General Information

- Ordering information
- Sirius series architecture
- Xsens Sirius series product variants
  - Xsens Sirius IMU
  - Xsens Sirius VRU
  - Xsens Sirius AHRS

This document provides information on the usage and technical details of the Xsens Sirius series. The Xsens Sirius series robust trackers (S#X##A or S#X##B) are rugged (IP68) devices which can be connected to a host through RS232, RS422, CAN or CAN-FD interface, or through USB using the USB connection cable(included in the Sirius series Development Kit).

The *Family Reference Manual* supplements this document. It reports generic information on the Xsens generic products, such as output definitions, algorithm details and installation tips.

The Xsens *Sirius series Hardware Integration Manual* supplements this document. In this document, notes on typical application scenarios, printed circuit board (PCB) layout, origin of measurement reference system, stress related considerations, reference designs and handling information can be found.

For testing and prototyping, Xsens provides the Devlopment Kits (DK) for the robust tracker. Technical details of the Development Kit and its usage can be found in the Xsens *Sirius series DK User Manual*.

The *MT Low Level Communication Protocol* document provides a complete reference for the protocols used to communicate with Xsens Motion Trackers on a low-level basis. The MT Low Level Communication Protocol document also describes the synchronization messages and settings in detail.

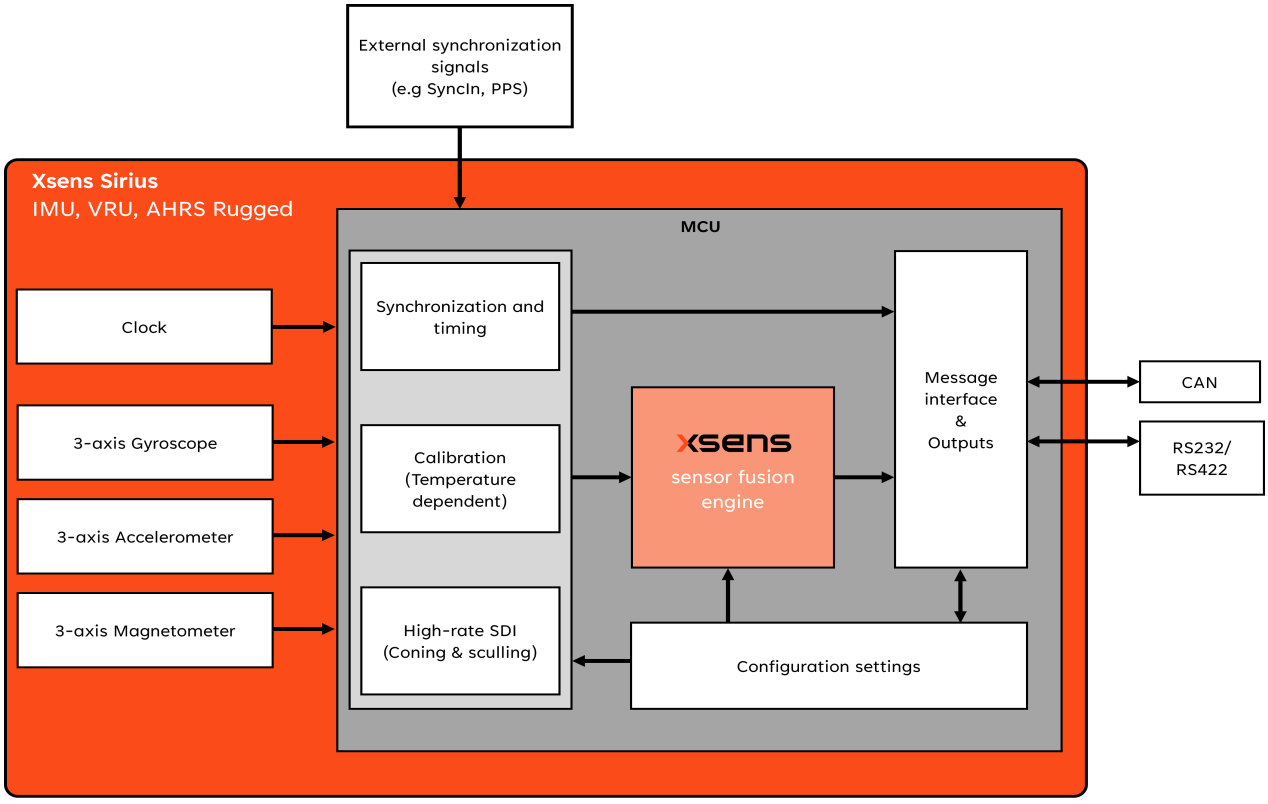
Ordering information

Ordering information for Sirius series products

Product Family	Part Number	Product Name	Description	Packing
Xsens Sirius IMU	S1M43A	Xsens Sirius IMU Rugged - RS232	IMU, IP68, 8g Acc, 300dps Gyro, RS232/CAN(-FD) Inertial data	Box (MOQ 1 unit)
	S1M43B	Xsens Sirius IMU Rugged - RS422	IMU, IP68, 8g Acc, 300dps Gyro, RS422/CAN(-FD) Inertial data	Box (MOQ 1 unit)
Xsens Sirius VRU	S1V43A	Xsens Sirius VRU Rugged - RS232	VRU, IP68, 8g Acc, 300dps Gyro, RS232/CAN(-FD) Inertial data, roll/pitch/yaw (unreferenced)	Box (MOQ 1 unit)
	S1V43B	Xsens Sirius VRU Rugged - RS422	VRU, IP68, 8g Acc, 300dps Gyro, RS422/CAN(-FD) Inertial data, roll/pitch/yaw (unreferenced)	Box (MOQ 1 unit)

Xsens Sirius AHRS	S1A43A	Xsens Sirius AHRS Rugged - RS232	AHRS, IP68, 8g Acc, 300dps Gyro, RS232/CAN(-FD) Inertial data, roll/pitch/yaw (referenced)	Box (MOQ 1 unit)
	S1A43B	Xsens Sirius AHRS Rugged - RS422	AHRS, IP68, 8g Acc, 300dps Gyro, RS422/CAN(-FD) Inertial data, roll/pitch/yaw (referenced)	Box (MOQ 1 unit)
	S1A43A-DK	Xsens Sirius AHRS/VRU/IMU Rugged - Development Kit - RS232	AHRS/VRU/IMU Development Kit, IP68, 8g Acc, 300dps Gyro, RS232/CAN(-FD) Inertial data, roll/pitch/yaw (referenced)	Box (MOQ 1 unit)
	S1A43B-DK	Xsens Sirius AHRS/VRU/IMU Rugged - Development Kit - RS422	AHRS/VRU/IMU Development Kit, IP68, 8g Acc, 300dps Gyro, RS422/CAN(-FD) Inertial data, roll/pitch/yaw (referenced)	Box (MOQ 1 unit)

