



Data sheet MTi 1-series

3D AHRS/VRU/IMU module

Document MT0512P, Revision A, 8 Jul 2015

Features

- Full-featured AHRS on 12.1 x 12.1 mm module
- Roll/pitch accuracy (dynamic) 1.0 deg
- Heading accuracy 2.0 deg
- Minimal requirements on host processor
- Uniform interface over product lifetime
 - No hardware/software interface changes
 - No EOL
- Always best-in-class inertial sensors incorporated
- Industry-leading signal processing pipeline (AttitudeEngine™) with vibration-rejection
- Robust and accurate orientation algorithm (XKF3™)
- API-compatible with all Xsens' Motion Trackers
 - Drivers and examples on ARM® mbed™
- Low power (45 mW @ 3.0V)

Applications

- Miniature aerial vehicles
- Heavy machinery/agriculture
- Robotics, pedestrian dead-reckoning
- Industrial grade VR/AR, HMD's and handheld devices

Related Resources

- www.xsens.com/MTi-1-series
- MTi 1-series DK User Manual (MT0513P)
- MT Low Level Communication Protocol Documentation (MT0101P)
- MTi White Paper: Next generation Xsens Motion Trackers for Industrial applications

Description

The MTi 1-series is a module outputting 3D orientation, 3D rate of turn, 3D accelerations, and 3D magnetic field, depending on the product configuration. It is available as an Inertial Measurement Unit (IMU), Vertical Reference Unit (VRU) or Attitude and Heading Reference System (AHRS).

This fully-functional self-contained module is easy to design in with limited hardware components to be added. The fully documented, industry-standard communication protocol allows for customization of the data message in terms of data, frequency and output format. Signals are fully processed onboard, requiring very little resources from the host and is very well suited for applications in simple MCU-operated environments. The host can read-out the data over SPI, I²C or UART.

With a roll/pitch accuracy of 1.0° RMS and yaw accuracy of 2° RMS under dynamic conditions, the output is excellent for control and stabilization of any object and navigation of e.g. unmanned vehicles.

| Product | MTi-1 IMU | MTi-2 VRU | MTi-3 AHRS |
|------------------|--------------|--------------|---------------|
| Motion data | • | • | • |
| Magnetic field | • | • | • |
| Roll/pitch | | • | • |
| Heading tracking | | • | • |
| Referenced yaw | | | • |

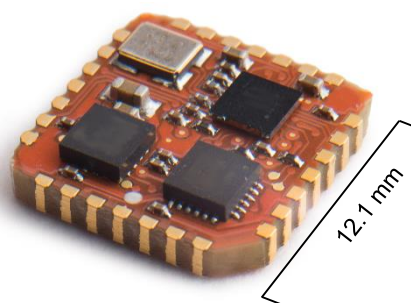


Figure 1: MTi 1-series

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1 General information

1.1 Ordering Information

| Part Number | Output | Package | Packing Method |
|------------------|---|-------------------------------|----------------|
| MTi-1-8A7G6 | IMU; inertial data | PCB, JEDEC-PLCC-28 compatible | Tray, MOQ: 20 |
| MTi-2-8A7G6-TR20 | VRU; inertial data, roll/pitch (referenced), yaw (unreferenced) | PCB, JEDEC-PLCC-28 compatible | Tray, MOQ: 20 |
| MTi-3-8A7G6-TR20 | AHRS; inertial data, roll/pitch/yaw | PCB, JEDEC-PLCC-28 compatible | Tray, MOQ: 20 |
| | | | |
| MTi-3-8A7G6-DK | Development kit for MTi 1-series, including MTi-3-8A7G6 | | Single unit |

Other packaging methods available on request (>1k units). Contact Xsens for more information.

