it is important to use an antenna that is suitable for the MTi-G-710. See section 7.3.1.3.

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5.7 Built-in self-test

All MTi's feature a built-in self-test (BIT). The self-test actuates the mechanical structures in the MEMS accelerometer and gyroscope by inducing an electric signal. This allows checking the proper functioning of the mechanical structures in the MEMS inertial sensors as well as the signal processing circuitry. For the magnetometer, the self-test checks the integrity of the sensor component.

A passed self-test will result in a valid self-test flag in the status byte. Because the self-test influences the sensor data, the self-test is only available in Config mode. For more information, refer to [LLCP], function **`RunSelftest`**.

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5.8 Test and Calibration parameters

Every MTi is calibrated and tested for calibration residuals that correspond to the specified performance of the MTi. This way, a device that leaves our facility has the same high quality that can be expected from Xsens.

The MTi applies calibration parameters internally and each MTi therefore contains individual test and calibration data in its eMTS (electronic Motion Tracker settings). It is digitally signed by a Test Person and states the calibration values determined during the calibration of the MTi at Xsens' calibration facilities. For reference, the values can be read by connecting the MTi to MT Manager and navigating to MT Settings – Modeling Parameters and MT Settings – Basic Test Report. It is also supplied as hardcopy with the MTi. The values are explained here in short:

"**Modeling Parameters**" are the values that describe the conversion from the physical phenomenon to a digital output in an orthogonal coordinate system:

Offsets (bits): Digital reading in bits of the sensor when no physical signal is measured. The barometer is a digital sensor and does not require calibration, hence the value is always 0.

Gain (bits): Gains (or scale factor) describe the relation between the digital reading in bits and the measured physical signal. The barometer is a digital sensor and does not require calibration, hence the value is always 0.

Alignment matrix: Non-orthogonality of the sensor triad. This includes non-orthogonality in the orientation of the sensitive system inside the MEMS sensor, the mounting of the sensors on the PCB of the MTi, the mounting of the PCB's and the misalignment of the OEM board in the MTi housing.

The "**Basic test Report**" describes the noise of the all internal sensors (note: barometer noise is not determined in the MTi Mk5 and is therefore always 0). Furthermore, it shows the Test & Calibration date and who performed the test and calibration.

Next to the basic Test and Calibration values shown in MT Manager, each device is calibrated according to more complicated models to ensure accuracy (e.g. non-linear temperature effect, cross coupling between acceleration and angular rate[6]).

[6] Also known as "g-sensitivity".

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5.9 Sensors data outputs

5.9.1 Physical sensor model

This section explains the basics of the individual calibration parameters of each MTi. This explains Test and Calibration parameters in MT Settings (see also 5.8).

The physical sensors inside the MTi (accelerometers, gyroscopes and magnetometers) are all calibrated according to a physical model of the response of the sensors to various physical quantities, e.g. temperature. The barometer and GNSS receiver do not require calibration. The basic model is linear and according to the following relation:

$$s = K_T^{-1}(u - b_T)$$

From factory calibration each MTi has been assigned a unique gain matrix, $\boldsymbol{K_T}$ and the bias vector, $\boldsymbol{b_T}$ This calibration data is used to relate the sampled digital voltages, $\boldsymbol{u}$, (unsigned integers from the 16 bit ADC's) from the sensors to the respective physical quantity, $\boldsymbol{s}$.

The gain matrix is split into a misalignment matrix, $\boldsymbol{A}$, and a gain matrix, $\boldsymbol{G}$. The misalignment specifies the direction of the sensitive axes with respect to the ribs of the sensor-fixed coordinate system ($\boldsymbol{S}$) housing. E.g. the first accelerometer misalignment matrix element $\boldsymbol{a_{1,x}}$ describes the sensitive direction of the accelerometer on channel one. The three sensitive directions are used to form the misalignment matrix:

$$A = \begin{bmatrix} a_{1,x} & a_{1,y} & a_{3,z} \\ a_{2,x} & a_{2,y} & a_{2,z} \\ a_{3,x} & a_{3,y} & a_{3,z} \end{bmatrix}$$

$$G = \begin{bmatrix} G_1 & 0 & 0 \\ 0 & G_2 & 0 \\ 0 & 0 & G_3 \end{bmatrix}$$

$$K_T = \begin{bmatrix} G_1 & 0 & 0 \\ 0 & G_2 & 0 \\ 0 & 0 & G_3 \end{bmatrix} \begin{bmatrix} a_{1,x} & a_{1,y} & a_{3,z} \\ a_{2,x} & a_{2,y} & a_{2,z} \\ a_{3,x} & a_{3,y} & a_{3,z} \end{bmatrix} + O$$

With $\boldsymbol{O}$ representing higher order models and temperature modelling, g-sensitivity corrections, etc.

Each individual MTi is modeled for temperature dependence of both gain and bias for all sensors and other effects. This modeling is not represented in the simple model in the above equations, but is implemented in the firmware with the temperature coefficient being determined individually for each MTi device during the calibration process.

The basic indicative parameters in the above model of your individual MTi can be found on the **MT Test and Calibration Certificate** and in the MT Manager (MT Settings dialog).

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5.9.2 Calibrated delta_q and delta_v outputs

This output is coning- and sculling compensated strap down integrated data in the sensor-fixed coordinate system (***S***) or (***O***). Note that the value of the output depends on the output frequency, as the values are integrated over a specific time.

Delta_q can also be noted as dq, delta_angle, del_q or OriInc. Delta_v can also be noted as dv, delta_velocity, del_v or VelInc.

Table 14: Output specifications Δq and Δv outputs

Output	Unit
Delta_q (DataID 0x8030)	a.u. (quaternion values)
Delta_v (DataID 0x4010)	m/s

It is possible to multiply consecutive delta_q values to find the total orientation change over a specific period. Note that this data is not drift free, as it has not been processed by the sensor fusion filters. Use the orientation output for drift free orientation.

5.9.3 Calibrated inertial and magnetic data outputs

Output of calibrated 3D linear acceleration, 3D rate of turn (gyro) and 3D magnetic field data is in sensor-fixed coordinate system (***S***) or (***O***).

The units of the calibrated data output are as follows:

Table 15: Output specifications inertial and magnetometer data outputs

Vector	Unit
Acceleration (DataID 4020)	m/s^2
Angular velocity (rate of turn) (DataID 0x8020)	rad/s
Magnetic field (DataID 0xC020)	a.u.(arbitrary units) normalized to earth field strength)

Calibrated data has been going through Strapdown Integration and Inverse Strapdown Integration.

5.9.4 Free acceleration

Free acceleration (Data ID 0x4030) is the acceleration in the local frame from which the local gravity is deducted. Output is in m/s^2.

