MTw Awinda User Manual

MTw Hardware, MT Manager, Awinda Protocol

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Revisions

Revision	Date	By	Changes
J	12 May 2016	HBE, MPA, MSC	• Updated to latest MTw Awinda hardware • Updated to latest MT SDK 4.5.5 • Updated descriptions of XKF3hm and SDI • Updated regulatory notices
K	07 Nov 2016	MSC	• Updated to latest MT SDK 4.6 • Updated synchronization description • Updated Orientation Reset
L	03 May 2018	JKO	• Updated figure for Schematics accelerometer position in MTw

Table of Contents

Abbreviations and Terms

Term	Description
Quaternion	An orientation representation of complex numbers. A unit length quaternion is a convenient parameterization of rotations.
Euler Angles	Representation of the spatial orientation of any frame of the space as a sequence of rotations from a reference frame.
Awinda Protocol	Patented wireless communication protocol specifically suited for real-time transmission of mathematically integrated data, such as constructed by a Strap Down Integration (SDI) algorithm.
Strap Down Integration	A method to compute an orientation/ position change given an angular velocity/acceleration of a rigid body. For example computing angle change using MEMS vibrating gyroscopes.
Delta Angle	Output of strap down integration of the angular velocity data.
Delta Velocity	Output of strap down integration of the acceleration data.
Personal Area Network	A personal area network (PAN) is that associated with the MTw development kit. A set of wireless clients communicates with a host wireless receiver that is remove from the subject wearing the wireless clients. The wireless receiver is connected directly to the host PC.
Body Area Network	Differing slightly from a PAN, with the Body Area Network (BAN), a local wireless receiver is also body-worn, this collects wireless data from all body-worn devices and transmits wireless data to a remote wireless receiver, which is connected directly to a host PC.

Abbreviation	Description
BAN	Body Area Network
BNC	BNC (Bayonet Neill-Concelman) connector. Common type of RF connector used for the coaxial cable. Used to connect Awinda Station to external devices for synchronization purposes.
DOF	Degrees Of Freedom
MT	Motion Tracker
MTB	MT Binary Communication Protocol
MTM	MT Manager
PAN	Personal Area Network
SDI	Strap down integration
SDK	Software Development Kit
TTL	Transistor–transistor logic. Used in the synchronization ports of the Awinda Station.
XFF	Xsens Firmware File format
XKF3hm	Xsens Kalman Filter 3 DOF for Human Motion

Default folders

Description	Files	Location
Main program	MT Manager MT SDK	C:\Program Files\Xsens\MT Manager
Documentation	MTw User Manual	https://documentation.xsens.com/mtw_user_manual
Documentation	MT SDK	C:\Program Files\Xsens\MT Software Suite 4.5.5\Documentation\MT SDK

1 Introduction

The MTw™ is a miniature wireless inertial measurement unit incorporating 3D accelerometers, gyroscopes, magnetometers (3D compass), and a barometer (pressure sensor). The embedded processor handles sampling, buffering, calibration and strap down integration of the inertial data as well as the wireless network protocol for data transmission. Combined with the MT Software Suite that includes the Xsens Kalman Filter for human motion (XKF3hm) on the host device, the MTw provides real-time 3D orientation for up to 20 wireless motion trackers in a network, while at the same time also providing calibrated 3D linear acceleration, angular velocity, (earth) magnetic field and atmospheric pressure data.

One of the unique features of the MTw is the patented Awinda™ radio protocol. The Awinda protocol is based on the IEEE 802.15.4 PHY. Using this basis ensures that standard 2.4 GHz ISM chipsets can be used. The Awinda protocol ensures time synchronization of up to 20 MTw's across the wireless network to within 10 μs. Awinda has been specifically developed with inertial sensor data in mind and will maintain the accuracy of 3D motion tracking even if data is temporarily lost in radio transmission, while maintaining very efficient use of the limited available bandwidth. Traditional radio protocols reserve a lot of time for acknowledgement of data packet reception and re-transmission of data, possibly causing the network throughput to drop. With Awinda, the data is internally sampled at 1kHz, and using Strap Down Integration (SDI) the data is transmitted to the Awinda Master (Awinda Station or Awinda USB Dongle). For real-time applications, this means that the accuracy is preserved even if data packets are lost. For post-processing and analysis, it means that there is no missing data. Buffered data on the MTw is made available to the host in a configurable re-transmission scheme that will flush the buffered data to the host when excess bandwidth is available.

The completely wireless nature of the MTw widens the possible areas of applications, improves the speed of donning the motion tracking systems onto test subjects, or patients. Because inertial sensor technology does not rely on line of sight and is not influenced by lighting conditions, the systems can be worn in the field, with no need for simulated environments.

Fields of use:

- Biomechanics
- Rehabilitation
- Sports and exercise science
- Ergonomics
- Virtual reality
- Animation
- Motion capture

2 Content Overview

2.1 Carrying Case with Contents

The MTw Awinda Development kit arrives in a case, approximately the size of a common briefcase.
A standard MTw Awinda Development kit contains:

- 6 MTw's
- 1 Awinda Station
  - 1 USB cable
  - 1 power cable
- Awinda USB Dongle
- 1 set of full body Velcro Body Straps

2.2 Motion Tracker (MTw)

MTw's are miniature inertial measurement units containing 3D linear accelerometers, 3D rate gyroscopes, 3D magnetometers and a barometer. The back of the casing holds a Velcro patch, enabling easy attachment of the sensor to the Velcro Body straps.
For more details see Section 4.1.

2.3 *Awinda Master*

2.3.1 Awinda Station

The Awinda Station controls the reception of synchronized wireless data from all wirelessly connected MTw's and charges up to 6 MTw's simultaneously.
It can receive wireless data from up to 32 MTw's. For more details see Section 4.2.

2.3.2 Awinda USB Dongle

The Awinda USB Dongle has the same wireless capabilities as the Awinda Station. It controls the reception of synchronized wireless data from all wirelessly connected MTw's. It can receive data from up to 32 MTw's. For more details see Section 4.3.

2.4 *Velcro Body Straps & Accessories*

The MTw Velcro Body Straps are a one-size fits all mounting system. These straps have a silicon layer to prevent the straps from falling down the body segment. The top layer of the straps is made of Velcro material. The sensors can be quickly and easily mounted to these straps due to the Velcro patch on the back of each sensor. For more details see Section 4.4.

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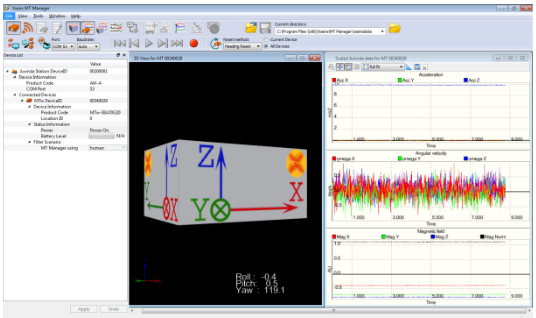
2.5 Software



The MTw Awinda development kit is supplied with a software suite consisting of MT Manager and a software development kit. MT Manager is for visualising and recording data. This facilitates quick and easy use of the MTw and Awinda Master.
The MT Software Development Kit (SDK) is provided, with example code in C#, C++ and MATLAB. The MT SDK is intended to make software application development for the MTw easily accessible. For more details see Section 6.13.

3 Getting Started

3.1 *Hardware Setup*

Connect the Awinda Master to the PC. The mains power supply is only needed on the Awinda Station for charging the MTw and while carrying out firmware updates. We recommend connecting the power supply immediately to charge the MTw's. For wireless communication between MTw's, the Awinda Station and the PC, it is not necessary to plug the Awinda Station to the mains power supply since the wireless interface in the Awinda Station is powered by USB from the PC.

See Section 4.1 for details about the MTw.
See Section 4.2 for details about the Awinda Station.
See Section 4.3 for details about the Awinda USB dongle.
See Section 4.4 for details about the MTw Body Straps and accessories.

3.2 *Software Installation*

Download MT Software Suite from the Xsens website (www.xsens.com). Follow the on-screen instructions.

- See Section 6.2 for detailed MT Manager installation instructions.

3.3 *Tips for Best Practice*

3.3.1 Magnetic Distortion

For best results when measuring with the Xsens MTw, it is advised to avoid highly magnetized areas when carrying out measurements, in particular in the beginning. XKF3hm uses the local magnetic field to compute heading. When this signal is distorted due to close proximity of a magnet, or ferromagnetic material (iron or steel), accuracy of results may decrease.

Check the magnetic norm of the environment. To check the magnetic norm, the system should be installed and running, with at least one MTw active. Open the inertial data graph and look at the Magnetic Norm curve (black line) while moving in the measurement area. Areas for which the magnetic norm variation remains within ±0.2 are best for carrying out measurements.

3.3.1.1 Types of Magnetic Disturbance

Figure 1 below gives an indication of how ferromagnetic objects lying in a homogenous magnetic field cause magnetic field distortions. It is clear from this figure that only when close to the (ferro-) magnetic material can the material be considered as disturbing, since the field lines bend towards the object when in close proximity. For more detailed information about the influence of magnetic field on orientation, see the PhD thesis "Inertial and magnetic sensing of human motion" D. Roetenberg 2006[1].

[1].http://www.xsens.com/images/stories/PDF/Inertial%20and%20Magnetic%20Sensing%20of%20Human%20Motion.pdf

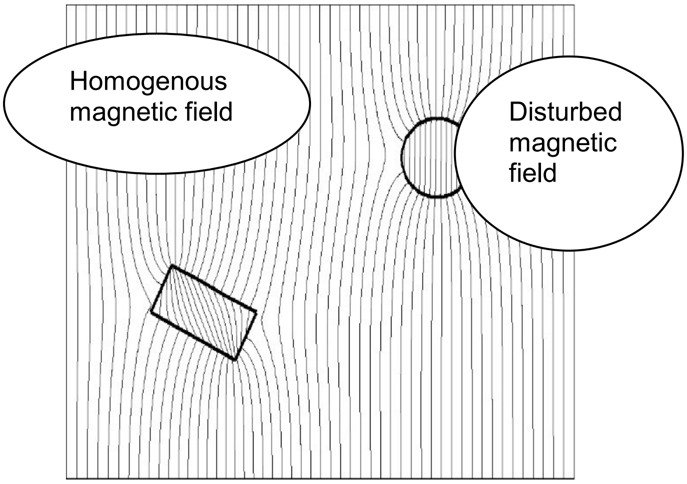


Figure 1: Simulation of ferromagnetic objects in free space with a homogeneous magnetic field

Homogenous magnetic field
As mentioned above, it is advised to avoid, at least starting a measurement in a highly disturbed magnetic environment (in a magnetic norm of about 2 or 3). If, however, the measurement begins with a magnetic norm of around 2 or 3, and remains within ±0.2 of this value, the orientation should remain accurate.

If the norm of the magnetic field has large fluctuations, or if the MTw is attached to an instrument or prosthesis that influences the magnetic field (e.g. ferromagnetic object), it is best to carry out Magnetic Field Mapping for this MTw (see section 7.1). This recalibrates the magnetometer of the MTw.

Varying magnetic field
The XKF3hm algorithm can compensate for areas of fast fluctuating magnetic fields. However, slow and large (>±0.2) changes are more difficult for the algorithm to compensate for, over periods of time longer than approximately 30s, which will influence heading accuracy.

NOTE:
Do not expose the MTw to very strong magnetic fields. There is a chance the MTw may become magnetized which will render the calibration values of the magnetic field sensors inside the MTw inaccurate. Performing a Magnetic Field Mapping on the MTw may recover the calibration if the magnetization is not too strong.

3.3.2 Settling Time

As with all filters of its kind, the XKF3hm filter is based on history. For this reason, some time is needed for the XKF3hm filters to settle to a stable state, this is referred to as “settling time”. Users should be aware that prior to a measurement, the MTw’s should be allowed to reach some filter stability. In practice this means, that users should try to minimise movement when making a wireless connection. Furthermore, depending on the update rate, users should minimise movement, or keep any movements to calm and slow movements for the first few seconds, to one minute after entering measurement mode.

3.3.3 Operating Conditions

The MTw has been designed to be used or worn close to the human body. Take care when exposing the MTw to strongly deviating environmental conditions. The recommended operating temperature is between 0°C and +50°C ambient temperature. If operated outside this temperature range performance may decrease or the device may become damaged. Fast transient temperature fluctuations may cause significant temperature gradients across the device. Such gradients cannot be properly modelled by temperature compensation and may therefore decrease performance. Additionally, operating around 0º may cause water particles to freeze and condense around the components, causing potential damage to the internal electronics. For optimal performance, the ambient temperature should remain as constant as possible during the measurement. Cold environments may provide shorter operation time of the trackers.

The MTw, Awinda Station and Awinda Dongle must be kept dry at all times. Condensation and water may damage the internal electronics. Using the MTw with the straps will protect the MTw to body moisture to a limited degree.

Protect the MTw from violent handling such as drops on hard surfaces. Excessive shocks or violent handling may damage the MTw or render the factory calibration no longer applicable. When handling the MTw at a desk, it is advised to place cushioning material between the desk and the MTw.

Do not put MTw's in the pockets in the suit case while in operation. Due to the high thermal insulation of the foam then surrounding the MTw the device will not be able to dissipate the small amount of heat that it generates during operation and it may become (too) hot.

3.3.4 Keeping the Hardware Clean

The housing of the MTw, Awinda Station and Awinda Dongle are waterproof. However, the housing is not watertight. To keep the hardware clean, use a damp cloth to wipe the surfaces.

3.3.5 Storage

If the MTw is not being used for a long time, please put them away half-charged. Store them in a cool and dry place

4 Hardware

The MTw Awinda Development Kit is comprised of both software and hardware. This section deals with all hardware aspects. The hardware of the MTw Awinda Development Kit includes the motion trackers, the Awinda Station, Awinda Dongle and the Body Straps with accessories.

4.1 Motion Trackers (MTw)

The MTw provides 3D angular velocity using rate gyroscopes, 3D acceleration using accelerometers, 3D earth magnetic field using magnetometers, as well as atmospheric pressure using the barometer. Combined with Xsens algorithms, 3D drift-free orientation is provided. The MTw is an excellent measurement unit for orientation measurement of human body segments, in particular because it is also designed to maintain very high accuracy time synchronization of the individual sensor readout across a wireless network of multiple units. This is essential when measuring joint angles accurately.

Front side of the MTw where the micro USB is connected. On the top is LED giving indications of device status.

Back side of the MTw, displaying various regulatory notices and 2D barcodes used by Xsens for quality control and tracking, as well as the MTw product code (MTW2-3A7G6) and serial number[2] (SN). Note that the last three digits of the SN are displayed in a large font, for the user to easily identify individual MTw's. This aids the user for example when placing MTw's on particular body segments.

The MTw is powered using a LiPo battery. The battery can be in operation for up to 6.5 hours, in stand-by for more than 48 hours (the MTw will shut down after two days of standby time) and is fully recharged after one hour docked in the Awinda Station (with a power supply connected to the Awinda Station). For

[2] Also known as Device ID.

more technical details on the MTw, sensor component specifications and orientation performance, see Section 11.1.

4.1.1 MTw LED Indications

The following lists the LED indications of the MTw, which are a combination of the device states and the Awinda protocol states of the MTw:

State	Description
Power-up	Blinking.
Docked and fully charged	ON
Charging	Slow fade from ON to OFF as a percentage [%] of battery status. A slow cycle means an almost full battery. A quick cycle means an almost empty battery.
Scanning	Pulsating.
Connected	Slow symmetric ON/OFF toggle in sync with Awinda Station (CONN LED).
Measuring	Fast symmetric ON/OFF toggle in sync with Awinda Station (CONN LED).
Battery Low	Quick Triple Pulses, overrides other states until charging again.
Flushing	Double pulse in sync with Awinda Station (CONN LED).
Stand-by	OFF. Blinks for 3 s, if a change in magnetic field has been detected, while searching for a radio connection.
Bootloader	2 quick pulses followed by a pause. See chapter 0 for trouble shooting.

4.1.2 MTw Stand-by Mode

Following a wireless connection, the MTw enters measurement mode. When the radio of the Awinda Master has been switched off, for longer than 30 seconds the MTw will enter stand-by mode. In this mode, the MTw will shut down its power, but monitor change in the signal from the accelerometer. See below for exiting standby mode.

4.1.3 Exiting stand-by mode

The MTw will monitor the accelerometer readings to decide whether it needs to wake up or to remain in standby mode. If the sensor decides it can wake up, it will check for a wireless link to an Awinda Master and become active in case a link is available.

In practice, to wake up MTw, reactivate the radio of the Awinda Master, and move the MTw; a simple 90 degree turn, or simply lifting it from the suit case to apply to the subject should be enough.

4.2 Awinda Station

Front view of the Awinda Station, showing the LEDs. A description of the LEDs is stated in Section 4.2.2 below. On top are docking spaces for 6 MTw's with regressed micro USB connectors. On the side is a foldable and rotatable 2.4 GHz antenna for maximum range.

Back view of the Awinda Station, showing the DC power connector, the USB connector and 4 BNC sync I/O connectors for synchronization with external devices[3]. See 11.2 for more technical specifications of the Awinda Station.

4.2.1 Awinda Station Synchronization Ports

On the back of the Awinda Station there are four BNC ports, two Sync In ports and two Sync Out. The ports have been configured to send (Sync Out) or receive (Sync In) TTL pulses 0-3.3V. For software configuration of the synchronization channels, see Section 6.8.

[3] Some dedicated synchronization manuals with common external devices can be found on the Xsens website (www.xsens.com)

4.2.2 Awinda Station Status LED

The Awinda Station has five LED indicators. From right to left, these indicators are:

LABEL	LED	DESCRIPTION
CHRG	OFF	When no mains power supply is connected to the Awinda Station.
[CHaRGer functionality]		GREEN: When 12V power supply is connected (mains power supply).
STAT	OFF	OFF: When no USB connection is present and when MT Manager is not started.
[STATus of the Awinda Station]		GREEN: Both USB connection present and MT Manager running connected to driver.
		ORANGE: USB connection to host PC is present.
		RED: Only power supply connected or error has occurred, e.g., a short-circuit of an MTw.
EXT	OFF	Remains off unless external connection made.
		GREEN: External connection e.g. sync port.
CONN	OFF	OFF: No wireless connection.
		GREEN slow blinking: (1 blink per second), radio switched on. When MTw connects, MTw LED and CONN LED blink synchronously. Fast blink: Measurement Mode.
DATA	OFF	OFF: No data received.
		GREEN: Measurement mode.
		ORANGE: Flushing. Flushing is the action of transferring data that has been stored on the MTw buffer, while the MTw was out of range and unable to transfer data in real-time to the Awinda Station.
		RED: Recording mode is active. This allows the remote monitoring that the host PC has initiated a recording successfully.

Note: The power supply is needed to charge the MTw's or to change from power off to power on. Only the power supply is needed for charging purposes (USB is not needed in this case). Power supply and USB connection are required for firmware updates.
Power supply is not needed for wireless communication (e.g. measurement/recording).

4.3 Awinda USB Dongle

See Section 11.3 for more technical specifications of the Awinda USB Dongle.

4.3.1 Awinda USB Dongle LED

The Awinda USB dongle has one white LED.

State	Description
Radio Off	LED off.
Scanning for MTw's	Pulsating LED.
Connected	Slow symmetric ON/OFF toggle (MTw blinks in sync with LED of dongle).
Measuring	Fast symmetric ON/OFF toggle (MTw blinks in sync with LED of dongle).

4.4 Body Straps and Accessories

The MTw Body Straps and Accessories have been designed to ensure that the user can enjoy as much flexibility as possible. The user may first attach the Velcro of the MTw onto the Velcro strap, then wrap the strap around the body segment (recommended). Alternatively, prepare the subject by first wrapping the straps around the body segments, then attach the MTw's to the appropriate locations.

4.4.1 Putting on the Straps

It is possible for the user to put the straps onto their own body segments, however, to ensure tight and stable fit, it is advisable to have someone else fasten them.

- Attach each MTw to the body strap with correct length and size for the associated body segment.
- Attach the straps to the appropriate body segments.[4]
- When using multiple MTw's, note the device ID of the MTw with respect to the body location, for distinguishing the sensors in data analysis
- For consistency, it is recommended to display the Xsens text in the correct orientation for reading – this means that the micro USB port should be the lowest point.
- Check that the straps are fastened tightly enough to the body.
  - To do this, the subject wearing the straps should walk or run for a few seconds, or perform sample movements that will be made during the measurements. If the straps become loose, re-tighten them and repeat the check.
  - It is not needed to stretch the straps maximally to ensure firm placement. The silicon layer on the straps is slip-resistant and prevents the strap from falling down.