1.2 Block Diagram

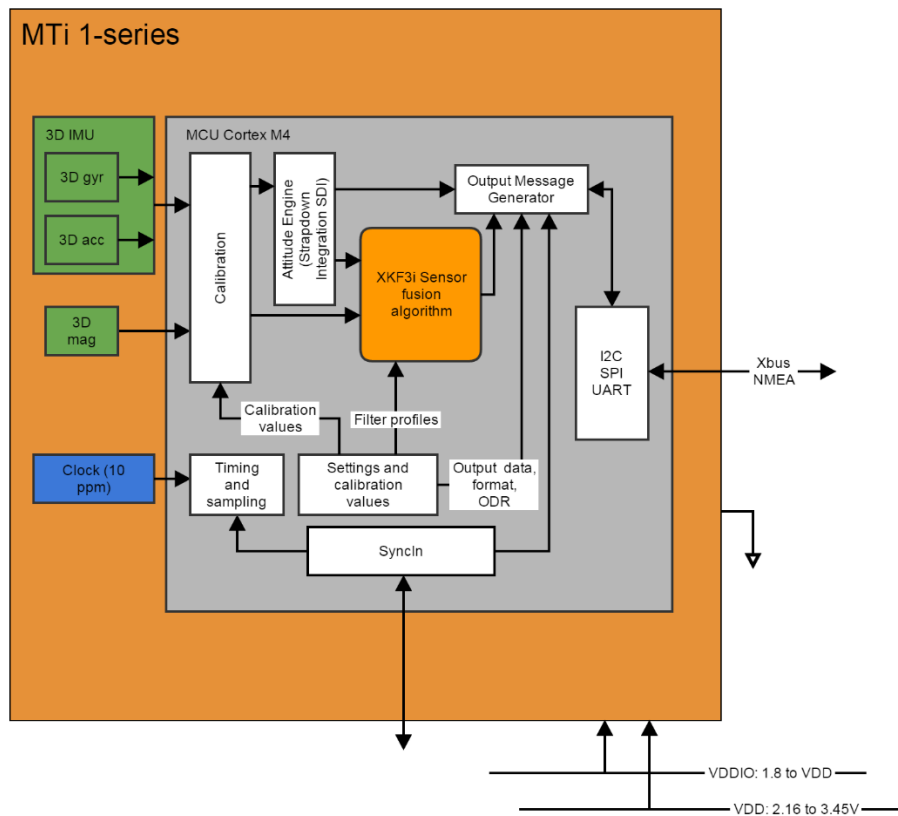


Figure 2: MTi 1-series module block diagram

1.3 Typical Application

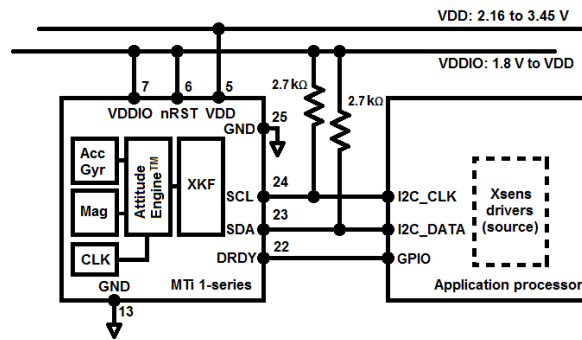
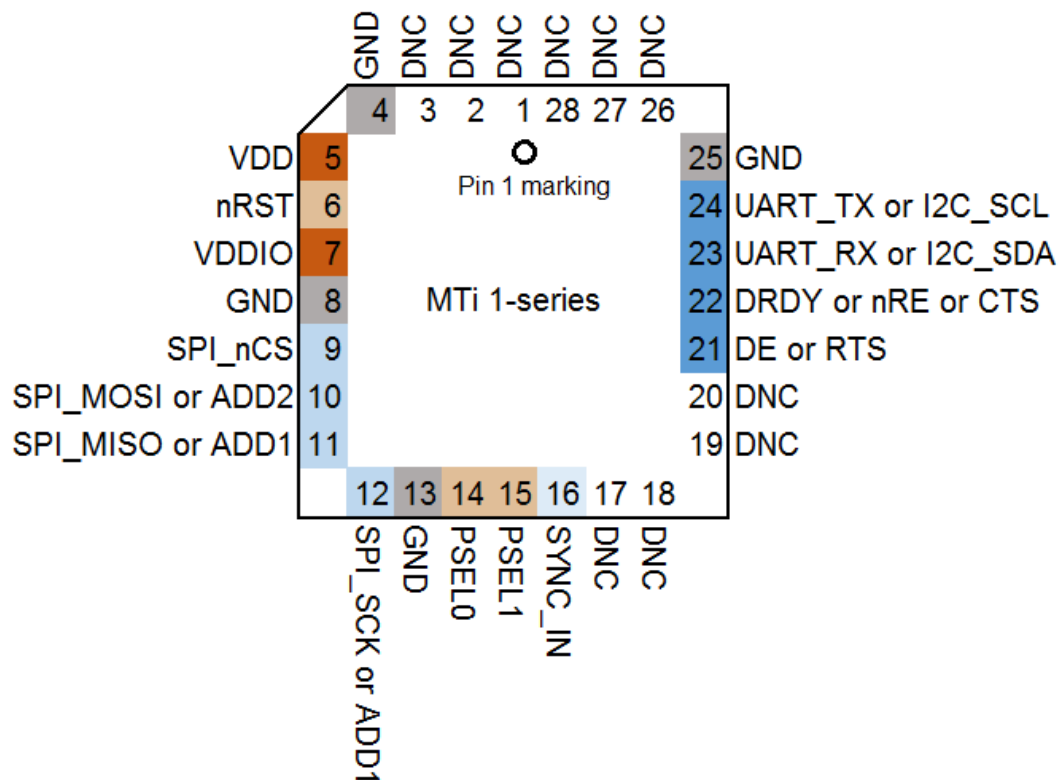


Figure 3: Typical application

1.4 Pin Configuration



1.5 Pin map

The pin map depends on the peripheral selection. See section 1.7 on how to set the peripherals.

| | PSEL: I²C | PSEL: SPI | PSEL: UART half duplex | PSEL: UART full duplex |
|----|---------------------------------|----------------------|-----------------------------------|-----------------------------------|
| 1 | DNC | DNC | DNC | DNC |
| 2 | DNC | DNC | DNC | DNC |
| 3 | DNC | DNC | DNC | DNC |
| 4 | GND | GND | GND | GND |
| 5 | VDD | VDD | VDD | VDD |
| 6 | nRST | nRST | nRST | nRST |
| 7 | VDDIO | VDDIO | VDDIO | VDDIO |
| 8 | GND | GND | GND | GND |
| 9 | DNC | SPI_DNCS | DNC | DNC |
| 10 | ADD2 ¹ | SPI_MOSI | DNC | DNC |
| 11 | ADD1 | SPI_MISO | DNC | DNC |
| 12 | ADD0 | SPI_SCK | DNC | DNC |
| 13 | GND | GND | GND | GND |
| 14 | PSEL0 | PSEL0 | PSEL0 | PSEL0 |
| 15 | PSEL1 | PSEL1 | PSEL1 | PSEL1 |
| 16 | SYNC_IN | SYNC_IN | SYNC_IN | SYNC_IN |
| 18 | DNC | DNC | DNC | DNC |
| 19 | DNC | DNC | DNC | DNC |
| 20 | DNC | DNC | DNC | DNC |
| 21 | DNC | DNC | DE | RTS |
| 22 | DRDY | DNC | nRE | CTS ² |
| 23 | I2C_SDA | DNC | UART_RX | UART_RX |
| 24 | I2C_SCL | DNC | UART_TX | UART_TX |
| 25 | GND | GND | GND | GND |
| 26 | DNC | DNC | DNC | DNC |
| 27 | DNC | DNC | DNC | DNC |
| 28 | DNC | DNC | DNC | DNC |

¹ I²C addresses, see Table 2: List of I²C addresses

² CTS cannot be left unconnected if the interface is set to UART full duplex. If HW flow control is not used, connect to GND.

1.6 Pin Descriptions

| Name | Type | Description |
|------------------|----------------------------|---|
| Power Interface | | |
| VDD | Power | Power supply voltage for sensing elements |
| VDDIO | Power | Digital I/O supply voltage |
| Controls | | |
| PSEL0 | Selection pins | These pins determine the signal interface. See table below. Note that when the PSEL0/PSEL1 is not connected, its value is 1. When PSEL0/PSEL1 is connected to GND, its value is 0 |
| PSEL1 | | |
| nRST | | Active low reset pin, connect to VDDIO if not used |
| ADD2 | Selection pins | I ² C address selection lines |
| ADD1 | | |
| ADD0 | | |
| Signal Interface | | |
| I2C_SDA | I ² C interface | I ² C serial data |
| I2C_SCL | | I ² C serial clock |
| SPI_nCS | SPI interface | SPI chip select |
| SPI_MOSI | | SPI serial data input (slave) |
| SPI_MISO | | SPI serial data output (slave) |
| SPI_SCK | | SPI serial clock |
| RTS | UART interface | Hardware flow control in UART full duplex mode (Ready-to-Send) |
| CTS | | Hardware flow control in UART full duplex mode (Clear-to-Send) |
| nRE | | Receiver control signal in UART half duplex mode |
| DE | | Transmitter control signal in UART half duplex mode |
| UART_RX | | Receiver data input |
| UART_TX | | Transmitter data output |
| SYNC_IN | Sync interface | SYNC_IN accepts a trigger which has the following functionality, depending on the configuration set in the firmware <ul style="list-style-type: none">- It sends out the latest available data message, or- It adjusts the bias of the clock onboard the MTi |
| DRDY | Data ready | Data ready pin indicates that data is available (SPI / I ² C) |

1.7 Peripheral interface selection

The MTi 1-series modules have four modes of peripheral interfacing. Only one mode can be used simultaneously and is determined by the state of peripheral selection pins PSEL0 and PSEL1 at startup. Table 1 specifies how the PSEL lines select the peripheral interface. Note that the module has internal pull-ups. Not connecting PSEL results in a value of 1, connecting PSEL to a GND results in a value of 0.

