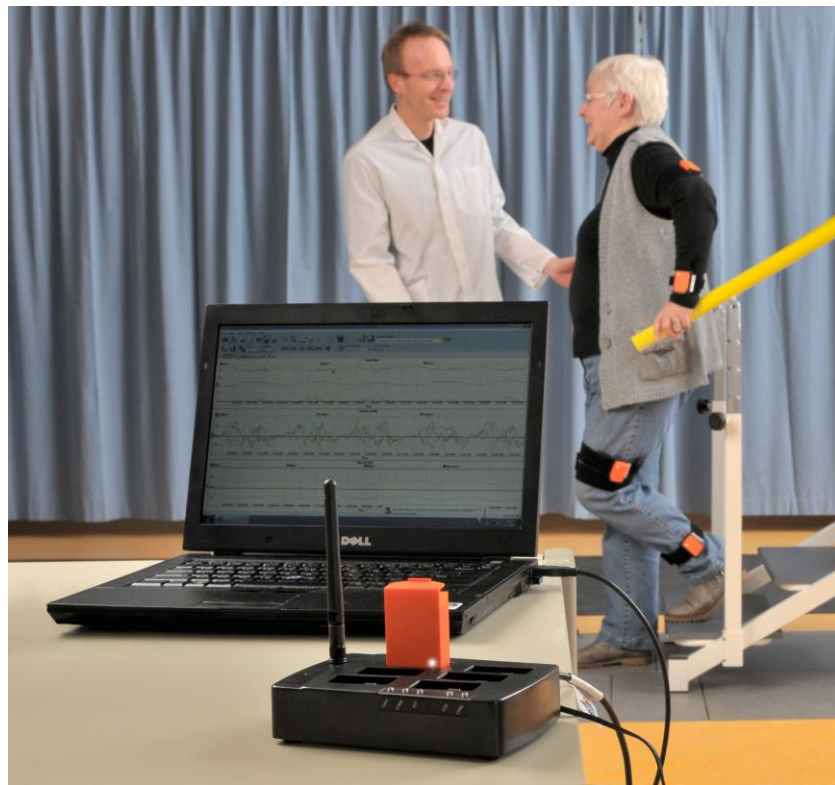


MTw User Manual

MTw Hardware, MT Manager, Awinda Protocol



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Revisions

Revision	Date	By	Changes
A	14 January 2011	CMO	First version.
B	15 April 2011	CMO	Updated for 3.7 Beta Updated Wireless configuration menu Updated Wireless States Additional Functionality: Stand-by Synchronisation with 3 rd party devices + examples
C	15 August 2011	CMO	Added Rotation Matrix export description Added note about not using maximum update rate to ensure retransmissions are possible during recordings.
D	4 November 2011	CMO	Updated for 3.8 Settling time advice added Added Awinda USB dongle-related information Added stand-by mode details Additional 3 rd party sync options implemented Update rate default value
E	14 February 2012	CMO	Updated for 3.8.1 Added Table 1 maximum and typical update rates and buffering times. Added information related to magnetic field disturbances (3.3.1)
F	9 January 2013	MHA	Added Awinda Station and Awinda Dongle to Declaration of Conformity CE and FCC

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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 third party devices for synchronisation 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 synchronisation ports of the Awinda Station.
XFF	Xsens Firmware File format
XKF-3	Xsens Kalman Filter 3 DOF
XKF-3w	Xsens Kalman Filter 3 DOF for MTw

Default Folders

Description	Files	Location
Main program	MT Manager MT SDK	C:\Program Files ... \Xsens\MT Manager
Documentation	MTw User Manual MTw SDK User Manual	C:\Program Files ... \Xsens\Documentation
Tutorials / Help files		C:\Program Files ... \Xsens\MT Manager

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 SDK with Xsens Kalman Filter on the host device the MTw provides real-time 3D orientation for up to 32 wireless motion trackers in a network, while at the same time also providing calibrated 3D linear acceleration, angular velocity and (earth) magnetic field and atmospheric pressure data.

One of the unique features of the MTw is the patent-pending 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 synchronisation of up to 32 MTw's across the wireless network to within 10 μ s. This is in a range comparable to the wired systems of Xsens (i.e. the Xbus). 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 initially sampled at 1800Hz, is down-sampled on the processor of the MTw to 600Hz. and using Strap Down Integration (SDI) the data is transmitted to the Awinda Station. 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 at 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 Development kit arrives in a case, approximately the size of a common briefcase.

A standard MTw Development kit contains:

- 6 MTw's
- 1 Awinda Station
 - 1 USB cable
 - 1 power cable
- Awinda USB Dongle
- 1 set of full body Click-in body straps
- CD with MT Manager and MT SDK
- User manual

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 casing has been designed with a click mechanism, to ease positioning on the body using click-in body straps. For more details see Section 4.1.

2.3 Awinda Station



The Awinda Station. It controls the reception of synchronised 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.

2.4 Awinda USB Dongle



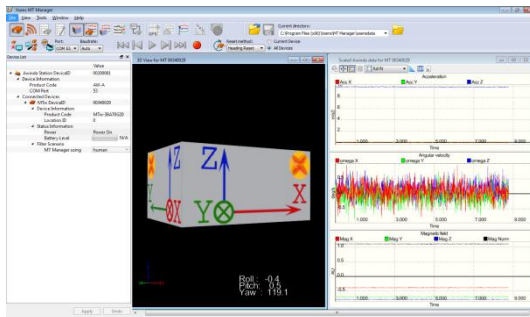
The Awinda USB Dongle has the same wireless capabilities as the Awinda Station. It controls the reception of synchronised wireless data from all wirelessly connected MTw's. It can receive data from up to 32 MTw's. For more details see Section 4.3.

2.5 Click-in Body Straps



The MTw Click-in body straps are a one-size fits all mounting system. They have specially designed click mechanism enabling the MTw to be quickly and easily clicked into place and removed again for charging. When clicked in, they maintain a robust connection to the strap. The straps are made from strong elastic material, backed with silicone rubber to ensure comfortable and close fixation to the skin. They are fastened using Velcro. For more details see Section 4.4.

2.6 Software



The MTw development kit is supplied with a visualising and recording software package, MT Manager. This facilitates quick and easy use of the MTw and Awinda Station.

In addition, a MT Software Development Kit (SDK) is provided, with example code in C, C++, LabView, MATLAB and Linux.¹ The MT SDK is intended to make software application development for the MTw easily accessible. For more details see Section 6.11.

¹ Future releases will include example code in Excel.

3 Getting Started

3.1 Hardware Setup

Dock the MTw's into the Awinda Station. Connect the Awinda Station to the PC, using the USB cable provided. The mains power supply is only needed for charging the MTw, turning it on from the Transport (or switched off) mode and while carrying out firmware updates, but 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 Click-in body straps.

3.2 Software Installation

Insert the CD supplied to run the MT Manager Installer (setup.exe). If using Windows XP/Vista/7 operating systems, install with 'Administrator' or 'Power User' rights. Follow the on-screen instructions.

- See Section 6.1 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 magnetised areas when carrying out measurements; in particular in the beginning. XKF-3w uses the local magnetic field to compute heading. When this signal is distorted due to close proximity of a strong 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 2006¹.

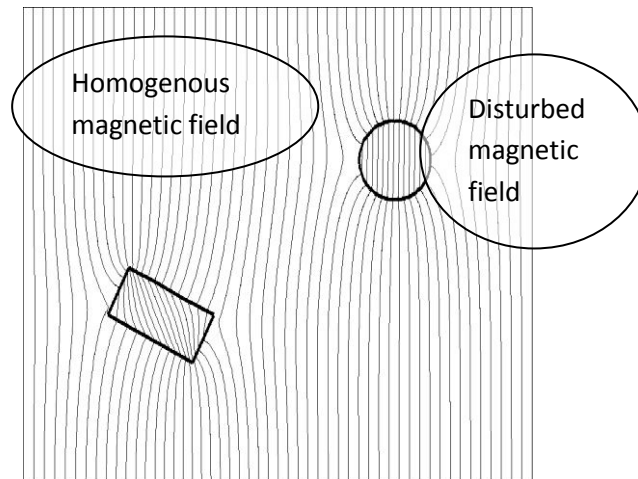


Figure 1: Simulation of ferromagnetic objects in free space with a homogeneous magnetic field

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 homogenous and highly disturbed magnetic field is due to the MTw fixed to an instrument, or a prosthesis, it is best to carry out magnetic field mapping for this MTw (see section 7.1). This instructs XKF-3w algorithm that the magnetic field has a new value.

Varying magnetic field

The XKF-3w algorithm can compensate for areas of fast fluctuating magnetic fields. However, slow, large ($> \pm 0.2$) changes are more difficult for the algorithm to compensate for, over periods of time longer than approximately 30s, since the algorithm will constantly be updating its new heading value.

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

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

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 XKF-3w filter is based on history. For this reason, some time is needed for the XKF-3w 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 -20°C and +55°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 0° 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 and Awinda Station 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 Absolute Maximum Ratings

Stresses above the absolute maximum ratings to the MTw may cause permanent damage to the device components.

3.3.4.1 Absolute Maximum Rating MTw

Shock (any axis)	TBD
Input Voltage	-0.3 V ... 6 V (note power is supplied only via USB)
Temperature During operation	-10 oC - +60 oC
Temperature During charging	0 °C - +45 °C

3.3.4.2 Absolute Maximum Rating AWINDA Station

DC Input Voltage	-0.3 V ... 16 V (Use included DC adapter)
SYNC (BNC) inputs	-0.5 to 3.8V
Operating Temperature	-20 °C - +80 °C

Exposure to absolute maximum rating conditions for extended periods may affect device reliability.

NOTE: Drops onto hard surfaces can cause shocks of greater than 20000 m/s² (2000 g) exceeding the absolute maximum rating of the device. Care should be taken when handling to avoid damage. Drops causing shock greater than absolute maximum ratings may not destroy the device but will permanently alter the properties of the physical motion sensors, which may cause the device to become inaccurate. If this occurs, please contact support@xsens.com to investigate if the MT should be returned for a check.

3.3.5 Keeping the Hardware Clean

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

4 Hardware

The MTw Development Kit is comprised of both software and hardware. This section deals with all hardware aspects. The hardware of the MTw development kit includes the motion trackers, the Awinda Station and the click-in body straps.

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 (MTw-38A70G20) and serial number¹ (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 3.5 hours, in stand-by for approximately 90 hours and is fully recharged after one hour docked in the Awinda Station (with a power supply connected to the Awinda Station). For more technical details on the MTw, sensor component specifications and orientation performance, see Section 11.1.

¹ Also known as Device ID.

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.

4.1.2 MTw Stand-by Mode

Following a wireless connection, the MTw is in operational or 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 magnetic field every second. See below for exiting standby mode.

4.1.3 Exiting stand-by mode

With MT SDK 3.8 instead of searching only for a wireless link, the MTw will monitor its magnetic field once every second. If the magnetic field has changed considerably, and there is a wireless link to an Awinda Master available, the MTw will automatically become active again.

To bring the MTw back from stand-by to operational mode, 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. As an alternative, this can also be done by changing the magnetic field around the MTw. Consider moving a pair of stainless steel scissors (NOT A MAGNET) over the MTw, to change the field and reactivate it.

4.1.4 Estimated battery life with stand-by mode activated

Bat. Capacity at sleep start [%]	Estimated time to full discharge in standby [hrs]	Measuring time left after 8 hrs in standby [hrs:min]
100	88	2:18
75	64	1:45
50	44	1:06
25	20	0:24
10	8	0:00

4.2 Awinda Station



Front view of the Awinda Station, showing the LEDs. A description of the LEDs are described 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 synchronisation with external devices¹. See 11.2 for more technical specifications of the Awinda Station.









4.2.1 Awinda Station Synchronisation 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 synchronisation channels, see Section 6.7.

¹

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 [STATus of the Awinda Station]	OFF	OFF: When no USB connection is present and when MT Manager is not started.
		GREEN: Both USB connection present and MT Manager running connected to driver.
		ORANGE: USB connection to host PC is present.
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 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 Click-in Body Straps

The MTw Click-in body straps have been designed to ensure that the user can enjoy as much flexibility as possible. The user may first insert the MTw into the strap, then fasten the strap to the body (recommended). Alternatively, prepare the subject by first attaching the straps, to the body locations, then insert the MTw's at the appropriate locations.

4.4.1 Putting MTw's into Strap Holders

Each system is supplied with a series of stickers, with the ID of the MTw printed. The user can use this to fix to the MTw holder on the straps, to enable the user to remember more easily where each MTw is fixed on the body. The user can also set a numerical Location ID in MT Manager Device List (Section 6.4.2) to code Location ID to, e.g., body segments.



To put the MTw into the holder of the straps, slip the MTw, gently into the “cup” of the holder.



Press the clip of the MTw against the MTw housing.



Press the MTw vertically into the housing.



Release the clip into the clasp of the holder. Take care to ensure that the MTw is completely and firmly restrained.

4.4.2 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.

- Before each use, pre-stretch the straps to remove any initial stiffness.

- Insert each MTw, into the correct strap holder. Note the location of the MTw ID with respect to the body location, for future use.
- For consistency, it is recommended to display the Xsens text in the correct orientation for reading – this means that the cup should be the lowest point.
- Attach the straps to the appropriate body segments.¹
- 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.

NOTE: When tightening the straps, pull the strap at the point where it runs through the plastic buckle, not just at the end!

4.4.3 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 Click-in 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. (See 4.4.4 for instructions for fastening the forearm strap.)
- For the upper arm, the location is less critical, as the upper arm has more musculature.
- On the lower leg, two locations have been described in literature as good placement.
 1. On the tibia, close to the knee².
 2. On the lateral side of the lower leg, aligned with the fibula, 6cm above the lateral malleolus³.
- 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

¹ Configuration sheets with recommended MTw positions for full body measurement are available upon request.