[4] Configuration sheets with recommended MTw positions for full body measurement are available in a dedicated tutorial video about the hardware setup of the MVN Awinda system on: https://tutorial.xsens.com/

4.4.2 Recommended Locations

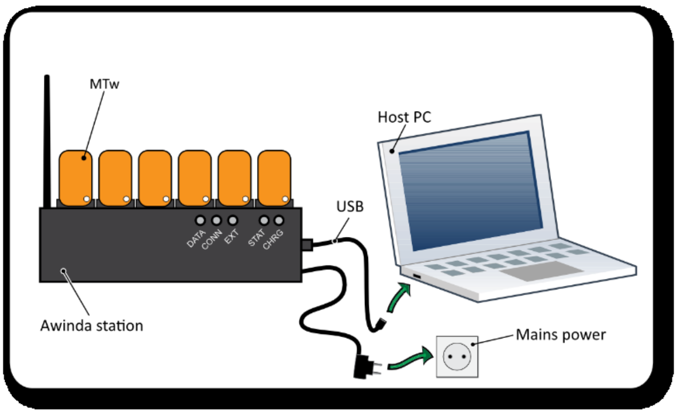
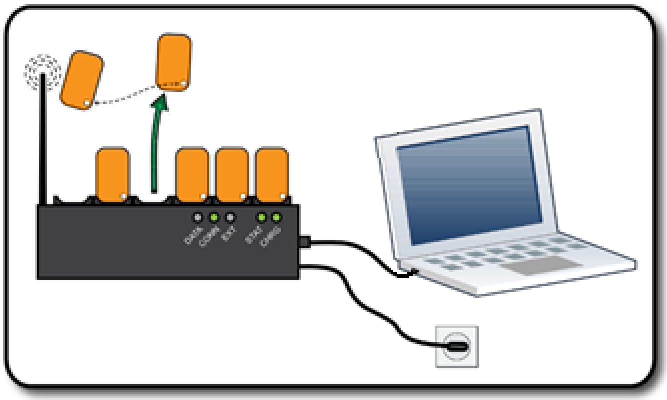
While inertial sensor technology facilitates freedom of movement and minimises restrictions imposed by camera and lighting, users should remain as vigilant when placing inertial sensors to the body as when placing any other human measurement system to the body. Users should be aware of skin motion artefact, which can occur with all forms of human (movement) measurement systems. When placing Xsens MTw to the body, using the Velcro body straps helps to ensure that the MTw is fastened tightly and robustly to the skin. The following points should be taken into consideration:

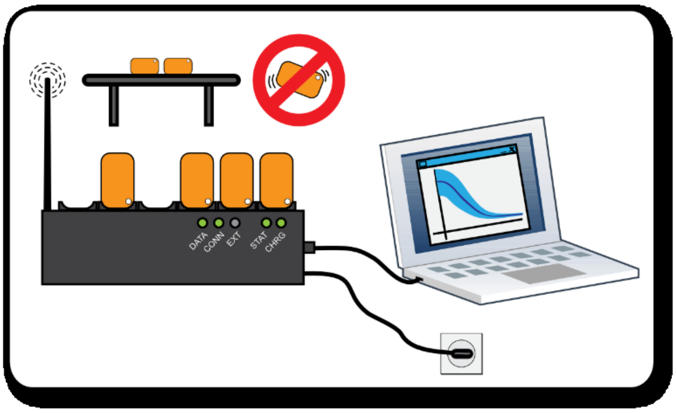
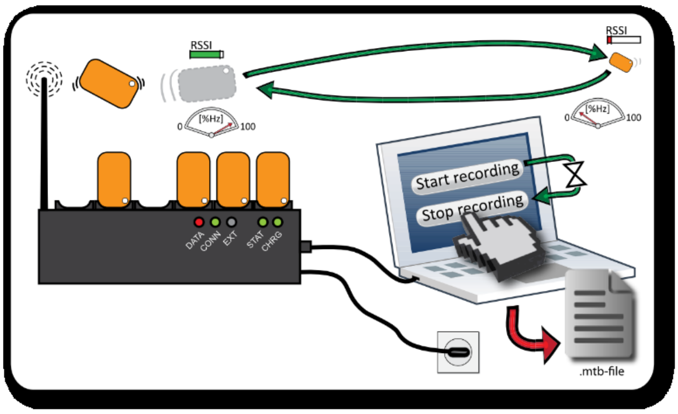
- Be aware of muscle contractions that may cause unwanted movement of the MTw
- Place MTw's on areas with least likelihood of moving due to a muscle contraction.
- For measurements of the extremities, for example forearm, take into account the measurement desired. At Xsens, we place the MT closer to the wrist, as this provides more information about 3D movement. Furthermore, the wrist area has less fatty tissue, decreasing the chances of skin motion artefact.
- For the upper arm, the location is less critical, as the upper arm has more musculature. It is recommended to place the sensor on the lateral side of the upper arm, in between the muscle groups of the biceps and the triceps.
- On the lower leg, two locations have been described in literature as good placement.
    1. On the tibia, close to the knee[5].
    2. On the lateral side of the lower leg, aligned with the fibula, 6cm above the lateral malleolus[6].
- For upper leg measurements, we recommend placing the MTw close to the knee, on the lateral thigh, as this has less probability of having fatty tissue, compared e.g. to closer to the hips. The silicone backed strap helps to ensure that this strap does not slide along the leg, during movement e.g. gait measurements.
- For pelvis motion measurement, tighten the pelvis strap (largest strap provided) around the pelvis bone, at the height of the anterior superior iliac spine. Place the MTw on the first layer of the strap, underneath the second layer if possible.

[5] Cloete, T.; Scheffer, C."Repeatability of an off-the-shelf, full body inertial motion capture system during clinical gait analysis" Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE 11 Nov 2010 pp 5125 - 5128

[6] Cutti AG, Ferrari A, Garofalo P, et al. 'Outwalk': a protocol for clinical gait analysis based on inertial & magnetic sensors. MED BIO ENG COMPUT, 2010; 48(1):17-25.

5 Recommended workflow

	To start up, the Awinda Master (Awinda Station OR Awinda Dongle) must be plugged into the USB port of the PC. The ID of the Master and docked MTw's is displayed in the device list if the Awinda station is connected to the mains power. See Section 6.5.
	Go to wireless configuration. Select a radio channel and switch the radio on (enable). See 6.6 and 6.6.2.
	When an MTw is undocked, its radio looks for a master to connect to. Instead of docking the MTw before use, the MTw can also be switched on by pressing the power button on the sensor. The wirelessly connected MTw's appear in the list. When all required MTw's are connected, set the update rate and enter measurement mode. See 6.6.6 for selecting the best update rate.

	When “Start Measurement on Wireless Master” is clicked, make sure that the MTw’s are kept still. For best results, data should be measured and recorded in the same environment as when measurement mode was initiated.
Like all filters of its kind, the XKF3hm filter is based on history. Therefore, time is needed for the XKF3hm filters to settle to a stable state. This time is called settling time, see 3.3.2. For about one minute after entering measurement mode, make calm, slow movements to warm up the filters (the actual time depends on the amount of trackers in use, but one minute should be sufficient).	
	To check if the filters have been stabilised, ensure that the orientation of the MTw doesn’t change, when the MTw is stationary (in a magnetically undisturbed environment). When in measurement mode, recording can be made.

6 MT Manager

Each MTw Awinda Development Kit is accompanied with MT Manager, an easy-to-use software interface facilitating visualisation, recording and exportation of data. Additionally, the MTw Software Development Kit (SDK) is provided, giving full access to all data and configurations of the MTw, with accompanying documentation and example codes to enable software developers to create customized (real-time) visualisation and recording application software. For more details about the SDK, see Section 6.13.

MT Manager is supported on Windows 7 and Windows 10. It is easy-to-use software with a familiar Windows user interface, which allows the user to:

- View and modify device settings and properties (limited modification possibilities for MTw)
- Configure the MTw wireless settings
- Configure synchronization with external devices
- Visualise in real-time:
    - 3D Orientation
    - 3D Inertial and magnetic data
    - Barometric pressure data
    - Status data
- Record native binary log files of data from motion trackers (.MTB files)
- Export mtb log files to ASCII (.txt)

MT Manager is an easy way of getting to know and to demonstrate the capabilities of Xsens Motion Trackers.

6.1 Supported devices

The following devices are supported by MT Manager:

- MTw2 and Awinda Masters (Awinda Station and Awinda USB dongle)
- MTi 1-series EVK
- MTi 10-series 4th generation
- MTi 100-series, including MTi-G-700 GPS/INS 4th generation
- MTi-G 3rd generation (legacy mode)

Note: not all features and functions available in MT Manager and in the MT SDK can be used in combination with all devices. For a clear overview of features and function available for the MTw, refer to the C/C++ Interface Availability in the MT Software Suite installation folder → Documentation → Xsens Device API Library → Modules → C/C++ Interface Availability.

6.2 Software Installation

If users have previously installed Xsens MT SDK[7], first uninstall the previous version of MT SDK, as well as the USB drivers from add or remove programs in the control panel. The USB drivers are listed as 'Windows Driver Package - Xsens USB-serial Converter Driver Package' in Add/Remove Programs. Uninstall all entries of these drivers from the list.

NOTE: Do not connect the Awinda Masters to the PC until the MT Software Suite is fully installed.

[7] Do not uninstall the MT SDK 3.3 if you need to continue to work with your (legacy) MTx, or Xbus Master. Do not uninstall MT Software Suite 4.2.1 if you need to continue to work with your MTw1 (MTw-38A70G20) since MT Software Suite 4.4 and newer does not support these sensors.

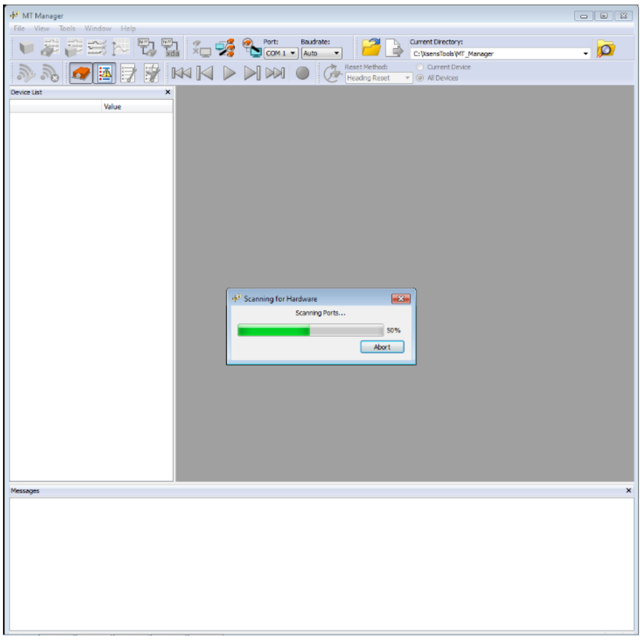
Download the MT Software Suite from the Xsens website (www.xsens.com). Run the .exe. Since MT Software Suite 4.4, the software does not require a license code anymore. Use the default installation folder or select preferred installation folder, and click next.

6.3 Connecting to MT Manager

Physically connect the Awinda Master, to the PC using the USB cable provided, or if the Awinda USB Dongle is in use, insert this into the USB port of the PC. Switch the MTw's on by pressing the power button on the sensor, or by undocking them from the (powered) Awinda station.

6.3.1 Automatic COM Port Scanning

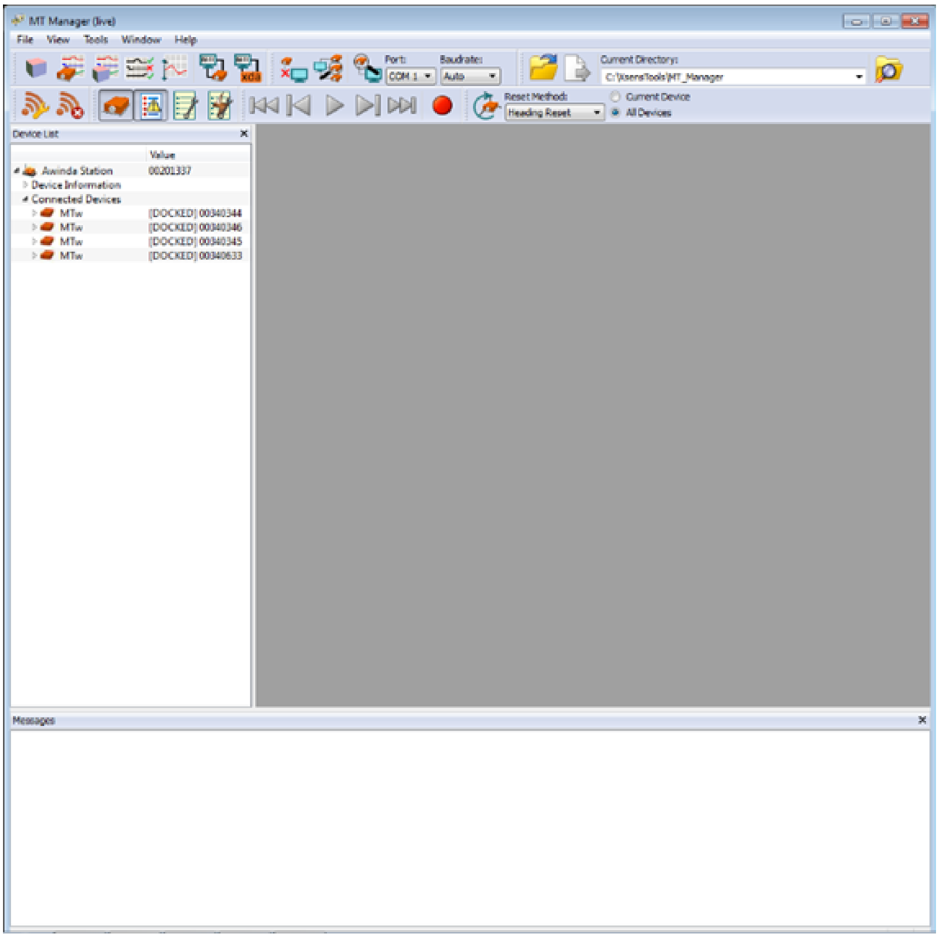
Upon execution of the MT Manager, all available COM ports on the host PC are automatically scanned for Xsens hardware. Progress is displayed during scanning in the status bar on the bottom right corner of the main window. If the PC has a large number of COM-ports (e.g. if Bluetooth drivers are installed) this may take some time.



Upon successful connection, the "Device List" sub-window appears with a list of connected devices and respective Device ID number (when necessary press the Device List icon).

The Wireless Configuration section (6.6) describes how to connect the MTw's as sub-systems (clients) of the Awinda Master.

NOTE: If synchronization configuration is needed first enable these settings (See Section 6.8) before carrying out the wireless configuration.

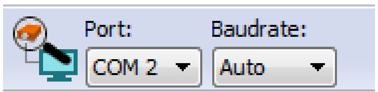


If the automatic scanning at start up does not reveal any connected devices, ensure that there is a USB connection and manually scan for ports using the functions in the connectivity toolbar.

6.4 Connectivity Toolbar

The following items are available on the connectivity toolbar, for manual COM port scanning/disconnecting.

Scan all ports



Scan single port

Disconnect all hardware[8]

6.4.1 Scan All Ports

All available COM ports are scanned for connected devices.

6.4.2 Scan Single Port

Choose an active COM port from the appropriate drop down menus to link this port to MT Manager, click “Scan single port”.

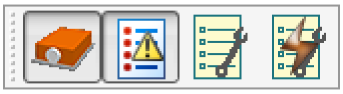
[8] This can also be used to close an open file.

6.4.3 Disconnect all hardware

To disconnect all hardware connected, select the “Disconnect” button, this will close the USB ports connecting all Awinda Masters.

This is different than to disconnect a single master. Note: do not combine dongle/station in using the default setup. When using 1 set of sensors, you only need 1 wireless master (Awinda station OR Awinda dongle). To disconnect a single Awinda Master, right click over the device in the Device List and select “Disconnect”. See 6.5 below.

6.5 Device Toolbar

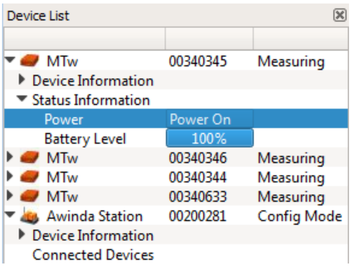


The device toolbar consists of the Device List, the Message Window, the MT Settings and the Output Configuration menu (resp.).

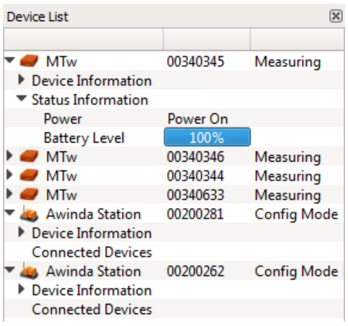
6.5.1 Device List

The Device List contains all of the information about the devices connected to MT Manager. It is predominantly a read-only menu, with the exception of the ability to power off single MTw’s and disconnect given Awinda Masters.

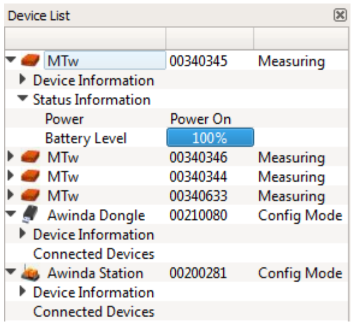
The default hardware setup for using 1 set of sensors is to use only 1 wireless master (Awinda station or Awinda dongle). It is possible to connect more than one Awinda Master (and associated MTw’s) at one time to MT Manager, in order to use 2 sets of sensors simultaneously in 1 software. The possible connections are shown below:



Single Station



Two Awinda Stations Connected



Wireless connection with Awinda USB Dongle

6.5.1.1 Power Off

It is possible to power off the MTw’s in three different ways.

1. In the device list, right click over the individual docked MTw and select “Power Off”.

2. It is also possible to more generically power off the hardware, using the Tools menu

    a. >Tools >Power Off > Power Off All Docked powers off only the MTw’s docked in the Awinda Station and connected to the PC, via USB cable and MT Manager.

b. >Tools >Power Off >Power Off Wireless System is the command needed to power off the MTw's that are wirelessly connected to a wireless master.
c. >Tools >Power Off >Power off All Devices powers off both docked and wirelessly connected MTw's.

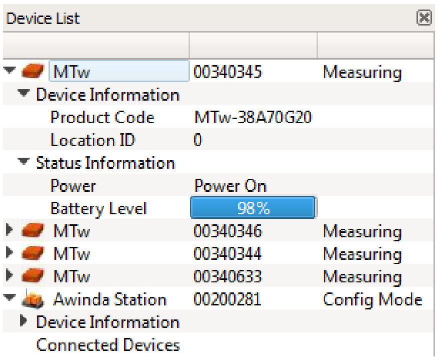
3. Hold the power button of the MTw for 5-6 seconds until the LED stops blinking.

It is best to power off unwanted MTw's before continuing with the wireless configuration. However, it is still possible to do this after wireless configuration.

6.5.1.2 Power On

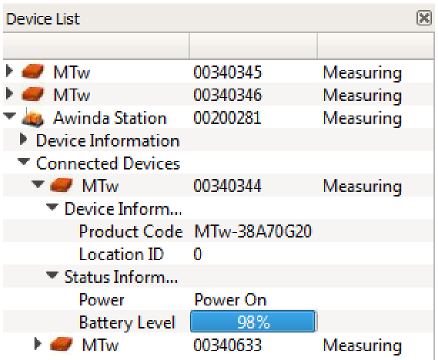
To re-enable the power of a powered down MTw, simply press the power button in the MTw, or dock the MTw back into an Awinda Station with the mains power supply connected; it will wake up by the power connection.

6.5.1.3 MTw status in the Device List



When MTw's are docked in the powered Awinda Station and connected to the PC, the Device list looks like that in the figure to the left.

Each MTw is treated as an independent device. It is in "Measuring" since the Awinda Station is measuring parameters such as the power status, battery level and Location ID.[9]



When the wireless configuration procedure has been performed, the Device List is updated.

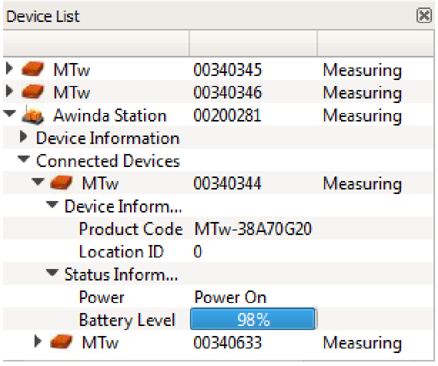
When MTw's are connected wirelessly, they become children of the Awinda Master and appear under the Awinda Master, under "Connected Devices". The state is still "Measuring" however now the inertial and magnetic data are available for measuring.

Remaining, MTw's that are docked in the Awinda Station still appear on the same level as the Awinda Master.

Other statuses that appear in the Device List are "Recording", when a recording is taking place, "Flushing", when retransmissions are being flushed to the Awinda Station and PC. If the Location ID is changed in the MT Settings, the MTw status changes briefly to "Config Mode". The status "Starting recording" indicates that the devices are waiting to start recording when a synchronization pulse is received by the Awinda station.

[9] Note that it is also possible to measure (and visualize and record) inertial data when docked, when enabled in preferences. This is not recommended.

6.5.1.4 Location ID



Users can view the numerical Location ID of docked MTw's in the Device List. This is useful for example if users want to use a numerical code for a given body segment.

The user must make the changes to the location ID in the MT Settings menu. See Section 6.5.3.

6.5.2 Message Window

Selecting and deselecting the Message Window icon activates and deactivates the Message window at the bottom of MT Manager. The Message Window gives the user information, primarily about errors detected during given steps.

6.5.3 MT Settings

In the MT Settings window several (low-level) settings can be viewed and some aspects can also be changed.

In this menu, the LocationID can be changed (and viewed in the Device List), this is useful for example if users want to code a given body segment to a number.

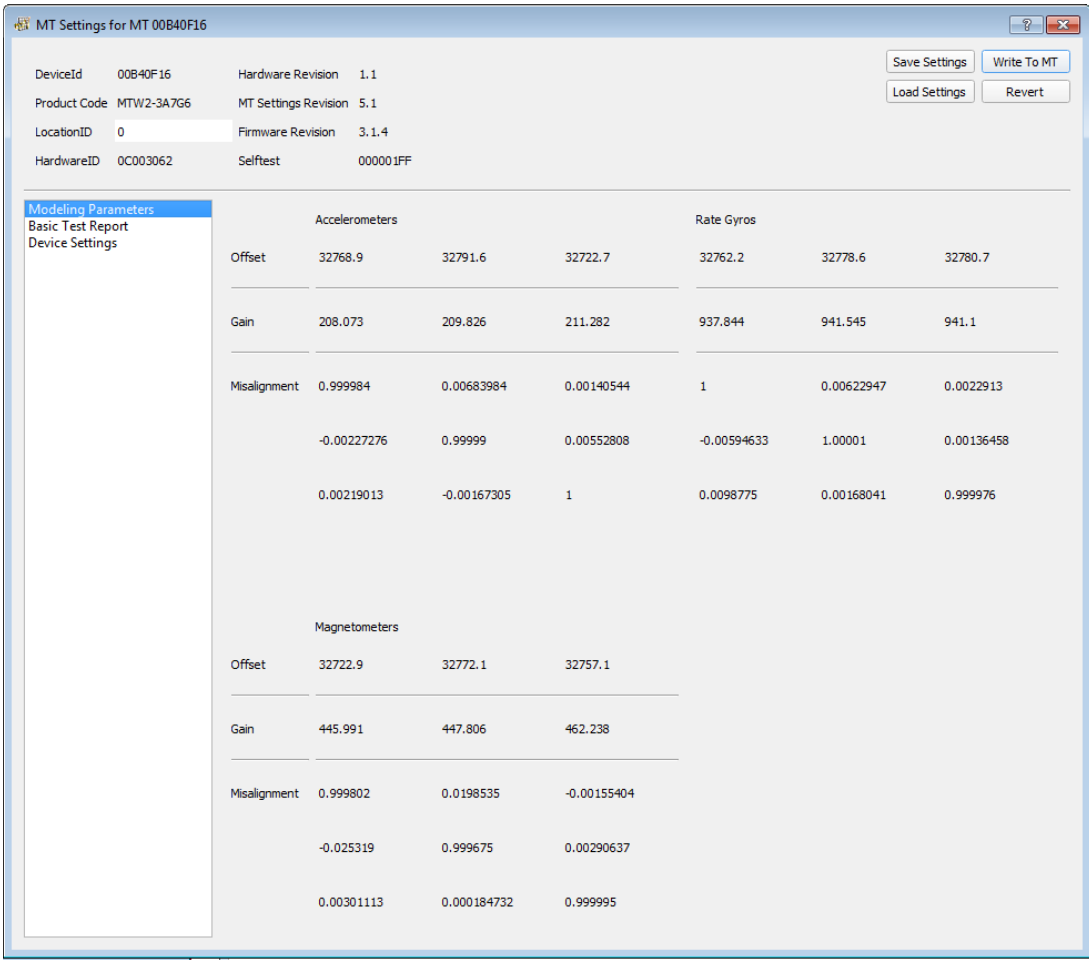
The sub menus of the MT Settings provide the user with information about the modelling parameters of the sensor components, a test report which is generated on its calibration at Xsens, communication options (simply information about which USB or virtual COM port the MTw is connected to) and filter settings. For the MTw, a single scenario is available which is the “46.1 Human”.