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5.9.5 Uncalibrated raw output mode

The MTi can give a sensor component readout output (SCR, DataID 0xA010 for the sensors data and 0xA020 for the gyroscope temperatures), i.e. digitized voltages of all sensors, before they are filtered or calibrated using Xsens' proprietary firmware and calibration parameters. These sensors are the gyroscopes (rate of turn), accelerometers (acceleration), magnetometer (magnetic field), barometer (static pressure) and temperatures (gyroscope temperatures and a general temperature sensor). When selecting sensor component readout, the following outputs are available:

Table 16: Output specifications Sensor Component Readout (SCR)

Sensor	Digital/analog	Unit	Maximum frequency
Gyroscopes	Analog sensor, 16 bit ADC	2-byte integer	2000 Hz
Accelerometers	Analog sensor, 16 bit ADC	2-byte integer	2000 Hz
Magnetometer	Digital sensor	a.u.	100 Hz
Barometer	Digital sensor	Pa	50 Hz
Temperature sensors	Analog sensor, 12 bit ADC	ºC	1 Hz

Note that these SCR-values of the gyroscopes and accelerometers are not calibrated for offset, gain, misalignment and temperature. Also, coning and sculling compensation is not applied. It is possible to post-process SCR data with MT Manager, and this output is very suitable if you need to perform your own calibration. Note that this output cannot be combined with any other output.

5.10 Reset of reference co-ordinate systems

In some situations, it may be that the MT sensor axes are not exactly aligned with the axes of the object of which the orientation has to be recorded. It may be desired to retrieve the orientation and/or calibrated inertial data in different sensor-fixed frame (S' instead of S) or a different earth-fixed local frame (L' instead of L). Refer to https://base.xsens.com/hc/en-us/articles/115004491465 for more information on the available orientation resets.

5.11 Timestamp and packet counter output

Each data message can be accompanied by a packet counter and/or timestamp. Refer to [LLCP] for detailed information on the various time outputs.

5.12 Status byte

The status byte includes information about the status of the MTi, its sensors, the filter and user inputs. Refer to [LLCP] for detailed information on the Status Word output.

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6 Communication

Communication with the MTi is done via the binary Xbus communication protocol, except for data coming from the MTi device in ASCII format (NMEA). The communication protocol is extensively documented in [LLCP].

6.1 Communication Timing

For many applications it is crucial to know exactly the various delays and latencies in a system. This has been extensively discussed in https://base.xsens.com/hc/en-us/articles/209306289.

6.2 Triggering and synchronization

In case multiple systems are used during a measurement it is important to have the measurement data synchronized between the systems. Processing synchronised data is much easier because there is no need to resample the data to compensate for timing inaccuracies like clock drift and clock deviations. Synchronization using multiple systems involves 2 important issues: starting the measurement at the same time and having a fixed time relationship of the sampling instances. Refer to https://BASE.xsens.com for more information on triggering: https://base.xsens.com/hc/en-us/articles/211592185

6.3 Internal clock accuracy

6.3.1 Clock of MTi's without GNSS receiver

The internal clock jitter of the MTi is less than 25ns.

The internal clock of the MTi which generates the sample timing based on the set sample period is accurate to ±10 ppm with a maximum of ±15 ppm (this differs per MTi) over the temperature operating range. Using a typical MT (with an accuracy of 10 ppm), this means that the worst case deviation after a 1 hour log is ± 0.036 seconds (= 3600 s · 10 ppm) or 15 sample counts in 1,440,000 at 400 Hz sample rate (± 25 ns/data packet @ 400 Hz).

6.3.2 Clock of MTi-G-710

In the event that the MTi-G-710 has a GNSS fix the bias of the clock will be estimated and on the long term there will be no deviation from GPS time. On the short time scale, the clock jitter is the determining factor. Note that only GPS time pulses (not other GNSS reference times) are used to determine the time reference. This clock bias estimation will improve the accuracy of the crystal used in the MTi-G-710, under normal operating conditions to <1ppm.
The time pulse used to correct the clock of the MTi-G has minor inaccuracies, caused by the following:

- Delay caused by distance between antenna phase centre to input pin of the GPS receiver module in the MTi-G-710. The cable delay is 5.5ns/m for PTFE, resulting in 16.5ns delay with the development kit antenna.
- Quantisation loss, clock of 23.104MHz, results in a resolution of 43ns.
- Rise time of timepulse 7-25ns, best results when loaded with a high impedance.
- Software delay, for handling the time pulse interrupt clock_ticks/300Mhz.

Delay caused by the antenna cable length is compensated for in the GNSS receiver, but will vary with cable length.

The internal clock jitter of the MTi is less than 25ns. The internal clock of the MTi which generates the sample timing based on the set sample period is accurate to ±10 ppm with a maximum of ±15 ppm (this differs per MTi) over the temperature operating range, if there is no availability of GPS. Using a typical MT (with an accuracy of 10 ppm), this means that the worst case deviation after a 1 hour log is ± 0.036 seconds (= 3600 s · 10 ppm) or 4 sample counts in 360,000 at 100 Hz sample rate (± 0.1 µs/sample @ 100 Hz).

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6.4 Serial Connection Settings

6.4.1 Serial or USB communication

The MTi has a parallel serial (RS232/RS422/RS485 or alternative UART) and USB interface. However, it is not possible to have communication on both the serial and USB interfaces simultaneously. Therefore, the MTi wakes up as a serial device, unless USB is detected. When a USB interface is detected, the communication will be done via that USB interface.

Default settings for serial connection can be found in [LLCP].

6.4.2 Transceiver voltage levels

The MTi's RS232 transceiver has RS232 compliant output levels and is compatible with TIA/EIA-232-F specifications. The MTi's RS485/RS422 transceiver has RS485 compliant output levels and is compatible with TIA/EIA-485-A specifications. The differential lines of the RS422/RS485 communication are terminated with a 120Ω resistor.

For completeness, the input and output voltage levels are listed below:

Table 17: Transceiver voltage levels

	Low value (binary 1)	High value (binary 0)
RS232 RX (sensor) [7]	< 0.8 V	> 2.5 V
RS232 TX (sensor)	< -5.0 V[8]	> 5.0 V[9]
RS422/RS485 RX (sensor) [10] Differential	< -0.2 V	> 0.2 V
RS422/RS485 TX (sensor)[11] Differential	< -2 V	> 2 V

[7] typical hysteresis is 0.4V
[8] typical value @ 25ºC and load of 3kΩ is -5.7 V
[9] typical value @ 25ºC and load of 3kΩ is 6.2 V
[10] typical hysteresis is 25mV
[11] with a total differential load resistance of 50Ω (MTi already has 120Ω termination resistance)

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7 Physical Specifications

7.1 Physical properties overview

All products of the MTi product range have the same mechanical and communication interfaces. Note that the RS422 version does not have an on-board USB interface.