² 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

³ 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.

the hips. The silicone backed strap, combined with the pelvis belt, this helps to ensure that this strap does not slide along the leg, during movement e.g. gait measurements.

- For pelvis motion measurement, place the MTw at the small of the back. Tightening the pelvis belt of the pelvis, we recommend using the MTw pelvis

4.4.4 Forearm Strap

The forearm straps have been designed slightly differently from the others, with an additional Velcro strap to ensure a tight fit. To fasten the forearm strap to the subject:



Ensure that the rubber touches the skin, to optimise subject comfort.



Fasten the inner (broad) Velcro strap.

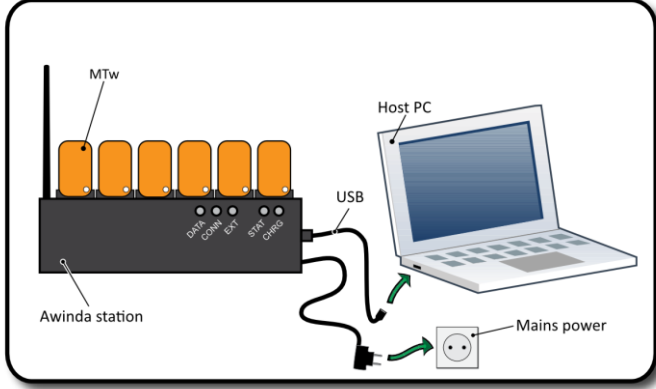

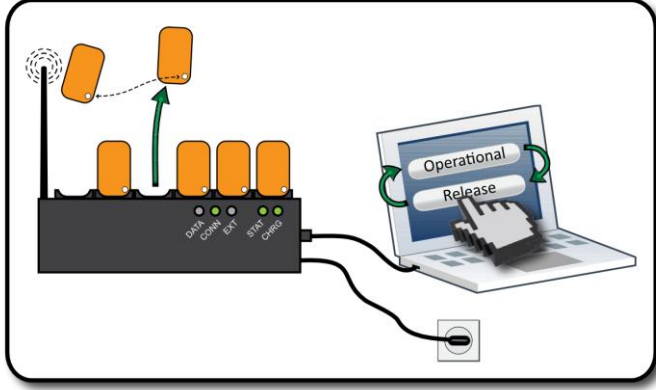


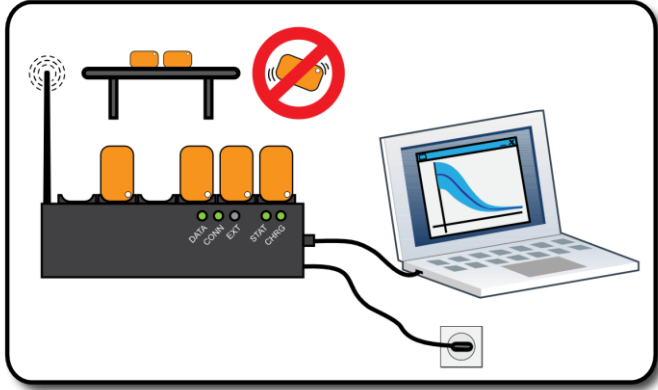
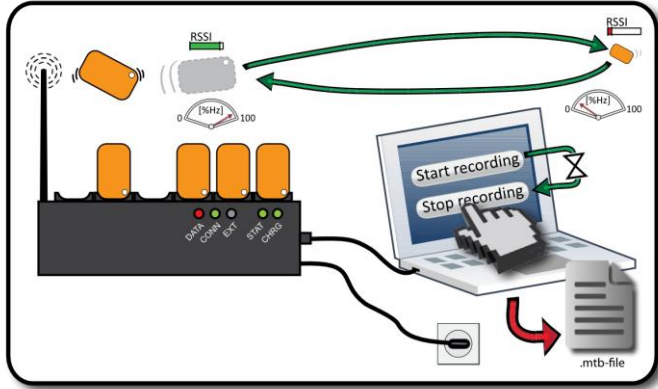
Insert the smaller Velcro strap into buckle.



Wrap around, ensuring a tight fit.

5 Recommended workflow

	<p>To start up, the Awinda Master must be plugged into the USB port of the PC.</p> <p>The ID of the Master and docked MTw's is displayed in the device list. See 0.</p>
	<p>Go to wireless configuration. Select a radio channel and switch the radio on (enable). See 6.5.</p>
	<p>When an MTw is undocked, its radio looks for a station to connect to.</p> <p>The wirelessly connected MTw's appear in the list.</p> <p>When all required MTw's are connected, set the update rate and either make operational or enter measurement mode directly.</p> <p>See 6.5.6 for selecting the best update rate.</p>

	<p>From operational mode, measurement mode can be initiated.</p> <p>When “Start Measuring” is clicked, make sure that the MTw is kept still.</p> <p>For best results, data should be measured and recorded in the same environment as when measurement mode was initiated.</p>
<p>Like all filters of its kind, the XKF-3w filter is based on history. Therefore time is needed for the XKF-3w filters to settle to a stable state. This time is called settling time, see 3.3.2.</p> <p>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).</p>	
	<p>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).</p> <p>When in measurement mode, recording can be made.</p>

6 MT Manager

Each MTw Development Kit is accompanied with MT Manager, an easy-to-use software interface facilitating visualisation, recording and exportation of inertial sensor 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 code to enable software developers to create customised (real-time) visualisation and recording application software. For more details about the SDK, please see Section 6.11.

The MT Manager software has been designed for Windows 7. It is easy-to-use software with familiar Windows user interface, which allows the user to:

- View and modify device settings and properties
- Configure the Awinda wireless interface
- Configure synchronisation with third party devices
- Real-time visualisation of:
 - 3D Orientation
 - 3D Inertial and magnetic data
 - Barometric pressure sensor data
 - Status data
- Record native binary log files of data from motion trackers (.MTB files)
- Log file export to ASCII

The MT Manager is therefore an easy way of getting to know and to demonstrate the capabilities of the Motion Tracker.

6.1 Software Installation

If users have previously installed Xsens MT SDK¹, 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 Station to the PC before fully installing the MT SDK.

Insert CD provided to install MT SDK on a computer running Windows using the MT SDK Setup application on the CD provided. The installation will start automatically² if "Autorun" is enabled on the CD player, otherwise, run the setup.exe file in the location of the CD ROM. Windows Vista/7 users, should choose "Open folder to view files" in the Autoplay dialog.

¹ Do not uninstall the MT SDK 3.3 if you need to continue to work with your MTi, MTx, MTi-G or Xbus Master since 3.8 only officially supports the MTw.

² If the installation application does not start automatically, double-click "setup.exe" in the root folder of your CD/DVD drive, e.g. E:\

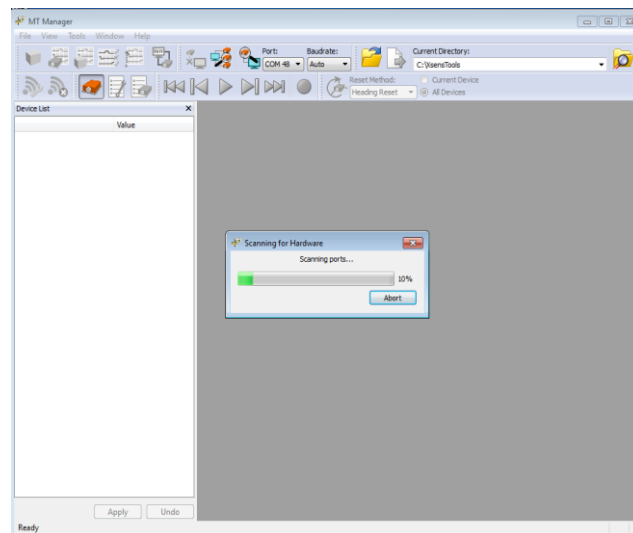
Right-click “Run setup.exe” and “run as administrator”. Follow the on-screen instructions. When prompted, enter the serial number for the product. This number can be found on the letter accompanying the MT SDK CD-ROM. Use the default installation folder or select preferred installation folder, and click next.

6.2 Connecting to MT Manager

To initialize the Awinda Station and MTw’s, dock the MTw’s in the Awinda Station. Physically connect the Awinda Station, to the PC using the USB cable provided.

6.2.1 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.

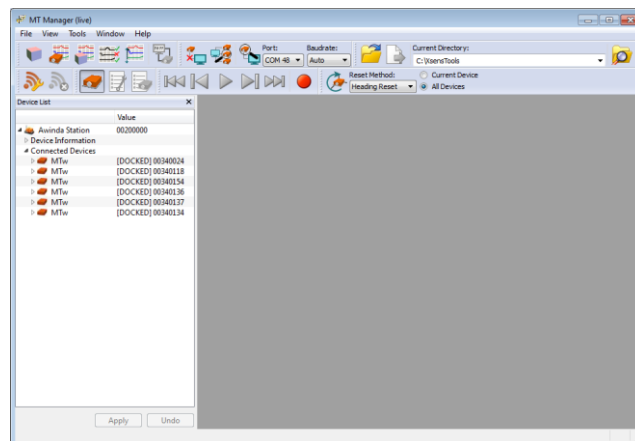


Upon successful connection¹, the “Device List” sub-window appears with a list of connected devices and respective Device ID number (when necessary press the Device List icon).

The Wireless Configuration section (6.4.2) describes how to connect the MTw’s as sub-systems (clients) of Awinda.

NOTE: If synchronisation configuration is needed first enable these settings (See section 6.7) before carrying out the wireless configuration.

¹ Please refer to Section 8 in case of problems.



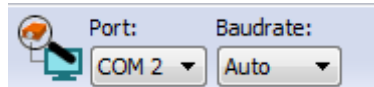
If the automatic scanning at start up does not reveal any connected devices, ensure that there is a USB connection and manually scan for ports using the functions in the connectivity toolbar.

6.3 Connectivity Toolbar

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



Scan all ports



Scan single port



Disconnect COM port¹

6.3.1 Scan All Ports

All available COM ports are scanned for connected devices.

6.3.2 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”.

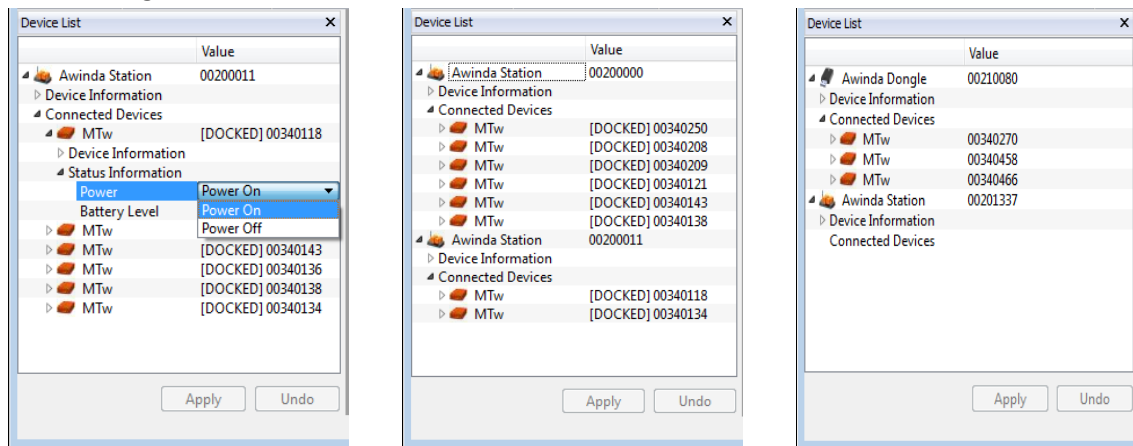
6.3.3 Disconnect COM Port

To disconnect all hardware connected, select the “Disconnect” button.

¹ This can also be used to close an open file.

6.4 Device List

The Device List contains all of the information about the devices connected to MT Manager. It is possible to connect more than one Awinda Station (and associated MTw's) at one time to MT Manager.



**Single Station: Power On
Power Off**

**Two Awinda Stations
Connected**

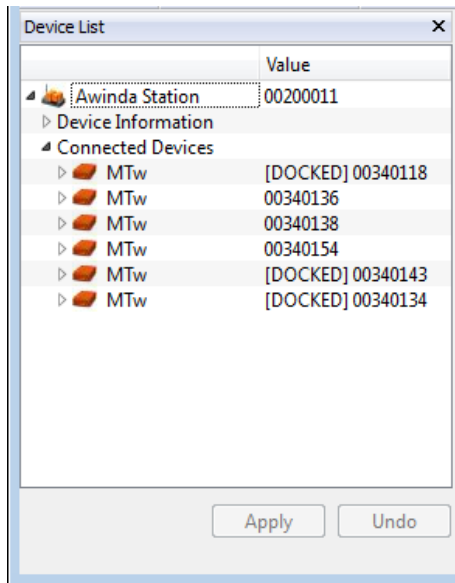
**Wireless connection with
Awinda USB Dongle**

6.4.1 Power On/Off

When docked it is possible to power off the MTw's, to a fully powered down "Transport Mode". To do this, select Power Off from the drop down, menu and click "Apply". It is important to "Apply" changes or they are lost after e.g. a rescan or if removed from the Station.

To re-enable the power, simply dock the MTw back into the Awinda Station; it will wake up by the power connection.

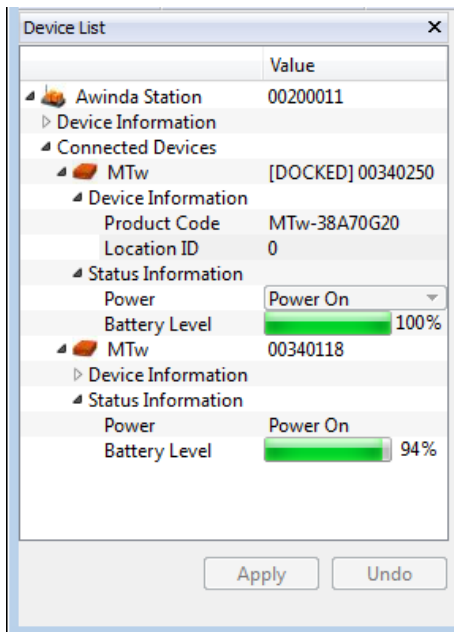
It is best to power off unwanted MTw's before continuing with the wireless configuration. If the user decides to power off the MTw after wireless configuration, it will be necessary to re-dock the MTw, Power Off and then reconfigure the wireless network.