Table 1. Peripheral interface selection

| Interface | PSEL0 | PSEL1 |
|------------------|-------|-------|
| I2C | 1 | 1 |
| SPI | 0 | 1 |
| UART half-duplex | 1 | 0 |
| UART full-duplex | 0 | 0 |

1.7.1 I²C

The MTi 1-series module can be configured to act as an I²C slave. The slave address is determined by the ADD0, ADD1 and ADD2 pins. These pins are pulled-up internally so when left unconnected the address selection defaults to ADD[0..2] = 111.

Further specifications TBC, available from November 2015.

Table 2. List of I²C addresses

| I ² C address | ADD0 | ADD1 | ADD2 |
|--------------------------|------|------|------|
| 0x1D | 0 | 0 | 0 |
| 0x1E | 1 | 0 | 0 |
| 0x28 | 0 | 1 | 0 |
| 0x29 | 1 | 1 | 0 |
| 0x68 | 0 | 0 | 1 |
| 0x69 | 1 | 0 | 1 |
| 0x6A | 0 | 1 | 1 |
| 0x6B (default) | 1 | 1 | 1 |

1.7.2 SPI

The MTi 1-series module can be configured to act as an SPI slave. Detailed specifications TBC, available from November 2015.

1.7.3 UART half duplex

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

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

When the MTi is transmitting data on its TX pin it will raise both the nRE and DE lines, else it will pull these lines low.

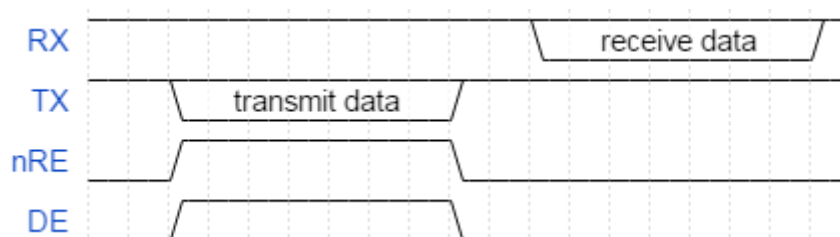


Figure 5 Behaviour of the nRE and DE lines

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

1.7.4 UART full duplex with RTS/CTS flow control

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

The CTS signal is an input for the MTi. The MTi checks the state of the CTS line at the start of every byte it transmits. If CTS is low the byte will be transmitted. Otherwise transmission is postponed until CTS is lowered. When during the transmission of a byte the CTS signal is raised then the transmission of that byte is completed before postponing further output. This byte will not be retransmitted. This behaviour is shown in the following image:

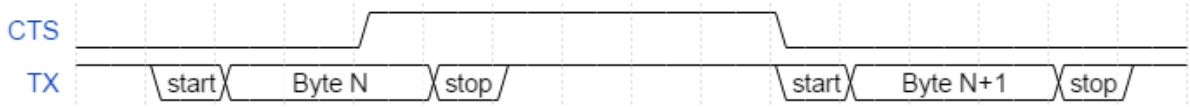


Figure 6 Data transmit behaviour under CTS

The RTS signal is an output for the MTi. If the RTS line is high, the MTi is busy and unable to receive new data. Otherwise the MTi's UART is idle and ready to receive. After receiving a byte the DMA controller of the MTi will transfer the byte to its receive FIFO. The RTS signal will be asserted during this transfer. So with every byte received the RTS line is raised shortly like shown in the following image:



Figure 7 RTS behaviour under data reception

This communication mode can be used without hardware flow control. In this case the CTS line needs to be tied low (GND) to make the MTi transmit.

1.8 Recommended external components

| Component | Description | Typical value |
|---|-----------------------------------|---------------|
| R _{pu} | I ² C pull-up resistor | 2.7 kΩ |
| R _{PSEL0} / R _{PSEL1} | Interface selection resistors | Up to 5kΩ |

Notes:

- R_{pu} is only needed when the MTi-1 is configured for I²C interface
- R_{PSEL} is only required when interface is not I²C. If the interface does not need to be switched, R_{PSEL0} and R_{PSEL1} can be connected directly to GND.

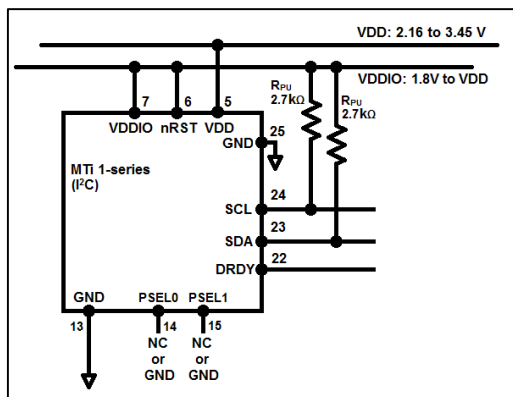


Figure 8: External components (I²C interface)

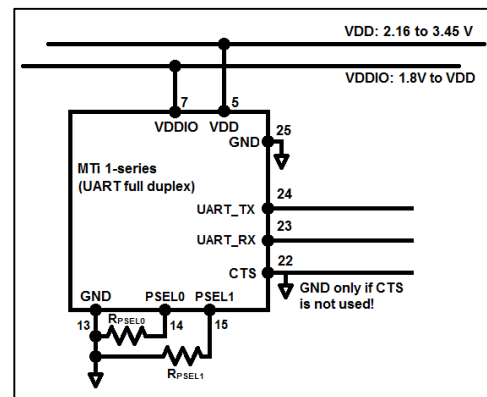


Figure 9: External components (UART interface)

2 MTi 1-series architecture

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

2.1 MTi 1-series configurations

The MTi 1-series is a fully-tested self-contained module that can 3D output orientation data (Euler angles (roll, pitch, yaw), rotation matrix (DCM) and quaternions), orientation and velocity increments (Δq and Δv) and sensors data (acceleration, rate of turn, magnetic field). The MTi 1-series module is available as an Inertial Measurement Unit (IMU), Vertical Reference Unit (VRU) and Attitude and Heading Reference System (AHRS). Depending on the product, output options may be limited to sensors data and/or unreferenced yaw.