Table 18: Physical properties overview

	MTi 10-series	MTi 100-series	
	MTi-##-%A8G#	MTi-###-%A8G#	MTi-G-710-%A8G#
Communication interface:	%=2: RS232, USB, UART (OEM only) %=4: RS485, USB, UART (OEM only) %=6: RS422, UART (OEM only); no USB		
Additional interfaces:	3x SyncOut/SyncIn		
Operating voltage:	4.5-34V; OEM only: 3V3 (+/- 100 mV, max ripple 20 mVp-p)		
Power consumption (RS232):	550 mW @ 5.1V	600 mW @ 5.1V	750 mW @ 5.1V
Temperature operating range:	-40 ºC – 85 ºC		
Specified performance operating range:	0 ºC – 55ºC		
Altitude operating range:	N/A	N/A	-900 m – 9000 m (baro) < 50000 m (GNSS)
Maximum velocity:	N/A	N/A	0-515 m/s
Outline dimensions:	57 x 42 x 24 mm (W x L x H)	57 x 42 x 24 mm (W x L x H)	57 x 42 x 24 mm (W x L x H)
Weight:	55g (cased) 11g (OEM)	55g (cased) 11g (OEM)	58g (cased) 11g (OEM)
MTBF	300.000 hrs (Ground Benign)	300.000 hrs (Ground Benign)	300.000 hrs (Ground Benign)

7.2 Power supply

7.2.1 Power consumption specification

The power consumption depends on the interface used. Table 19 shows the power consumption with respect to the interface.

Table 19: Power consumption depending on communication interface

Product series	USB	RS232	RS422/RS485
MTi 10-series	478 mW	512 mW	581 mW
MTi 100-series	522 mW	559 mW	640 mW
MTi-G-710	664 mW	717 mW	871 mW

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7.2.2 Alternative 3V3 power supply

In case there is only a 3V3 power supply available or when there are significant constraints on the power consumption, there is the possibility for users of the OEM version to operate the MTi on 3V3.

Note that this is only possible on the OEM version and that the power circuit is not protected. Furthermore, there are constraints on the ripple and voltage level itself, see section 7.1 for power supply requirements. It is advised to use the standard power supply of 4.5-34V.

The hardware of the MTi is designed in such a way that power is automatically drawn from either the standard VCC (4.5-34V) or the alternative 3V3 power. When there is a voltage applied both to the standard VCC and the alternative 3V3, the MTi will not start up.

Refer to section 7.3 for the pin configuration, including 3V3.

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7.3 Mechanical and electrical interface specifications

7.3.1 Encased MTi connectors overview

The MTi is available as OEM version and encased version. The encased version has an external 9-pins connection for power and data and one SMA connector for the antenna (MTi-G-710 only). The colour of the hexagonal nut, together with the colour of the base plate, indicates whether the MTi is an MTi 10-series or MTi 100-series. A grey/silver base plate and nut indicates an MTi 10-series, a dark grey/black base plate and nut indicates an MTi 100-series.

7.3.1.1 Power and data connection

For connection with the Fischer receptacle (Fischer part number: DBPU 102 A059-130), Xsens supplies two cables. The cable with product code CA-USB-MTi can be used to connect the MTi to any USB port (except for MTi's with an RS422 interface). The cable with product code CA-MP2-MTi allows access to all 9 pins of the Fischer connector on the MTi.

7.3.1.2 Pin configuration casing receptacle

CA-USB-MTi

Connect the cable to the MTi and the USB cable to any USB port. Under Windows 7, the Xsens USB driver will be automatically installed if not already installed. In order to lock the CA-USB-MTi to the casing (this will prevent vibration of the push-pull sleeve to be transferred to the casing and MEMS sensors), screw the round nut clockwise. Be sure not to tighten too fast. To unplug the CA-USB-MTi, screw the round locking counter clock wise and pull the connector out of the receptacle by sliding the sleeve of the connector backwards.

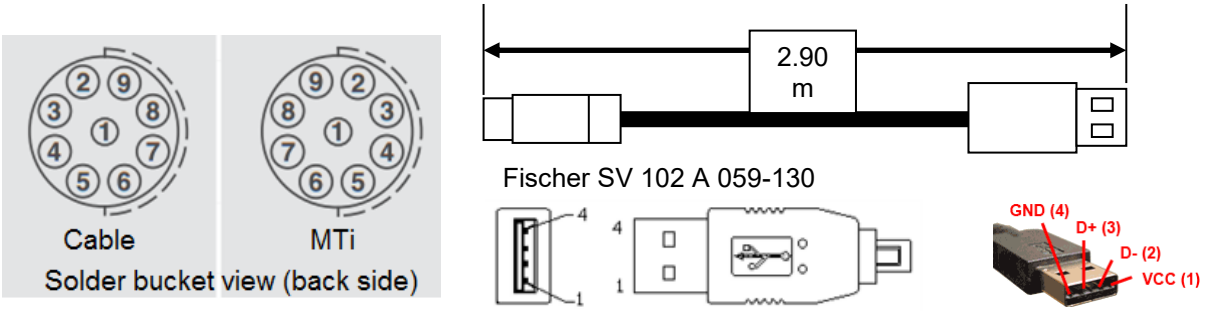

Figure 10: Drawing of CA-USB-MTi

Table 20: Pin configuration CA-USB-MTi

Functionality	Wire colour	Wire gauge	Fischer pin #	USB pin #	10-pins OEM header
GND	Black	AWG26	1	4	4, 8
NC			2		
NC			3		
Vin	Red	AWG26	4	1	1
NC			5		
NC			6		
NC			7		
USB DP (D+)	Green	AWG28	8	3	9
USB DM (D-)	White	AWG28	9	2	7

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CA-MP2-MTi

Cable CA-MP2-MTi allows for full control of the MTi. Hardware synchronization options are available, as well as easy access to the serial interface. Although the USB connection wires of the CA-MP2-MTi are connected it is not recommended to use the USB connection as the shielding of the CA-MP2-MTi cable is not attached to the Molex header. The part number of the Fischer connector is SS 102A059-130 Gunfire.