When the wireless configuration has been performed, the Device List is updated such that all connected MTw's are listed, with the indication of whether they are still in the Awinda Station (docked) or wirelessly connected.

MTw's docked or wirelessly connected is shown as a Connected Device in the Device List. Still docked (and not previously configured wirelessly) have the index "[DOCKED]".

6.4.2 Location ID



Users can change 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.

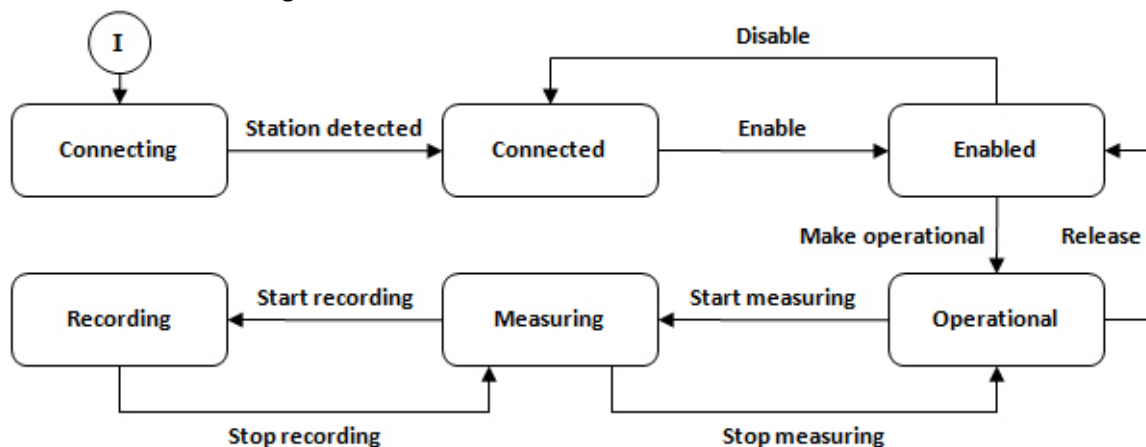
After making changes in the Device List, click Apply to make sure changes are implemented.

6.5 Wireless Configuration

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

State	Description
Connecting	The Station is plugged into the USB connection and MT Manager tries to establish the link to the Station.
Connected	The Station is plugged in to the USB and detected by MT Manager. The radio is not transmitting.
Enabled	The station 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.
Operational	All the necessary MTw's are connected and no more new MTw's can connect. The system is ready to start the measurements using the indicated maximum frame rate or the user can specify a lower one.
Measuring	The MTw's are measuring and transmitting data to the station. The station relays the measurements to MT Manager.
Recording	Any missed data packets are retransmitted in this state, provided that the maximum update rate is not selected.

The state transition diagram is illustrated below:



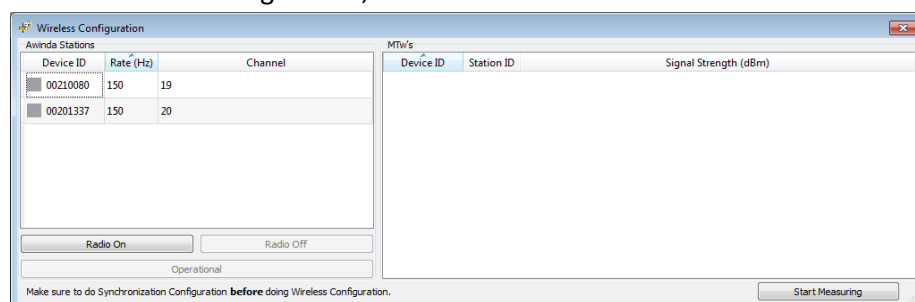
State	Transition	Description	Next State
Connecting	Station detected	MT Manager and Station are connected.	Connected
Connected	Enable	User indicated that the system can be enabled.	Enabled
Enabled	Make operational	User indicated that system can become operational.	Operational
	Disable	User indicated that the system is to be disabled.	Connected
Operational	Start measuring	User indicated that the system can start measuring.	Measuring
	Release	User indicates that system is no longer operational, but still enabled.	Enabled
Measuring	Stop measuring	User indicates that measuring can be stopped.	Operational
	Start recording	User indicates that the recording is to be started.	Recording
Recording	Stop recording	User indicates that the recording can be stopped.	Measuring

It is possible to enable and disable the radio link using the wireless configuration window. Likewise, rejecting and accepting motion trackers for a given Awinda Station.

6.5.1 Setting Up a Wireless Network in MT Manager

NOTE: If synchronisation with third party devices is needed first enable these settings (See section 6.7) 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.

6.5.2 Choosing a Radio Channel

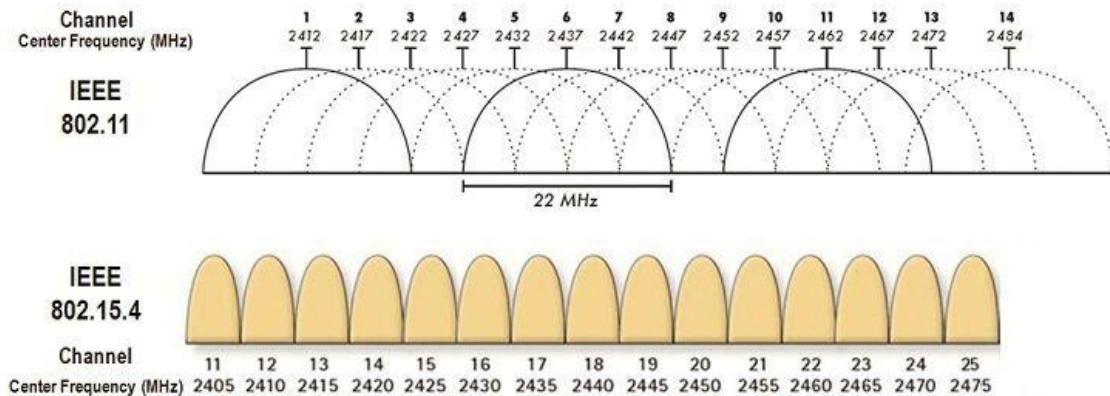


Figure 2: Overview of channels operating around 2.4GHz; for ease of channel selection

Figure 2 provides an overview of the allowed channels for operating on IEEE 802.15.4, the standard that Awinda 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.

6.5.3 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.

6.5.4 Turn Radio On

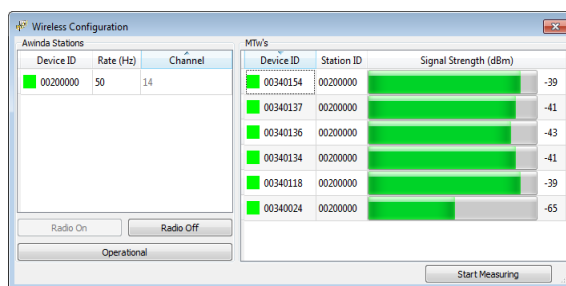
After selecting the radio channel for the wireless communication, click "Radio On". The radio transceiver of the Awinda Master will turn on and it which will search for MTw's on this channel.

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.)

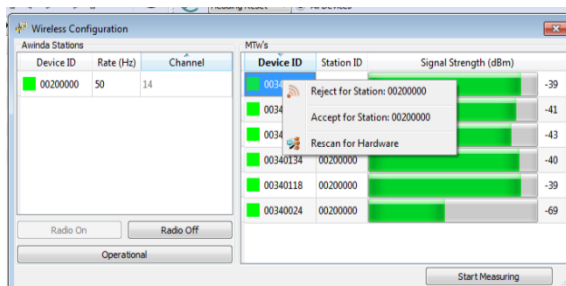
6.5.5 Connecting MTw's to an Awinda Master



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 Station: <StationID>". Where Station ID is the serial number of the Awinda Master in use.

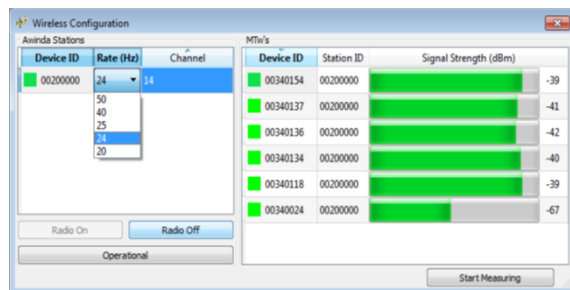
Initially, if a user has rejected the MTw for a given station, this is depicted as “Unknown”. A rescan shows that the MTw was rejected by the user “Blacklisted”.

To reconnect a rejected MTw and Awinda Master, right-click the MTw and select “Accept for Station: <Station 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 should power it off in the Device List, while docked in the Awinda Station, before starting the wireless configuration. See Section 6.4.1.

6.5.6 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.

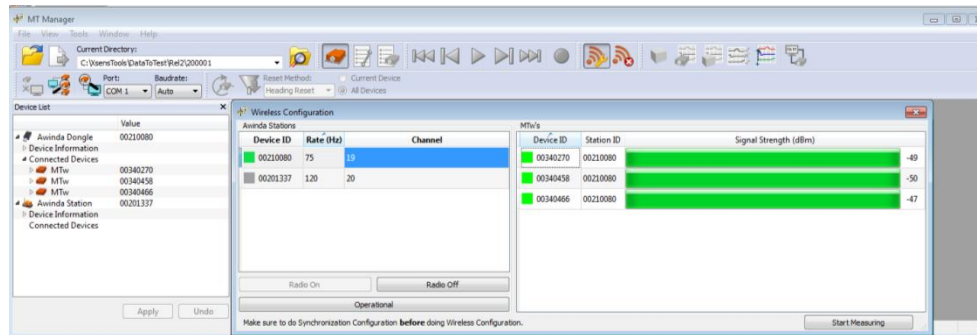
NOTE: The default update rate is always one value less than the maximum, to ensure that retransmissions are possible during recording. Users can increase this to maximum but caution should be taken as this will reduce or remove the possibility of retransmissions.

Table 1 provides an indication of the maximum and typical update rates for a number of MTw’s. The buffering time is also indicated. This is the amount of time that data can be expected to be stored on the MTw, if the user goes beyond the specified radio transmission range.

Table 1: Typical and maximum update rates and buffering times

Amount of MTw’s	UR [Hz] (max – no retransmissions)	Buffering time[s] (max)	UR [Hz] (typical – allowing retransmissions)	Buffering Time [s] (typ)
1	150	7	120	9
2	120	9	100	10
4	100	10	75	14
6	75	14	60	17
12	50	20	40	26
18	40	26	30	34

6.5.7 Wireless Connection with the Awinda USB Dongle



The procedure to connect to the Awinda USB Dongle is the same as connecting to the Awinda Station. Therefore, follow the steps described above. One possible scenario when using the Dongle is that it is possible that both the Station and the Dongle (therefore two Awinda Masters) are connected to the PC via the USB port. If only a wireless connection with the Dongle is needed, then ensure that the radio of the <Station ID> of the Dongle is activated during the wireless configuration procedure.

6.5.8 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 click "Operational" to enter operational mode and ensure that the configured MTw's are bound to that Awinda Station. When in operational mode, no new MTw's can be added to the wireless network. Before configuring the second Awinda Station, first ensure that the radio channel is different from the previously configured Station, then proceed with wireless configuration of the second Station.

6.5.9 Operational and Measurement Modes

When only one Awinda Station is in use, when all MTw's have been detected and accepted for the measurement, the user can go directly to recordings, the user does not need to select "Operational" but can go directly to "Start Measuring".

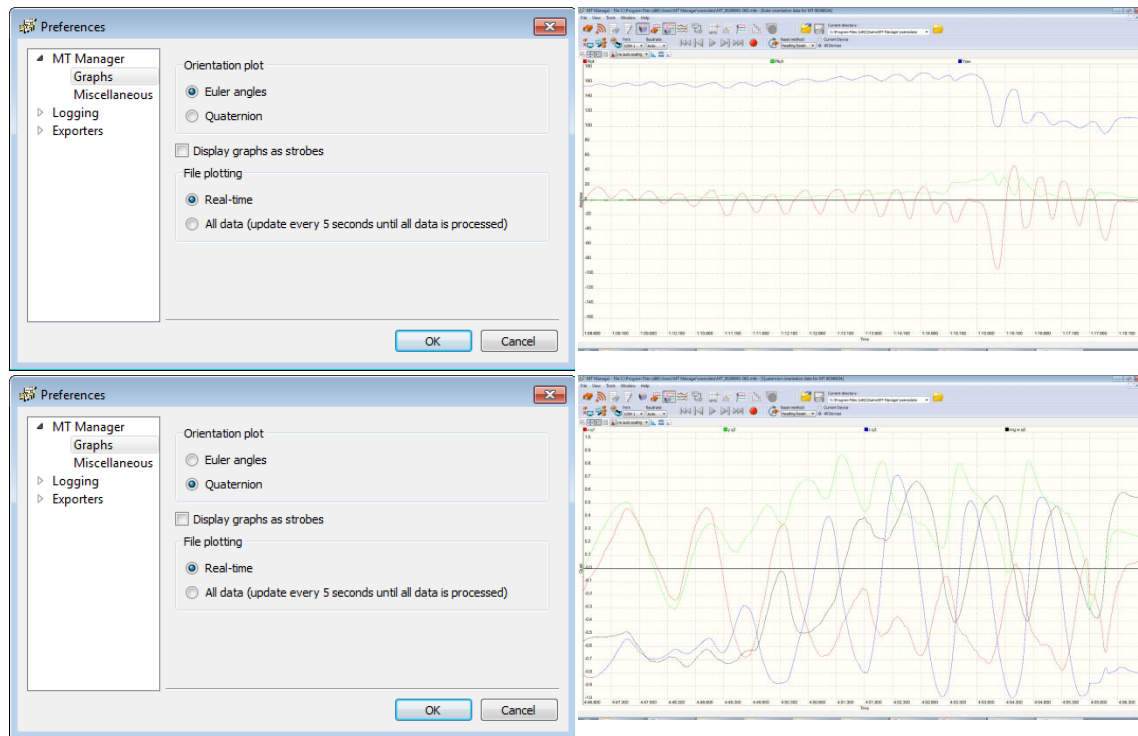
With Start Measuring command, MT Manager will close the wireless configuration menu, rescan the COM ports and update the Device List. Remember to keep MTw's very still at this time.