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

2.1.1 MTi-1 IMU

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

2.1.2 MTi-2 VRU

The MTi-2 is a 3D vertical reference unit (VRU). Its orientation algorithm (XKF3™) outputs 3D orientation data with respect to a gravity referenced frame: drift-free roll, pitch and unreferenced yaw. In addition, it outputs calibrated sensor data: 3D acceleration, 3D rate of turn and 3D earth-magnetic field data. All modules of the MTi 1-series are also capable of outputting data generated by the strapdown integration algorithm (the AttitudeEngine™ outputting orientation and velocity increments Δq and Δv). The 3D acceleration is also available as so-called free acceleration which has gravity subtracted. Although the yaw is unreferenced, though still superior to gyroscope integration. With the feature Active Heading Stabilization (AHS, see section 7.2) the drift in unreferenced yaw can be limited to 1 deg after 60 minutes, even in magnetically disturbed environments.

2.1.3 MTi-3 AHRS

The MTi-3 supports all features of the MTi-1 and MTi-2, and in addition is a full gyro-enhanced Attitude and Heading Reference System (AHRS). It outputs drift-free roll, pitch and true/magnetic North referenced yaw and sensors data: 3D acceleration, 3D rate of turn, as well as 3D orientation and velocity increments (Δq and Δv), and 3D earth-magnetic field data. Free acceleration is also available for the MTi-3 AHRS.

2.2 Signal processing pipeline

The MTi 1-series is a self-contained module, so all calculations and processes such as sampling, coning and sculling compensation and the Xsens XKF3™ sensor fusion algorithm run on board.

2.2.1 Strapdown integration

The Xsens optimized strapdown algorithm (AttitudeEngine™) performs high-speed dead-reckoning calculations at 1 kHz allowing accurate capture of high frequency motions. This approach ensures a high bandwidth. Orientation and velocity increments are calculated with full coning and sculling compensation. At an output data rate of up to 100 Hz, no information is lost, yet the output data rate can be configured low enough for systems with limited communication bandwidth. These orientation and velocity increments are suitable for any 3D motion tracking algorithm. Increments are internally time-synchronized with the magnetometer data.

2.2.2 XKF3™ Sensor Fusion Algorithm

XKF3 is a sensor fusion algorithm, based on Extended Kalman Filter framework that uses 3D inertial sensor data (orientation and velocity increments) and 3D magnetometer, also known as '9D' to optimally estimate 3D orientation with respect to an Earth fixed frame.

XKF3 takes the orientation and velocity increments together with the magnetic field updates and fuses this to produce a stable orientation (roll, pitch and yaw) with respect to the earth fixed frame.

The XKF3 sensor fusion algorithm can be processed with filter profiles. These filter profiles contain predefined filter parameter settings suitable for different user application scenarios.

The following filter profiles are available:

- **General** – suitable for most applications. Supported by the MTi-3 module.
- **Dynamic** – assumes that the motion is highly dynamic. Supported by the MTi-3 module.
- **High_mag_dep** – heading corrections rely on the magnetic field measured. To be used when magnetic field is homogeneous. Supported by the MTi-3 module.
- **Low_mag_dep** – heading corrections are less dependent on the magnetic field measured. Heading is still based on magnetic field, but more distortions are expected with less trust being placed on magnetic measurements. Supported by the MTi-3 module.
- **VRU_general** – Roll and pitch are the referenced to the vertical (gravity), yaw is determined by stabilized dead-reckoning, referred to as Active Heading Stabilization (AHS) which significantly reduces heading drift, see also section 7.2. Consider using VRU_general in environments that have a heavily disturbed magnetic field. The VRU_general filter profile is the only filter profile available for the MTi-2-VRU, also supported by the MTi-3 module

2.2.3 Frames of reference used in MTi 1-series

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

The following data is outputted in corresponding reference coordinate systems:

| Data | Symbol | Reference coordinate system |
|-----------------------|--|--|
| Acceleration | a_x, a_y, a_z | Sensor-fixed |
| Rate of turn | $\omega_x, \omega_y, \omega_z$ | Sensor-fixed |
| Magnetic field | m_x, m_y, m_z | Sensor-fixed |
| Free acceleration | a_x, a_y, a_z | Local Tangent Plane (LTP), default ENU |
| Velocity increment | $\Delta v_x, \Delta v_y, \Delta v_z$ | Local Tangent Plane (LTP), default ENU |
| Orientation increment | $\Delta q_0, \Delta q_1, \Delta q_2, \Delta q_3$ | Local Tangent Plane (LTP), default ENU |
| Orientation | Euler angles, quaternions or rotation matrix | Local Tangent Plane (LTP), default ENU |

Local Tangent Plane (LTP) is a local linearization of the Ellipsoidal Coordinates (Latitude, Longitude, Altitude) in the WGS-84 Ellipsoid.

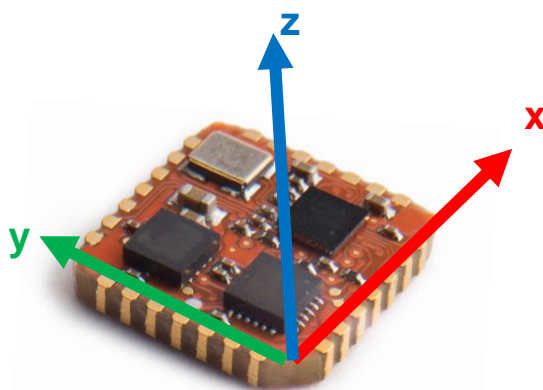


Figure 10: Default sensor fixed coordinate system for the MTi 1-series module

It is straightforward to apply a rotation matrix to the MTi, so that the velocity and orientation increments, free acceleration and the orientation output is output using that coordinate frame. The default reference coordinate system is East-North-Up (ENU) and the MTi 1-series has predefined output options for North-East-Down (NED) and North-West-Up (NWU). Any arbitrary alignment can be entered. These orientation resets have effect on all outputs that are by default outputted with an ENU reference coordinate system.