Please note that it is not advised to change the filter settings in this menu. However, if very exact latitude, longitude, altitude or gravitational parameters are known, the filters may provide somewhat more accurate orientation data.

Note: Caution is advised when making changes, in order to avoid unwanted changes, causing your devices to work improperly and/or inaccurately.

To implement a change on the motion tracker, select “Write to MT”. “Save Settings” saves the settings in MT Manager only. “Load Settings” can be used to retrieve previously saved settings to speed up writing the settings to the motion tracker.

It is always possible to revert a device to its Factory Settings using “Revert”.



6.5.3.1 Output configuration settings

The Output configuration window has been developed for the MTi Xsens Motion Tracker. For MTw, this window is a read-only pane, since MTw does not possess an on-board processor.

6.6 Wireless Configuration

When the Awinda Master is connected to MT Manager, the system can be in one of the following states:

State	Description
Init	The Master is plugged into the USB connection and MT Manager tries to establish the link to the Station.
Config	The Master is plugged in to the USB and detected by MT Manager. The radio is not transmitting.
Enabled	The Master is broadcasting (i.e. radio enabled) on the specified channel and MTw's can detect this transmission and connect. MTw's that connect but should not be part of the configuration can be rejected when the Awinda Master is in this state.

State	Description
Measuring	The MTw's are measuring and transmitting data to the Master. The Master relays the measurements to MT Manager.
Recording	Any missed data packets are retransmitted in this state, provided that the update rate is less than maximum.

The state transition diagram is illustrated in Figure 2 below.

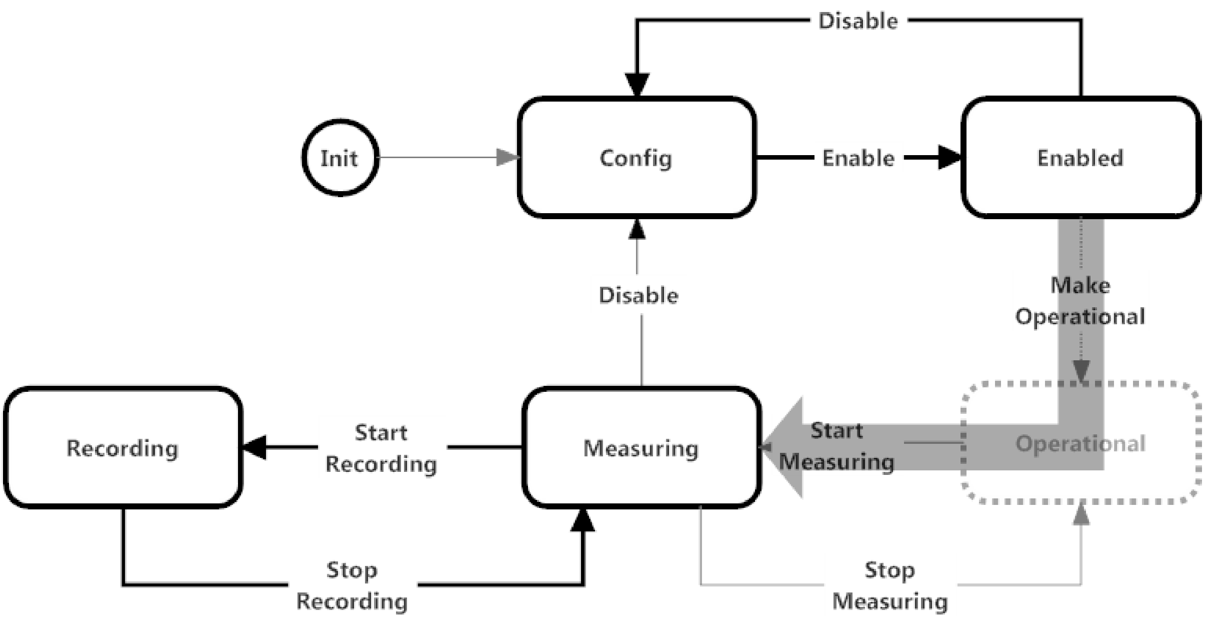


Figure 2: Awinda System State Transition Diagram

State	Transition	Description	Next State
Init	Station detected	MT Manager and Master are connected.	Config
Config	Enable	User indicates that the system can be enabled.	Enabled
Enabled	Start measuring	User indicates that the system can start measuring.	Measuring
	Disable	User indicates that the system is to be disabled.	Config
Measuring	Disable	User indicates that measuring stops. System is disabled.	Config
	Start Recording	User indicates that the recording is to be started.	Recording
Recording	Stop recording	User indicates that the recording can be stopped.	Measuring

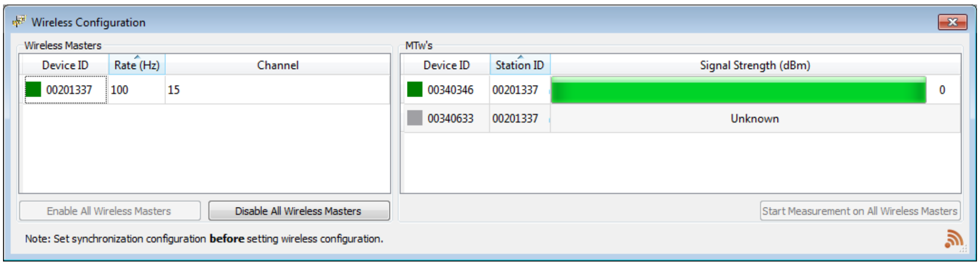
Figure 2 and the associated table below Figure 2 shows the states and the transitions for MTw with an Awinda Master. Note that, the diagram shows the presence of the "Operational" state. This state still exists, but it is no longer required that MTw users manually set the Master into this state, since it is set to the measurement state directly after this. The new interface speeds up the wireless connection between the Awinda Master and the MTw for users of MT Manager.

The user should note that knowing and understanding the states and transitions becomes important when creating a self-built application. MT Manager performs the state transitions for the user as they propagate through the wireless configuration menu. Users are advised to refer to the MT SDK User Manual if more detailed information is required for building applications.

6.6.1 Setting Up a Wireless Network in MT Manager

NOTE: If synchronization with external devices is needed first enable these settings (See Section 6.8) before carrying out the wireless configuration.

To configure the wireless network to be used, including selection of MTw's, and the update rates, go to > Tools > Wireless Configuration, or use the shortcut button:



As shown above, the wireless configuration menu is split into two sections:
1. On the left hand side are details about the detected Awinda Master(s). Here also the Update Rate and the Radio Channel, per Awinda Master can be configured.
2. On the right hand side are details about the MTw and the associated radio signal strength.

6.6.2 Choosing a Radio Channel

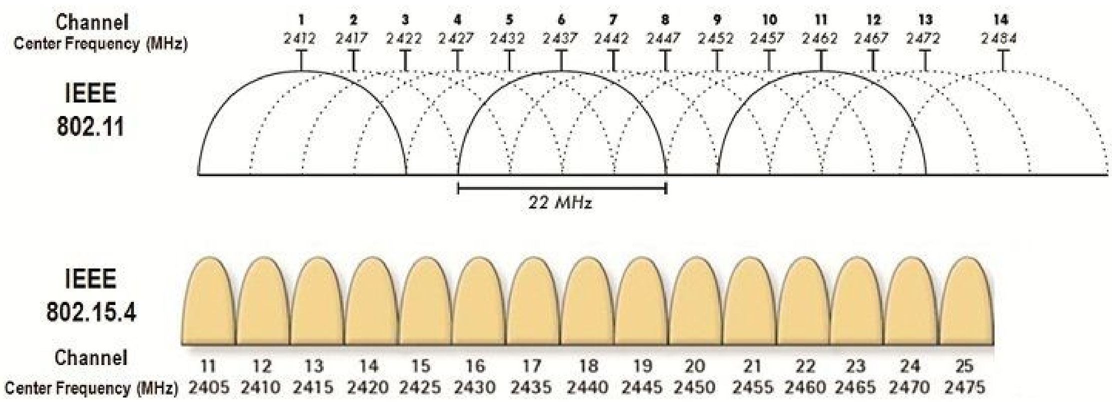


Figure 3: Overview of channels operating around 2.4GHz; for ease of channel selection

Figure 3 provides an overview of the allowed channels for operating on IEEE 802.15.4, the standard that the Awinda protocol is based on, around 2.4 GHz. The bottom row of the figure shows the channels on the 2.4GHz, the top row shows how WiFi channels use the spectrum. This should indicate to the user that the best channels to use when you know which channel WiFi is on. When in an environment where WiFi is also expected to be in prevalent use, but you are not sure which channels, try Channels 11, 15, 20 or 25.

Bluetooth uses all of the spectrum around 2.4 GHz, but will (try to) avoid channels in use by other systems including Awinda channels.

6.6.3 Select Radio Channel for Wireless Connection

A number of wireless frequency channels are available to connect the Awinda Master with the MTw's. When the wireless configuration menu is open, create the wireless network by first selecting the radio channel for communication between the Awinda Master and the MTw's.

To select the radio channel, double click on the value under the heading "Channel" and select the radio channel from the drop down menu. This channel will be enabled on the Awinda Master.

6.6.4 Enable Wireless Master

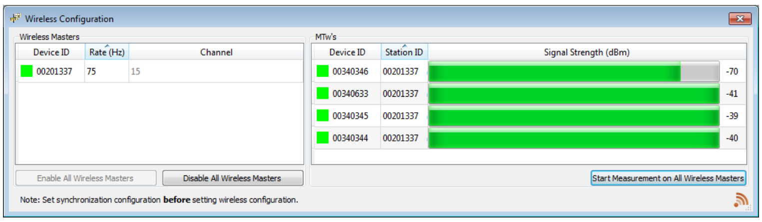
After selecting the radio channel for the wireless communication, click "Enable Wireless Master". The radio transceiver of the Awinda Master will turn on and it will search for MTw's on this channel.

For a wireless connection between the Awinda Master (either the Awinda Station or the Awinda USB Dongle) and the MTw's, the MTw's should not be docked in the Awinda Station, because while docked, the radio of the MTw is turned off. It is advised to remove the MTw's one by one instead of all at once.

When no longer docked to the Awinda Station the MTw will activate its radio and start to search for an Awinda Master to connect wirelessly to. All possible channels are scanned, but the MTw will connect to the channel, which has an Awinda Master available. If multiple Awinda Masters are active, the MTw will automatically pick the channel with the best (strongest) wireless link. Since each channel is scanned, it will take a few seconds to connect.

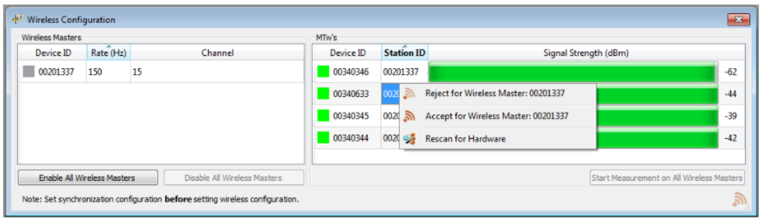
NOTE: If you experience a very poor wireless connection, or slow detection of MTw's, select a different wireless channel in the wireless configuration or turn-off potential sources of 2.4 GHz radiation (Bluetooth, WiFi, walkie-talkies, etc.).

6.6.5 Connecting MTw's to an Awinda Master



When a connection has been established between the Awinda Master and the MTw's, each MTw appears in the list on the right hand side, with an indication of the signal strength. As each new MTw is detected, the maximum Update Rate (marked as "Rate (Hz)") will decrease as appropriate.

The LED on the MTw will blink synchronously with the LED of the Awinda USB Dongle or with the CONN LED of the Awinda Station, when a successful link has been established.



The user should decide which of the detected MTw's to use in the measurements. To disconnect a given Awinda Master and an MTw, right click over the MTw, and select "Reject for Wireless Master: <Device ID>". Where Device ID is the serial number of the Awinda Master.

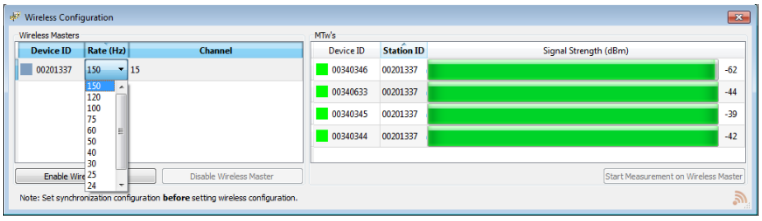
Initially, if a user has rejected the MTw for a given Master, this is depicted as "Unknown". A rescan shows that the MTw was rejected by the user.

To reconnect a rejected MTw to an Awinda Master, right-click the MTw and select "Accept for Wireless Master: <Device ID>".

Rejecting an MTw does not cause it to power off; it stops communication between that MTw and the Awinda Master.

NOTE: To power off the MTw, the user is advised to hold the power button on the MTw for 5-6 seconds until the LED stops blinking. See Section 6.5.1.1.

6.6.6 Update Rate



As each MTw makes a connection with the Awinda Master, the Maximum Update Rate decreases accordingly.

It is possible to select an update rate, by double clicking the value under "Rate (Hz)", a drop down menu will appear with the available update rates.

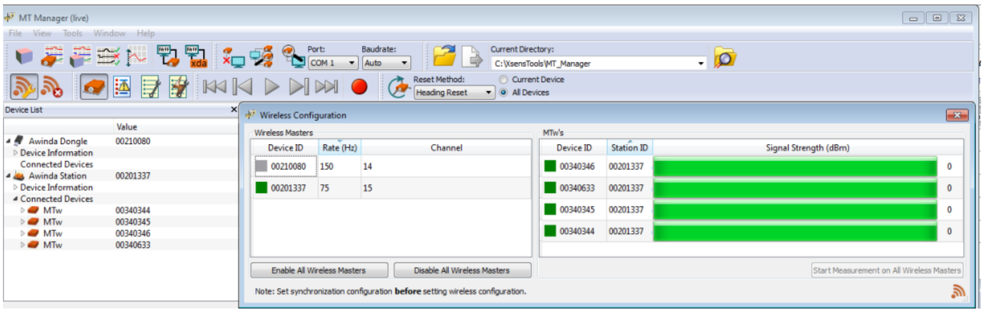
NOTE: The default update rate is always one value less than the maximum, to ensure that retransmissions are possible during recording. Users can increase this to maximum but caution should be taken as this will reduce or remove the possibility of retransmissions.

Table 1 provides the update rates for a number of MTw's and the available retransmission slots. Each MTw has a buffer of 1024 samples that can be used to buffer the data. The corresponding time is determined by the update rate of the device. The MTw will try to retransmit the data, but is dependent on the available retransmission slots as indicated by the last column of Table 1.

Table 1: Update rates and available retransmission slots for MTw

Amount of MTw's	Update Rate [Hz]	Available retransmission slots
1-5	120	2
6-9	100	2
10	80	3
11-20	60	4
21-32	40	1

6.6.7 Wireless Connection with the Awinda USB Dongle



It is also possible that both the Station and the Dongle (therefore two Awinda Masters) are connected to the PC via the USB ports.

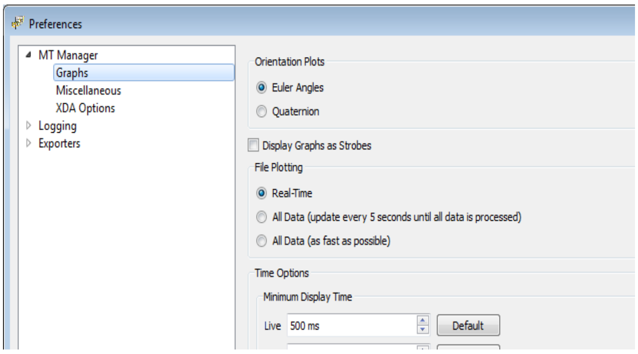
6.6.8 Wirelessly Connecting More than One Awinda Master

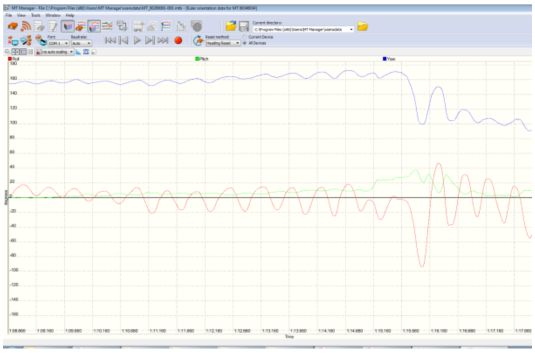
If more than one Awinda Master is in use, the user should first configure the MTw's of one Master, then the other. Before configuring the second Awinda Master, first ensure that the radio channel is different from that previously configured, then proceed with wireless configuration of the second Station.

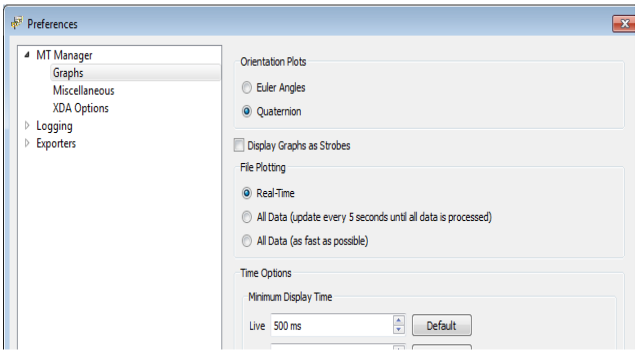
6.7 *Preferences*

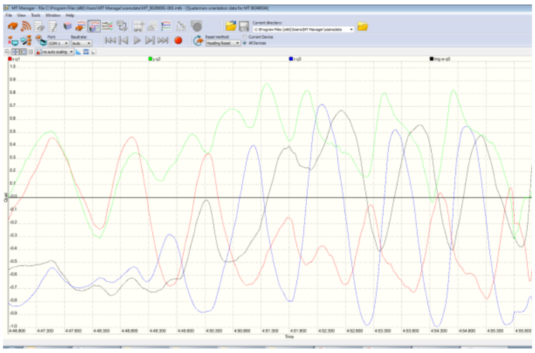
The graphs can be visualised as either Euler angles or quaternions. For more information about quaternions and Euler angles, see Section 11.7.

6.7.1 Preferences: Graphs

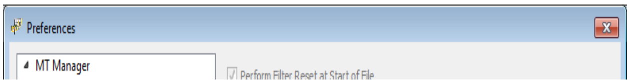








6.7.2 Preferences: Miscellaneous



Show docked MTw's in Device List (see 6.5).
Log and visualize data for docked MTw's (see 6.7.2.2).
New since MT Manager 4.1 (incorporating MTw into the entire MT family):
Enable RS485 Compatibility is not intended for MTw users, therefore MTw should not enable this.
The warn messages are related to the message terminal (new for MTw since MT 4.1.5). See Section 6.10.2 and the MT Manager User Manual for more details.

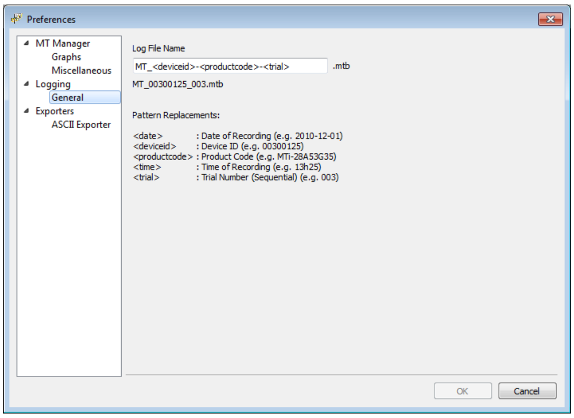
6.7.2.1 Show Docked MTw's in Device List

This is related to how the Device List handles docked MTw's. The default setting is to show docked MTw's at all times. If checked (default), docked and powered on MTw's will appear in the Device List, even after wireless configuration. In the Device List it will be possible to power off, and to observe the battery level of docked MTw's. If unchecked, after a wireless configuration, docked MTw's will not appear in the Device List.

6.7.2.2 Log and Visualize Data for Docked MTw’s

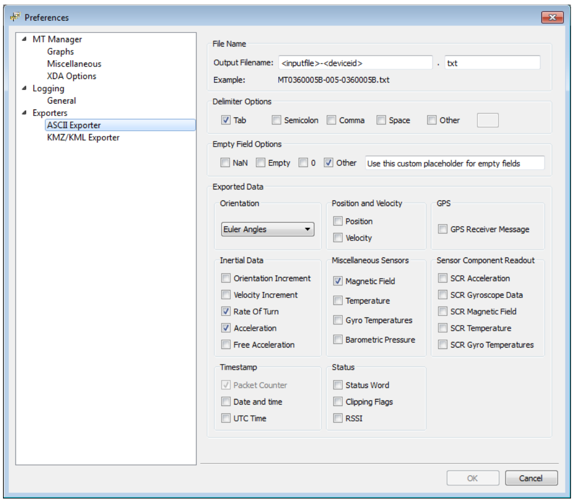
This setting is related to how the recording function handles docked MTw’s. The default setting is unchecked, which means that data will not be recorded from docked MTw’s. If checked, data from docked and powered on MTw’s will be recorded. This may be useful for users wishing to use for example only the barometer signal from the docked MTw’s, without using battery power.
Note: If this option is selected, the update rate of these MTw’s is always 100Hz, and separate files are generated for each docked MTw.

6.7.3 Preferences: Logging



Logging/file names.
It is possible to change the naming in which the log files are saved.
The Xsens default (and recommended) is “MT_” followed by the device ID and trial number. However the user may input custom text, as well as pre-set values, such as date, time etc.

6.7.4 Preferences: ASCII Exporter



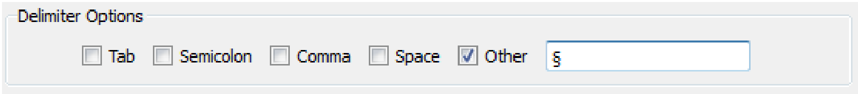
Following a recording, it is possible to export the values.