The MTw's are now detected as clients of the active wireless motion tracker network with the Awinda Station as the master device, as shown in the Device List. All MTw's are time synchronised with each other to a global time base given by the Awinda Station.

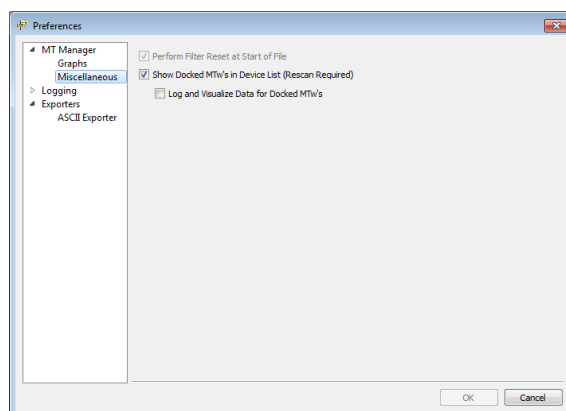
6.6 Preferences

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

6.6.1 Preferences: Graphs



6.6.2 Preferences: Miscellaneous



Show docked MTw's in Device List (see 6.4).

Log and visualize data for docked MTw's (see 6.6.2.2).

6.6.2.1 Show Docked MTw's in Device List

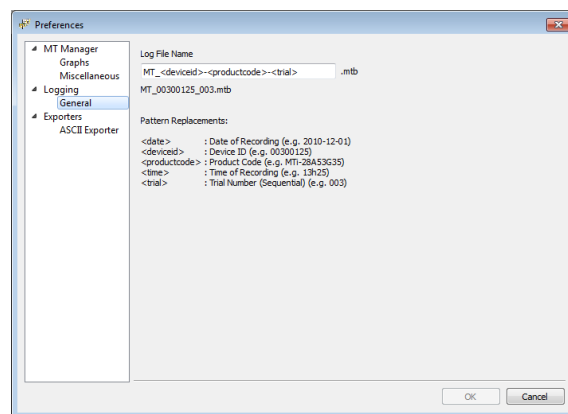
This is related to how the Device List handles docked MTw's. The default setting is to show docked MTw's, at all times. If checked (default), docked, and powered on MTw's will appear in the Device List, even after wireless configuration. In the Device List it will be possible to power off, and to observe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

6.6.2.2 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 stored in the data files. 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.

6.6.3 Preferences: Logging

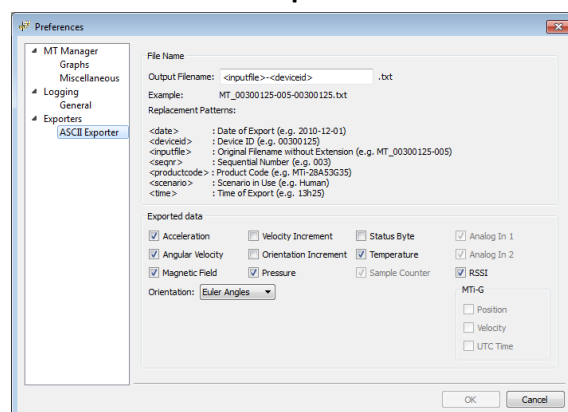


Logging/file names.

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 preset values, such as date, time etc.

6.6.4 Preferences: Exporters



Following a measurement, it is possible to export the values. Section 11.7 provides a description of each Orientation Output Mode.

Note:

- 1) Acceleration and Angular Velocity are values derived from the SDI values.
- 2) Orientation is always exported, as default. To undo this, select "none" from the drop-down menu in the list.

6.7 Synchronisation

MT Manager for MTw provides a very easy to use interface, with many possibilities to facilitate all kinds of synchronisation with third party devices. The user should decide which

type of synchronisation to implement, based on the synchronisation possibilities of their own systems. For synchronisation, one system must be in control, therefore sends the synchronisation signal (Master/Sync Out), and the other attached systems are controlled by and receive this signal (Slave/Sync In).

The hardware clock of the Awinda Station is very accurate. As an indication of the clock accuracy, the error in the Awinda Station's clock has a maximum of 1 μ s every second (1 ppm).

Therefore, in general, the recommended scenario is that Xsens is the master sending the control signals during synchronisation.

There are four synchronisation ports on the Awinda Station, onto which BNC connectors can be attached. Two sync ports (Line 1 and Line 2) are available for Sync In and two for Sync Out. For each synchronisation port, there are a number of possible synchronisation possibilities.

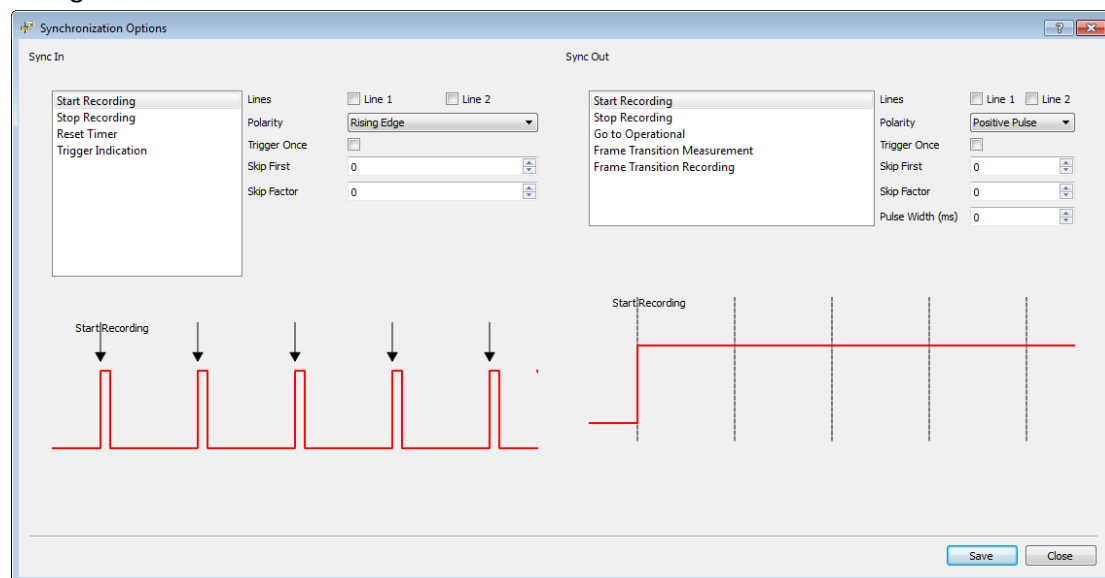
See Section 11.8 for synchronisation examples.

6.7.1 Synchronisation Settings in MT Manager

NOTE: Set the synchronisation settings before carrying out the wireless configuration step.

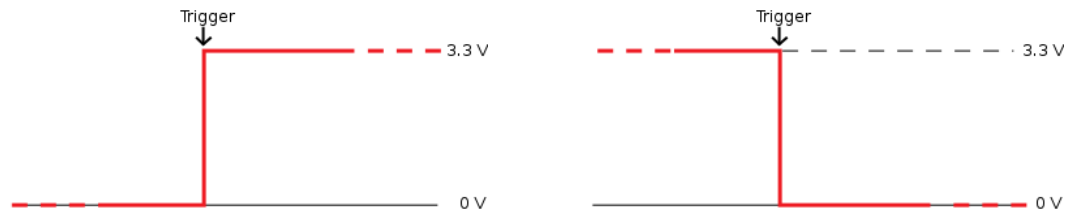
NOTE: It is not possible to set synchronisation settings during a wireless connection.

To configure the software for synchronisation control, go to >Tools, >Synchronisation Configuration.



6.7.2 Sync In

Sync In means that a third party device sends a control signal to the Awinda Station. The Awinda station can detect polarity 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. On the Awinda Station, this will be the next frame.
Stop Recording	External system sends a stop recording trigger.
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 to MT Manager.

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	It is not recommended to selected Trigger once, if more than one recording using synchronisation 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 sends the same signal to generate both a start and stop recording. Take for example the command to start recording and stop recording, one signal sent to the Awinda Station can generate two different commands. Therefore if both start and stop are on the same sync line, skip first should be 1 for stop recording, ensuring that the second trigger, not the first, causes 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.

6.7.3 Important Notices for Sync In

When the Awinda Station is configured to start recording upon receipt of a trigger, it initialises recording at the start of the following frame. The Awinda Station cannot trigger a start recording command between frames since 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 external trigger indication.

Recording should not be stopped between frames, since data received in a given frame was measured during the previous frame. Therefore, the Awinda Station stops recording immediately after the current frame.

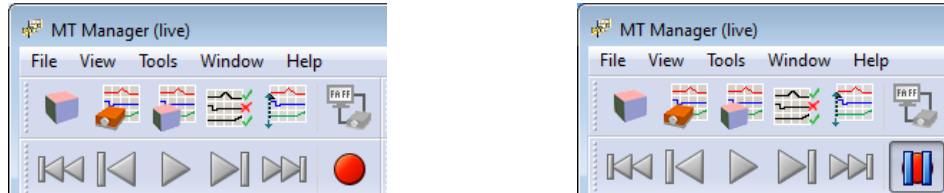
Rising and falling edge polarity: This command is particularly useful for the "Trigger indication" action for the following purposes:

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.

6.7.3.1 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:



6.7.4 Sync Out

Sync Out is the command that enable the Xsens system to send a trigger pulse for synchronisation purposes. A control signal is sent via the Awinda Station, from MT Manager to the third party hardware. As with sync In, a combination of events are possible, based on a number of parameters.

Event	Description
Start Recording	Upon clicking the record button in MT Manager, the Awinda Station starts the recording and consequently sends a start recording trigger to the third party system.
Stop Recording	Upon clicking the record button in MT Manager, the Awinda Station stops recording and sends a stop recording trigger to the third party system.
Go to Operational	This feature gives the maximum flexibility because it speeds up the preparation of the instrumentation and the subject (if synchronising at the time of the operational mode) or, once the preparation is done, to synchronize and record data only when strictly necessary (if synchronising every time you record)
Frame 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 that "Start Measuring" is selected.
Frame Transition Recording	See Frame transition Measurement Selecting this option, the frame transition is sent from the moment that a recording is started. This is a very useful option to implement, to ensure that during a recording, the clocks of the synchronised systems are known, ensuring that any drift can be compensated for.

The default polarity of the output line is low. However, for input triggers that assume high polarity, the polarity of the line must be set beforehand. This is possible, using 'Go to operational' with a polarity positive pulse and infinite pulse-width.

A number of parameters can be set for each action:

Parameter	Description
Line	The sync line to activate.
Polarity	Positive pulse (where the polarity is initially low [0V] and goes high [3.3V]). Negative pulse (where polarity is initially high [3.3V] and goes low [0V]).
Trigger Once	It is not recommended to selected Trigger once, if more than one recording using synchronisation 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 the third party system. It may also be needed if the third party, 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	Some systems wait for a signal of a minimum pulse width before generating the desired synchronisation action. The Awinda Station can send a pulse with a duration of up to 99ms to a third party 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 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 and/or calibrated inertial (and magnetic) data 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 object reset that defines how the MTw is oriented with respect to the coordinate axes to which it is attached. After the object reset, both the inertial (and magnetic) and orientation data are expressed with respect to the axes of the object. See Section 11.6.5.
4. A combined object/heading reset, referred to as alignment. See Section 11.6.6.

NOTE: For all co-ordinate 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.



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.

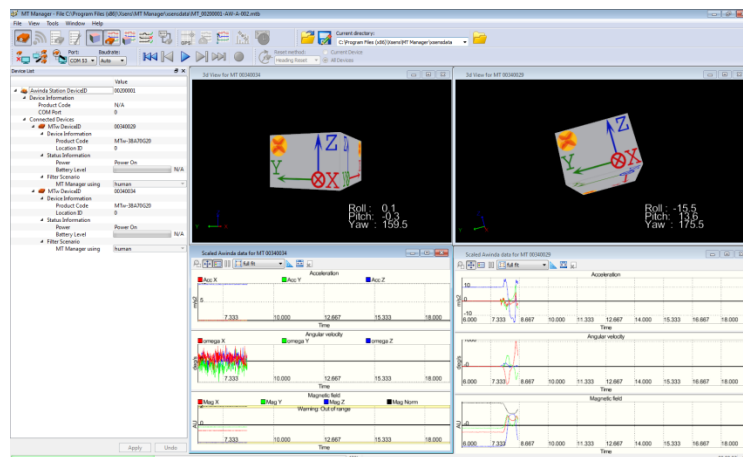
6.9 Recording Data

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.



To review the data, graphically, open the .MTB file, open the desired type of graph (inertial, or orientation data) and 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.