Sirius series architecture



Xsens Sirius series module diagram

The diagram in the figure above shows a simplified architecture of the Sirius series motion tracker. The Xsens Sirius series motion tracker contains a 3-axis gyroscope, 3-axis accelerometer, 3-axis magnetometer, a high-accuracy crystal and a low-power micro-controller unit (MCU). The MCU applies calibration models (unique to each sensor and including orientation, gain and bias offsets, plus more advanced relationships such as non-linear temperature effects and other higher order terms) and runs the Xsens optimized strapdown algorithm, which performs high-rate dead-reckoning calculations up to 10 kHz, allowing accurate capture of high frequency motions and coning & sculling compensation. The Xsens sensor fusion engine combines all sensor inputs and optimally estimates the orientation at an output data rate of up to 400 Hz. The output data of the Xsens Sirius series is easily configured and customized for an application's needs and can be set to use one of various filter profiles available within the Xsens sensor fusion engine. In this way, the Xsens Sirius series limits the load and the power consumption on the user application's processor. The user can communicate with the module by

means of three different communication interfaces; RS232 or RS422 and CAN(-FD)[1]. The USB interface is available using the USB connection cable which comes with a Development Kit or by using third party equipment (e.g. RS232 to USB converter).

Xsens Sirius series product variants

The Sirius Robust Tracker is a fully tested self-contained module available as an:

- Inertial Measurement Unit (IMU),
- Vertical Reference Unit (VRU),
- Attitude and Heading Reference System (AHRS)

It can output 3D orientation data (Euler angles, rotation matrix or quaternions), orientation and velocity increments (Δq and Δv), and calibrated sensor data (acceleration, rate of turn, magnetic field and pressure). Depending on the product variant, output options may differ.

Xsens Sirius IMU

The Xsens Sirius IMU Robust Tracker is an IP68 rated IMU that outputs calibrated 3D rate of turn, 3D acceleration, 3D magnetic field. The S1M43A/S1M43B also outputs coning and sculling compensated orientation increments and velocity increments (Δq and Δv). Advantages over a simple gyroscope-accelerometer combo-sensor are the inclusion of synchronized magnetic field, on-board signal processing and the easy-to-use synchronization and communication protocol. The signal processing pipeline and the suite of output options allow access to the highest possible accuracy at any output data rate up to 2000 Hz. Moreover, the testing and calibration is already performed by Xsens and results in a robust and reliable sensor module, which enables a short time to market for the users.