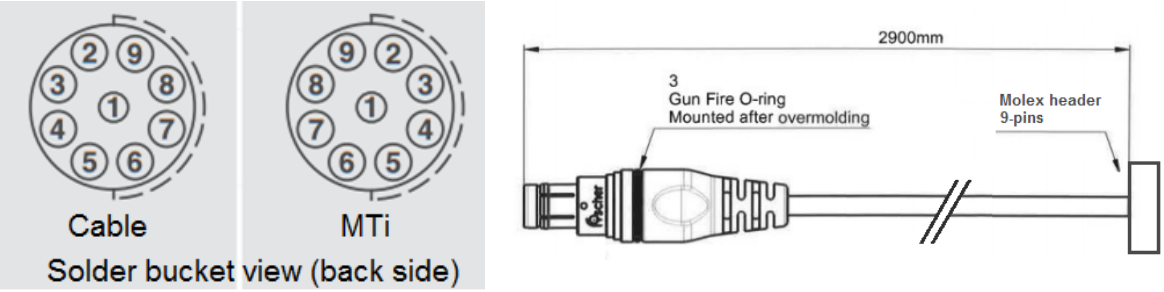

Figure 11: Drawing of CA-MP2-MTi

Table 21: Pin Configuration table CA-MP2-MTi

Functionality	Wire colour CA-MP2	Wire gauge	Fischer pin no.	Molex pin no.	10-pins header (OEM)
GND	Black	AWG28	1	2	4,8
RS232 TX / RS422_Z (TX-) / RS485_B (TxD/RxD-)	Yellow	AWG28	2	4	5
RS232 RX / RS422_Y (TX+) / RS485_A (TxD/RxD+)	Grey	AWG28	3	5	3
Vin (4.5-30V)	Red	AWG28	4	1	1
SyncIn[12]	Blue	AWG28	5	7	2
SyncOut	Pink	AWG28	6	9	6
ClockSync	Brown	AWG28	7	8	10
USB DP (D+) / RS422_A (RX+)	Green	AWG28	8	3	9
USB DM (D-) / RS422_B (RX-)	White	AWG28	9	6	7
Shielding	SH	N/A	SH	N/A	

7.3.1.3 GNSS Antenna

The MTi-G-710 requires an active patch antenna that can be connected to SMA connector in the front panel of the MTi-G-710. See also https://base.xsens.com/hc/en-us/articles/209434509.

[12] SyncIn referred to as “In 1“ in software.

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7.3.2 OEM connections overview

7.3.2.1 Power and data

All MTi's are available as OEM-board as well. The connection from the OEM board to the push-pull connector of the encased version is a flexible PCB, which has put to vibration test according to MIL-STD 202. The OEM board contains two headers, one 10-pins header and one 14-pins header. Details of the headers are:

Table 22: Part numbers headers on MTi OEM

Description	Manufacturer	Part number
5x2 (10 pins dual row) box header, pitch 1.27 mm	Samtec	FTS-105-01-F-DV-P-K
3x2 (6 pins dual row) box header, pitch 1.27 mm	Samtec	FTS-103-01-F-DV-P-K

The two headers have several functions, some are reserved for future use. The 10-pins header offers basic functionality, the 14-pins header features advanced options. Note that MTi's with an RS422 interface don't have a USB interface. Make sure to always apply a common ground (see https://base.xsens.com/hc/en-us/articles/211592185-Synchronization-with-the-MTi).

Table 23: Pin connections OEM headers

Pin	Functionality		Pin	Functionality
10_1	Vin (4.5-34V)		6_1	GND
10_2	SyncIn		6_2	Vin (3V3)
10_3	RS232 RX / RS422_Y (TX+) / RS485_A (TxD/RxD-)		6_3	UART_TX
10_4	GND		6_4	UART_RX
10_5	RS232 TX / RS422_Z (TX-) / RS485_B (TxD/RxD+)		6_5	GND
10_6	SyncOut		6_6	Reserved
10_7	USB DM (D-) / RS422_B (RX-)			
10_8	GND			
10_9	USB DP (D+) / RS422_A (RX+)			
10_10	ClockSync			

Pin 1 of the 10-pins header and pin 1 of the 6-pins header are labelled on the PCB.

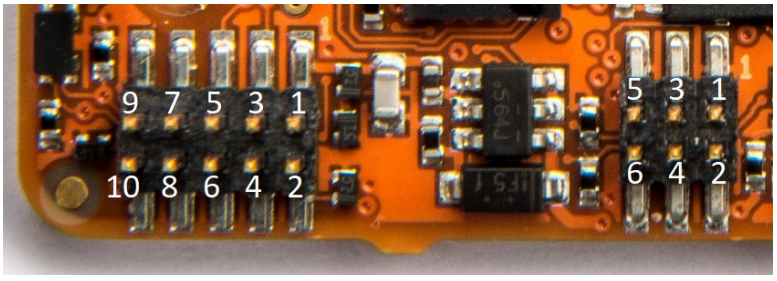

Figure 12: The pins of the headers on the MTi-OEM are cearly marked

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Start-up procedure
The MTi starts up with communication over the serial (RS232/RS485/RS422) interface by default:

- If alternative UART is set, the MTi will switch to alternative UART
- If USB is detected, the MTi will switch to USB communication
- WakeUp message sent
- If WakeUp is not interrupted, the MTi will be put in Measurement Mode.
- Plugging in USB at any time will let the MTi switch to USB immediately.

When for some reason, the MTi becomes unresponsive in serial mode and unplugging/connecting the MTi does not solve the communication problem, just connect the MTi to a USB port and check the settings of the device. For RS422 devices, there is a restore communication procedure (see [MTM], not available for alternative UART).

Alternative UART
With the MTi-OEM, the alternative UART is available. This UART interface is a direct serial interface with 3V3 CMOS levels. It can be used e.g. on embedded systems. To configure the MTi to communicate via this alternative UART, use the command SetExtOutputMode (see [LLCP]). This setting will be stored in the non-volatile memory, so the device will start up communicating over this alternative UART, unless a USB connection is detected.

7.3.2.2 GNSS receiver

The MTi-G-710 needs an active antenna. The connection on the OEM board of the MTi-G-710 is done with an u.FL miniature coax. See also https://base.xsens.com/hc/en-us/articles/209434509.

7.3.2.3 Connecting with the OEM board

Connecting to the OEM board is possible by using sockets with a pitch of 1.27 mm. Notable manufacturers are Samtec, Molex and Hirose. Two examples of such sockets are:

Table 24: Part numbers for sockets that fit the headers on the MTi OEM

Socket	Manufacturer	Part number	Distributor Part number
10-pins 1.27 mm pitch	Samtec	FFSD-05-01-N	Farnell: 1753841
6-pins 1.27 mm pitch	Samtec	FFSD-04-01-N	Digikey: FFSD-04-01-N

Note that there is no Samtec connector (cable part) for a 6-pins receptacle. This means that you can use an 8-pins or 10-pins header.

These connectors can be connected to ribbon cables without tools to make a cable like below. On the right is an application of such a cable.