6.10 Saved and Exported Data

MT Manager can export data logged in .MTB files 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 11.5 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)
- Trigger In timestamps
- Status Byte

Abbreviation	Data	Unit
Counter	Sample counter	(-), wraps at 65535
Temperature	Temperature inside housing	°C
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
Acc_X	Acceleration x-axis	m/s ²
Acc_Y	Acceleration y-axis	m/s ²
Acc_Z	Acceleration 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
Pressure	Atmospheric pressure	mBar
Roll/Pitch/Yaw	Orientation Euler angles format (3)	deg
Quat *	Orientation quaternion format (4)	Unit quaternion
Mat [R#][C#]	Rotation matrix format [Row][Column] (3x3). (Direction Cosine matrix)	Unit vectors
Trigger In 1	Awinda converted time stamp values of trigger indications sent to Sync In 1 of the Awinda Station	Milliseconds
Trigger In 2	Awinda converted time stamp values of trigger indications sent to Sync In 2 of the Awinda Station	Milliseconds
Status	N/A for MTw and / or MT SDK 3.7 Beta	
RSSI	Received Signal Strength Indicator by Station	dBm

Abbreviation	Data	Unit
	from each connected MTw	

6.11 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#, LabVIEW and MATLAB.

From MT SDK 3.8 there is also a 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 steel prosthesis, 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 file of MT Manager. In this directory is also a user manual for 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.

First create a wireless connection for the given MTw (see Section 6.4.2, but pay particular attention to the instructions below):

Note: MFM can be run for one MTw at a time. Therefore for each MTw that should be mapped, use the following instructions, 1-3 depends on user preference, 4-10 applies to both methods of choice.

In MT Manager do the following:

	Power off unnecessary MTw's	Wirelessly reject unnecessary MTw's
1	Dock all MTw's	Undock all MTw's
2	Power off all but one MTw in the device list	Wireless configuration
3	Wireless configuration for remaining MTw	Reject all but one MTw
4	Set update rate to 100Hz	
5	Start Measuring	
6	Close MT Manager	
7	Activate MFM	
8	Follow instructions for MFM	
9	Close MFM	
10	Repeat above for remaining MTw's to be mapped.	

7.2 Firmware Updater

With new software releases, it can be expected that new firmware is required for the Awinda Station, Awinda USB Dongle and MTw's. Xsens supplies a firmware updater. The firmware updater is found in START> All Programs > Xsens > Firmware Updater.



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 >Documentation >Firmware Updater User Manual.

Note that the maximum amount of devices that the firmware updater can handle for an MTw system, is 16 devices. In theory this can be two MTw kits comprising for example:

2x Awinda Stations

2x Awinda USB Dongles

12x MTw's (6 docked in each Awinda Station).

8 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.
The MTw is no longer visible in the Device List.	It is possible that MTw's have been removed and replaced too quickly in the Awinda Station, therefore no longer recognised in MT Manager. MTw is powered off.	Place the MTw into another station socket. Note: When the MTw is left unplugged for a while (few minutes), the MT Manager will find it again.
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. 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.
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		Check all cable connections. Unplug the USB cable and power supply from the Awinda Station, wait 30 seconds and then re-plug

Problem	Possible cause	Solution
found in the Device List.		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) perform Wireless configuration step again (Section 6.4.2).
Re-enable radio does not always find trackers used before.		Re-dock the MTw(s), rescan ports and perform Wireless configuration step again (Section 6.4.2).
RSSI in Wireless configuration is full, while I cannot receive data from the MTw.	MTw and Awinda Station no longer wirelessly connected.	Re-dock the MTw(s) perform Wireless configuration step again (Section 6.4.2).
MTw in Wireless Configuration is shown as disconnected, but RSSI appears to have a good strength.	MTw and Awinda Station are not wirelessly connected. Related to above issue.	Re-dock the MTw(s), rescan ports and perform Wireless configuration step again (Section 6.4.2).
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 contains a small radio transmitter and receiver. During communication with the Awinda Station it receives and transmits radio frequency (RF) electromagnetic fields (microwaves) in the frequency range 2400 of 2500 MHz (IEEE 802.15.4 PHY compliant). 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

NOTE: 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.

10.3 CE Declaration of Conformity

We, **Xsens Technologies B.V.**, of
Pantheon 6a
7521 PR Enschede
The Netherlands

declare under our sole responsibility that our product:

MTw-38A##G##
AWNDDNG
AW-A

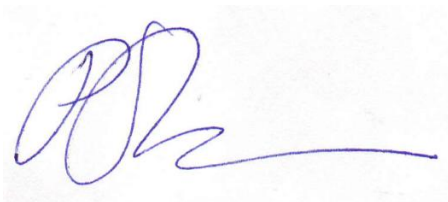
to which this declaration relates, conforms to the following Standards and other Normative Documents:

EN 61326-1 (2006)
EN 61326-1 (2006)
EN 61000-3-2 (2006)
EN 61000-3-3 (1995) + A1 (2001) + A2 (2005)
EN 60950-1: 2006 Safety of information technology equipment

Environment to be used is light industrial / laboratory

Class of emission is B.

January 13 2011 Enschede, the Netherlands



Per Slycke
CTO
Xsens Technologies B.V.

10.4 FCC Declaration of Conformity

We, **Xsens Technologies B.V.**, of
Pantheon 6a
7521 PR Enschede
The Netherlands

declare under our sole responsibility that our product:

MTw-38A##G##
AWNDDNG
AW-A

to which this declaration relates, have been tested and found to comply with the limits for a Unintentional Radiator as described in 47 CFR 15 (2007 May, 04 Edition) Class B Digital Device, pursuant to 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.

January 13 2011 Enschede, the Netherlands



Per Slycke
CTO
Xsens Technologies B.V.

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	± 1200 deg/s	± 160 m/s ²	± 1.5 Gauss	300 -1100 mBar ¹
Linearity	0.1 % of FS	0.2 % of FS	0.2 % of FS	0.05 % of FS
Bias stability ²	20deg/hr	-	-	100 Pa/year
Noise	0.05deg/s/√Hz	0.003m/s ² /√Hz	0.15mGauss/√Hz	0.85 Pa/√Hz
Alignment error	0.1 deg	0.1 deg	0.1 deg	-
Bandwidth ³	100Hz (max.)	100 Hz (max.)	20 Hz (max.)	-

11.1.2 Orientation Performance

Dynamic Range	all angles in 3D
Angular Resolution ⁴	0.05 deg
Static accuracy (Roll/Pitch)	<0.5 deg
Static Accuracy ⁵ (Heading)	1 deg
Dynamic Accuracy ⁶	2 deg RMS

11.1.3 MTw Physical Properties

Accelerometers	MEMS solid state, capacitive readout
Rate gyroscope	MEMS solid state, monolithic, beam structure, capacitive readout
Magnetometer	Magneto-Impedance sensor elements
Barometer	Piezo-resistive sensor element
Weight	27g
Housing dimensions	34.5 x 57.8 x 14.5mm (W x L x H)

¹ (-500 -.9000 m above sea level)

² As measured from the Allan variance diagram.

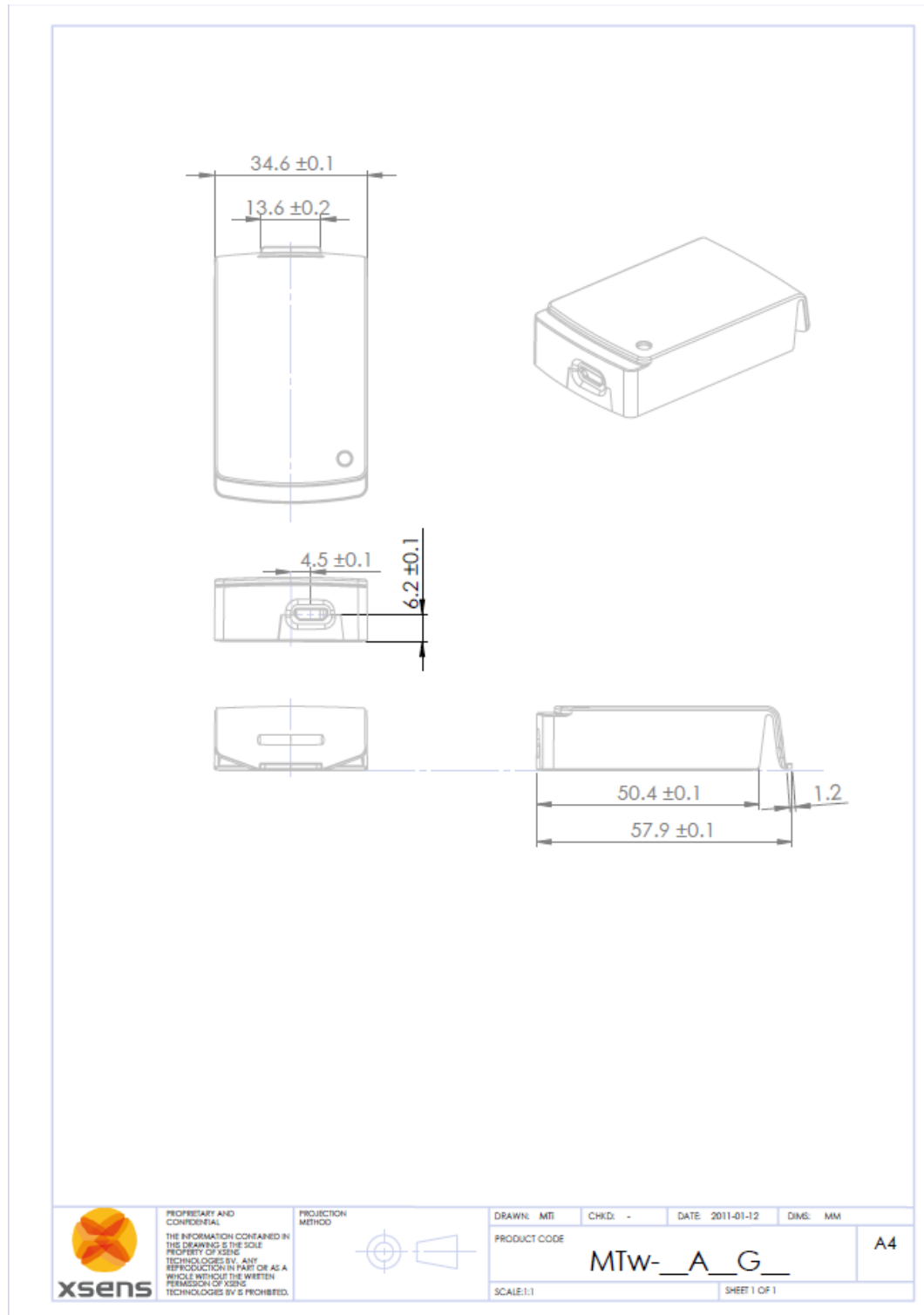
³ Half of the chosen sampling rate.

⁴ 1 σ standard deviation of zero-mean angular random walk

⁵ In homogenous magnetic environment

⁶ May depend on type of motion

11.1.4 Schematics MTw Housing Specifications



11.1.5 Charging / Discharging MTw's

The MTw's are equipped with LiPo batteries, with a capacity of 220mAh. Fully charged, it has a run-time of 2.5-3.5hrs, depending on the data rate and temperature. Charging will take ~1hrs at room temperature. Do not exceed charging ambient temperature of 0 °C to +45 °C.

NOTE: If the MTw isn't used for a long time, please put them away half-charged. Store them in a cool and dry place

11.2 Awinda Station Technical Specifications

The Awinda Station uses the Awinda protocol to receive and time-synchronize data from up to 32 MTw's simultaneously.

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

Synchronisation with third party devices

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

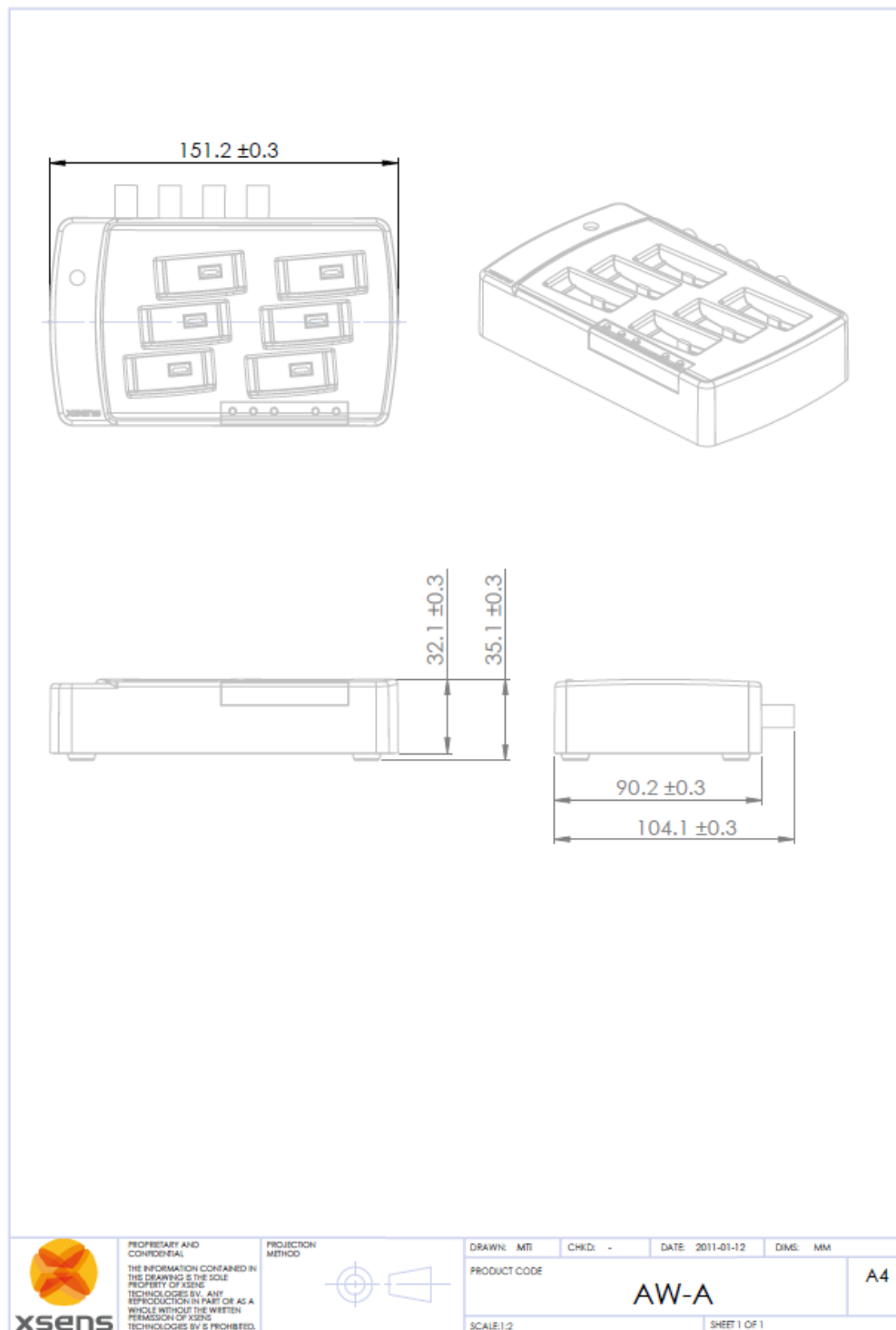
Power supply

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 32 MTw's simultaneously.