Section 11.7 provides a description of each Orientation Output Mode.

Note:
1) Acceleration and Rate of Turn (angular velocity) are values derived from the SDI values.

6.7.4.1 ASCII Exporter – Delimiter Options

It is possible to customise the type of delimiter needed to easily import into external software.

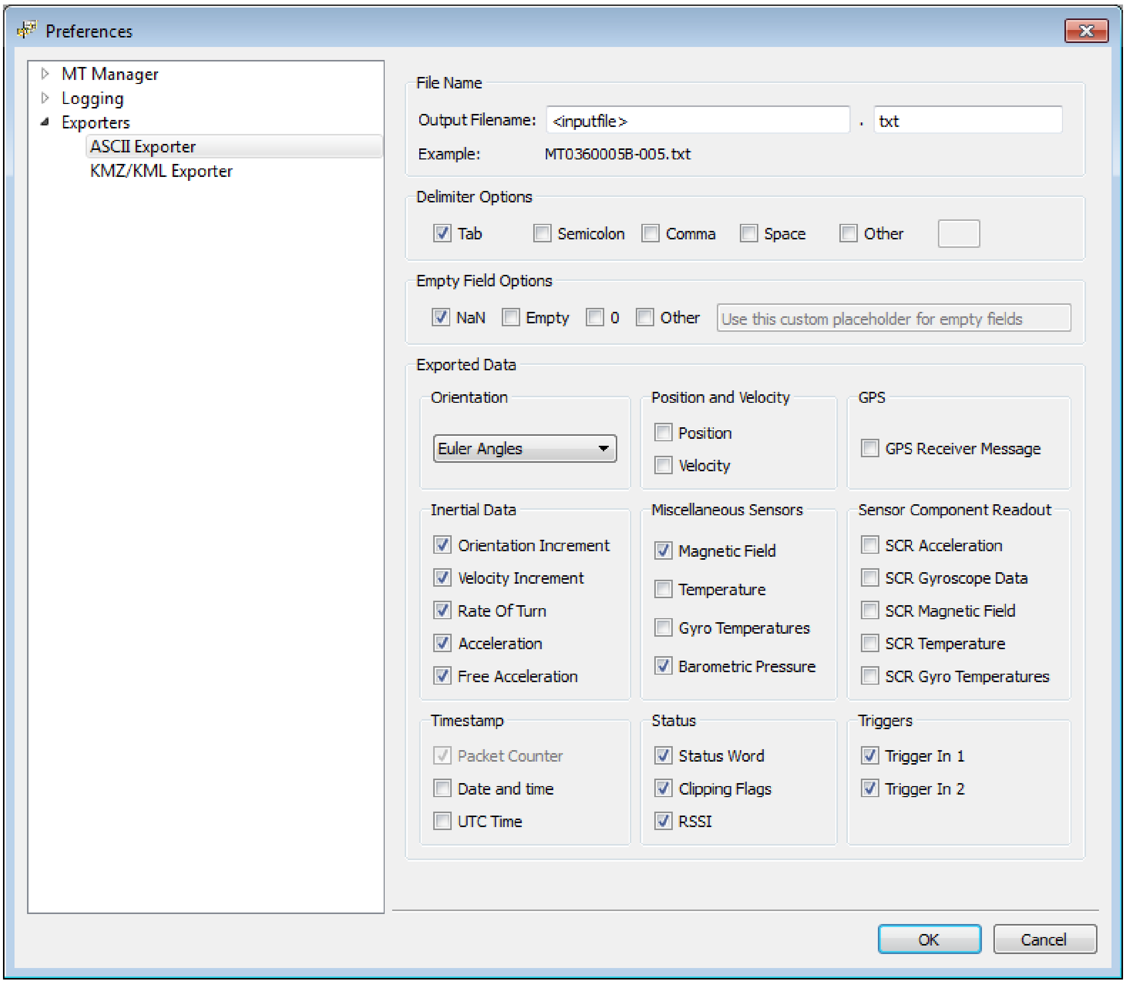


6.7.4.2 ASCII Exporter – Empty field options

This option is only applicable to the latest MTi devices since they can transmit data from various components at different sample frequencies.

6.7.4.3 ASCII Exporter – Exported data

The ASCII Exporter menu is very comprehensive due to the types of devices supported by MT Manager. Note that not all data described are sent by all devices. MTw exports all data shown as ticked in the image below



Orientation is always exported, as default. To undo this, select "None" from the drop-down menu in the list.

6.8 *Synchronization*

MT Manager for MTw provides an easy to use interface to facilitate synchronization with external devices (e.g third party devices). The user should decide which type of synchronization to implement, based on the synchronization possibilities of their own systems. For synchronization, one system must be in control and send the synchronization signal (Master/Sync Out). The other attached systems are controlled by and receive this signal (Slave/Sync In).

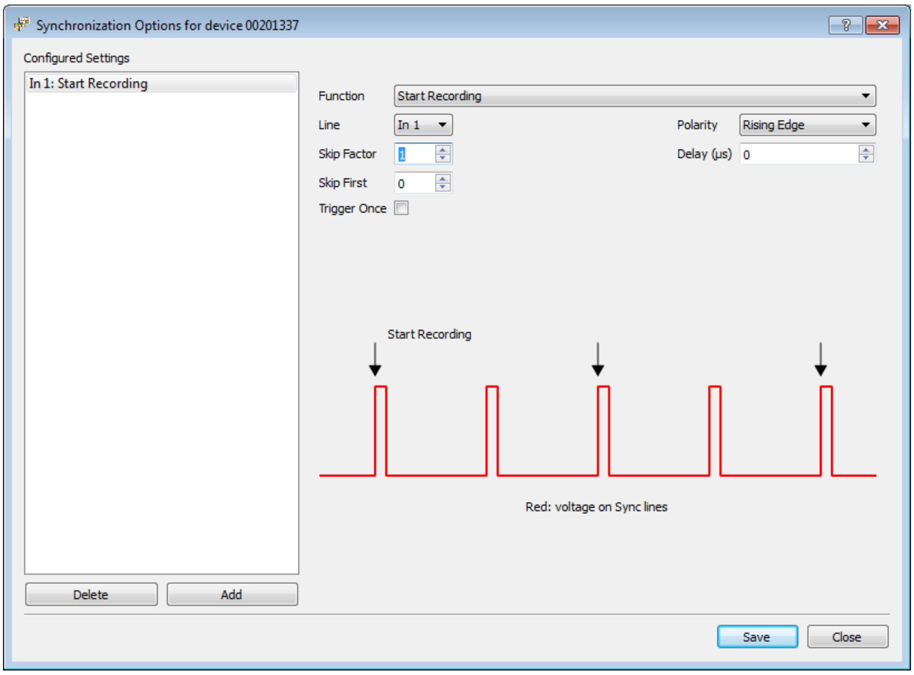
The hardware clock of the Awinda Master is very accurate. As an indication of the clock accuracy, the error in the Awinda Master's clock has a maximum of 1 µs every second (1 ppm). Therefore, in general, the recommended scenario is that Xsens is the master sending the control signals during synchronization.

The Awinda Station has four sync ports in the form of BNC connectors. Two sync ports (Line 1 and Line 2) are available for Sync In and two for Sync Out. For each sync port, there are a number of possible synchronization possibilities.

See Section 11.9 for synchronization examples.

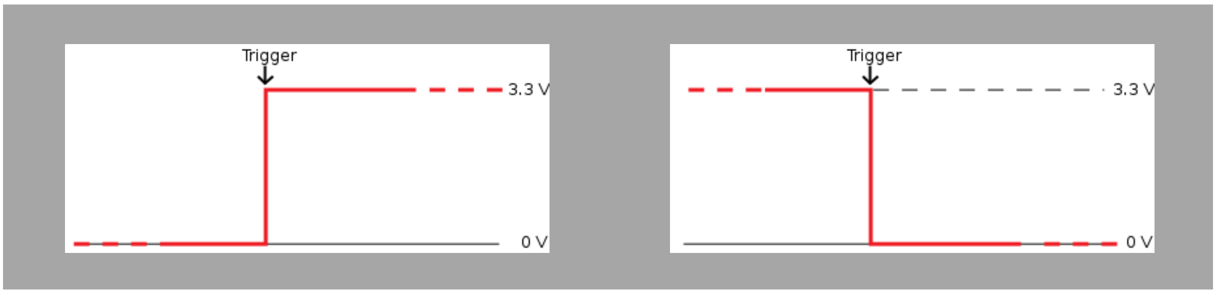
6.8.1 Synchronization Settings in MT Manager

NOTE: Set the synchronization settings before carrying out the wireless configuration step.
NOTE: It is not possible to set synchronization settings during a wireless connection.
To configure the software for synchronization control, select the Awinda station in the Device List and go to >Tools, >Synchronization Configuration.



6.8.2 Sync In

Sync In means that an external device sends a control signal to the Awinda Station. The Awinda Station can detect level changes on the input lines. This trigger may be a rising or falling edge as illustrated in the following figures:



When a trigger is detected on one of the input lines, the Awinda station can be configured to perform a certain action. A combination of any of the following are possible, on each Sync In port:

Event	Description
Start Recording	External system sends a start recording trigger. Upon receiving this trigger, the Awinda Station will begin recording at the start of the first frame following the trigger.
Stop Recording	External system sends a stop recording trigger. The Awinda station will stop recording at the end of the current frame.
Reset Timer	The outgoing timer of the Awinda station will be set to 0.
Trigger Indication	The Awinda Station receives a generic signal, determines the timestamp of a trigger and sends it. This is stored in the MTData2 packet.

A number of parameters can be set for each action:

Parameter	Description
Line	The sync line to activate.
Polarity	Rising or falling edge, or rising and falling.
Trigger Once	Only the first trigger event will be used. It is not recommended to select Trigger once, if more than one recording using synchronization of multiple systems will be made.
Skip First	The number of initial occurrences of the sync trigger to skip. This is useful if a well-defined delay is expected, or if the external signal uses the same sync line to generate for example start and stop recording. If both start and stop are on the same sync line, skip first should be 1 for stop recording, ensuring that the second trigger, instead of the first, causes the recording to stop.
Skip Factor	The number of occurrences of the sync trigger to skip in between trigger signals. In the same way that was described in Skip First (above), skip factor, for start and stop recording on one sync line should be set to 1, to ensure that the first trigger starts the recording and the second stops etc.

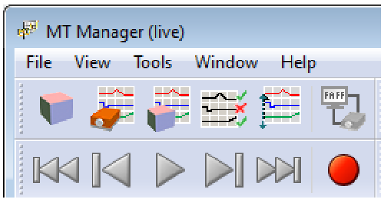
NOTE: The Rising and falling edge polarity command is particularly useful for the "Trigger indication" action for the following purposes:

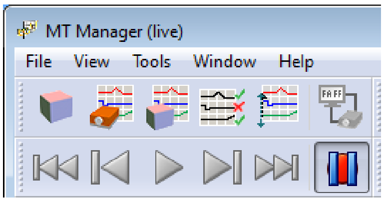
- An external system is connected and the behaviour with respect to its output signals is not exactly known. The Awinda system can be configured to send a trigger indication to the driver at every change of polarity. The user can then set the Awinda system to record and log the incoming trigger indications (only one MTw is required). These logs can be correlated with the actual actions performed.

- Another useful example is to detect when a switch action occurs. An example can be a foot-switch. A configured trigger indication with rising and falling edge sensitivity could detect this.

6.8.2.1 Sync In in MT Manager:

When Sync In is in use, after configuration, and when ready to record, users should click Record, to prepare the system for the external trigger. The record icon changes from the normal red dot to one with the pause symbol overlaid:





6.8.3 Sync Out

Sync Out is the command that enables the Xsens system to send a trigger pulse for synchronization purposes. A control signal is sent from the Awinda Station to the external hardware. As with Sync In, a combination of events are possible, based on a number of parameters.

Event	Description
Start Recording	When the Awinda Station starts the recording, it will send a start recording trigger to the external system.
Stop Recording	When the Awinda Station stops recording, it will send a stop recording trigger to the external system.
Go to Operational	A Sync Out trigger on “Go to Operational” is meant to be used for setting the initial signal level on a sync out line. **NOTE:** in general, this functionality is not needed since the level s automatically adapted based on the input settings.
Interval Transition Measurement	A frame transition at the Station can be used to give a signal to the external system, indicating the end of the strap-down integration interval over which data is calculated. Selecting this option, the frame transition is sent from the moment the Awinda system starts measuring.
Interval Transition Recording	See Interval Transition Measurement Selecting this option, the frame transition is sent from the moment that a recording is started, which can be used by the external device to capture the timing of the recording in its local time.

A number of parameters can be set for each action:

Parameter	Description
Line	The sync line to activate.
Polarity	Positive (where the polarity is initially low [0V] and goes high [3.3V]). Negative (where polarity is initially high [3.3V] and goes low [0V]).

Trigger Once	Only the first trigger event will be sent. It is not recommended to select Trigger once, if more than one recording using synchronization of multiple systems will be made.
Skip First	Number of initial sync pulses to skip. This command is useful if a well-defined delay is expected between the Xsens and external system. It may also be needed if the external system, like the Xsens system uses the same pulse properties to trigger different actions. See description provided above for Sync In.
Skip Factor	Number of sync pulses, between the sync pulses delivered, to skip. See Sync In Table description.
Pulse Width	The duration of the pulse in ms. Some systems wait for a signal of a minimum pulse width before generating the desired synchronization action. The Awinda Station can send a pulse with a duration of up to 99ms to an external system. It is not recommended to send a signal longer than a frame width. Specify 0 ms to generate an infinite pulse width.

6.8.4 Important Notices for Sync

When a recording is started, either by starting recording in MT Manager/XDA or when the Awinda Station is configured to start recording upon receipt of a trigger, the actual recording is initialized at the start of the following frame. The recording cannot be started between frames since it will not be able to reproduce a full window in that case. This is caused by the fact that the data received in a given frame is measured in the previous one. Therefore, delaying the recording in this way ensures that data is not recorded prior to the start recording indication.

Recording will also not be stopped between frames, for the same reason that data received in a given frame was measured during the previous frame. Therefore, the Awinda Station stops recording immediately after the current frame.

The system will generate a start and stop recording pulse at the start of the first frame and end of the last frame. This also means that the number of pulses generated will be one more than the actual recorded intervals.

6.9 Orientation Reset

In some situations, it may occur that the MTw 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 output the orientation in an object-fixed frame, as opposed to a sensor-fixed frame. Four methods have been added to the software to facilitate in obtaining the output in the desired coordinate frames.

1. Setting an arbitrary rotation matrix to rotate S to the chosen object coordinate system O. See Section 11.6.3.
2. A heading reset that redefines the X-axis of the global coordinate frame while maintaining the Z-axis along the vertical (also known as "boresighting"). After the heading reset the orientation will be expressed with respect to the new global (earth fixed) reference frame. See Section 11.6.4
3. An inclination reset that defines how the MTw is oriented with respect to the coordinate axes to which it is attached. After the inclination reset, the orientation as well as the inertial (and magnetic) data will be expressed with respect to the axes of the object. See Section 11.6.5.
4. A combined inclination/heading reset, referred to as alignment. See Section 11.6.6.

NOTE:
1. For all coordinate system reset functions it is important to remember that the housing of the MTw cannot be considered an accurate reference. Placement and subsequent aligning must be done very carefully otherwise (alignment) errors may be induced.
2. The user should be aware that when a reset takes place, data is stored according to the reset performed. MTw does not store new alignments on board, so a rescan after the orientation reset, or restart of MT Manager, results in a loss of this reset value.


The Orientation Reset menu allows the orientation of the MTw to be reset in a number of ways. To reset the MTw, align it in the correct manner and select the type of reset needed from the drop-down menu beside the icon indicated above. Determine if the reset should be applied to one or all MTw's. If the reset should be applied to only one MTw, select the MTw to be reset from the Device List, select the "Current Device" radio button, then click the reset button.

6.10 Visualising Data

In MT Manager it is possible to view real-time and recorded data.
Orientation data can be visualised either using the 3D box view, or using the orientation graphs (as described above, either quaternion or Euler orientations can be viewed). Sensor component data can be visualised using the "Inertial Data" graph to view the accelerometer, gyroscope and magnetometer data in one graph. The pressure graph is used to display atmospheric pressure, as measured by the barometer. In addition to the inertial and pressure data, the MT Status view is very useful to users to help determine the quality of the data being visualised.

6.10.1 MT Status

The MT Status graph displays the status for the following quantities:

- Selftest enabled.
- Filter Valid; indicates the accuracy of the filter (XKF) therefore if the user should trust the data.
- Bias estimate (not available for MTw).
- Clipping flags; indicates if a measurement of a sensor component exceeds the sensing range therefore if the user should trust the data.

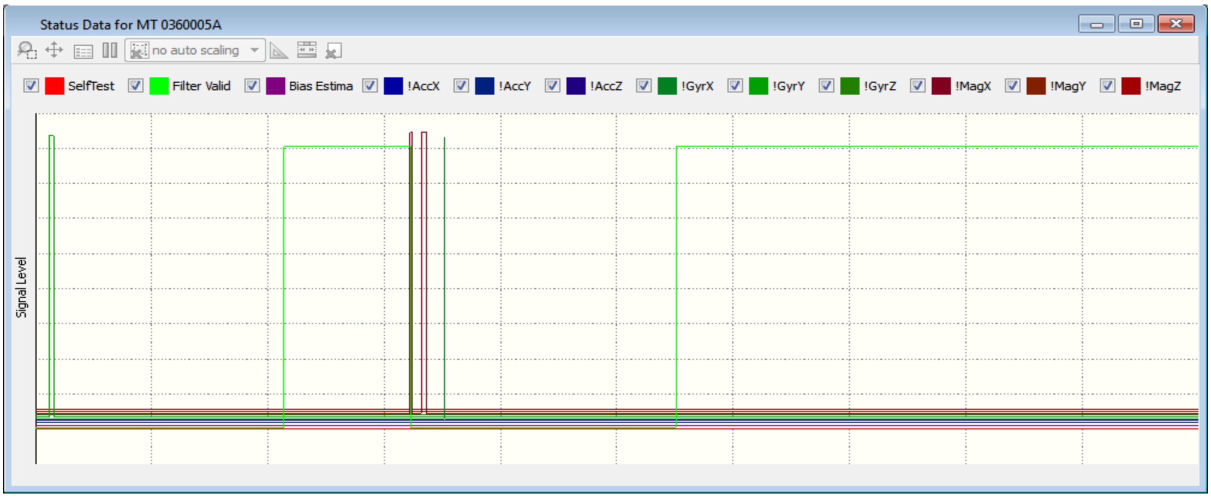
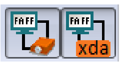


Figure 4: The status window of an MTw. In this example, one gyroscope and one magnetometer are clipping

Colour	Status data description
Red	Motion Tracker has successfully started up all sensor components.
Light green	Filter Valid: low= "not accurate", high= "accurate"
Dark purple	Bias estimate not available for MTw
Dark blue (3x)	Clipping flags for the accelerometers
Dark green (3x)	Clipping flags for the gyroscopes
Dark red (3x)	Clipping flags for the magnetometers

The user should keep this information in mind when analysing data. Data (for example orientation) measured while sensing component has experienced clipping, during erroneous bias estimations, during low estimation of the filter accuracy over the time periods that the self-test has failed is considered unreliable data and should be ignored, when possible. Status words and clipping flags can be exported to ASCII to ensure that only trustworthy data is further processed.

6.10.2 Message terminals



Data from the motion trackers can also be visualised in its binary form, in the message terminals
The message terminal shows in real-time messages sent to and received from the device or the Xsens Device API (XDA). The message terminal can also be used to compose low-level messages in order to quickly understand the communication protocol.
The Message Terminal has been designed for all Xsens products, therefore not all commands are required by MTw users. If more detailed information is required, please see the general user manual for MT Manager.

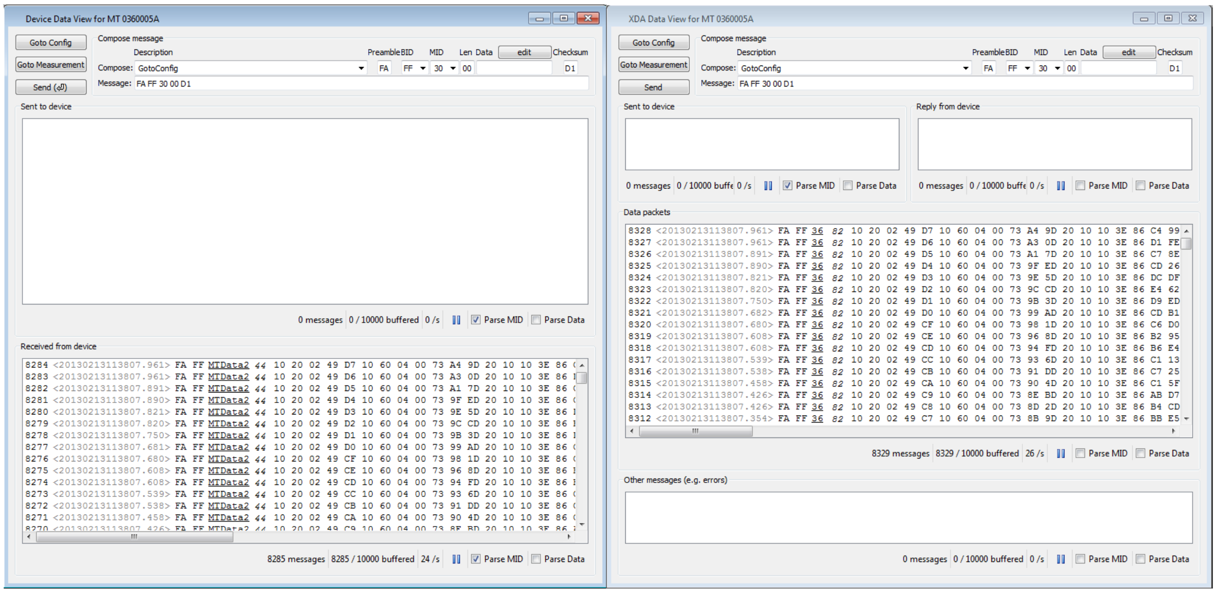
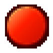


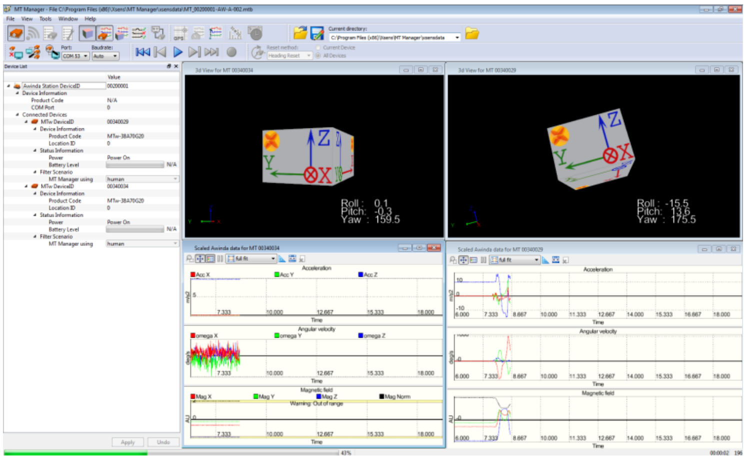
Figure 5: The message terminals for the device (left) and XDA (right)

6.11 Recording Data

Before recording data, ensure that the directory stated in the File Control menu is correct. To record data, use the red icon in the Recording & Playback menu.