3 3D Orientation and performance specifications

3.1 3D Orientation specifications

Table 3. Orientation specifications

| Parameter | | Typ | Unit | Comments |
|---------------|---|-------|------------------|--|
| Roll/pitch | Static | 0.75 | deg | |
| | Dynamic | 1.0 | deg | |
| Yaw (heading) | Static/dynamic, Magnetic field referenced | 2.0 | deg | MTi-3 AHRS only in a homogenous magnetic field and a filter profile using magnetic field as reference. |
| | VRU_general filter profile (unreferenced yaw) | <1 | deg after 60 min | Active Heading Stabilization (AHS) feature. See section 7.2 for more information. |
| | Output data rate | 0-100 | Hz | Accuracy and latency independent of output data rate. Output data rate may be any integer divider of 100 Hz or may be triggered by an external pulse (SYNC_IN) |

3.2 Sensors specifications³

Table 4. Gyroscope specifications

| Parameter | Min | Typ | Max | Unit | Comments |
|---------------------------|-------|------|-------|---------|--|
| Full range | ±2000 | | | deg/s | |
| Non-linearity | | 0.1 | | % of FS | |
| Sensitivity variation | | 0.05 | | % | Over temperature range |
| Noise density | | 0.01 | | %s/√Hz | |
| g-sensitivity | | | 0.001 | deg/s/g | |
| In-run bias stability | | 10 | | deg/h | |
| Zero-rate output | | ±0.1 | | deg/s | Bias variation after calibration, bias is continuously estimated by XKF3i |
| Bias repeatability (1 yr) | | 0.5 | | deg/s | The bias is continuously estimated by XKF3i. |
| Bandwidth | | 180 | | Hz | |
| Natural frequency | | 26 | | kHz | This is the resonating frequency of the mass in the gyro. The higher the frequency, the higher the accuracy. |

Table 5. Accelerometers specifications

| Parameter | Min | Typ | Max | Unit | Comments |
|-----------------------|-----|------|-----|---------|------------------------|
| Full range | ±16 | | | g | |
| Non-linearity | | 0.5 | | % of FS | |
| Sensitivity variation | | 0.05 | | % | Over temperature range |
| Noise density | | 200 | | μg/√Hz | |
| Zero-g output | | ±2 | | mg | |
| In-run bias stability | | 0.1 | | mg | |
| Bandwidth | | 180 | | Hz | |

³ As Xsens continues to update the sensors on the module, these specifications may change

Table 6. Magnetometer specifications

| Parameter | Min | Typ | Max | Unit | Comments |
|---------------|------|-----|-----|---------|----------|
| Full range | ±1.9 | | | Gauss | |
| Non-linearity | | 0.1 | | % of FS | |
| Noise density | | 200 | | μG/√Hz | |

Table 7. Alignment specifications

| Parameter | Typ | Unit | Comments |
|--------------------------------------|------|------|----------|
| Non-orthogonality (accelerometer) | 0.05 | deg | |
| Non-orthogonality (gyroscope) | 0.05 | deg | |
| Non-orthogonality (magnetometer) | 0.05 | deg | |
| Alignment (gyr to acc) | 0.05 | deg | |
| Alignment (mag to acc) | 0.1 | deg | |
| Alignment of acc to the module board | 0.2 | deg | |

4 Sensor calibration

Each MTi is individually calibrated and tested over its temperature range. The (simplified) sensor model of the gyroscopes, accelerometers and magnetometers can be represented as following:

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

- s = sensor data of the gyroscopes, accelerometers and magnetometers in rad/s, m/s² or a.u. respectively
- K_T^{-1} = gain and misalignment matrix (temperature compensated)
- u = sensor value before calibration (unsigned 16-bit integers from the sensor)
- b_T = bias (temperature compensated)

Xsens' calibration procedure calibrates for many parameters, including bias (offset), alignment of the sensors with respect to the module PCB and each other and gain (scale factor). All calibration values are temperature dependent and temperature calibrated. The calibration values are stored in non-volatile memory in the MTi.

5 System and electrical specifications

5.1 Interface specifications

Table 8. Communication interfaces

| Interface | | Min | Typ | Max | Units |
|-----------|---------------------------------------|-----|-------|------|-------|
| I2C | Host I ² C interface speed | | | 400 | kHz |
| SPI | Host SPI Interface speed | | | 21 | MHz |
| | Clock duty cycle | 30 | 50 | 70 | % |
| UART | Baudrates | | 921.6 | 4000 | kbps |

Table 9. Auxiliary interfaces

| Interface | | Min | Max | Unit | Comments |
|-----------|--------------------------------|--------------------|-------------|------|-----------------------|
| SYNC_IN | V _{IL} | | 0.3 * VDDIO | V | Digital input voltage |
| | V _{IH} | 0.45 * VDDIO + 0.3 | | V | Digital input voltage |
| | V _{HYS} | 0.45 * VDDIO + 0.3 | | V | |
| nRST | V _{IL} | | 0.3 * VDDIO | V | Digital input voltage |
| | V _{IH} | 0.45 * VDDIO + 0.3 | | V | Digital input voltage |
| | V _{HYS} | 0.45 * VDDIO + 0.3 | | V | |
| | Generated reset pulse duration | 20 | | µs | |

5.2 System specifications

Table 10. System specifications

| Interface | | Min | Typ | Max | Comments | |
|-------------------|---|------|------|------|----------|-------------------------------------|
| Size | Width/Length | 12.0 | 12.1 | 12.2 | mm | PLCC-28 compatible |
| | Height | 2.45 | 2.55 | 2.65 | mm | |
| Weight | | | 0.66 | | gram | |
| Temperature | Operating temperature | -40 | | +85 | °C | Ambient temperature, non-condensing |
| | Specified performance operating temperature | 0 | | +60 | °C | |
| Power consumption | | | 44 | | mW | VDD 3.0V; VDDIO 1.8V |
| Timing accuracy | | | 10 | | ppm | |

5.3 Electrical specifications


Table 11. Electrical specifications

| | Min | Typ | Max | Unit | Comments |
|------------------|--------------------|-----|-------------|------|------------------------|
| VDD | 2.16 | | 3.45 | V | |
| VDDIO | 1.8 | | VDD | V | |
| V _{IL} | | | 0.3 * VDDIO | V | Digital input voltage |
| V _{IH} | 0.45 * VDDIO + 0.3 | | | V | Digital input voltage |
| V _{HYS} | 0.45 * VDDIO + 0.3 | | | V | Digital input voltage |
| V _{OL} | | | 0.4 | V | Digital output voltage |
| V _{OH} | VDDIO - 0.4 | | | V | Digital output voltage |

5.4 Absolute maximum ratings

| | Min | Max | Unit | Comments |
|-----------------------------|-----|-----------|------|---------------------------------|
| Storage temperature | -40 | +125 | °C | |
| Operating temperature | -40 | +85 | °C | |
| VDD | 0.3 | 4.0 | V | |
| VDDIO | 0.3 | VDD + 0.5 | V | |
| Acceleration ⁴ | | 10,000 | g | Any axis, unpowered, for 0.2 ms |
| ESD protection ⁵ | | ±2000 | V | Human body model |

⁴  This is a mechanical shock (g) sensitive device. Proper handling is required to prevent damage to the part.