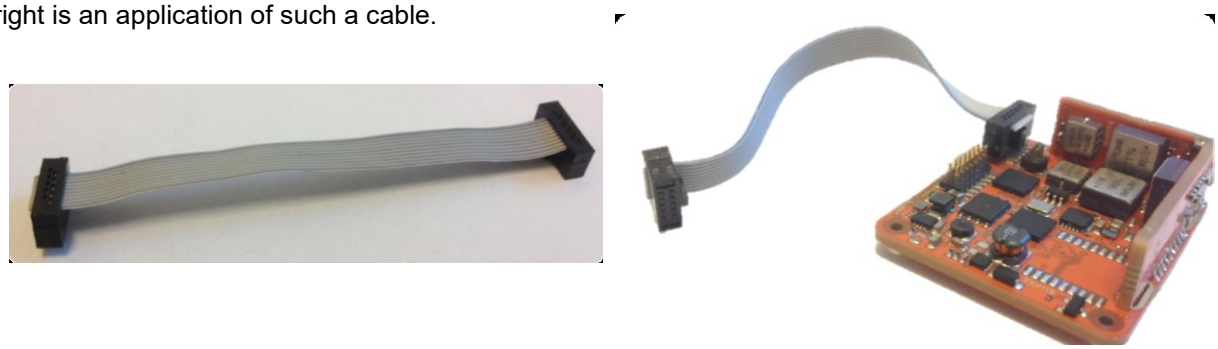

Figure 13: Standard ribbon cables can be used for connecting the MTi OEM to another board

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7.3.3 Additional interface specifications

The MTi has three IO lines on the main 10 pins connector (and thus on the 9-pins external Fischer connector). These 3 lines can be configured individually for synchronization purposes (see section 6.2). Make sure to always apply a common ground (see https://base.xsens.com/hc/en-us/articles/211592185-Synchronization-with-the-MTi)

Table 25: Interface specifications of the synchronization lines

Fischer pin nr	OEM-1 pin nr	Name	Value high/low	Input resistance/ output load	Absolute max input
5	2	SyncIn	Low value: 0 - 0.8 V High value: 2.5 -20 V	Input resistance: ~100 kΩ	0-20V
6	6	SyncOut	Low value: 0 - 0.4 V High value: > 2.9 V	Output load: >330 Ω	N/A
		1 PPS	Low value: 0 - 0.4 V High value: > 2.9 V	Output load: >825 Ω	N/A
7	10	ClockSync	Low value: 0 - 0.8 V High value: 2.5 -20 V	Input resistance: ~100 kΩ	0-20V

For the descriptions of the synchronization functions, see [LLCP].

7.3.4 Cable specifications

Cables CA-MP2-MTi and CA-USB#-MTi are custom made for Xsens. The outer diameter is 0.85 +/- 0.10 mm. The PUR jacket conforms to standard UL Style 20549.

The minimum bending radius is 4.75 mm (static) and 9.5 mm (flexible).

7.3.5 Using the MTi Mk5 with an external USB converter

Xsens offers a cable to use the MTi with USB and SyncIn. This cable also offers an interface via a virtual COM-port instead of WinUSB. The cables in Table 26 can be ordered from the Xsens' webshop (https://shop.xsens.com).

Table 26: Wire colours in the USB converters

Wire color	Receptacle pin no.	CA-USB2-MTI (RS232)	CA-USB4-MTI (RS485)	CA-USB6-MTI (RS422)
Red	1	Vin (4.5-34V)	Vin (4.5-34V)	Vin (4.5-34V)
Black	2	GND	GND	GND
Green	3	USB DP (D+)	USB DP (D+)	RS422_Y
Yellow	4	RS232 TX	RS485_A (TxD/RxD-)	RS422_Z
Grey	5	RS232 RX	RS485_B (TxD/RxD+)	RS422_A
White	6	USB DM (D-)	USB DM (D-)	RS422_B
Blue	7	SyncIn / Active	SyncIn / Active	SyncIn / Active
Brown	8	Clock sync In	Clock sync In	Clock sync In
Pink	9	SyncOut	SyncOut	SyncOut

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7.4 Housing mechanical specifications

The top casing of the MTi is made of anodized Aluminum 6082. The bottom plate is made of anodized Aluminum 6082 The MTi connector socket and housing assembly features rubber O-ring sealing. The MTi-100 series feature a vent that allows for the inside pressure to be the same as the ambient pressure without compromising the ingress protection.

7.4.1 Environmental protection of the housing

All encased MTi's are designed to withstand usage in application where dust and occasional water splashing can be expected. However, Xsens in house testing has confirmed that the casing and connector can withstand temporary environmental circumstances equivalent to Protection Classification IP67 (sealed against dust, 30 minutes immersion at depth of 1 m).

7.4.2 Dimensions MTi

The MTi 10-series and the MTi 100-series (including MTi-G-710) have an identical footprint and (position of the) connector. Differences in casings are limited to colour, barometer holes (MTi 100-series only) and SMA connector (MTi-G-710 only).

7.4.3 Mounting the MTi-OEM

The MTi-OEM has four mounting holes (holes for M1.6 screws). In order to lower and tighten the screws, it is convenient to use a piece of heat shrink tube placed over the holes.

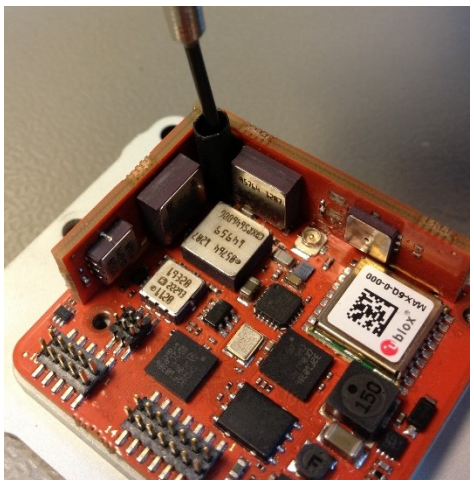

Figure 14: Using a heat shrink tube to position the mounting screws

Make sure when mounting the MTi to maintain a clearance of at least 3.4 mm +/- 0.1 mm from the surface of the PCB.