 Record button in the Playback & Recording menu

When the data is recording the icon appears depressed. To stop the recording, click the same icon. Data is automatically saved in the directory specified. The record button will be depressed until all data is downloaded (flushed) from the trackers.



6.12 Saved and Exported Data

MT Manager can replay saved MTB files. To review the data in MT Manager, open the MTB file and select the desired data to view. Data is easily visualised using the 3D orientation box, or using graphs (inertial, orientation, pressure or status data). Select the "Play" icon in the Playback & Recording menu. The progress of the recorded file during playback is seen in the green progress bar at the bottom left-hand-side of the screen.

Data from the MTB files can be exported to ASCII format, with the following content:

- Sample Counter – is always exported to ensure that data from all MTw's are correctly allocated.
- SDI data (Velocity Increment, Orientation Increment). See Section 11.4 for more information.
- Inertial (and magnetic) calibrated sensor data (3D acceleration, angular velocity, magnetic field, pressure). Please note that while the terminology is inertial data, the data received by MT Manager for the accelerometers and gyroscopes are actually data from the SDI. This means integrated values. This data has been converted to calibrated sensor data.
- Orientation data
  - The output orientation can be presented in different conventions:
  - Unit normalised Quaternions (also known as Euler parameters)
  - Euler angles: roll, pitch, yaw (XYZ Earth fixed type, also known as Cardan)
  - Rotation Matrix (Direction Cosine Matrix)
- Awinda wireless network properties
  - RSSI: Received Signal Strength Indicator (It is advised to use this to check what the signal strength was during measurements)
- Status Word this is a 32-bit output of ones and zeros indicating the status of filter and components.
- Clipping flags a selection of the StatusWord data, indicating if a given sensor component has exceeded its range

- Trigger In 1 and/or 2– polarity, time stamp and frame number.

Abbreviation	Data	Unit
PacketCounter	Sample counter	(-), wraps at 65535
StatusWord	32-bit status, see Section 11.8 for information on the Status Word	N/A
Clipping Flags	0 refers to no clipping. 1 indicates that a sensor component clipped. This data is a selection of the StatusWord output.	N/A
RSSI	Received Signal Strength Indicator by Master from each connected MTw	dBm
Acc_X	Acceleration x-axis	m/s^2
Acc_Y	Acceleration y-axis	m/s^2
Acc_Z	Acceleration z-axis	m/s^2
FreeAcc_X	Acceleration minus gravity, x axis	m/s^2
FreeAcc_Y	Acceleration minus gravity, y axis	m/s^2
FreeAcc_Z	Acceleration minus gravity, z axis	m/s^2
Gyr_X	Angular rate x-axis	rad/s
Gyr_Y	Angular rate y-axis	rad/s
Gyr_Z	Angular rate z-axis	rad/s
Mag_X	Magnetic field x-axis	arbitrary unit; magnetic field strength at Xsens is 1
Mag_Y	Magnetic field y-axis	arbitrary unit; magnetic field strength at Xsens is 1
Mag_Z	Magnetic field z-axis	arbitrary unit; magnetic field strength at Xsens is 1
VelInc_X	Velocity increment from SDI, x-axis	m/s
VelInc_Y	Velocity increment from SDI, y-axis	m/s
VelInc_Z	Velocity increment from SDI, z-axis	m/s
OriInc_w	Orientation increment quaternion from SDI, real component	Unit quaternion
OriInc_x	Orientation increment quaternion from SDI, x-axis	Unit quaternion
OriInc_y	Orientation increment quaternion from SDI, y-axis	Unit quaternion
OriInc_z	Orientation increment quaternion from SDI, z-axis	Unit quaternion
Pressure	Atmospheric pressure	Pa
Roll/Pitch/Yaw	Orientation Euler angles format (3)	deg
Quat *	Orientation quaternion format (4)	Unit quaternion

Abbreviation	Data	Unit
Mat [R#][C#]	Rotation matrix format [Row][Column] (3x3). (Direction Cosine matrix)	Unit vectors
TrigIn1_Polarity	Polarity of the received signal	1: Rising Edge 2: Falling Edge 3: Both
TrigIn1_Timestamp	The time stamp of the trigger Awinda converted time stamp values of trigger indications sent to SyncIn 1 of the Awinda Station	Milliseconds
TrigIn1_Framenumber	The frame number in which the trigger was received	N/A
TrigIn2_Polarity	Polarity of the received signal	1: Rising Edge 2: Falling Edge 3: Both
TrigIn2_Timestamp	The time stamp of the trigger Awinda converted time stamp values of trigger indications sent to SyncIn 2 of the Awinda Station	Milliseconds
TrigIn2_Framenumber	The frame number in which the trigger was received	N/A

6.13 Application Software Development for the MTw

The MT Manager Windows® GUI application software created by Xsens uses exactly the same SDK/API available to developers (xsens_cmt.dll) with the dynamic library interface. This is the same API that is provided for software development in the Software Development Kit (SDK). Source code for the lower levels of the API (drivers) are supplied for reference but are not recommended to use for application development on Windows or Linux.

Static LIBs as well as DLLs are provided for developers for both 32-bit and 64-bit platforms. The DLL also includes a COM interface for easy application development in applications that support the COM-interface, such as MATLAB, Excel, LabVIEW etc.

For detailed documentation on the API please refer to the Application Programming Interface (API) reference documentation made available as HTML and the supplied example source code for C#, C++, and MATLAB.

Since MT SDK 3.8 there is also a (beta) Linux version of the SDK.

7 Xsens Peripheral Software

7.1 Magnetic Field Mapper (MFM)

When an MTw is mounted to an object that contains ferromagnetic materials, the measured (Earth) magnetic field can become distorted, causing errors in measured orientation. To correct for known magnetic disturbances, for example, an MTw attached to a prosthesis containing ferromagnetic materials, a separate software product has been developed to allow users to remap the magnetic field of the MTw. This software is called Magnetic Field Mapper (MFM) and is located in the installation folder of MT Manager. This directory also contains a user manual with instructions on how to execute MFM, in terms of software steps and how to orientate the MTw during the process. The user manual for the MFM is generic since it is useful for all Xsens products.

In MT Manager do the following:

	Procedure to perform MFM for MTw's
1	Power off all MTw's that do not need MFM
2	Dock all MTw's that need to be mapped
3	Wireless configuration for MTw's to be mapped (See Section 6.6.1)
4	Start Measuring
5	Close MT Manager
6	Activate MFM
7	Follow instructions for MFM
8	Close MFM

7.2 Firmware Updater

With new software releases, it can be expected that new firmware is required for the Awinda Station, Awinda Dongle and MTw's. Xsens supplies a firmware updater. The latest firmware updater can be downloaded from here: www.xsens.com/mt-software-suite

It is important to select Awinda system and to follow the on-screen instructions. There are step by step instructions in the user manual. START > All Programs > Xsens >Firmware Updater >Firmware Updater User Manual.

8 System requirements

MT Manager is suitable for Windows 7 and Windows 10. The following system setup is recommended to run the software:

- Windows 7/10 (other Windows platforms are possible, but not extensively tested)
- Processor: 1.7 GHz or faster
- USB port (2.0 or higher)
- Graphics card with 3D hardware acceleration and OpenGL support. Contact your graphics card manufacturer to ensure your graphics card drivers are up to date.

NOTE: MT Manager is designed to assign a low priority to graphics functions if your computer cannot update the screen smoothly due to insufficient computing resources. This is intentional to avoid interfering with the core functionality.

Troubleshooting and Support

Problem	Possible cause	Solution
Installation is aborted due to previously installed version.	Drivers are still present from the previous Xsens MT SDK installations.	Use Add/Remove Programs on the Control Panel to remove the previously installed version. Then re-try installing the desired version.
After Wireless configuration MTw appears to spin.	Too much movement when entering measurement mode. Filter not initialised correctly.	Keep motion trackers as still as possible when entering measurement mode from wireless configuration. See Settling Time (Section 3.3.2) for details. Rescan ports to reinitialise the filters.
COM ports have been scanned, but no devices detected.	It is possible that an incorrect baudrate has been selected; this means that the device cannot be found.	Select "Auto" in the baudrate drop down menu. Then rescan all COM ports.
No Awinda Station/MTw's found by MT Manager.	The host PC/laptop may not have properly installed the USB drivers for the Awinda Station.	Check all cable connections. Un-plug the USB cable and power supply from the Awinda Station, close MT Manager. Wait 30 seconds and then re-plug and reopen MT Manager.
Awinda Station "freezes".	A corruption has occurred in the USB driver between the Awinda Station and the PC.	Unplug the USB cable and power supply from the Awinda Station, close MT Manager. Wait 30 seconds and then re-plug and reopen MT Manager.
Following rescan, no Awinda Station, and /or fewer than expected MTw's found in the Device List.		Check all cable connections. Un-plug the USB cable and power supply from the Awinda Station. Wait 30 seconds and then re-plug it.
Re-entering wireless network after out of range, MTw(s) not detected in MTM.	MTw and Awinda Station lost wireless connection for an undesired length of time.	Re-dock the MTw(s) and perform Wireless configuration step again (Section 6.6.1).
MTw sensor is in bootloader mode		Switch the MTw off by pressing the button 5-6 seconds and switch it on again.
Re-enable radio does not always find trackers used before.		Re-dock the MTw(s), rescan ports and perform Wireless configuration step again (Section 6.6.1).

Problem	Possible cause	Solution
RSSI in Wireless configuration is full, while I cannot receive data from the MTw.	MTw and Awinda Master no longer wirelessly connected.	Re-dock the MTw(s) perform Wireless configuration step again (Section 6.6.1).
MTw in Wireless Configuration is shown as disconnected, but RSSI appears to have a good strength.	MTw and Awinda Master are not wirelessly connected. Related to above issue.	Re-dock the MTw(s), rescan ports and perform Wireless configuration step again (Section 6.6.1).
A discrepancy of a sample count is detected between MTw's at the beginning or end of an exported file.	Due to the nature of wireless transmission, this may occur.	Always allocate exported data to a given sample count. NB - also to prevent possible problems of missing samples.

8.1 Customer Support

Xsens Technologies B.V. is glad to help you with any questions you may have about the MTw or about the use of the technology for your application. Please use the FAQ or contact Xsens Customer Support:

- Internet and FAQ: http://www.xsens.com/support
- Telephone: Xsens HQ +31 88 97367 00 / Xsens US office 310-481-1800

To be able to help you, please mention your Motion Tracker **Device ID** (on the back of the device) and **software license registration number** in your e-mail.

9 Warranty Liability

Xsens Technologies B.V. warrants the products manufactured by it to be free from defects in material and workmanship for a period of 1 year 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.

10 Regulatory Notices

10.1 Radio Frequency Exposure and Emission

The MTw, Awinda dongle and station contains a small radio transmitter and receiver. During communication with the Awinda Master it receives and transmits radio frequency (RF) electromagnetic fields (microwaves) in the frequency range 2400 of 2500 MHz. The output power of the radio transmitter is very low. When using the system, you will be exposed to some of the transmitted RF energy. This exposure is well below the prescribed limits in all national and international RF safety standards and regulations.

Most modern electronic equipment, for example, in hospitals and cars, is shielded from RF energy. However, certain electronic equipment is not.

Therefore:
Note: This equipment emits RF energy in the ISM (Industrial, Scientific, Medical) band. Please insure that all medical devices used in proximity to this device meet appropriate susceptibility specifications for this type of RF energy (CE or FCC marked).

Turn off this electronic device before entering an area with potentially explosive atmosphere. It is very rare, but any electronic device could generate sparks. Sparks in such areas could cause an explosion or fire resulting in bodily injury or even death. Areas with a potentially explosive atmosphere are often, but not always, clearly marked. They include fuelling areas, such as petrol station, below deck on boats, fuel or chemical transfer or storage facilities, and areas where the air contains chemicals or particles, such as grain, dust, or metal powders.

10.2 FCC Statement

This equipment has been tested and found to comply with the limits for a Class B digital device, pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses and can radiate radio frequency energy and, if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna
- Increase the separation between the equipment and receiver
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected
- Consult the dealer or an experienced radio/TV technician for help.

FCC Caution: Any changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate this equipment.
This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

Radiation Exposure Statement for Awinda Station:
This equipment complies with FCC radiation exposure limits set forth for an uncontrolled environment. This equipment should be installed and operated with minimum distance 20cm between the radiator & your body.
This transmitter must not be co-located or operating in conjunction with any other antenna or transmitter.

This MVN Awinda product contains

FCC ID: MTw2: QILMTW2-3A7G6
Awinda Station: QILAW-A2
Awinda Dongle: QILAW-DNG2

10.3 CE Declaration of Conformity for MTw2, Awinda Station, Awinda Dongle

RF_061, Issue 04

EC Declaration of Conformity

Hereby,

Name of manufacturer:	Xsens Technologies B.V.
Address:	Pantheon 6a
City:	Enschede
Country:	The Netherlands

declares that this equipment:

Product description:	Wireless Motiontracker system
Type designation(s):	MTW2-3A7G6, AW-A2, AW-DNG2
Trademark:	MVN Awinda

is in compliance with the essential requirements and other relevant provisions of Directive 1999 / 5 / EC

with reference to the following standards:

EN 300 440-2 V1.4.1
EN 301 489-1 V1.9.2
EN 301 489-17 V2.2.1
EN 60950-1: 2010

Date:	May 27, 2015
City:	Enschede
Name:	Per Slycke
Signature:	

10.4 FCC Declaration of Conformity MTw2

DECLARATION OF CONFORMITY (DoC)

Equipment:	**Wireless Awinda Sensor**
Trademark(s) and Model(s):	**MVN Awinda MTW2-3A7G6**
Manufacturer:	**Xsens Technologies B.V.**
FCC ID in case other parts of this equipment are subject to certification:	**QILMTW2-3A7G6**

This device complies with Part 15 of the FCC Rules.

Operation is subject to the following two conditions:

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

The following test reports are subject to this declaration:

Test report number:	Issue date:
20153144305 Ver 1.00	**6/8/2015**

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

Company name:	Xsens Technologies B.V.
Name/Title:	**Per Slycke CTO**
Address:	**Pantheon 6a, 7521 PR Enschede, The Netherlands**
Phone:	**+31(0)889736700**
Fax:	**+31(0)889736701**
E-mail:	**Per.Slycke@Xsens.com**
Date:	**23/06/2015**
Signature:	

10.5 FCC Declaration of Conformity Awinda Station

DECLARATION OF CONFORMITY (DoC)

Equipment:	**Wireless Awinda Station**
Trademark(s) and Model(s):	**MVN Awinda AW-A2**
Manufacturer:	**Xsens Technologies B.V.**
FCC ID in case other parts of this equipment are subject to certification:	**QILAW-A2**

This device complies with Part 15 of the FCC Rules.

Operation is subject to the following two conditions:

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

The following test reports are subject to this declaration:

Test report number:	Issue date:
20153144303 Ver 1.00	**6/8/2015**

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

Company name:	Xsens Technologies B.V.
Name/Title:	**Per Slycke CTO**
Address:	**Pantheon 6a, 7521 PR Enschede, The Netherlands**
Phone:	**+31(0)889736700**
Fax:	**+31(0)889736701**
E-mail:	**Per.Slycke@Xsens.com**
Date:	**23/06/2015**
Signature:	

Document MW0502P.L

10.6 FCC Declaration of Conformity Awinda Dongle

DECLARATION OF CONFORMITY (DoC)

Equipment:	**Wireless Awinda Dongle**
Trademark(s) and Model(s):	**MVN Awinda AW-DNG2**
Manufacturer:	**Xsens Technologies B.V.**
FCC ID in case other parts of this equipment are subject to certification:	**QILAW-DNG2**

This device complies with Part 15 of the FCC Rules.

Operation is subject to the following two conditions:

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

The following test reports are subject to this declaration:

Test report number:	Issue date:
20153144304 Ver 1.00	**6/8/2015**

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

Company name:	Xsens Technologies B.V.
Name/Title:	**Per Slycke CTO**
Address:	**Pantheon 6a, 7521 PR Enschede, The Netherlands**
Phone:	**+31(0)889736700**
Fax:	**+31(0)889736701**
E-mail:	**Per.Slycke@Xsens.com**
Date:	**23/06/2015**
Signature:	

10.7 Certificate of Radio Equipment in Japan MTw2

telefication bv
The Netherlands
Chamber of Commerce
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www.telefication.com

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Certificate

Of

Radio Equipment in JAPAN

No.: 152150087/AA/00

Telefication, operating as Conformity Assessment Body (CAB ID Number: 201) with respect to Japan, declares that the listed product complies with the Technical Regulations Conformity Certification of Specified Radio equipment (ordinance of MPT N° 37,1981)

Product description:	**Wireless Awinda Sensor**
Trademark:	**MVN Awinda**
Family name:	**--**
Type designation:	**MTW2-3A7G6**
Serial No:	**--**
Hard-|Software release No:	**MW111415|3.0.6**
Manufacturer:	**Xsens Technologies B.V.**
Address:	**Pantheon 6a**
City:	**7521 PR Enschede**
Country:	**Netherlands**

This certificate is granted to:

Name:	**Xsens Technologies B.V.**
Address:	**Pantheon 6a**
City:	**7521 PR Enschede**
Country:	**Netherlands**

This certificate has THREE Annexes.

Zevenaar, 23 September 2015

i.o.

W.J.M. Jong
Manager Product Certification

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10.8 Certificate of Radio Equipment in Japan Awinda Station

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Chamber of Commerce
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Certificate

Of

Radio Equipment in JAPAN

No.: 152150085/AA/00

Telefication, operating as Conformity Assessment Body (CAB ID Number: 201) with respect to Japan, declares that the listed product complies with the Technical Regulations Conformity Certification of Specified Radio equipment (ordinance of MPT N° 37,1981)

Product description: **Wireless Awinda Station**
Trademark: **See annex 3**
Family name: **--**
Type designation: **See annex 3**
Serial No: **See annex 3**
Hard-|Software release No: **AW140520|3.0.5**

Manufacturer: **Xsens Technologies B.V.**
Address: **Pantheon 6a**
City: **7521 PR Enschede**
Country: **Netherlands**

This certificate is granted to:

Name: **Xsens Technologies B.V.**
Address: **Pantheon 6a**
City: **7521 PR Enschede**
Country: **Netherlands**

This certificate has THREE Annexes.

Zevenaar, 23 September 2015

i.o.

W.J.M. Jong
Manager Product Certification

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10.9 Certificate of Radio Equipment in Japan Awinda Dongle

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Certificate

Of

Radio Equipment in JAPAN

No.: 152150086/AA/00

Telefication, operating as Conformity Assessment Body (CAB ID Number: 201) with respect to Japan, declares that the listed product complies with the Technical Regulations Conformity Certification of Specified Radio equipment (ordinance of MPT N° 37,1981)

Product description: **Wireless Awinda Dongle**
Trademark: **MVN Awinda**
Family name: **--**
Type designation: **AW-DNG2**
Serial No: **--**
Hard-|Software release No: **AM140520|3.0.5**

Manufacturer: **Xsens Technologies B.V.**
Address: **Pantheon 6a**
City: **7521 PR Enschede**
Country: **Netherlands**

This certificate is granted to:

Name: **Xsens Technologies B.V.**
Address: **Pantheon 6a**
City: **7521 PR Enschede**
Country: **Netherlands**

This certificate has THREE Annexes.

Zevenaar, 23 September 2015

i.o.