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

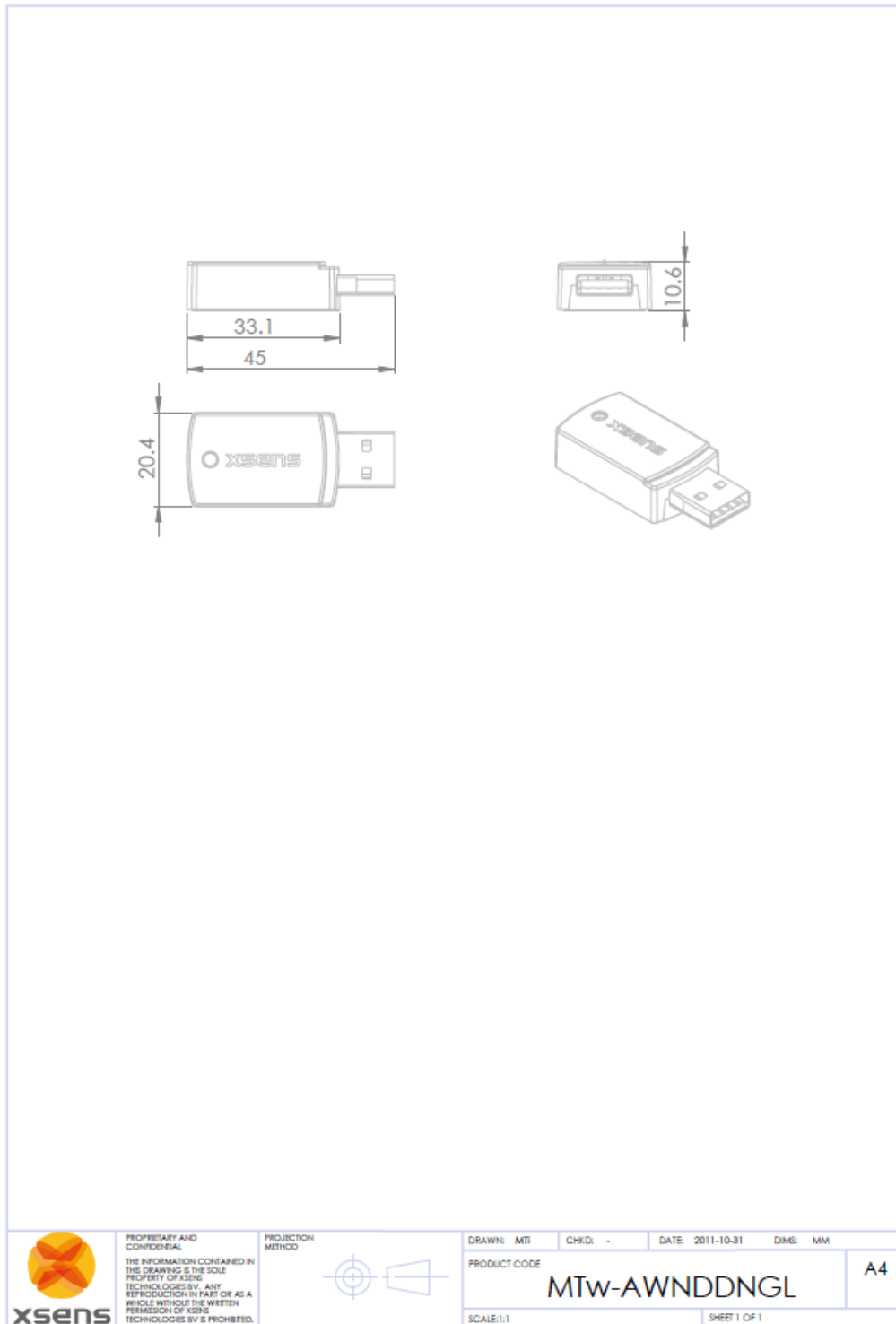
Power supply

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

Communication

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

11.3.1 Schematics Awinda USB Dongle Housing Specifications



11.3.2 Physical, Electrical and RF Properties

	MTw	AWINDA Station	Awinda Dongle
Communication	Wireless 2.4GHz/USB	Wireless 2.4GHz/ USB	Wireless 2.4GHz/

interface			USB
Wireless transmit range indoor /outdoor	~20m / 70m	~50m	~20m
Synchronization accuracy	< 10 μ s	<1ppm clock drift	<1ppm clock drift
Additional interfaces:	NA	2 x Sync In (BNC) 2 x Sync Out (BNC)	NA
Operating voltage	4.65-5.25 V	4.65-5.25V / 12V	4.65-5.25V
Power consumption ¹	~265 mW	10W max ²	< 440mW
Battery runtime	~3-4 hrs ³	NA	NA
Charge time	~1 hrs	NA	NA
Temperature Operating Range	-10°C to 60°C (discharge)	-20 to 85°C	-20 to 85°C
Specified performance Operating Temperature Range	0°C to 55°C	0 to 55 °C	0 to 55 °C
Housing Dimensions	34.5 x 57.8 x 14.5mm (W x L x H)	148 x 104 x 61.9 mm (L x W x H) Note: Awinda dimensions with antenna attached, but not raised.	45x20.4x10.6mm with USB connector 33x20.4x10.6mm without
Weight	27g	200g	8g

¹ Power consumption for the MTw depends on the chosen frame rate.

² Power consumption during charging of 6 empty MTw's.

³ Battery runtime when fully charged depends on the chosen frame rate and ambient temperature.

11.4 Xsens Kalman Filter

The orientation of the MTw is computed by Xsens Kalman Filter for 3 degrees-of-freedom (3DoF) orientation (XKF-3w). XKF-3w uses signals of the rate gyroscopes, accelerometers and magnetometers to compute a statistical optimal 3D orientation estimate of high accuracy with no drift for both static and dynamic movements.

The design of the XKF-3w algorithm can be explained as a sensor fusion algorithm where the measurement of gravity (by the 3D accelerometers) and Earth magnetic north (by the 3D magnetometers) compensate for otherwise slowly, but unlimited, increasing (drift) errors from the integration of rate of turn data (angular velocity from the rate gyros). This type of drift compensation is often called attitude and heading referenced and such a system is often called an Attitude and Heading Reference System (AHRS). For the MTw, a specific Xsens Kalman Filter (XKF-3-w) has been developed to deal with the nature of wireless transmissions (e.g. irregular updates due to temporal packets losses) and the use of high-accuracy strap down integration. In-depth documentation/whitepapers will be provided at a later date. For specific questions, please contact support@xsens.com.

11.4.1 Using the Acceleration of Gravity to Stabilize Inclination (Roll/Pitch)

XKF-3w stabilizes the inclination (i.e. roll and pitch combined, also known as “attitude”) using the accelerometer signals. An accelerometer measures gravitational acceleration plus acceleration due to the movement of the object with respect to its surroundings.

XKF-3w uses the assumption that on average the acceleration due to the movement is zero. Using this assumption, the direction of the gravity can be observed and used to stabilize the attitude. The orientation of the MT in the gravity field is accounted for so that centripetal accelerations or asymmetrical movements cannot cause a degraded orientation estimate performance. This assumption is surprisingly powerful, almost all moving objects undergo accelerations if they are moving, but in most cases the average acceleration with respect to the environment during some period of time is zero. The key here is the amount of time over which the acceleration must be averaged for the assumption to hold. During this time, the rate gyroscopes must be able to track the orientation to a high degree of accuracy. In practice, this limits the amount of time over which the assumption holds true. For the class of miniature MEMS rate gyroscopes used in the MT this period of time is about 10-20 seconds maximum.

However, for some applications this assumption does not hold. For example an accelerating automobile may generate significant accelerations for time periods lasting longer than the maximum time the MT’s rate gyroscopes can reliably keep track of the orientation. This will severely degrade the accuracy of the orientation estimates with XKF-3, because the use scenario (application) does not match the assumptions made. Note however, that as soon as the movement does again match the assumptions made, XKF-3w will recover and stabilize. The recovery to optimal accuracy can take some time.

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

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

By default, the heading is stabilised using the local (earth) magnetic field. In other words, the measured magnetic field is used as a compass. If the local Earth magnetic field is temporarily disturbed, XKF-3w will track this disturbance instead of incorrectly assuming there is no disturbance. However, in case of structural magnetic disturbance (>10 to 20 s) the computed heading will slowly converge to a solution using the 'new' local magnetic north. Note that the magnetic field has no direct effect on the inclination estimate.

If the MTw is rigidly strapped to an object containing ferromagnetic materials, structural magnetic disturbances will be present. Using an Xsens a technique 'magnetic field mapping' (i.e. a 3D calibration for soft and hard iron effects), these magnetic disturbances can be completely accounted for, allowing the MTw to be used as if it would not be secured to an object containing ferromagnetic materials.

11.4.3 Initialisation

The XKF-3w algorithm not only computes orientation, but also keeps track of variables such as sensor biases or properties of the local magnetic field. For this reason, the orientation output may need some time to stabilize once the MTw is put into measurement mode. Time to obtain optimal stable output depends on a number of factors. An important factor determining stabilizing time is determined by the time to correct for small errors on the bias of the rate gyroscopes. The bias of the rate gyroscope may slowly change due to different effect such as temperature change or exposure to impact. To reduce stabilizing time, the last computed gyroscope bias can be stored in the sensor unit non-volatile memory. If the MT 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, XKF-3w will converge faster and reach optimal robustness faster if it is started in an area without magnetic disturbances.

11.5 Strap Down Integration¹

Strap down integration (SDI) is a method used to compute an orientation/position change given an angular velocity and linear acceleration of a rigid body. Angular velocity and acceleration data in the MTw is sampled at a very high frequency to maintain accuracy under very dynamic conditions such as vibrations and impacts. The sampling frequency is too high to be transmitted wirelessly, and would typically present a computational load that is too high on the receiving host device (e.g. PC). Therefore the data that has been sampled at a high frequency is digitally filtered and down-sampled to 600 Hz and calibrated using the

¹ Further information about strap down integration for the MTw is available in the MTw Whitepaper.

individual device calibration¹ values on the embedded microprocessor (MCU) of the MTw. Based on this data the MTw further calculates velocity increments and orientation increments using an SDI algorithm. The main advantage of using the SDI algorithm is that full 3D tracking accuracy can be maintained even if the output update rate from the MTw is very low (<100 Hz). An additional advantage is that the MTw can continue to track the 3D motion internally when facing transient data loss in the RF transmission and immediately report the full 3D velocity and orientation increment as soon as the RF link is restored (data packets again received by the Awinda Station), without the need to re-transmit all the data that was lost which would a) cause a large delay during real-time tracking b) use a lot of precious RF bandwidth and consume unnecessary power. The specific use of SDI data in combination with such a specialized RF protocol, Xsens has named the Awinda protocol².

NOTE: Velocity and orientation increments resulting from the embedded SDI can easily be converted back to acceleration and angular velocity values. At high enough update rates there is no or negligible loss of accuracy due to this conversion. What is “high enough” is partly also determined by the dynamics of the movement. Xsens recommends the use of SDI values rather than acceleration and angular velocity values for further calculations as they represent the highest degree of accuracy.

¹ 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.

² Patents pending.

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 co-ordinate system as defined in the figure below. This co-ordinate system is body-fixed to the device and is defined as the sensor co-ordinate system (S). The 3D orientation output is discussed in Section 11.6.2.

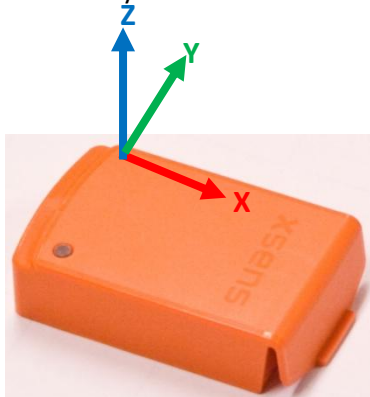
The co-ordinate system is aligned to the external housing of the MTw.

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 co-ordinate system and the bottom part of the plastic housing is guaranteed to $<3^\circ$.

The non-orthogonality between the axes of the body-fixed co-ordinate system, S, is $<0.1^\circ$. 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 $<0.1^\circ$.