⁵  This is an ESD-sensitive device. Proper handling is required to prevent damage to the part.

6 MTi 1-series settings and outputs

The MTi 1-series module uses the Xsens-proprietary Xbus protocol, which is compatible with all Xsens Motion Tracker products.

6.1 Message structure

The communication with the MT is done by messages which are built according to a standard structure. The message has two basic structures; one with a standard length and one with extended length. The standard length message has a maximum of 254 data bytes and is used most frequently. In some cases the extended length message needs to be used if the number of data bytes exceeds 254 bytes.

An MT message (standard length) contains the following fields:

| Xbus header | | | | DATA | CHECKSUM |
|-------------|-----|-----|-----|------|----------|
| Preamble | BID | MID | LEN | | |

An MT message (extended length) contains these fields:

| Preamble | BID | MID | LEN ^{ext} | LEN | DATA | CHECKSUM |
|----------|-----|-----|--------------------|-----|------|----------|
|----------|-----|-----|--------------------|-----|------|----------|

| Field | Field width | Description |
|------------------------|------------------|--|
| Preamble | 1 byte | Indicator of start of packet → 250 (0xFA) |
| BID | 1 byte | Bus identifier or Address → 255 (0xFF) |
| MID | 1 byte | Message identifier |
| LEN | 1 byte | For standard length message: Value equals number of bytes in DATA field. Maximum value is 254 (0xFE) For extended length message: Field value is always 255 (0xFF) |
| EXT LEN | 2 bytes | 16 bit value representing the number of data bytes for extended length messages. Maximum value is 2048 (0x0800) |
| IND ID | 1 byte | The type of indication received |
| DATA (standard length) | 0 – 254 bytes | Data bytes (optional) |
| DATA (extended length) | 255 – 2048 bytes | Data bytes |
| Checksum | 1 byte | Checksum of message |

Details on the Xbus protocol message structure can be found in the MT Low Level Communication Protocol documentation (LLCP).

6.2 Output settings

The section below only describes the most important set of MTData2 data messages. For all messages supported by the MTi 1-series, refer to the MT Low Level Communication Protocol documentation (LLCP).

The Output Configuration message sets the output of the device. Each data message has a DataID which consists of a data type and a number format. The table below shows the most important MTData2 Data identifiers. The message SetOutputconfiguration holds the DataID and the output frequency.

SetOutputConfiguration

MID 192 (0xC0)

DATA OutputConfig (N*4 bytes)

Set the output configuration of the device.

The data is a list of maximum 32 data identifiers combined with a desired output frequency. The response message contains a list with the same format, but with the values actually used by the device. Each entry in the list contains:

| Offset | Value |
|--------|----------------------------|
| 0 | Data Identifier (2 bytes) |
| 2 | Output frequency (2 bytes) |

| Group Name | Type Name | XDA type name ⁶ | Hex Value |
|-------------------------|-------------------|---------------------------------|-----------|
| Timestamp | | XDI_TimestampGroup | |
| | Packet Counter | XDI_PacketCounter | 1020 |
| | Sample Time Fine | XDI_SampleTimeFine | 1060 |
| Orientation Data | | XDI_OrientationGroup | |
| | Quaternion | XDI_Quaternion | 201y |
| | Rotation Matrix | XDI_RotationMatrix | 202y |
| | Euler Angles | XDI_EulerAngles | 203y |
| Acceleration | | XDI_AccelerationGroup | |
| | Delta V (dv) | XDI_DeltaV | 401y |
| | Acceleration | XDI_Acceleration | 402y |
| | Free Acceleration | XDI_FreeAcceleration | 403y |
| Angular Velocity | | XDI_AngularVelocityGroup | |
| | Rate of Turn | XDI_RateOfTurn | 802y |
| | Delta Q (dq) | XDI_DeltaQ | 803y |
| Magnetic | | XDI_MagneticGroup | |
| | Magnetic Field | XDI_MagneticField | C02y |
| Status | | XDI_StatusGroup | |
| | Status Word | XDI_StatusWord | E020 |

y: The hex value of the Format bits (see table below). The value is formed by doing a bitwise OR of the available fields

⁶ XDA: Xsens Device API. Communication protocol in C, to be used on external processors.

| Field | Format | Description | Short name |
|-------------------|--------|--|------------|
| Precision | | | |
| | 0x0 | Single precision IEEE 32-bit floating point number | Float32 |
| | 0x1 | Fixed point 12.20 32-bit number | Fp1220 |
| | 0x2 | Fixed point 16.32 48-bit number | Fp1632 |
| | 0x3 | Double precision IEEE 64-bit floating point number | Float64 |
| Coordinate system | | | |
| | 0x0 | East-North-Up coordinate system | ENU |
| | 0x4 | North-East-Down coordinate system | NED |
| | 0x8 | North-West-Up | NWU |

Example: the DataID for quaternions in NED coordinate system with fixed point 16.32 number format is represented as 0x2016.

6.3 MTData2

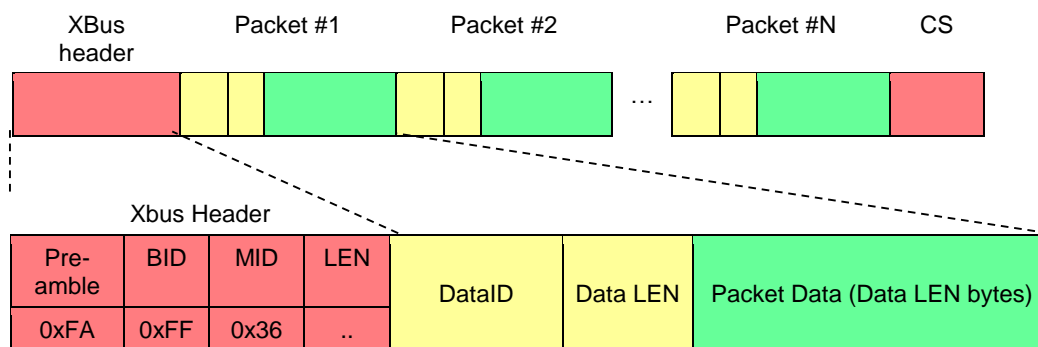
Data is represented in the MTData2 message.