W.J.M. Jong
Manager Product Certification

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11 Appendices

11.1 MTw Technical Specifications

11.1.1 MTw Performance

	Angular velocity	Acceleration	Magnetic field	Pressure
Dimensions	3 axes	3 axes	3 axes	-
Full Scale	± 2000 deg/s	± 160 m/s^2	± 1.9 Gauss	300 -1100 mBar[10]
Non-linearity	0.1 % of FS	0.5 % of FS	0.1 % of FS	0.05 % of FS
Bias stability [11]	10deg/hr	0.1mg	-	100 Pa/year
Noise	0.01deg/s/√Hz	200 µg/√Hz	0.2mGauss/√Hz	0.85 Pa/√Hz
Alignment error	0.1 deg	0.1 deg	0.1 deg	-
Bandwidth	180Hz	180 Hz	10-60 Hz (var.)	-

11.1.2 Orientation Performance

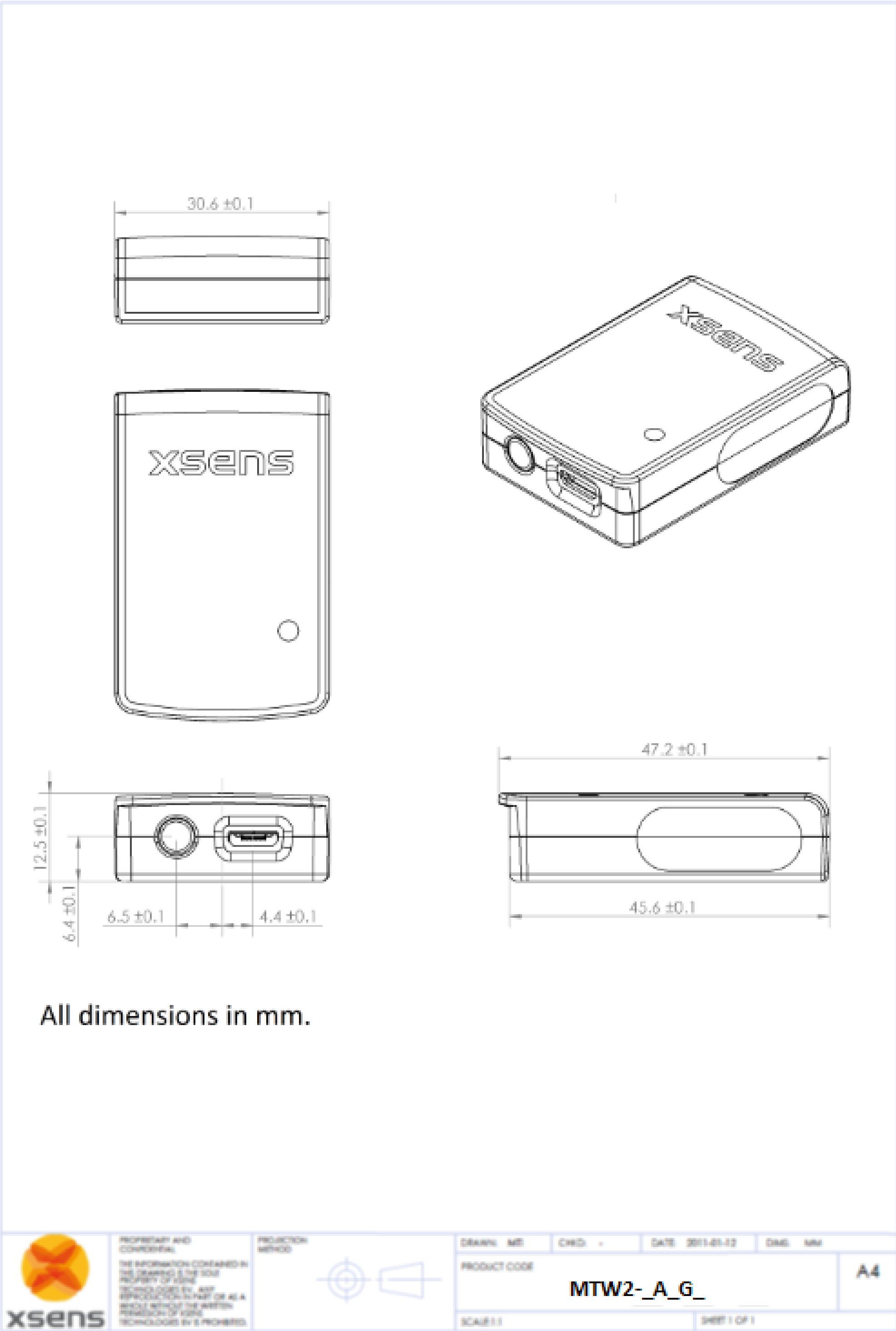
Dynamic Range	all angles in 3D
Static accuracy (Roll/Pitch)	0.5 deg RMS
Static Accuracy[12] (Heading)	1 deg RMS
Dynamic Accuracy (Roll/Pitch)	0.75 deg RMS
Dynamic Accuracy (Heading)[13]	1.5 deg RMS

11.1.3 MTw Physical Properties

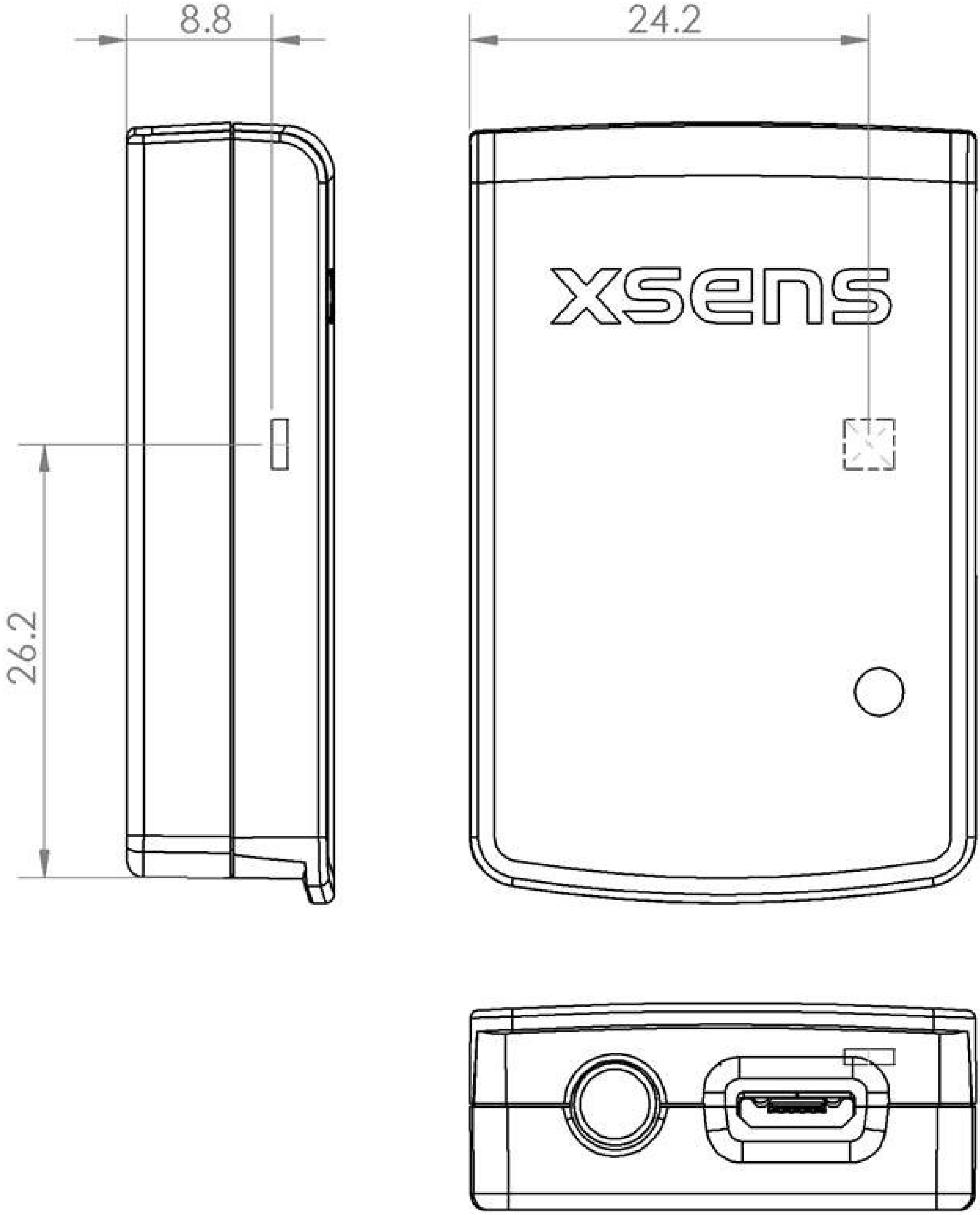
Accelerometers	MEMS solid state, capacitive readout
Rate gyroscope	MEMS solid state, capacitive readout
Magnetometer	Magneto-Impedance sensor elements
Barometer	Piezo-resistive sensor element
Weight	16g
Housing dimensions	47 x 30 x13mm

[10] (-500 -.9000 m above sea level)
[11] As measured from the Allan variance diagram.
[12] In homogeneous, undisturbed magnetic environment
[13] In homogeneous, undisturbed magnetic environment

11.1.4 Schematics MTw Housing Specifications



11.1.5 Schematics accelerometer position in MTw



11.2 Awinda Station Technical Specifications

The Awinda Station uses the Awinda protocol to receive and time-synchronize data from up to 20 MTw's simultaneously.

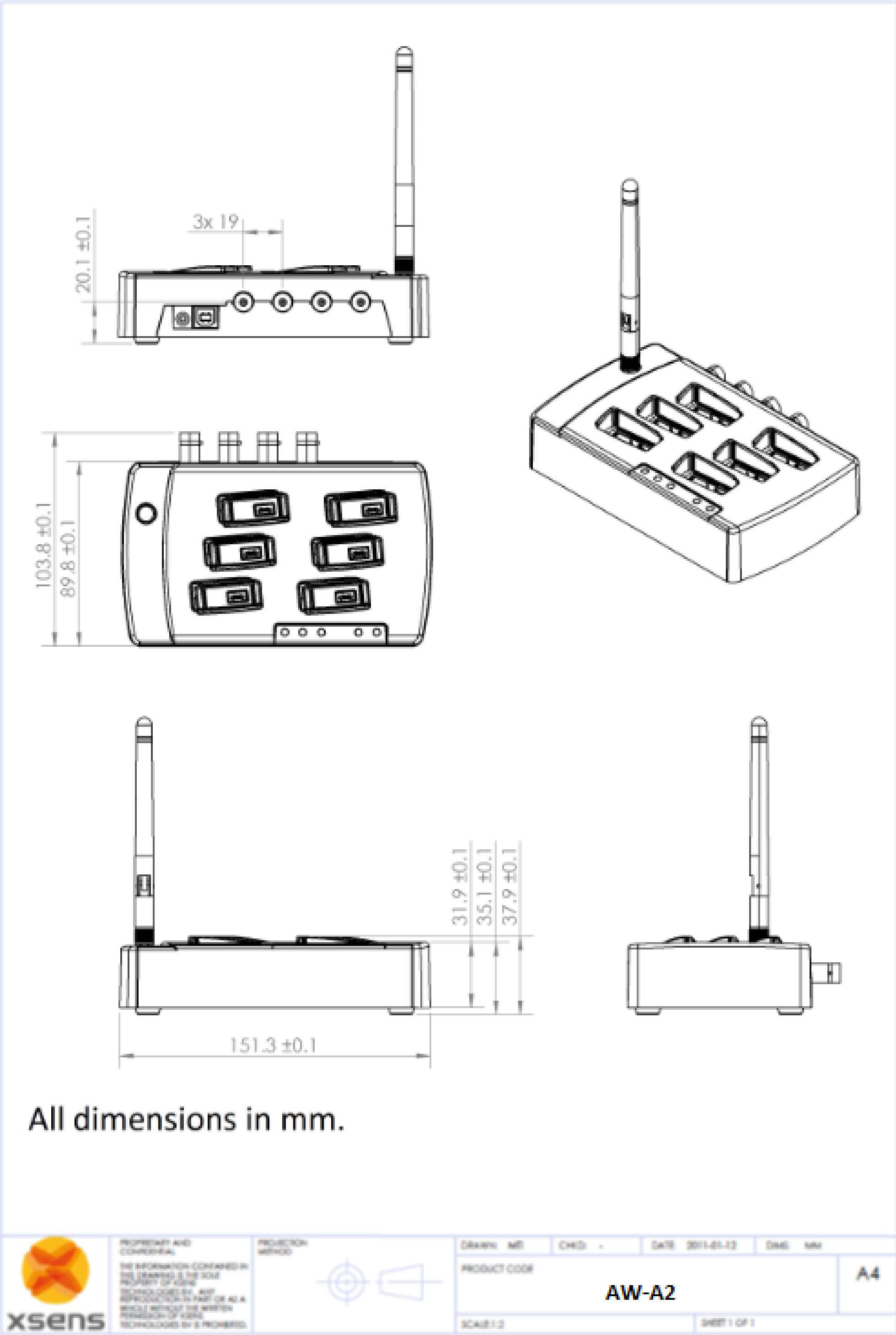
- Data from multiple MTw's time-synchronized to within 10µs, with a reasonable radio link.
- Charges up to 6 MTw's simultaneously.
- LED indicators for MTw status.

Synchronization with third party devices
The Awinda Station has four AUX sync I/O BNC connectors for synchronization with third party devices. These have TTL levels of 0-3.3V.

Power supply
A power adapter is shipped with the MTw Development kit, to power the Awinda Station (necessary for charging the MTw's). The power adapters have EU/US/UK plugs and electrical properties: 100-240V AC/12 V DC 1.5A.

Communication
The Awinda Station interfaces with the PC using a USB cable, supplied with the system.

11.2.1 Schematics Awinda Station Housing Specifications



11.3 Awinda USB Dongle Technical Specifications

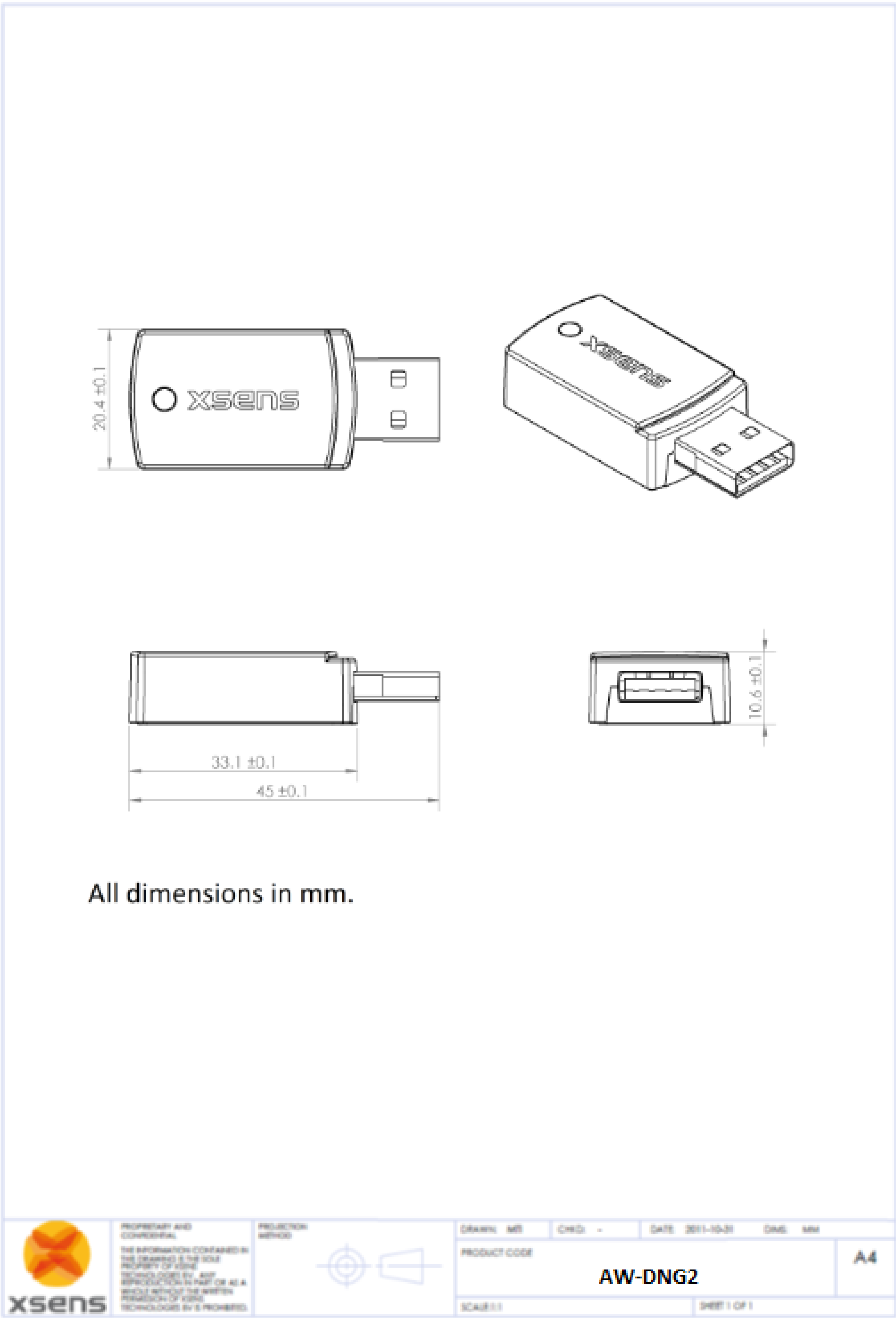
The Awinda USB Dongle uses the Awinda protocol to receive and time-synchronize data from up to 20 MTw's simultaneously.

- Data from multiple MTw's time-synchronized to within 10μs, with a reasonable radio link.
- LED indicators for MTw connectivity status.

Power supply
The USB Dongle uses only 440mW therefore does not require external power supply, meaning that it is ideal for outdoor use.

Communication
The Awinda USB Dongle interfaces with the PC via USB.

11.3.1 Schematics Awinda USB Dongle Housing Specifications



11.3.2 Physical, Electrical and RF Properties

	MTw	AWINDA Station	Awinda Dongle
Communication interface	Wireless 2.4GHz/USB	Wireless 2.4GHz/ USB	Wireless 2.4GHz/ USB
Wireless transmit range indoor /outdoor	~20m / 70m	~50m/20m	~20m/10m
Synchronization accuracy	< 10µs	<1ppm clock drift	<1ppm clock drift
Additional interfaces:	NA	2 x Sync In (BNC) 2 x Sync Out (BNC)	NA
Battery runtime	~6 hrs[14]	NA	NA
Charge time	~1 hrs	NA	NA
Temperature Operating Range	-10ºC to 60ºC (discharge)	-25 to 85ºC	-25 to 80ºC
Specified performance Operating Temperature Range	0ºC to 50ºC	0 to 65 ºC	0 to 65 ºC
Housing Dimensions	47x30x13mm	148x104x31.9 mm Note: Awinda Station dimensions without antenna attached	20.4x45x10.6mm Note: with USB connector
Weight	16g	200g	8g

NOTE: Drops onto hard surfaces can cause shocks of greater than 20000 m/s2 (2000 g) exceeding the absolute maximum rating of the device. Care should be taken when handling to avoid damage. Drops causing shocks 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. If this occurs, please contact support@xsens.com to investigate if the MTw should be returned for a check.

11.4 Strap Down Integration[15]

Strap down integration (SDI) is a method used to compute orientation and velocity increments by integrating angular velocity measured by a gyroscope and acceleration measured by an accelerometer. The angular velocity and acceleration data are sampled and calibrated[16] at a high frequency (1kHz) by the embedded MCU of the MTw to maintain accuracy under dynamic conditions such as vibrations and impacts. Due to the high sampling frequency, the data cannot be transmitted wirelessly and would typically present a computational load that is too high on the receiving host device (e.g. PC). The SDI algorithms take care of reducing the data rate. The main advantage of using the SDI algorithm is that the accuracy is maintained at any output data rate. An additional advantage of the SDI algorithm for the

[14] Battery runtime when fully charged depends on the chosen frame rate and ambient temperature.
[15] Further information about strap down integration for the MTw is available in the MTw Whitepaper.
[16] The devices are calibrated at the factory by Xsens and is a highly sophisticated process compensating for component errors that are not stochastic (i.e. they can be modeled). Compensation models include bias, gain, misalignment, g sensitivity, temperature effects, etc.

MTw is that it can cope with transient data loss in the RF transmission without losing accuracy. The specific use of SDI data in combination with an RF link is called the Xsens Awinda protocol[17].

NOTE: Velocity and orientation increments resulting from the embedded SDI can easily be converted back to equivalent acceleration and angular velocity.

11.5 Xsens Kalman Filter

The orientation of the MTw is computed by Xsens Kalman Filter for 3 degrees-of-freedom (3DoF) orientation for Human Motion (XKF3hm). XKF3hm is an algorithm that fuses 3D inertial data and 3D magnetometer data to optimally estimate 3D orientation with respect to an earth fixed coordinate frame. On top of that, XKF3hm has been developed to deal with wireless transmissions (e.g. irregular updates due to temporal packets losses). The input to the filter is provided by the SDI algorithms in combination with the data from the magnetometer.

11.5.1 Underlying Principles

In a situation in which a well-calibrated IMU is kept still in an environment with no nearby ferromagnetic materials, the 3D orientation can be straightforwardly computed using the signals from an accelerometer and a magnetometer, much like using a water level and a compass needle. However, when the sensor rotates or is moved around, just the accelerometer and magnetometer are not sufficient anymore. To accurately track the 3D orientation, the use of a gyroscope is essential. The process to combine the information from these different sources of information is called sensor fusion, accomplished by XKF3hm.

The two input sources of XKF3hm are complementary to each other by nature. The gravitational and magnetic components give stabilizing information on the long term, while the gyroscope and accelerometer, pre-processed by the SDI algorithms, give high-bandwidth, responsive movement signals. Continuous integration of inertial sensing signals using SDI captures movements that are short-term accurate, high-bandwidth and high in resolution. However, inevitably the inherent integration drift grows over time. This drift is stabilized by applying some carefully chosen and precisely formulated assumptions on the dynamics and sensor characteristics providing the 3D orientation in real-time.

11.5.2 Estimation of Inclination (roll/pitch)

Estimating roll and pitch is in general not that difficult. By quickly converging to the accelerometer estimated vertical direction will give the feeling of a rather accurate inclination (roll/pitch). However, when transient accelerations are present, and the low-frequent component measured by the accelerometer is not just gravity anymore, inclination errors easily show up. XKF3hm is able to handle transient acceleration and provide accurate roll and pitch angles. Still, long-term accelerations (e.g. accelerating automobile) may degrade the orientation performance, because the movement does not match the assumptions on the motion during these long term accelerations. As soon as the movement matches the assumptions made again, XKF3hm will recover and stabilize

NOTE: To be able to accurately measure orientations as well as position in applications which can encounter long term accelerations, Xsens offers a solution that incorporates a GPS receiver (the MTi-G).

11.5.3 Using the Earth Magnetic Field to Stabilise Heading (Yaw)

In contrast to the estimation of inclination, the estimation of heading is much more challenging. To start, the Earth magnetic field that provides the reference direction is often (heavily) distorted by common materials in buildings (steel constructions, reinforced concrete), furniture, vehicles, surrounding

[17] Patented.

electronic equipment and the (mobile) electronic device itself. The algorithm must deal efficiently with all these sources of error. Secondly, the user relies on the heading estimate provided when navigating through a building with all these distortions and can easily continuously monitor the output.

There are fundamental limits to the accuracy in heading that can be obtained using gyroscopes, accelerometers and magnetometers alone. XKF3hm provides the most accurate heading estimate available given the input data and fundamental limitations. This is further enhanced by the use of SDI which enables the dead-reckoning to be extremely accurate and relied on for much longer periods of time when necessary. On top of this, XKF3hm also implements years of practical application knowledge to present the user with a consistent heading output that matches the application, which becomes especially important in difficult situations closer to the fundamental limits of what can be computed using the input signals

11.5.4 Initialisation

The XKF3hm algorithm does not only compute orientation, but also keeps track of variables such as sensor biases or properties of the local magnetic field in the background. For this reason, the orientation output may need some time to stabilize once the MTw is put into measurement mode. The 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 changes slowly due to different effect such as temperature change or exposure to impact. To reduce stabilizing time, the last computed gyroscope bias can be stored in the sensor unit non-volatile memory. If the MTw is used after only a short period of power-off the gyro biases will generally not have changed a lot and the stabilizing time will typically be less than 10 seconds. Furthermore, XKF3hm will converge faster and reach optimal robustness faster if it is started in an area without magnetic disturbances.

11.6 Coordinate Systems

11.6.1 Calibrated Sensor Readings

All calibrated sensor readings (accelerations, angular velocity, earth magnetic field, pressure) are in the right handed Cartesian coordinate system as defined in the figure below. This coordinate system is body-fixed to the device and is defined as the sensor coordinate system (S). The 3D orientation output is discussed in Section 11.6.2.