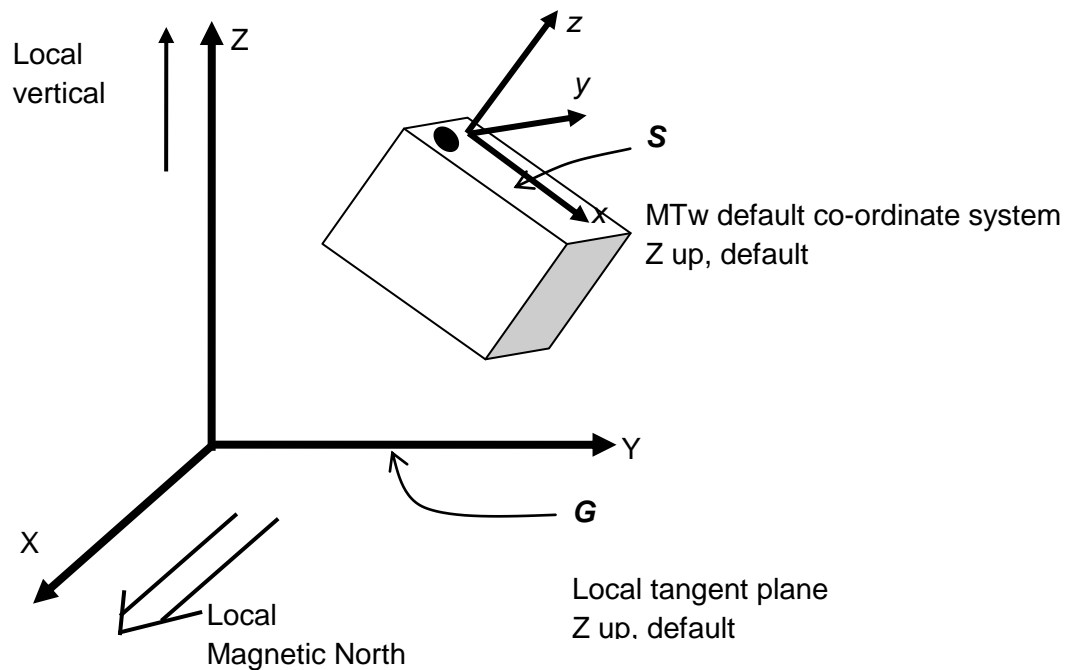
11.6.2 Orientation Coordinate System

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



- X positive when pointing to the local magnetic North.
- Y according to right handed co-ordinates (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 co-ordinate system, S, and the earth-fixed co-ordinate system, G, using the earth-fixed co-ordinate system, G, as the reference co-ordinate system.



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

For 3D orientation data:

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

For inertial and magnetic data:

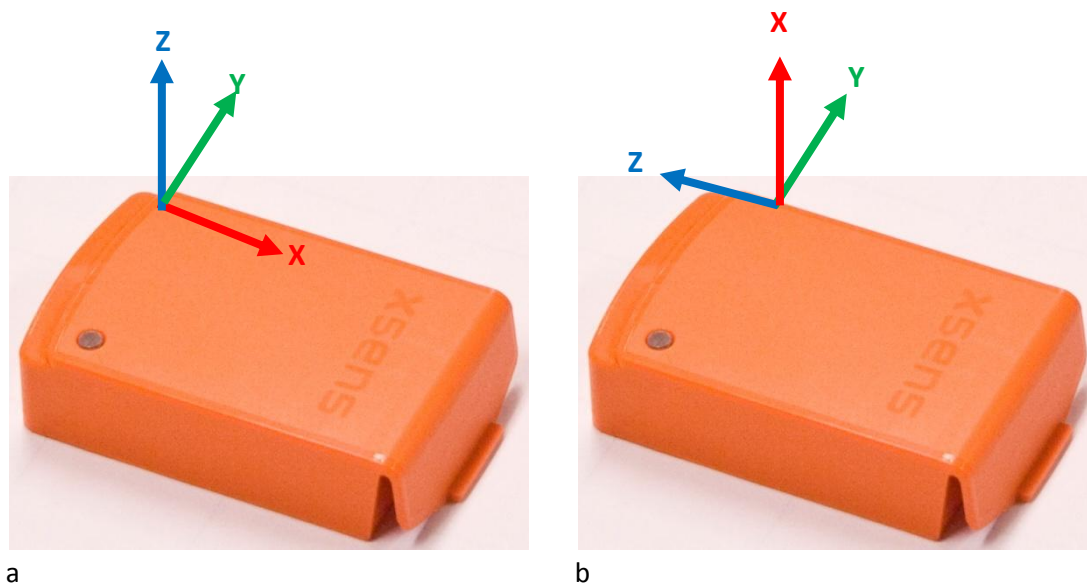
$$\mathbf{s}_O = R_{OS} \mathbf{s}_S$$

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.



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 Object Reset

The object 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 object reset, the S coordinate frame is changed to S' as follows:

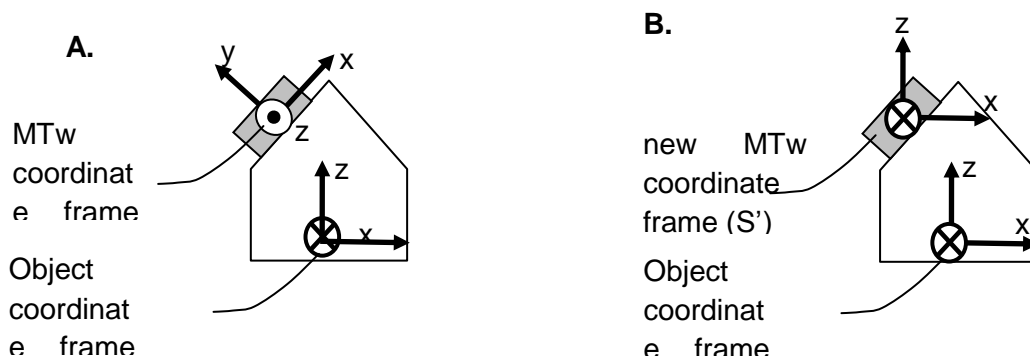
- the S' Z-axis is the vertical (up) at time of reset.

- 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 object reset is conducted, both inertial (and magnetic) and orientation data will be output in the new coordinate frame (S').

The object 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) object 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 Object reset and the Heading reset in a single time instant. This has the advantage that all co-ordinate 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).

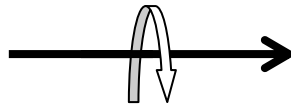
NOTE: Once this alignment reset is conducted, both inertial (and magnetic) and orientation data will be output with respect to the new S' coordinate frame.

11.7 Orientation Output Modes

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

- Unit Quaternions (also known as Euler parameters)
- Euler angles¹: 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.



11.7.1 Quaternion Orientation Output

A unit quaternion vector can be interpreted to represent a rotation about a unit vector \mathbf{n} through an angle α .

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

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

$$q_{GS} = (q_0, q_1, q_2, q_3)$$

$$|q| = 1$$

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 .

¹ 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 $\pm 90^\circ$). 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.

The inverse (q_{SG}) is defined by the complex conjugate (\dagger) 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 co-ordinate system (S) to the global reference co-ordinate 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 co-ordinate system (G) to the sensor co-ordinate 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).

- $\phi = \text{roll}^1 = \text{rotation around } X_G, \text{ defined from } [-180^\circ \dots 180^\circ]$
- $\theta = \text{pitch}^2 = \text{rotation around } Y_G, \text{ defined from } [-90^\circ \dots 90^\circ]$
- $\psi = \text{yaw}^3 = \text{rotation around } Z_G, \text{ defined from } [-180^\circ \dots 180^\circ]$

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 $\pm 90^\circ$). 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 sequences⁴.

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} :

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

¹ "roll" is also known as: "bank"

² "pitch" is also known as: "elevation" or "tilt"

³ "yaw" is also known as: "heading", "pan" or "azimuth"

⁴ Woltring HJ. 3-D attitude representation of human joints: A standardization proposal. Journal of Biomechanics. 1994;27 (12):1399-1414.

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 .

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

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

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

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

$$\begin{aligned} R_{GS} &= R_{\psi}^Z R_{\theta}^Y R_{\phi}^X \\ &= \begin{bmatrix} \cos \psi & -\sin \psi & 0 \\ \sin \psi & \cos \psi & 0 \\ 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} \cos \theta & 0 & \sin \theta \\ 0 & 1 & 0 \\ -\sin \theta & 0 & \cos \theta \end{bmatrix} \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos \phi & -\sin \phi \\ 0 & \sin \phi & \cos \phi \end{bmatrix} \\ &= \begin{bmatrix} \cos \theta \cos \psi & \sin \phi \sin \theta \cos \psi - \cos \phi \sin \psi & \cos \phi \sin \theta \cos \psi + \sin \phi \sin \psi \\ \cos \theta \sin \psi & \sin \phi \sin \theta \sin \psi + \cos \phi \cos \psi & \cos \phi \sin \theta \sin \psi - \sin \phi \cos \psi \\ -\sin \theta & \sin \phi \cos \theta & \cos \phi \cos \theta \end{bmatrix} \end{aligned}$$

As defined here R_{GS} , rotates a vector in the sensor co-ordinate 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, R_{SG} rotates a vector in the global reference co-ordinate system (G) to the sensor co-ordinate 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 =

a	b	c	d	e	f	g	h	i
---	---	---	---	---	---	---	---	---

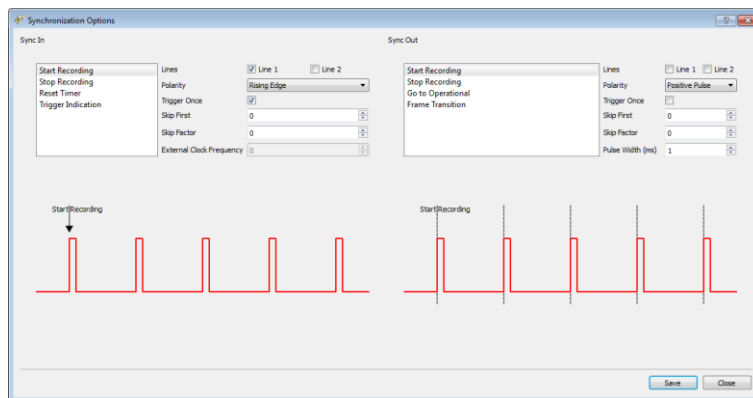
MID 50 (0x32)

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

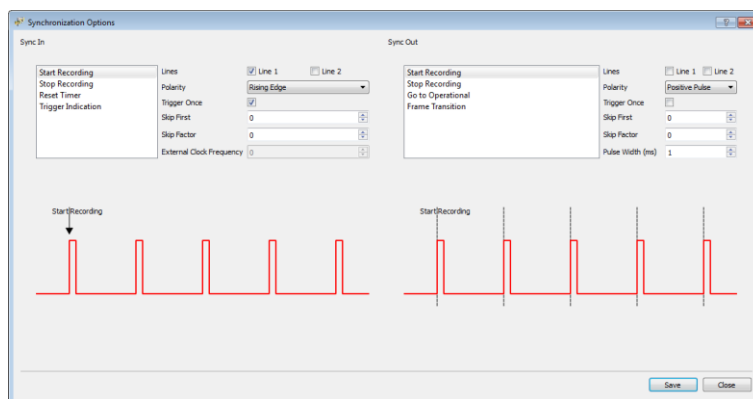
11.8 Synchronisation Examples

11.8.1 Start and stop recording of third party devices using single pulse

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



Select Start Recording
 Check the check box for Line 1
 Polarity: Rising Edge¹
 Trigger Once: Unchecked²
 Skip First = 0
 Skip Factor = 1 (so that every other pulse will start a recording in MT Manager)



Select Stop Recording
 Check the check box for Line 1
 Polarity: Rising Edge
 Check the check box for Trigger Once: Unchecked
 Skip First = 1 (first trigger starts recording, so it should not also send a signal to stop - or this causes confusion for Awinda Station)
 Skip Factor = 1 (so that every other pulse will stop a recording in MT Manager)

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.

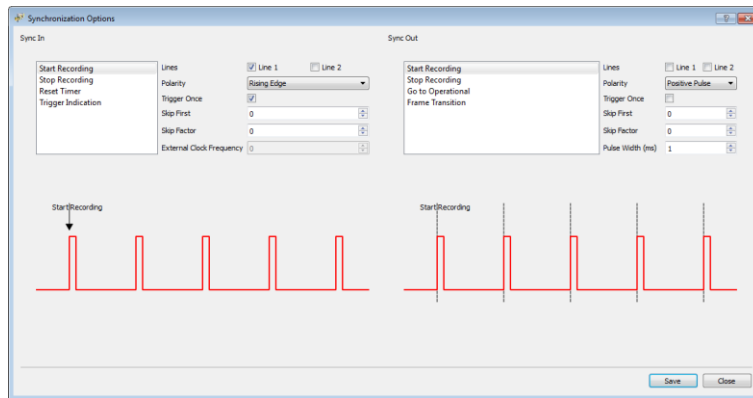
11.8.2 Start and stop recording of third party devices with infinite pulse width

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 a third party devices sends a pulse of infinite length.

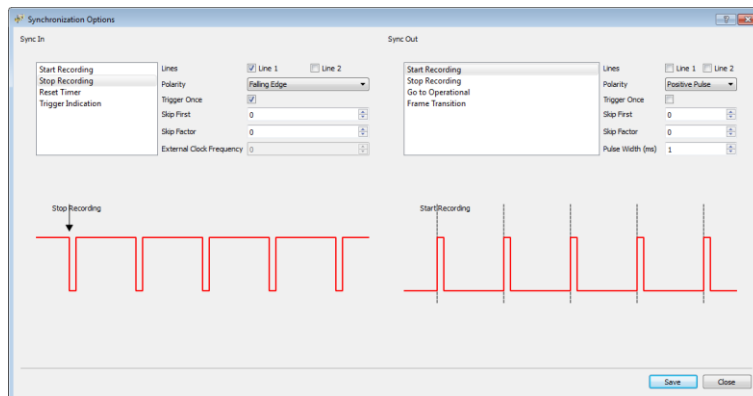
To do this, the following settings should be input:

¹ Note that this setting depends on the signal from third party system.

² To ensure that a series of recordings can be made.