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7.4.4 MTi 10-series technical drawing

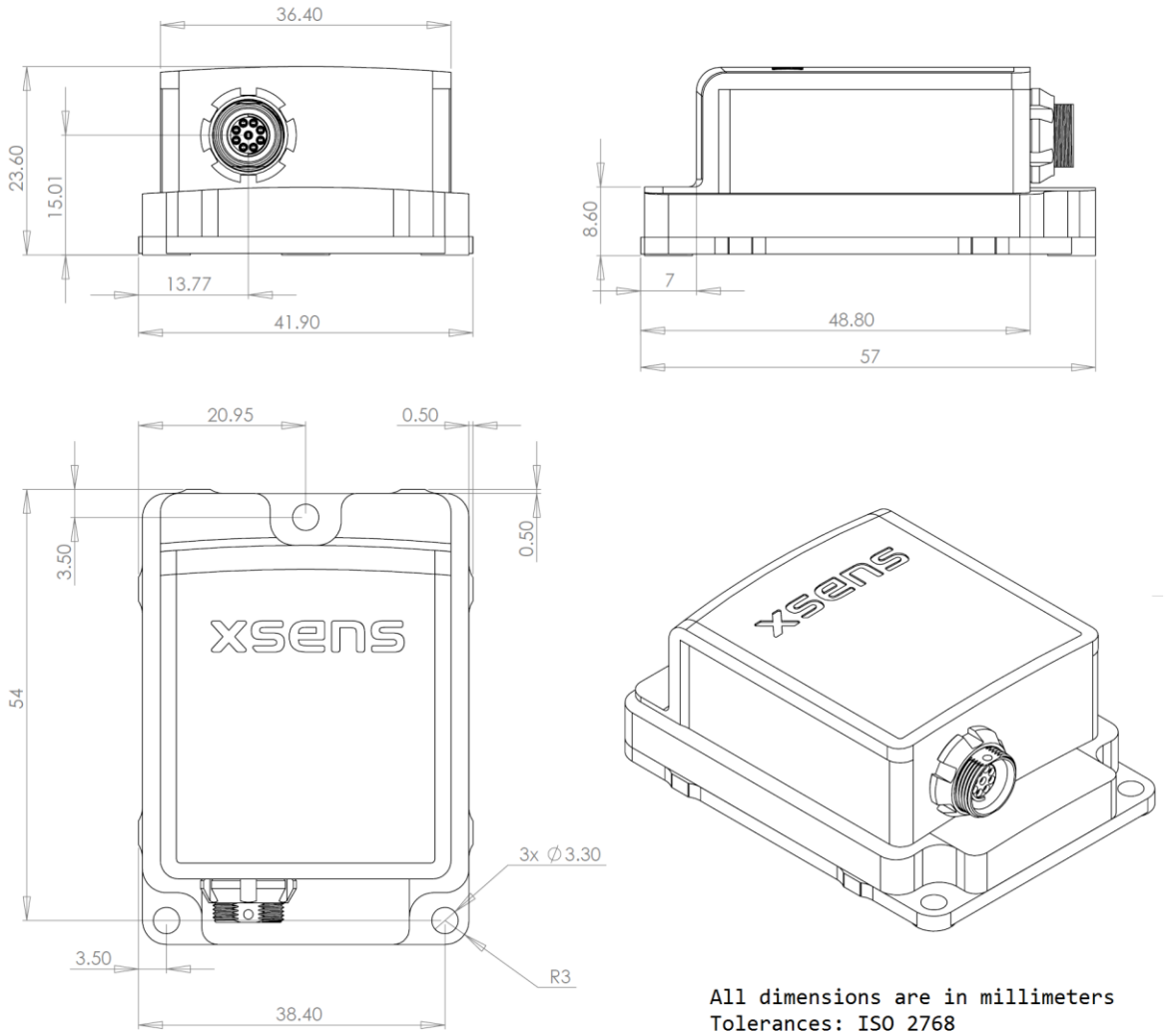

Figure 15: MTi 10-series technical drawing

CAD drawings (STEP) are available at BASE:
https://base.xsens.com/hc/en-us/articles/202295371-3D-models-of-MTi

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7.4.5 MTi 100-200-300 technical drawing

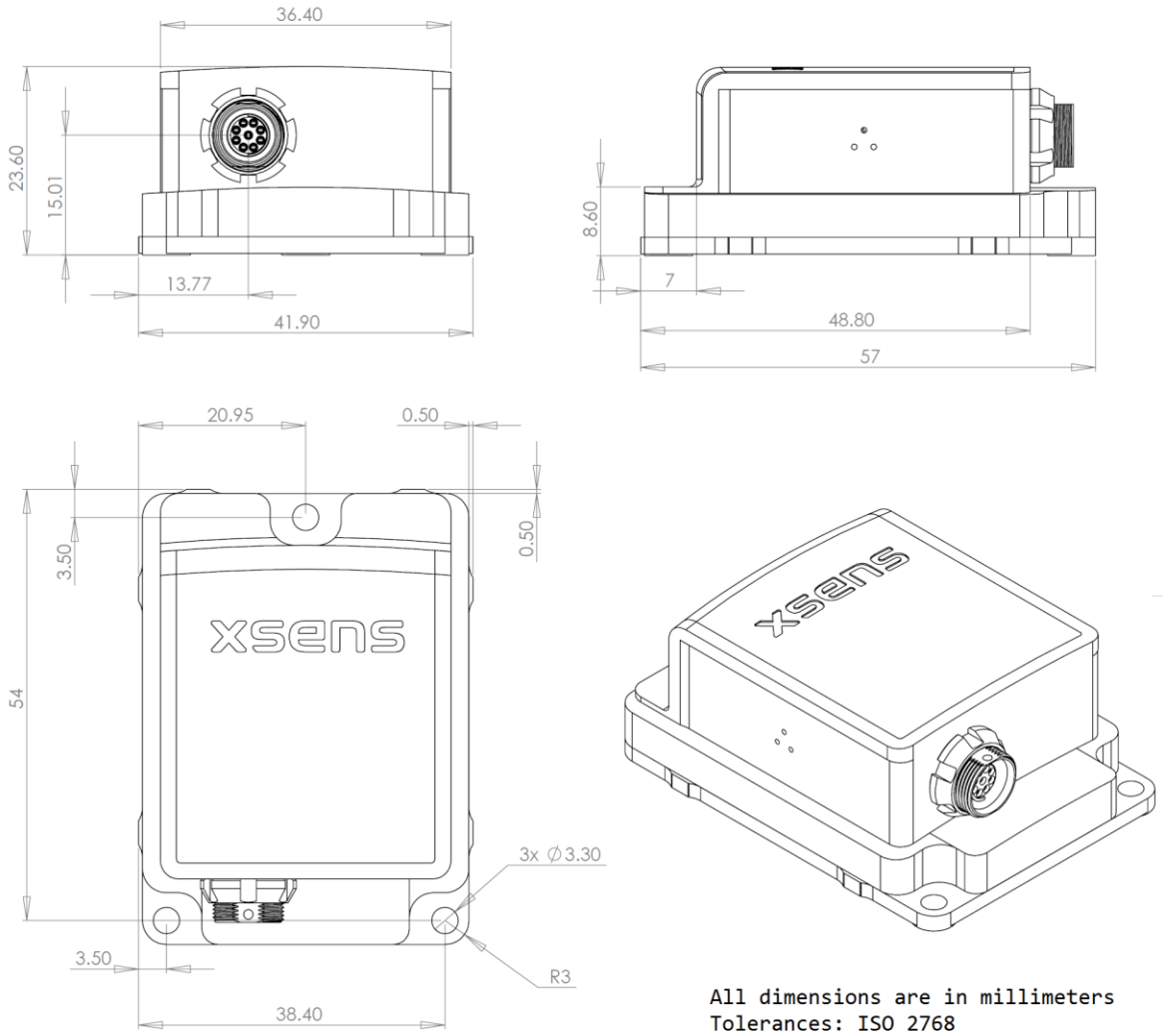

Figure 16: MTi 100-series technical drawing

CAD drawings (STEP) are available at BASE:
https://base.xsens.com/hc/en-us/articles/202295371-3D-models-of-MTi