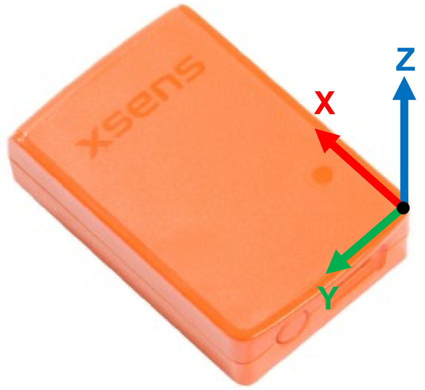
The coordinate system is aligned to the external housing of the MTw.

High accuracy alignment between the (plastic) housing and the sensor-fixed output coordinate system (S) is not possible for the MTw for obvious reasons. The actual alignment between the S coordinate system and the bottom part of the plastic housing is guaranteed to <3°.

The non-orthogonality between the axes of the body-fixed coordinate system, S, is <0.1°. This also means that the output of 3D linear acceleration, 3D angular velocity (gyro) and 3D magnetic field data all will have orthogonal XYZ readings within <0.1°.

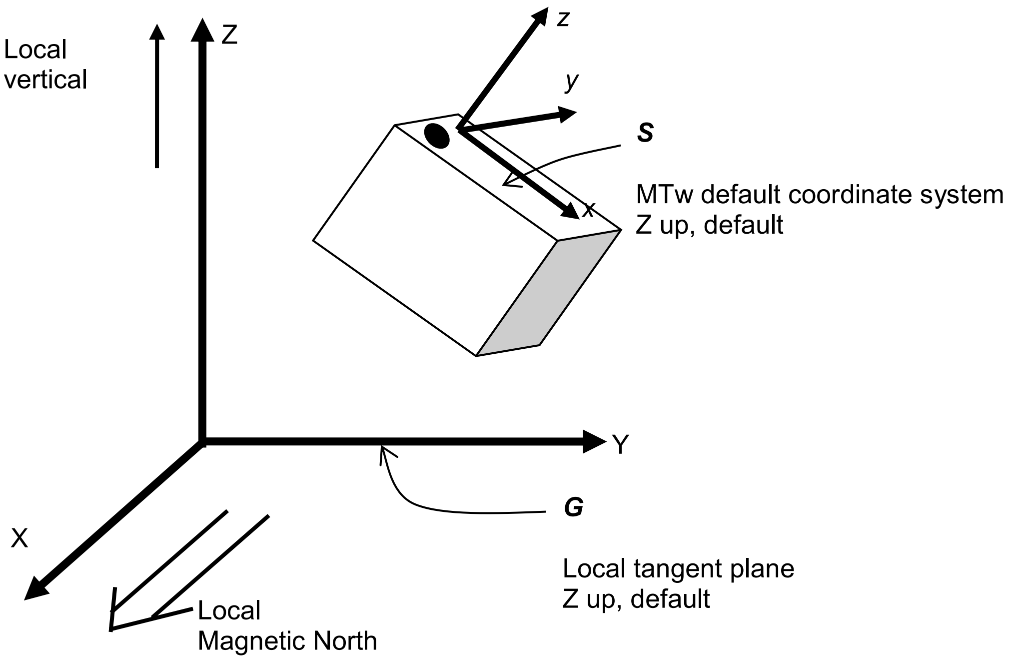
11.6.2 Orientation Coordinate System

The MTw calculates the orientation between the sensor-fixed coordinate system, S, and an earth-fixed reference coordinate system, G. By default, the local earth-fixed reference coordinate system used is defined as a right handed Cartesian coordinate system with:



- X positive when pointing to the local magnetic North.
- Y according to right handed coordinates (West).
- Z positive when pointing up.

The 3D orientation output (independent of output mode, see Section 11.7) is defined as the orientation between the body-fixed coordinate system, S, and the earth-fixed coordinate system, G, using the earth-fixed coordinate system, G, as the reference coordinate system.



Please refer to Section 11.7 for further details on output coordinate systems and different options to redefine the output coordinate systems.

True North vs. Magnetic North
As defined above the output coordinate system of the MTw is with respect to local Magnetic North. The deviation between Magnetic North and True North (known as the magnetic declination) varies depending on your location on earth and can be roughly obtained from various models of the earth's magnetic field as a function of latitude and longitude.

11.6.3 Arbitrary Alignment

If the measured kinematics is required in an object coordinate system (O) with a known orientation with respect to standard sensor coordinate frame (S), the object alignment matrix can also be set with an arbitrary but known orientation. This is useful if the MTw can only be fastened in one specific orientation.

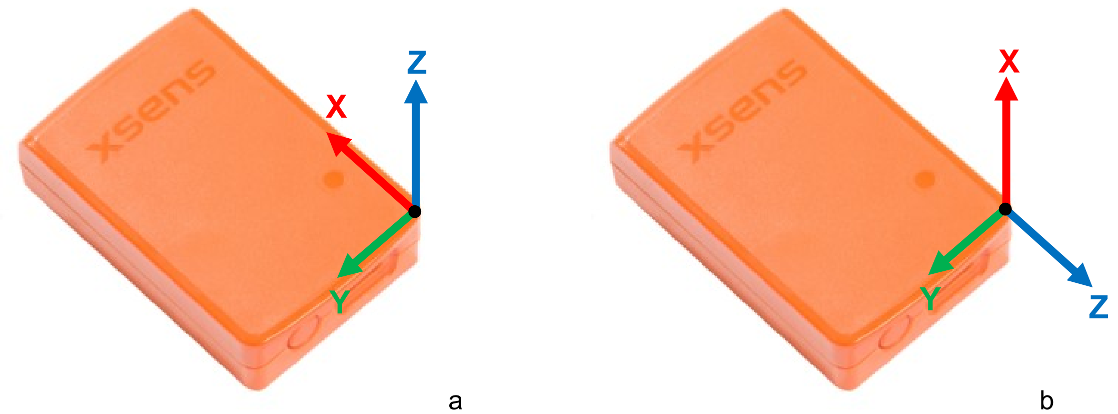
The object alignment matrix (R_{OS}) is applied to the output data (R_{GS}) according to the following equations.

$$R_{GO} = R_{GS}\left(R_{OS}\right)^T$$

Example
The object alignment matrix is given by:

$$R_{OS} = \begin{bmatrix} 0 & 0 & 1 \\ 0 & 1 & 0 \\ -1 & 0 & 0 \end{bmatrix}$$

Here O represents the object coordinate system and S the standard sensor coordinate system described in Section 11.6.2. Once the object alignment matrix is set to R_{OS}, the sensor output will be expressed with respect to the object coordinate system shown in figure (b), below.



a b

11.6.4 Heading Reset

It is often important that the global Z-axis remains along the vertical (defined by local gravity vector), but the global X-axis has to be in another direction. In this case a heading reset may be used, this is also known as “bore sighting”. When performing a heading reset, the new global reference frame is chosen such that the global X-axis points in the direction of the sensor while keeping the global Z-axis vertical (along gravity, pointing upwards). In other words: The new global frame has the Z axis along gravity, pointing upwards, the X-axis in the plane spanned by the vertical and the sensor X-axis, perpendicular to the global Z-axis and the Y-axis such that a right handed coordinate system is formed.
NOTE: After a heading reset, the yaw may not be exactly zero, this occurs especially when the X-axis is close to the vertical. This is caused by the definition of the yaw when using Euler angles, which becomes unstable when the pitch approaches ± 90 deg.

11.6.5 Inclination Reset

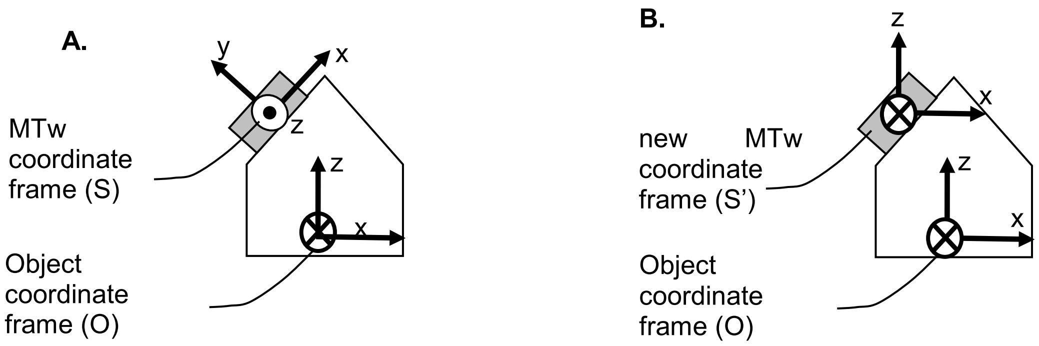
The inclination reset function aims to facilitate in aligning the MT coordinate frame (S) with the coordinate frame of the object to which the MT is attached (O). After an inclination reset, the S coordinate frame is changed to S’ as follows:

- the S’ Z-axis is the vertical (up) at time of reset.
- the S’ X-axis equals the S X-axis, but projected on the new horizontal plane.
- the S’ Y-axis is chosen as to obtain a right handed coordinate frame.

NOTE: Once this reset is conducted, the orientation data as well as the inertial (and magnetic) data will be output with respect to the new S’ coordinate frame.

The inclination reset can be used to set the MTw coordinate frame to that of the object to which it is attached (see figure below). The MTw has to be fixated in such a way that the X-axis is in the XZ-plane of the object coordinate frame (situation A). This means that the MTw can be used to identify the X-axis of the object. To preserve the global vertical, the object must be oriented such that the object z-axis is vertical. The object reset causes the new S' coordinate frame and the object coordinate frame to be aligned (situation B).

NOTE: Since the sensor X-axis is used to describe the direction of the object X-axis, the reset will not work if the sensor X-axis is aligned along the Z-axis of the object.



MTw coordinate frame before (A) and after (B) inclination reset. The new Z-axis of the sensor coordinate frame will be along the vertical. The new direction of the X-axis will be the old X–axis that is projected onto the horizontal plane.

11.6.6 Alignment Reset

The alignment reset combines the Inclination reset and the Heading reset in a single time instant. This has the advantage that all coordinate systems can be aligned with a single action. Note that the new global reference x-axis (heading) is defined by the object X-axis (to which XZ-plane of the MTw has been aligned).

NOTE: Once this alignment reset is conducted, the orientation data as well as the inertial (and magnetic) data will be output with respect to the new S' coordinate frame.

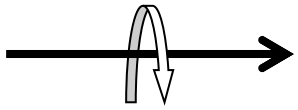
11.7 Orientation Output Modes

The orientation, calculated by the MTw is the orientation of the sensor-fixed coordinate system (S) with respect to a Cartesian earth-fixed coordinate system (G). The output orientation can be presented in different parameterizations:

- Unit Quaternions (also known as Euler parameters)
- Euler angles[18]: 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.

[18] 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 deg). 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.



11.7.1 Quaternion Orientation Output

A unit quaternion vector can be interpreted to represents a rotation about a unit vector n through an angle α.

$$q_{GS} = (cos(\frac{\alpha}{2}), \mathbf{n} sin(\frac{\alpha}{2}))$$

A unit quaternion itself has unit magnitude, and can be written in the following vector format;

qGS = (q0,q1,q2,q3)

|q| = 1

Quaternions are an efficient, non-singular description of 3D orientation and a quaternion is unique up to sign:

q = -q

An alternative representation of a quaternion is as a vector with a complex part, the real component is the first one, q_0.

The inverse (q_{SG}) is defined by the complex conjugate (†) of q_{GS}. The complex conjugate can be calculated:

$$q_{GS}^{\dagger} = (q_0, -q_1, -q_2, -q_3) = q_{SG}$$

As defined here q_{GS} rotates a vector in the sensor coordinate system (S) to the global reference coordinate system (G).

$$\mathbf{x_G} = q_{GS} \mathbf{x_S} q_{GS}^{\dagger} = q_{GS} \mathbf{x_S} q_{SG}$$

Hence, q_{SG} rotates a vector in the global reference coordinate system (G) to the sensor coordinate system (S), where q_{SG} is the complex conjugate of q_{GS}.

11.7.2 Euler Angles Orientation Output Mode

The definition used for 'Euler-angles' here is equivalent to 'roll, pitch, yaw/heading' (also known as Cardan). The Euler-angles as orientation output are provided as XYZ Earth fixed type (subsequent rotation around global X, Y and Z axis, also known as aerospace sequence).

- φ = roll[19] = rotation around X_G, defined from [-180º…180 º]

[19] "roll" is also known as: "bank"

- θ = pitch[20] = rotation around Y_G, defined from [-90 º …90 º]
- ψ = yaw[21] = rotation around Z_G, defined from [-180 º …180 º]

NOTE: Due to the definition of Euler angles there is a mathematical singularity (gimbal lock) when the sensor-fixed X-axis is pointing up or down in the earth-fixed reference frame (i.e. pitch approaches ±90º). This singularity is in no way present in the quaternion or rotation matrix output mode. The singularity cannot be compensated for but only avoided using the rotation matrix output, then manually extract Euler Angles by using different Euler sequences[22].

The Euler-angles can be interpreted in terms of the components of the rotation matrix, R_{GS}, or in terms of the unit quaternion, q_{GS};

$$
\begin{aligned}
\phi_{GS} &= \tan^{-1}\left(\frac{R_{32}}{R_{33}}\right) = \tan^{-1}\left(\frac{2q_2q_3 + 2q_0q_1}{2q_0^2 + 2q_3^2 - 1}\right) \\
\theta_{GS} &= -\sin^{-1}(R_{31}) = -\sin^{-1}(2q_1q_3 - 2q_0q_2) \\
\psi_{GS} &= \tan^{-1}\left(\frac{R_{21}}{R_{11}}\right) = \tan^{-1}\left(\frac{2q_1q_2 + 2q_0q_3}{2q_0^2 + 2q_1^2 - 1}\right)
\end{aligned}
$$

Here, the arctangent ($\tan^{-1}$) is the four quadrant inverse tangent function.

NOTE: that the output is in degrees and not radians.

11.7.3 Rotation Matrix Orientation Output Mode

The rotation matrix (also known as Direction Cosine Matrix, DCM) is a well-known, redundant and complete representation of orientation. The rotation matrix can be interpreted as the unit-vector components of the sensor coordinate system S expressed in G. For R_{GS} the unit vectors of S are found in the columns of the matrix, so column 1 is X_S expressed in G etc. A rotation matrix norm is always equal to one (1) and a rotation R_{GS} followed by the inverse rotation R_{SG} naturally yields the identity matrix I^3.

$$||R|| = 1 \qquad\qquad R_{GS}R_{SG} = I^3$$

The rotation matrix, $\boldsymbol{R_{GS}}$, can be interpreted in terms of quaternions;

$$
\begin{aligned}
R_{GS} &= \begin{bmatrix} q_0^2 + q_1^2 - q_2^2 - q_3^2 & 2q_1q_2 - 2q_0q_3 & 2q_0q_2 + 2q_1q_3 \\ 2q_0q_3 + 2q_1q_2 & q_0^2 - q_1^2 + q_2^2 - q_3^2 & 2q_2q_3 - 2q_0q_1 \\ 2q_1q_3 - 2q_0q_2 & 2q_2q_3 + 2q_0q_1 & q_0^2 - q_1^2 - q_2^2 + q_3^2 \end{bmatrix} \\
&= \begin{bmatrix} 2q_0^2 + 2q_1^2 - 1 & 2q_1q_2 - 2q_0q_3 & 2q_1q_3 + 2q_0q_2 \\ 2q_1q_2 + 2q_0q_3 & 2q_0^2 + 2q_2^2 - 1 & 2q_2q_3 - 2q_0q_1 \\ 2q_1q_3 - 2q_0q_2 & 2q_2q_3 + 2q_0q_1 & 2q_0^2 + 2q_3^2 - 1 \end{bmatrix}
\end{aligned}
$$

[20] “pitch” is also known as: “elevation” or “tilt”
[21] “yaw” is also known as: “heading”, “pan” or “azimuth”
[22] Woltring HJ. 3-D attitude representation of human joints: A standardization proposal. Journal of Biomechanics. 1994;27 (12):1399-1414.

or in terms of Euler-angles (according to the XYZ Euler sequence);

$$R_{GS} = R_{\psi}^{Z} R_{\theta}^{Y} R_{\phi}^{X}$$

$$= \begin{bmatrix} \cos\psi & -\sin\psi & 0 \\ \sin\psi & \cos\psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos\theta & 0 & \sin\theta \\ 0 & 1 & 0 \\ -\sin\theta & 0 & \cos\theta \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\phi & -\sin\phi \\ 0 & \sin\phi & \cos\phi \end{bmatrix}$$

$$= \begin{bmatrix} \cos\theta\cos\psi & \sin\phi\sin\theta\cos\psi - \cos\phi\sin\psi & \cos\phi\sin\theta\cos\psi + \sin\phi\sin\psi \\ \cos\theta\sin\psi & \sin\phi\sin\theta\sin\psi + \cos\phi\cos\psi & \cos\phi\sin\theta\sin\psi - \sin\phi\cos\psi \\ -\sin\theta & \sin\phi\cos\theta & \cos\phi\cos\theta \end{bmatrix}$$

As defined here $\boldsymbol{R_{GS}}$, rotates a vector in the sensor coordinate system (***S***) to the global reference system (***G***):

$$\mathbf{x_G} = R_{GS}\mathbf{x_S} = (R_{SG})^T \mathbf{x_S}$$

It follows naturally that, $\boldsymbol{R_{SG}}$ rotates a vector in the global reference coordinate system (***G***) to the sensor coordinate system (***S***).

For the rotation matrix (DCM) output mode it is defined that:

$$R_{GS} = \begin{bmatrix} a & d & g \\ b & e & h \\ c & f & i \end{bmatrix} = \begin{bmatrix} R_{11} & R_{12} & R_{13} \\ R_{21} & R_{22} & R_{23} \\ R_{31} & R_{32} & R_{33} \end{bmatrix}$$

$$R_{SG} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & i \end{bmatrix}$$

Here, also the row-order/column-order is defined.

The output definition in rotation matrix (DCM) output mode is:

`MTData` `DATA =`
MID 50 (0x32)

a	b	c	d	e	f	g	h	i

All data elements in DATA field are FLOATS (4 bytes) , unless specified otherwise by modifying the OutputSetting Data Format field.

11.8 Status Word

The Status Word is a new output for MTw. The table below indicates the meaning of this output. In the ASCII export, this will be a column with 32 possibilities of ones and zeros. These indicate if a parameter is true or not. For example, a 1 is expected at the first bit (Selftest) indicating that the Selftest was successful.
The only exception for this is at bits 3 to 4, in which case, the possible patterns are explained.

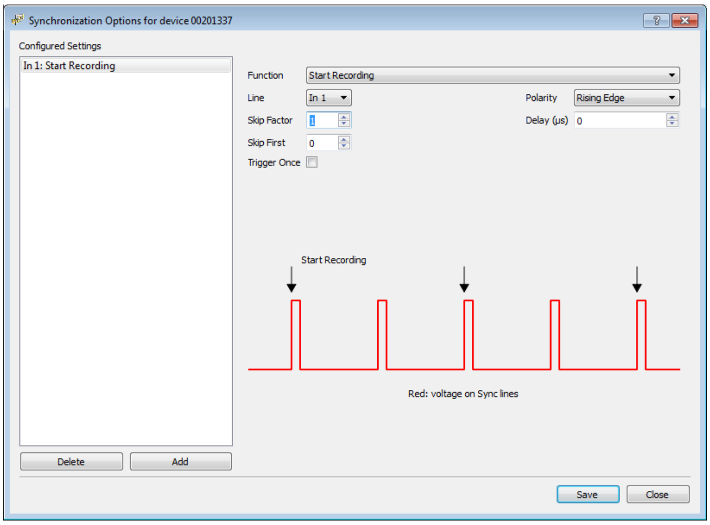
Bits	Field	Description
0	Selftest	This flag indicates if the tracker passed the latest self-test. For MTw this means that the system is running and communicating with MT Manager.
1	Filter Valid	This flag indicates if input into the orientation filter is reliable and / or complete. If for example the measurement range of internal sensors is exceeded, orientation output cannot be reliably estimated and the filter flag will drop to 0.
2	GPS fix	This flag indicates if the GPS unit has a proper fix. The flag is only available in MTi-G units.
3:4	NoRotationUpdate Status	(This flag indicates the status of the no rotation update procedure in the filter after the SetNoRotation message has been sent. 11: Running with no rotation assumption 10: Error: Rotation detected, procedure not started (sticky) 01: Estimation complete, some samples rejected (sticky) 00: Estimation complete, no errors
5	Timestamp GPS synced	
6	Timestamp clock synced	
7	On/Off	
8	Clipflag Acc X	If set an out of range acceleration on the X axis is detected
9	Clipflag Acc Y	If set an out of range acceleration on the Y axis is detected
10	Clipflag Acc Z	If set an out of range acceleration on the Z axis is detected
11	Clipflag Gyr X	If set an out of range angular velocity on the X axis is detected
12	Clipflag Gyr Y	If set an out of range angular velocity on the Y axis is detected
13	Clipflag Gyr Z	If set an out of range angular velocity on the Z axis is detected
14	Clipflag Mag X	If set an out of range magnetic field on the X axis is detected
15	Clipflag Mag Y	If set an out of range magnetic field on the Y axis is detected
16	Clipflag Mag Z	If set an out of range magnetic field on the Z axis is detected
17:18	Reserved	Reserved for future use
19	Clipping Indication	This flag indicates going out of range of one of the sensor components (is set when one or more bits from 8:16 are set)
20	Reserved	Reserved for future use
21	SyncIn Marker	When a SyncIn is detected, this bit will rise to 1

Bits	Field	Description
22	SyncOut Marker	When SyncOut is active this bit will rise to 1
23:25	Filter Mode	Indicates the Filter Mode, currently only available for MTi-G-700: 000: Without GPS (filter profile is in VRU mode) 001: Coasting mode (GPS has been lost <60 sec ago) 011: With GPS (default mode of MTi-G-700) Not used for MTw.
26:31	Reserved	Reserved for future use

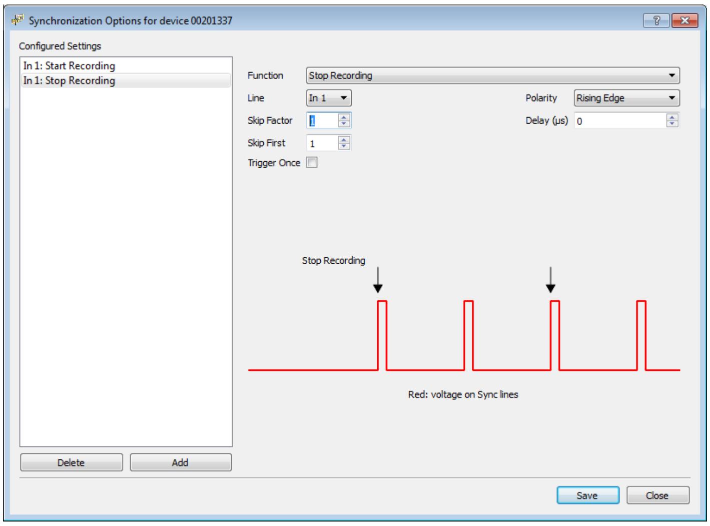
11.9 Synchronization Examples

11.9.1 Start and stop recording of external devices using single pulse

External device starting and stopping recording of Xsens system, on Line 1 of the Sync In port.