Select Start Recording
 Check the check box for Line 1
 Polarity: Rising Edge
 Trigger Once: Uncheck (if more than one recording desired)
 Skip first = 0
 Skip factor = 0

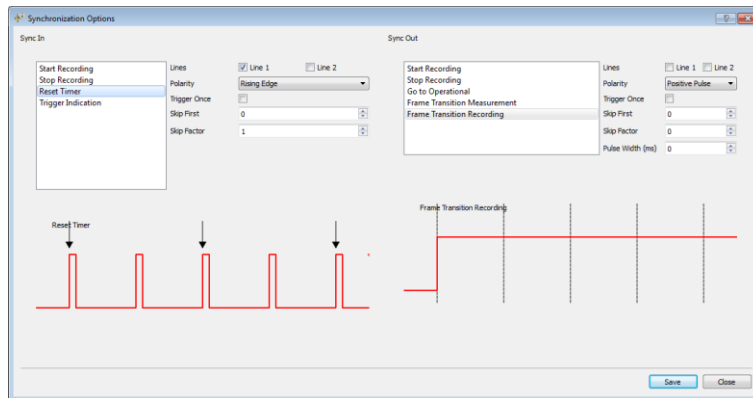


Select Stop Recording
 Check the check box for Line 1
 Polarity: Falling Edge
 Trigger Once: Uncheck (if more than one recording desired)
 Skip first = 0
 Skip factor = 0

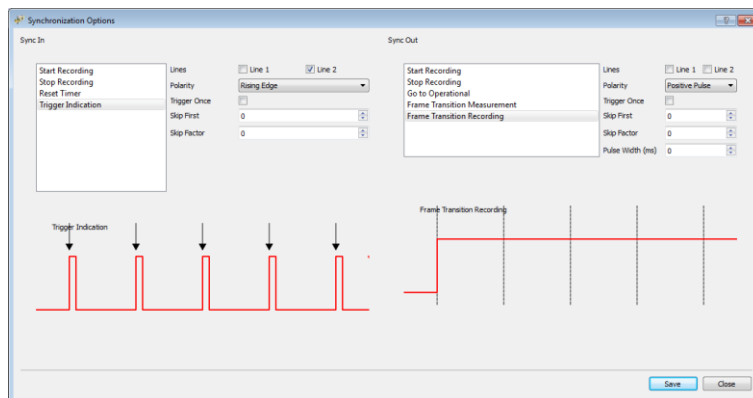
11.8.3 Start and stop recording of third party devices including trigger indication pulses

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 11.8.1.
In addition:
Select Reset Timer
Check the check box for Line 1
Polarity: Rising Edge
Trigger Once: Uncheck
Skip first = 0
Skip factor = 1



Select Trigger Indication
Check the check box for Line 2
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 synchronisation situation, there should only be one master. It is necessary to elect a master, either one of the connected Awinda Stations, or a third party device.

11.8.4 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 synchronised, the time synchronisation between the Awinda Stations themselves, running in MT Manager has not been tested. One way of ensuring good time synchronisation between the Awinda Stations is to use two separate PCs, connect each Awinda Station to a given PC and synchronise the Awinda Stations as with a third party 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
<ul style="list-style-type: none"> • Rising Edge • Skip First = 0 • Skip Factor = 1 	<ul style="list-style-type: none"> • Rising Edge • Skip First = 1 • Skip Factor = 1 	<ul style="list-style-type: none"> • Positive Pulse • Skip First = 0 • Skip Factor = 0 • Pulse Width = 10ms 	<ul style="list-style-type: none"> • Positive Pulse • Skip First = 0 • Skip Factor = 0 • Pulse Width = 10ms

11.8.5 Synchronising with Noraxon EMG

Synchronisation 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 synchronisation signal (Xsens is Sync Out and Noraxon is Sync In) and how to receive the synchronisation signal (Noraxon is Sync Out, Xsens Sync In).

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

Hardware requirements:

Noraxon Hardware	Xsens Hardware
<ul style="list-style-type: none"> • Wireless EMG transmitters • 1 TeleMyo DTS (plus antenna) 	<ul style="list-style-type: none"> • 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”.

11.8.5.2 Software Setup in MT Manager

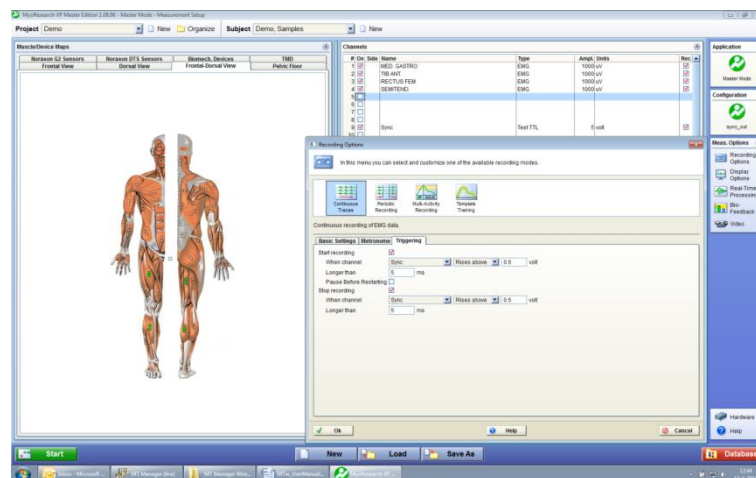
Synchronisation on Sync Out Line 1:

Sync Out	
<ul style="list-style-type: none"> • Select Start Recording • Check the check box for Line 1 • Polarity: Rising Edge • Trigger Once: Uncheck • Skip first = 0 • Skip factor = 0 • Pulse width = 10 ms 	<ul style="list-style-type: none"> • Select Stop Recording • Check the check box for Line 1 • Polarity: Rising Edge • Trigger Once: Uncheck • Skip First = 0 • Skip Factor = 0 • Pulse width = 10 ms

- Set up the wireless configuration in MT Manager.

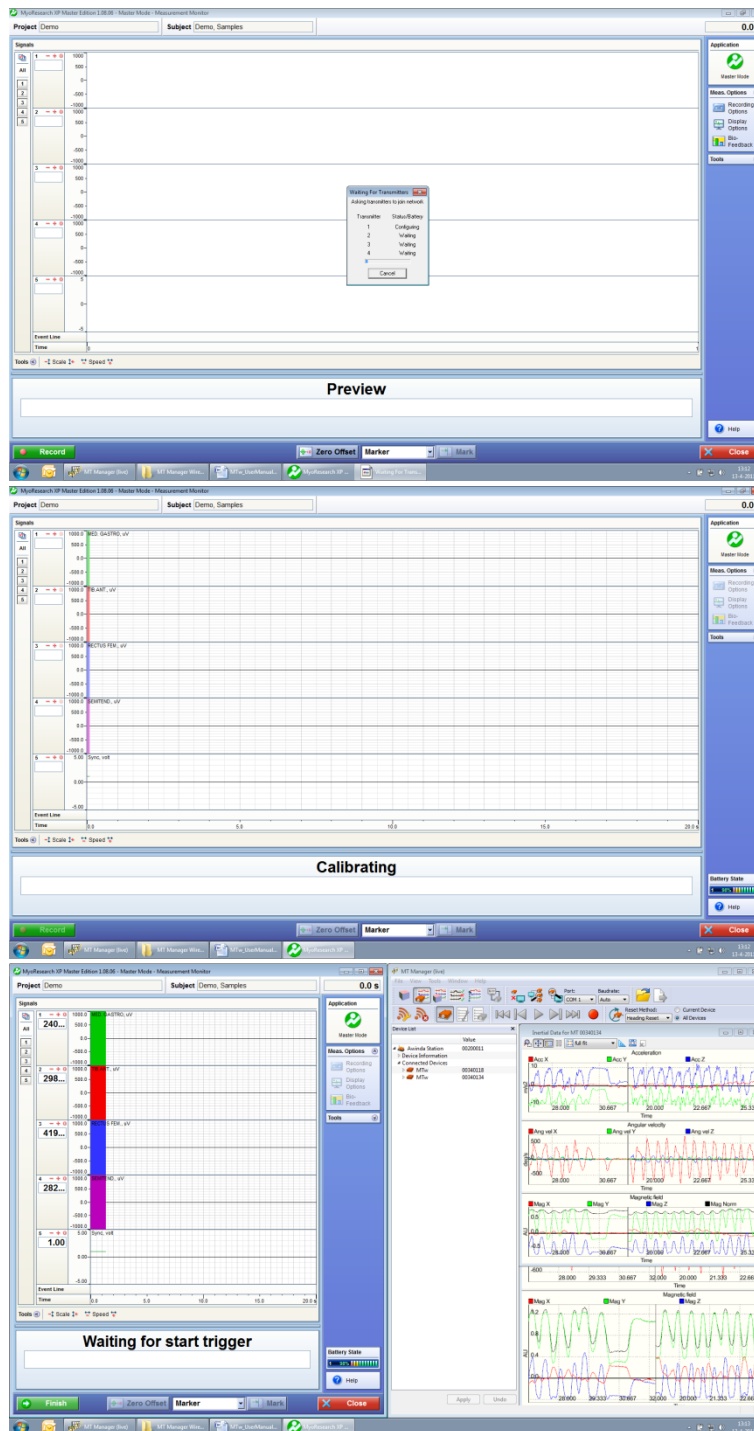
11.8.5.3 Software Setup Noraxon MyoResearch Software:

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 synchronisation 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.

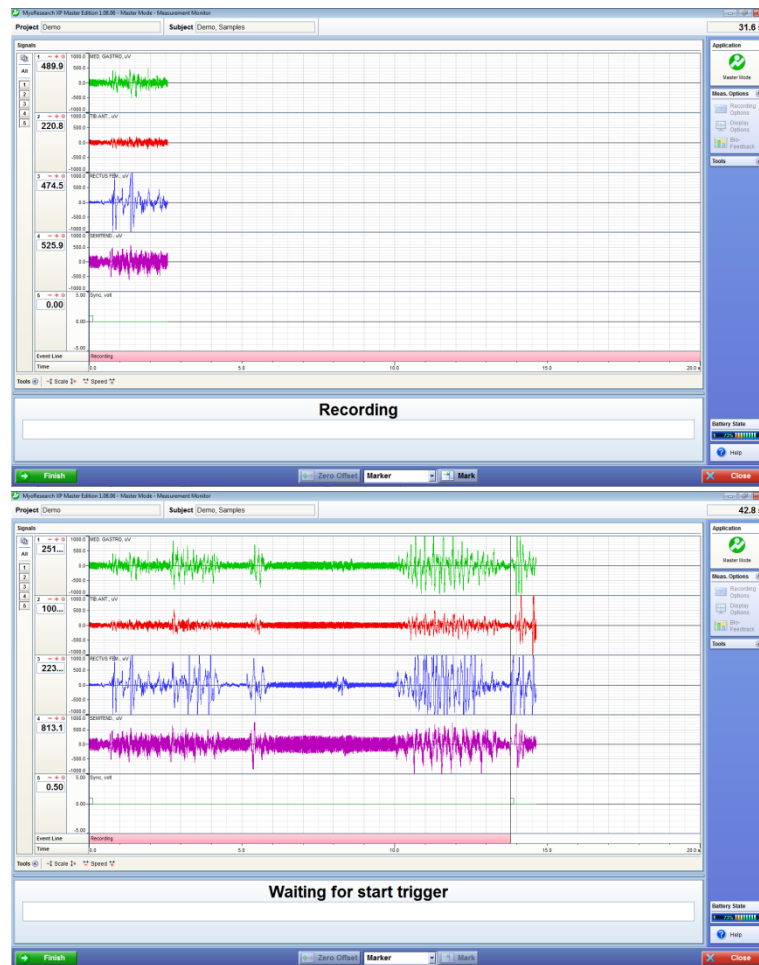
- Check the check box beside “Start Recording”;
- Go to the drop down menu beside “When Channel”, select “Sync”;
 - Select Rises Above (ensure that this is also the direction indicated on the mini-receiver);
 - Input e.g. 0.5V
 - Longer than 5ms
- Repeat settings for Stop Recording.
- Navigate further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

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

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

Hardware requirements:

Noraxon Hardware	Xsens Hardware
<ul style="list-style-type: none"> • Wireless EMG transmitters • 1 TeleMyo DTS (plus antenna) • 1 TeleMyo mini-receiver (plus antenna) 	<ul style="list-style-type: none"> • 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 minireceiver.
 Connect the external antenna to the TeleMyo DTS.
 When successfully connected and switched on, the TeleMyo DTS will display “WiFi ready”.

11.8.5.5 Software Setup: MT Manager

Synchronisation on the Sync In Line 1 port:

Sync In	
<ul style="list-style-type: none"> • Select Start Recording • Check the check box for Line 1 • Polarity: Rising Edge • Trigger Once: Uncheck • Skip first = 0 • Skip factor = 1 	<ul style="list-style-type: none"> • Select Stop Recording • Check the check box for Line 1 • Polarity: Rising Edge • Trigger Once: Uncheck • Skip First = 1 • Skip Factor = 1

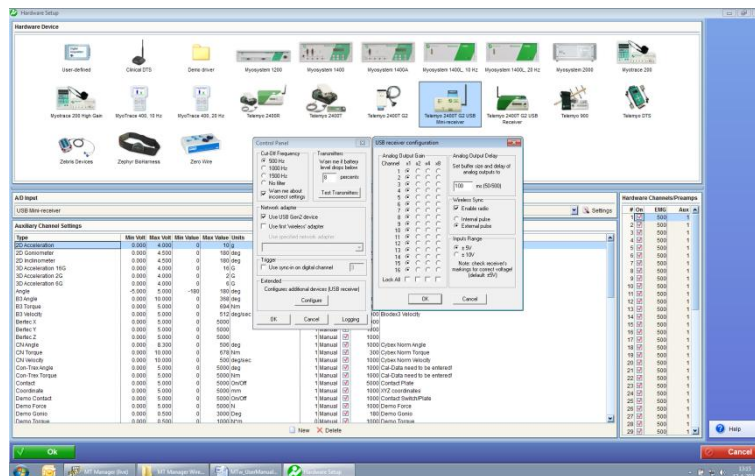
Set up the wireless configuration in MT Manager.

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 6.7.2.

11.8.5.6 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 $\pm 5V$



The rest of the software setup is the same as described in Section 11.8.5.6 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.