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7.4.6 MTi-G-700/710 technical drawing

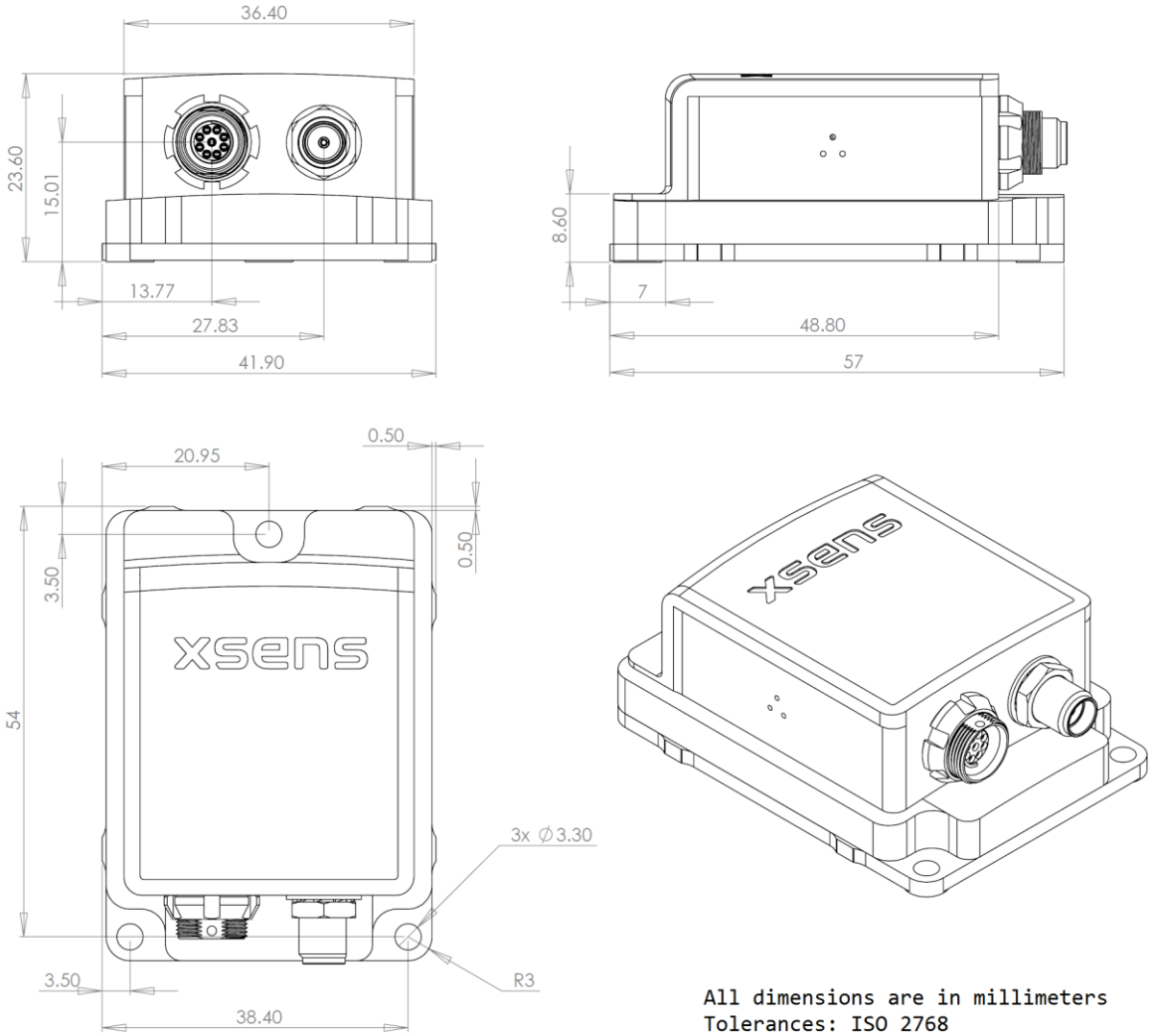

Figure 17: MTi-G-710 technical drawing

CAD drawings (STEP) are available at BASE:
https://base.xsens.com/hc/en-us/articles/202295371-3D-models-of-MTi

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7.4.7 MTi OEM technical drawing