Click “Add” to add a sync setting.
Select Start Recording
Select Line In1
Polarity: Rising Edge[23]
Trigger Once: Unchecked[24]
Skip Factor = 1 (so that every other pulse will start a recording in MT Manager)
Skip First = 0
Delay = 0µs



Click “Add” to add a sync setting.
Select Stop Recording
Select Line In1
Polarity: Rising Edge
Trigger Once: Unchecked
Skip Factor = 1 (so that every other pulse will stop a recording in MT Manager)
Skip First = 1 (first trigger starts recording, so it should not also send a signal to stop - or this causes confusion for Awinda Station)
Delay = 0µs

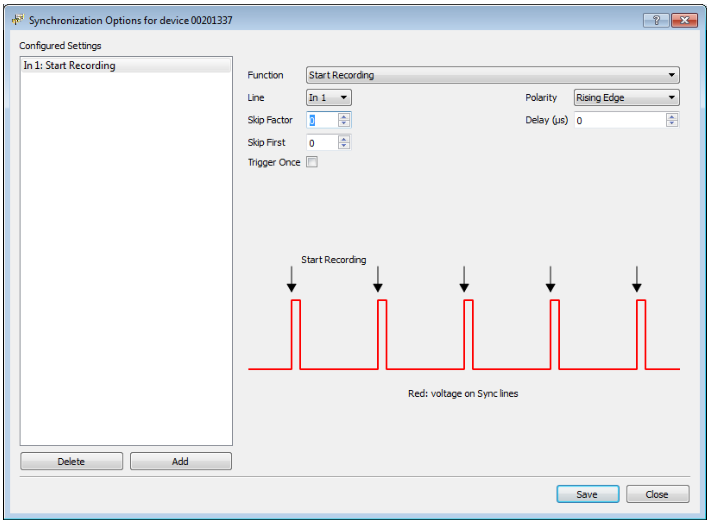
The above example indicates how to allow a signal of 3.3V enter the Sync In 1 port, of the Awinda Station. The first upward going pulse (and subsequent odd numbered pulses), received on the Awinda Station, will start recording (Polarity = rising edge). The second upward going pulse (and subsequent even numbered pulses), received on the Awinda Station, will stop recording.

[23] Note that this setting depends on the signal from external system.
[24] To ensure that a series of recordings can be made.

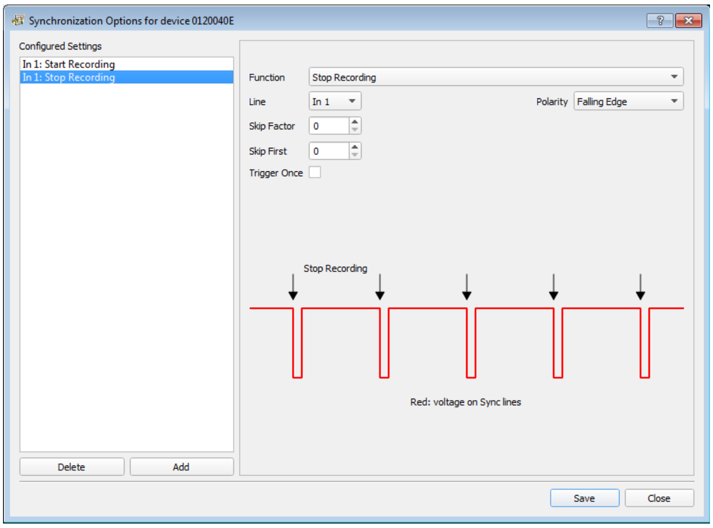
11.9.2 Start and stop recording of external party devices with infinite pulse width

It is of course also possible, to configure that for example the upward rising edge causes the start of recording and the negative direction edge causes stop recording, this may be useful in the event that an external device sends a pulse of infinite length.

To do this, the following settings should be input:



Click "Add" to add a sync setting.
Select Start Recording
Select Line In1
Polarity: Rising Edge
Trigger Once: Uncheck (if more than one recording desired)
Skip first = 0
Skip factor = 0
Delay = 0 µs

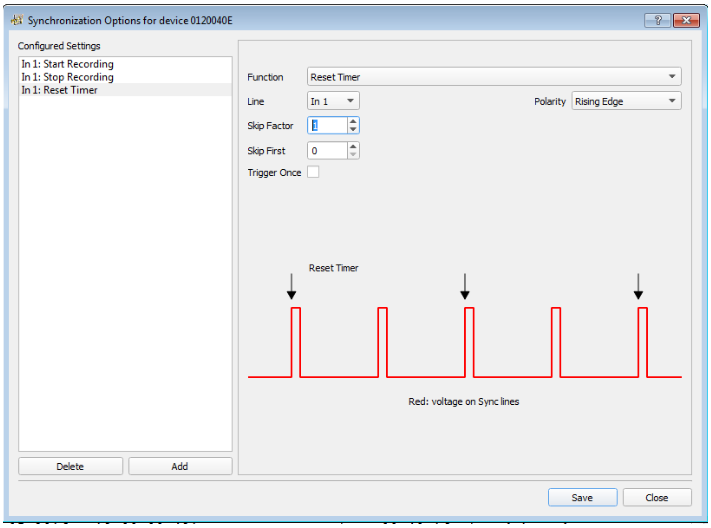


Click "Add" to add a sync setting.
Select Stop Recording
Select Line In1
Polarity: Falling Edge
Trigger Once: Uncheck (if more than one recording desired)
Skip first = 0
Skip factor = 0
Delay = 0 µs

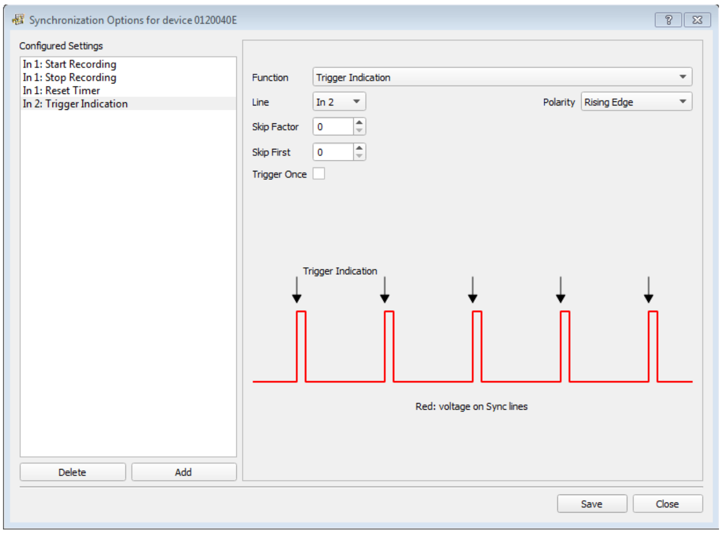
11.9.3 Start and stop recording of external devices including trigger indication pulses

In some instances it may be desired to have a trigger indication in the data, for example using a manual trigger button, or using an external clock. The following example shows how to do this.
Note: The trigger indication below has been indicated in this example as coming through via the Sync In 2 channel, while start, stop recording and reset timer come through in the Sync In 1.if Sync In 1 is also used for the trigger indication, one should additionally insert the amount of pulses expected

between the start and stop recording, therefore changing the skip factor for stop recording to a large number equivalent to the number of pulses expected between start and stop recording. If this is known, it can be very efficient, otherwise it may be limiting. The example shows a simplified method, independent of time needed for recording or number of trigger pulses expected.



Use the setting of 11.9.1. In addition:
Click Add
Select Reset Timer
Select Line In1
Polarity: Rising Edge
Trigger Once: Uncheck
Skip factor = 1
Skip first = 0
Delay = 0 µs



Click Add
Select Trigger Indication
Select Line In2
Polarity: Rising Edge
Trigger Once: Uncheck
Skip first = 0
Skip factor = 0

Note:
Stop recording time may not be on the last sample recorded.
Stop recording timestamp is showed in both Trigger In 1 and 2, independent if the trigger was set on Sync In1 or Sync In 2, this is because the signal comes directly from the Awinda Station, independent of the line used.
Trigger Indications can be exported to ASCII using the exporter and selecting the Trigger In 1 and / or Trigger In 2 in the preferences menu.

Reset timer resets the timer of the sync events (the amount of milliseconds shown in the Trigger In events when the data is exported. The exported sample counter, always exported as the first column will not be reset.
In any synchronization situation, there should only be one master. It is necessary to select a master, either one of the connected Awinda Stations, or an external device.

11.9.4 Synchronising Two Awinda Stations

Using more than one Awinda Station per MT Manager is possible. While the data received from each MTw to each Awinda is perfectly time synchronized, the time synchronization between the Awinda Stations themselves, running in MT Manager has not been tested. One way of ensuring good time synchronization between the Awinda Stations is to use two separate PCs, connect each Awinda Station to a given PC and synchronize the Awinda Stations as with an external device.

To do this, select which Awinda Station (and MT Manger) will provide the Sync Out signal (connect the BNC to the correct port) and which will receive the Sync In signal (ensure correct BNC port connection).

The following settings have been successfully tested in MT Manager to start and stop a series of recordings using one Awinda Station as the control:

Sync In		**Sync Out**	
Start Recording	Stop Recording	Start Recording	Stop Recording
• Rising Edge • Skip First = 0 • Skip Factor = 1	• Rising Edge • Skip First = 1 • Skip Factor = 1	• Positive Pulse • Skip First = 0 • Skip Factor = 0 • Pulse Width = 10000µs	• Positive Pulse • Skip First = 0 • Skip Factor = 0 • Pulse Width = 10000µs

11.9.5 Synchronising with Noraxon EMG

Synchronization was successfully tested between MT Manager and Noraxon TeleMyo system.

The steps described below describe how to make it possible for the Awinda Station to send a synchronization signal (Xsens is Sync Out and Noraxon is Sync In) and how to receive the synchronization signal (Noraxon is Sync Out, Xsens Sync In).

11.9.5.1 Awinda Station Sends Sync Signal (Noraxon Receives Sync Signal)

Hardware requirements:

Noraxon Hardware	**Xsens Hardware**
• Wireless EMG transmitters • 1 TeleMyo DTS (plus antenna)	• MTw • Awinda Station

Both systems of course also need related cables to connect to each other (with BNC connectors at each end) and a USB cable to connect to the PC.

In addition to the normal MTw hardware setup, also connect the BNC connector from the TeleMyo DTS to Sync Out 1 on the Awinda Station. Connect the USB connection between the TeleMyo DTS and the PC. When switched on, the DTS will display “USB ready”.

11.9.5.2 Software Setup in MT Manager

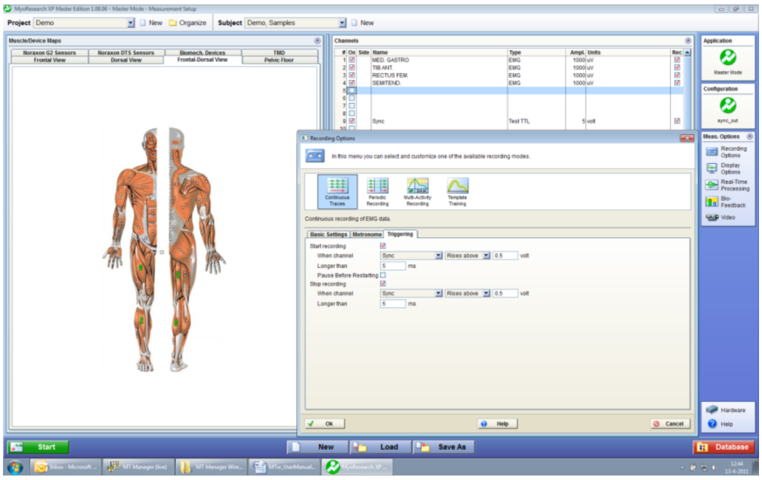
Synchronization on Sync Out Line 1:

Sync Out	
• Select Start Recording • Check the check box for Line 1 • Polarity: Rising Edge • Trigger Once: Uncheck • Skip first = 0 • Skip factor = 0 • Pulse width = 10000μs	• Select Stop Recording • Check the check box for Line 1 • Polarity: Rising Edge • Trigger Once: Uncheck • Skip First = 0 • Skip Factor = 0 • Pulse width = 10000μs

- Set up the wireless configuration in MT Manager.

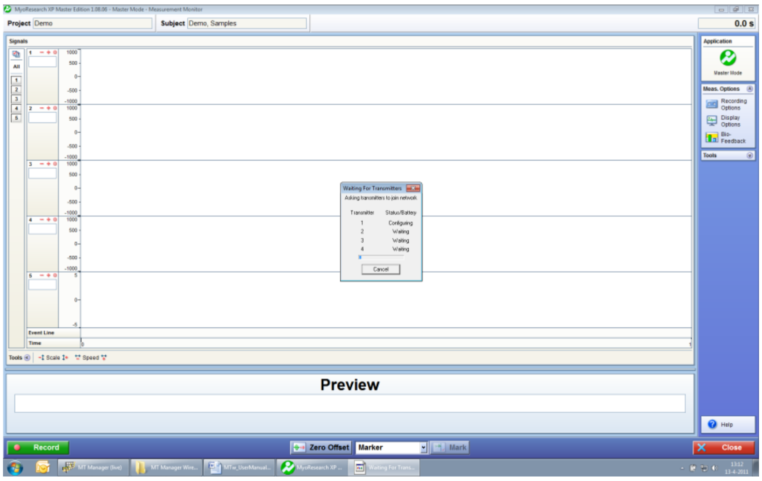
11.9.5.3 Software Setup Noraxon MyoResearch Software:

The example given below is for is gait analysis, measuring the medial gastrocnemius, tibialis anterior, semitendinosus and the rectus femoris. For an 8-Channel EMG system, Channel 9 is selected as the synchronization line in the Noraxon MyoResearch Software. If a 16 channel system is in use, this is the 17th channel.

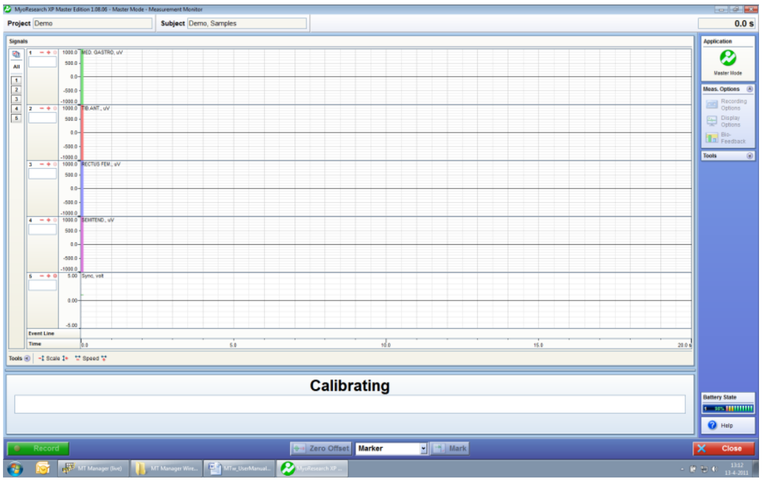


Return to the main menu, under >Measuring Options, go to >Recording Options, then >Triggering tab.

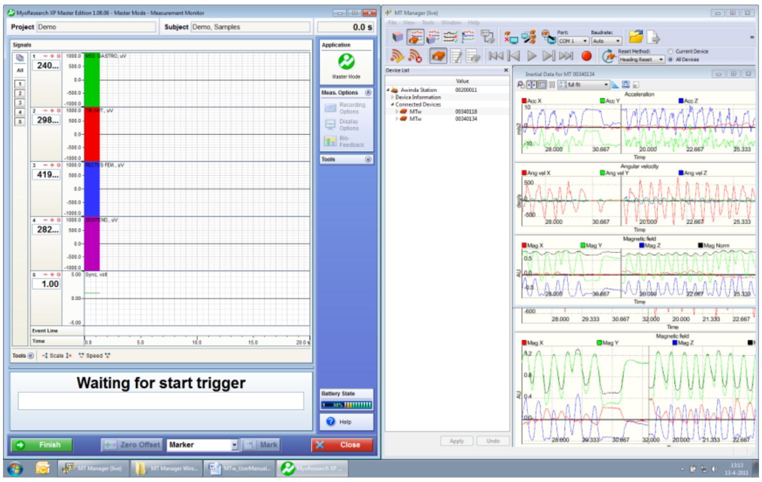
- Check the check box beside “Start Recording”;
- Go to the drop down menu beside “When Channel”, select “Sync”;
  - Select Rises Above (ensure that this is also the direction indicated on the mini-receiver);
  - Input e.g. 0.5V
  - Longer than 5ms
- Repeat settings for Stop Recording.
- Navigate further through the software.



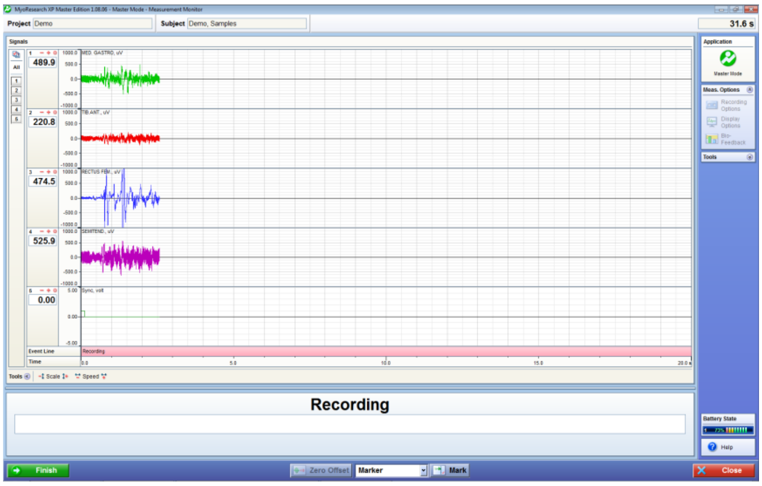
The Noraxon software initialises the EMG signals.



When this screen is reached, click record, on the bottom left hand side of the screen on the Noraxon software.



The software indicates that it is waiting for the trigger.



Press Record in MT Manager, the button is depressed and the Noraxon software indicates that recording has started.

Repressing record in MT Manager will stop the recording on both systems, where Noraxon will again indicate waiting for start trigger.

11.9.5.4 Awinda Station Receives Sync Signal (Noraxon Sends Sync Signal)

For the Xsens system to send the synchronization commands, the mini-receiver from Noraxon is not needed.

Hardware requirements:

Noraxon Hardware	Xsens Hardware
• Wireless EMG transmitters • 1 TeleMyo DTS (plus antenna) • 1 TeleMyo mini-receiver (plus antenna)	• MTw • Awinda Station

Both systems of course also need related cables to connect to each other (with BNC connectors at each end) and a USB cable to connect to the PC.

In addition to the normal MTw hardware setup, set up the hardware of the Noraxon system as follows:
USB port of TeleMyo mini-receiver to USB of PC.
Connect jack connector to Sync Out port of TeleMyo mini-receiver to BNC connection Sync In 1 of Awinda Station.
Manual trigger pulse, jack connector to Sync In port of TeleMyo minirecevier.

Connect the external antenna to the TeleMyo DTS.
When successfully connected and switched on, the TeleMyo DTS will display “WiFi ready”.

11.9.5.5 Software Setup: MT Manager

Synchronization on the Sync In Line 1 port:

Sync In	
• Select Start Recording • Check the check box for Line 1 • Polarity: Rising Edge • Trigger Once: Uncheck • Skip first = 0 • Skip factor = 1	• Select Start Recording • Check the check box for Line 1 • Polarity: Rising Edge • Trigger Once: Uncheck • Skip first = 0 • Skip factor = 1

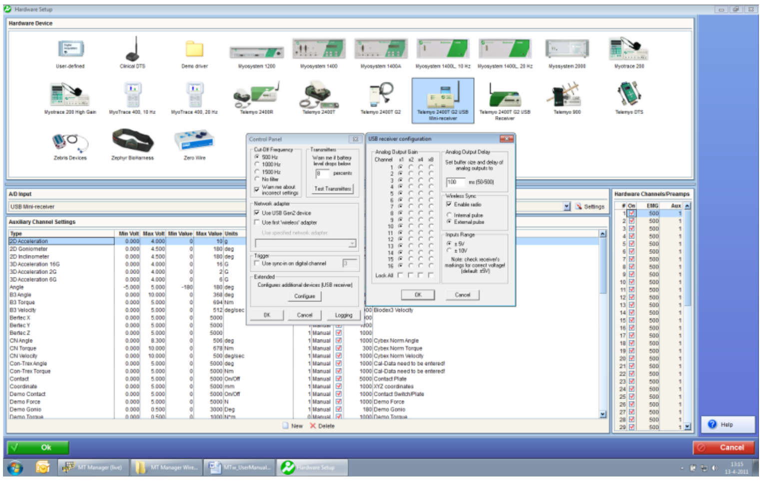
Set up the wireless configuration in MT Manager.

To initialise recording, click the Record button. To indicate that MT Manager is waiting for an external pulse, the icon changes from the normal red dot to one with the pause symbol overlaid, as shown in Section 6.8.2.

11.9.5.6 Software Setup: Noraxon MyoResearch Software:

Based on the output settings described for MT Manager, the settings for Noraxon MyoResearch software can remain the same. The difference is that instead of the trigger pulse coming from the record button in MT Manager, this now comes from the manual button connected to the mini-receiver. Additionally, the mini-receiver should be set up as follows:

- Go to the hardware menu;
- Select the TeleMyo mini-receiver from the list of icons;
- Select: settings;
- Select: Configure;
- Ensure that the wireless sync is “External Pulse” and Input Range is ±5V



The rest of the software setup is the same as described in Section 11.9.5.6 above. However, instead of clicking Record in MT Manager, one should click the hardware trigger supplied by Noraxon, to generate a manual trigger to both systems.