MTData2

MID 54 (0x36)

DATA DATA (length variable)

The MTData2 message contains output data according the current OutputConfiguration. An MTData2 message consists of one or more packets, each containing a specific output. The layout of an MTData2 message is shown below:



An example data message is depicted below (explanation of the message, divided into parts, in the table):

FA FF 36 35 10 20 02 51 BC 10 60 04 00 21 49 AF 40 10 0C 39 B9 D8 00 B7 DD 80 00 3C C9 26 98 80 30 10 3F 80 00 01 B6 ED 60 01 36 94 A0 00 36 1E 60 00 E0 20 04 00 00 00 87 A0

| Part of message (0x) | Meaning |
|--|---|
| FA FF 36 35 | Xbus Header with total length of message (0x35) |
| 10 20 02 51 BC | DataID 0x1020 (Packet counter), length 0x02, data (0x51 BC) |
| 10 60 04 00 21 49 AF | DataID 0x1060 (Sample Time fine), length 0x04, data |
| 40 10 0C 39 B9 D8 00 B7 DD 80 00 3C C9 26 98 | DataID 0x4010 (velocity increment), length 0x0C, data |
| 80 30 10 3F 80 00 01 B6 ED 60 01 36 94 A0 00 36 1E 60 00 | DataID 0x8030 (orientation increment), length 0x10, data |
| E0 20 04 00 00 00 87 | DataID 0xE020 (StatusWord), length 0x04, data |
| A0 | Checksum |

6.4 Synchronization and timing

The MTi 1-series modules can easily be synchronized with other sensors or sensor systems. The MTi accepts a pulse and can then transmit the latest available data. This SYNC_IN functionality does not influence the accuracy of the data as internally the MTi 1-series keeps estimating the orientation at its maximum frequency. Acceleration data and rate of turn data is also outputted with the shortest possible latency.

The Sync Settings are set with the SetSyncSettings message:

SetSyncSettings

MID 44 (0x2C)

DATA Setting List (N*12 bytes)

Set the synchronization settings of the device.

Settings

Each setting describes either a system event that should trigger a sync in event that should trigger a system action.

SYNC_IN setting

| Offset (bytes) | Setting | Size (bytes) | Description |
|----------------|-----------------------|--------------|--|
| 0 | Function | 1 | Value 8: Send Latest |
| 1 | Line | 1 | Value 2: SYNC_IN |
| 2 | Polarity | 1 | Which line transition to respond to. One of: Rising Edge (1), Falling Edge (2) or Both (3) |
| 3 | | | Ignored for MTi 1-series |
| 4 | Skip First | 2 | The number of initial events to skip before taking action. |
| 6 | Skip Factor | 2 | The number of events to skip after taking the action before taking action again. |
| 8 | | | Ignored for MTi 1-series |
| 10 | Delay or Clock period | 2 | Delay after receiving a sync pulse to taking action (100µs units, range [0..60000]) |

7 Magnetic interference

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

7.1 Magnetic Field Mapping

When the distortion is deterministic, i.e. when the distortion moves with the MTi, the MTi can be calibrated for this distortion this type of errors are usually referred to as soft and hard iron distortions. The Magnetic Field Mapping procedure compensates for both hard-iron and soft-iron distortions.

In short, the magnetic field mapping (calibration) is performed by moving the MTi together with the object/platform that is causing the distortion. On an external computer (Windows or Linux), the results are processed and the updated magnetic field calibration values are written to the non-volatile memory of the MTi 1-series module. The magnetic field mapping procedure is extensively documented in the Magnetic Field Mapper User Manual (MT0202P), available in the MT Software Suite.

7.2 Active Heading Stabilization (AHS)

It is often not possible or desirable to connect the MTi 1-series module to a high-level processor/host system, so that the Magnetic Field Mapping procedure is not an option. Also, when the distortion is non-deterministic the Magnetic Field Mapping procedure does not yield the desired result. For all these situations, the on-board XKF3 sensor fusion algorithm has integrated an algorithm called Active Heading Stabilization (AHS).

The AHS algorithm delivers excellent heading tracking accuracy. Heading tracking drift in the MTi 1-series can be as low as 1 deg per hour, while being fully immune to magnetic distortions.

AHS is only available in the **VRU_general** filter profile. This filter profile is the only filter profile in the MTi-2 VRU and one of the 5 available filter profiles in the MTi-3 AHRS.

8 Package and handling

Note that this is a mechanical shock (g) sensitive device. Proper handling is required to prevent damage to the part.
Note that this is an ESD-sensitive device. Proper handling is required to prevent damage to the part.

8.1 Package drawing

The MTi 1-series module is compatible with JEDEC PLCC28 IC-sockets.