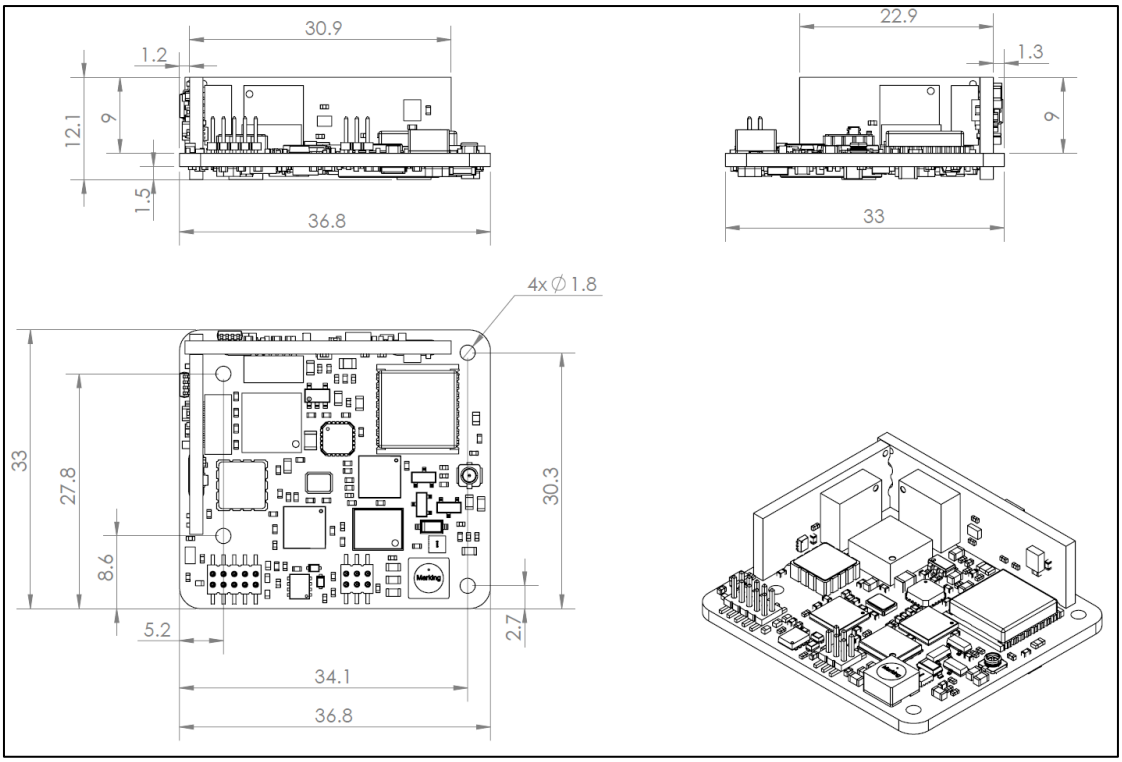

Figure 18: MTi OEM technical drawing

CAD drawings (STEP) are available at request via sales@xsens.com

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8 Important notices

8.1 Safety instructions

- It is recommended to study the instructions below
- Do not place the MTi near strong magnetic fields.
- Do not use cables or connectors other than described in this manual.

8.2 Absolute maximum ratings

Stresses above Absolute Maximum Ratings may cause permanent damage to the device.

Shock (any axis):	20000 m/s^2 (2000 g) 0.5 ms (half-sine)
Input Voltage:	-60 V … 34 V
Alternative Input Voltage:	3.3 V +/- 0.1 V
ESD:	8 kV; above 2 kV possibility of data loss and/or temporary connection loss
Interface inputs:	-25 V … 25 V (RS232 RX) -11.7 V … 15 V (RS422, RS485 A and B inputs) -0.3 V …3.6 V (alternative UART)
SyncIn:	0 – 20 V
Operating/Storage Temperature:	-40 °C … 85 °C
Humidity:	Casing is IP67 (for OEM: 95% max, non-condensing)

Stresses beyond those listed here may cause permanent damage to the device. Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

NOTE: Drops onto hard surfaces can cause shocks of greater than 20000 m/s^2 (2000 g) exceed the absolute maximum rating of the device. Care should be taken when handling to avoid damage. Drops causing shock greater than absolute maximum ratings may not destroy the device but will permanently alter the properties of the physical motion sensors, which may cause the device to become inaccurate.

8.3 Maintenance

The MTi will not require any maintenance if properly used (see also section 8.1 and 8.2). However, if the Motion Tracker is not functioning according to the specifications please contact Xsens or your local distributor (www.xsens.com/support).

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8.4 RoHS compliance

April 2017

ROHS2 COMPLIANT STATEMENT

To Whom it may concern,

With this letter Xsens certifies that all Xsens products are RoHS2 6/6 compliant.

Xsens Technologies B.V.

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8.5 REACH statement

September 2016

REACH STATEMENT

To Whom it may concern,

We hereby confirm that;

- Xsens Products do not contain substances on the REACH SVHC candidate list in concentrations greater than 0.1% by weight per article.

- Xsens Products do not contain substances on Annex XIV and Annex XVII of Regulation (EC) No 1907/2006.

- Xsens Products are not intended to release any substances under normal and reasonably foreseeable conditions of use.

- Xsens will continue to monitor the developments of the REACH legislation to insure continued compliance and update Customers of any changes.

- Xsens has been compliant since the REACH legislation became in force (1st of June 2007).

- Xsens is in compliance with REACH SVHC update – June 2016.

Kind regards,

Xsens Technologies B.V.

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8.6 Warranty and liability

Xsens Technologies B.V. warrants the products manufactured by it to be free from defects in material and workmanship for a period of two years from the date of delivery. Products not subjected to misuse will be repaired, replaced or credit issued at the sole option of Xsens Technologies B.V. Contact Xsens via www.xsens.com/support for return material authorization (RMA) prior to returning any items for calibration, repair or exchange. The product **must be returned in its original packaging** to prevent damage during shipping.

The warranty shall not apply to products repaired or altered or removed from the original casing by others than Xsens Technologies B.V. so as, in Xsens Technologies B.V. opinion, to have adversely affected the product, products subjected to negligence, accidents or damaged by circumstances beyond Xsens Technologies B.V.'s control.

NOTE: Xsens reserves the right to make changes in its products in order to improve design, performance, or reliability.

Subject to the conditions and limitations on liability stated herein, Xsens warrants that the Product as so delivered shall materially conform to Xsens' then current specifications for the Product, for a period of one year from the date of delivery. ANY LIABILITY OF XSENS WITH RESPECT TO THE SYSTEM OR THE PERFORMANCE THEREOF UNDER ANY WARRANTY, NEGLIGENCE, STRICT LIABILITY OR OTHER THEORY WILL BE LIMITED EXCLUSIVELY TO PRODUCT REPAIR, REPLACEMENT OR, IF REPLACEMENT IS INADEQUATE AS A REMEDY OR, IN XSENS' OPINION IMPRACTICAL, TO REFUND THE PRICE PAID FOR THE PRODUCT. XSENS DOES NOT WARRANT, GUARANTEE, OR MAKE ANY REPRESENTATIONS REGARDING THE USE, OR THE RESULTS OF THE USE, OF THE PRODUCT OR WRITTEN MATERIALS IN TERMS OF CORRECTNESS, ACCURACY, RELIABILITY, OR OTHERWISE. Xsens shall have no liability for delays or failures beyond its reasonable control.

8.7 Customer Support

Xsens is glad to help you with any questions you may have about the MTi, or about the use of the technology for your application. The fastest way is Xsens' Help Center, where engineers and other Xsens users meet. Please visit this Help Center, contact Xsens' distributor or if you are a direct customer of Xsens our Customer Support:

- ➔ Help center: https://base.xsens.com
- ➔ Support page (software downloads): https://www.xsens.com
- ➔ Distributor network: https://www.xsens.com/en/company-pages/company/distributors
- ➔ Telephone EMEA/Pacific: +31(0)88-9736700 (+31 88 XSENS 00)
- ➔ telephone US (Los Angeles, CA): +1 310-481-1800

To be able to help you, please mention your Motion Tracker **Device ID** (on the side of the device) in your e-mail.

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