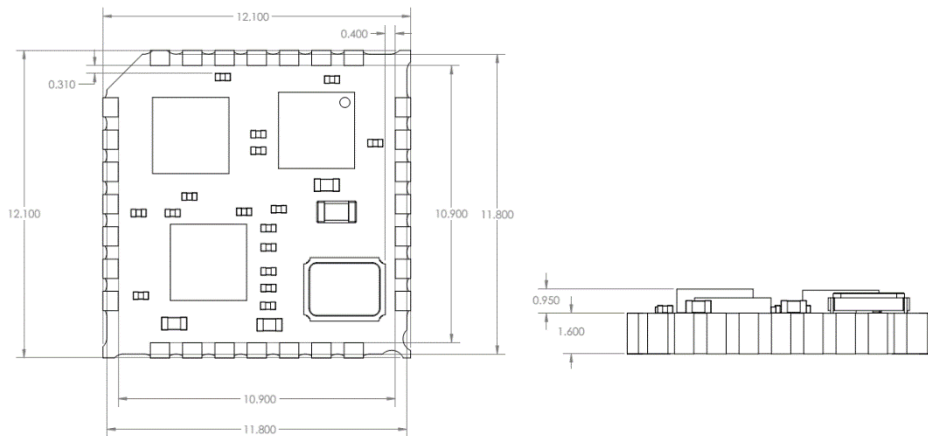


Figure 11: General tolerances are +/- 0.1 mm

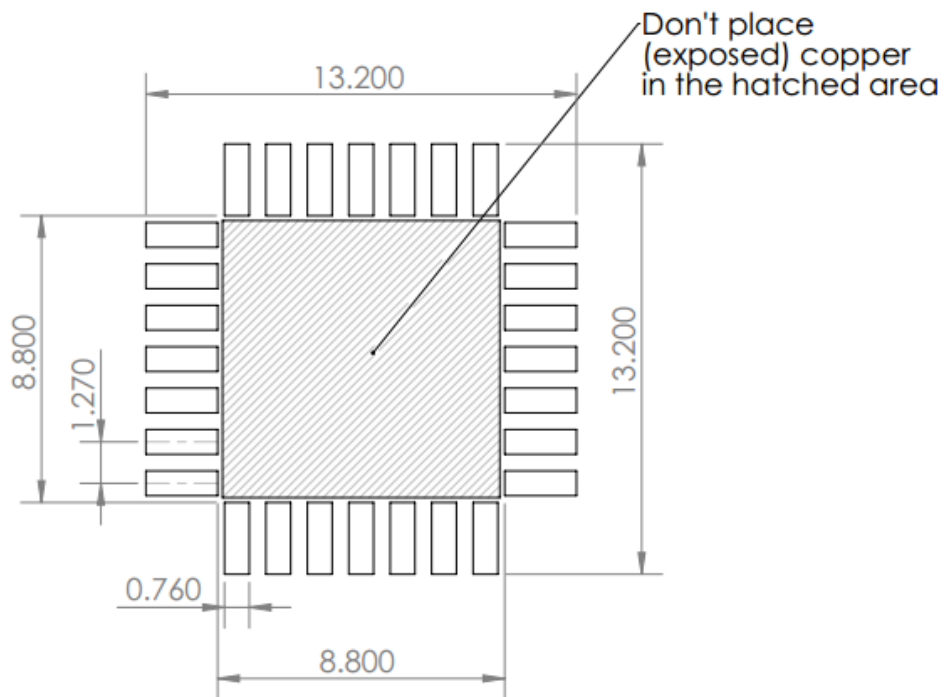


Figure 12: Recommended MTi 1-series module footprint

8.2 Packaging

The MTi 1-series module is shipped in trays. Trays are available with a MOQ of 20 modules. A full tray contains 152 modules.

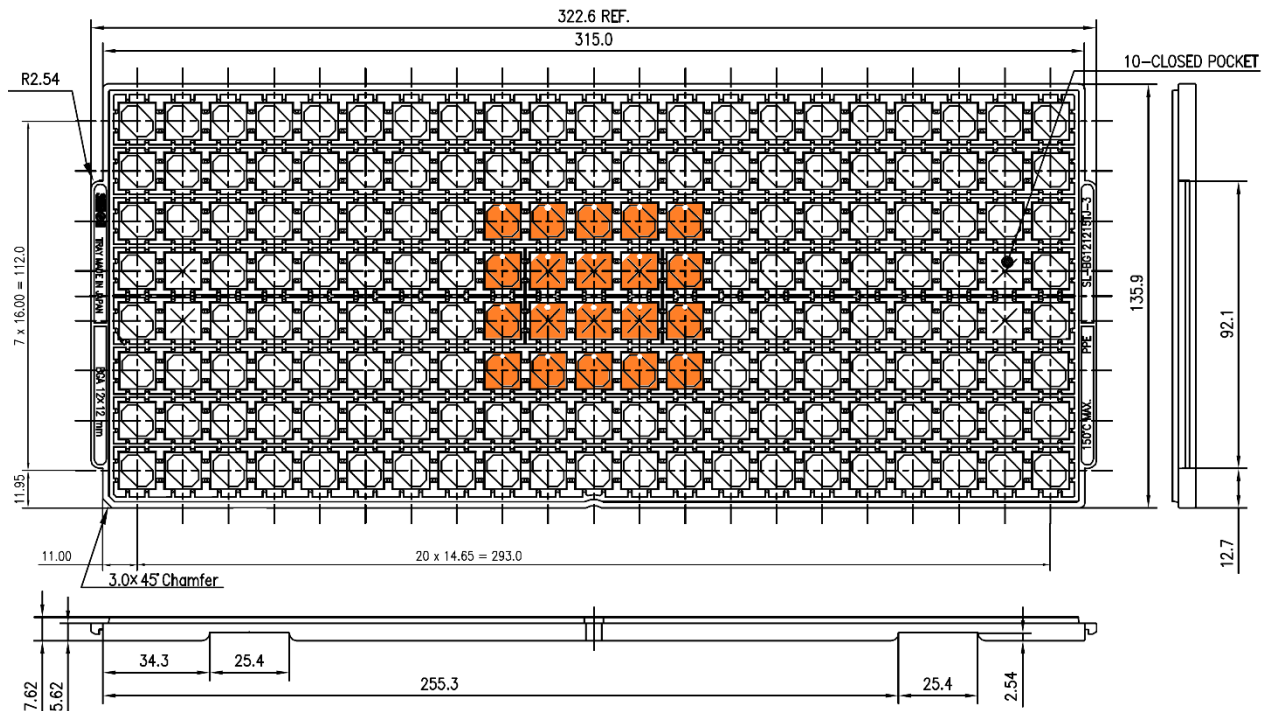


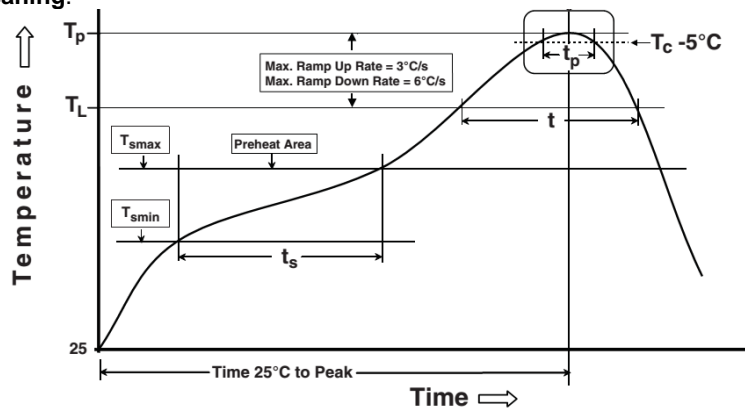
Figure 13: A tray containing 20 MTi 1-series modules

8.3 Reflow specification

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

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

The sensor fulfils the lead-free soldering requirements of the above-mentioned IPC/JEDEC standard, i.e. reflow soldering with a peak temperature up to 260°C. Recommended Preheat Area (t_s) is 80-100 sec. The minimum height of the solder after reflow shall be at least 50µm. This is required for good mechanical decoupling between the MTi 1-series module and the printed circuit board (PCB) it is mounted on. Assembled PCB's may **NOT** be cleaned with ultrasonic cleaning.



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9 Trademarks and revisions

9.1 Trademarks

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9.2 Revisions

| Revision | Date | By | Changes |
|----------|------------|-----|-----------------|
| A | 8 Jul 2015 | MHA | Initial release |

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