Xsens Sirius VRU

The Xsens Sirius VRU Robust Tracker is a 3D VRU. On top of the functionality of the Xsens Sirius IMU, its algorithm computes 3D orientation data with respect to a gravity referenced frame: drift-free roll, pitch and unreferenced yaw. Although the yaw is unreferenced, it is superior to only gyroscope integration as a result of advanced on-board sensor fusion. The 3D acceleration is also available as so-called free acceleration, which has the local-gravity subtracted. The drift in unreferenced heading can be limited by using the Active Heading Stabilization (AHS) functionality. See Signal processing and algorithms for more details. The raw sensor signals are combined and processed at a high frequency to produce a real-time data stream with the device's 3D orientation (roll, pitch and yaw) up to 400 Hz.

Xsens Sirius AHRS

The Xsens Sirius AHRS Robust Tracker supports all features of the Xsens Sirius IMU and VRU, and, in addition, is a full magnetometer-enhanced AHRS. In addition to the roll and pitch, it outputs a yaw (heading) output that is referenced to the Earth's magnetic field and calibrated sensor data: 3D acceleration, 3D rate of turn, 3D orientation and velocity increments (Δq and Δv) and 3D magnetic field data. The raw sensor signals are combined and processed at a high frequency to produce a real-time data stream with the device's 3D orientation (roll, pitch and yaw) up to 400 Hz.

[1] RS232 and RS422 are available depending on the model, but a model with RS232 will not have RS422, and vice versa.

Signal processing and algorithms

This section discusses the Xsens Sirius series signal processing and algorithm description.

- Signal processing pipeline
  - Strapdown integration
- Xsens sensor fusion algorithm for VRU and AHRS product types
- Data output
  - Xbus output
  - NMEA output
  - CAN output
- Magnetic interference
  - Magnetic Field Mapping (MFM)
- Frames of reference

Signal processing pipeline

The Xsens Sirius series is a self-contained product. All calculations and processes such as sampling, coning & sculling compensation and the Xsens sensor fusion algorithm run on board.

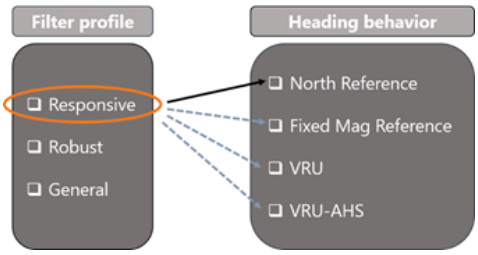
Strapdown integration

The Xsens optimized strapdown algorithm performs high-rate dead-reckoning calculations up to 10 kHz, allowing accurate capture of high frequency motions. This approach ensures a high bandwidth. Orientation and velocity increments are calculated with full coning & sculling compensation. These orientation and velocity increments are suitable for any 3D motion tracking algorithm. Increments are internally time-synchronized with other sensors. The output data rate can be configured for different frequencies. See #Output data rates. The inherent design of the signal pipeline with the computation of orientation and velocity increments ensures there is absolutely no loss of information at any output data rate. This makes the Xsens Sirius series also attractive for systems with limited communication bandwidth.

Xsens sensor fusion algorithm for VRU and AHRS product types

The Xsens Sirius VRU and AHRS run the newest Xsens sensor fusion algorithm implementing the latest Xsens insights. It optimally estimates the orientation with respect to an Earth fixed frame utilizing the 3D inertial sensor data (orientation and velocity increments) and 3D magnetometer data.

The Xsens sensor fusion algorithm uses assumptions to obtain the orientation estimations. Since the assumptions may be more or less valid based on the characteristics of the typical dynamics of the application, and since the magnetic field differs per application, the Xsens algorithm makes use of a set of filter profiles to be able to use the correct assumptions given the application. This way, the algorithm can be optimized for different types of movements and conditions.
With the Xsens Sirius VRU and AHRS, the user can configure different algorithm behaviours by selecting a “base” filter profile and, next to that, a heading behaviour. See image below.



Filter profile and heading behaviour selection: a tiered approach

The “base” filter profile selection affects the general behaviour of the device, mainly based on the nature of the typical expected dynamics of the application. The heading behaviour, as the name suggests, affects the heading/yaw output of the MTi, and determines how the magnetometer measurements are interpreted. This tiered approach gives more freedom to select the desired behaviour for different user application scenarios. The tables below summarize the filter profile and heading behaviour options.

Every application is different and results may vary from setup to setup. It is recommended to reprocess recorded data with different filter profiles in MT Manager to determine the best filter profile for your specific application.#1

Filter profiles for Xsens Sirius VRU and AHRS

Name	Product	Description	Typical applications

Name	Product	Description	Typical applications
Responsive	Xsens Sirius VRU and AHRS	This filter profile is designed for indoor applications as well as applications that experience high dynamics and jerky movements. When the MTi is static, an automatic gyro bias estimation is performed in the background.	• Outdoor/Indoor handling objects • Indoor ground vehicles • Outdoor/Indoor head tracker • Indoor mapping, outdoor mapping if handheld (e.g. tripods with camera, backpack) • Industrial robotic arm
Robust	Xsens Sirius VRU and AHRS	This filter profile is suitable for most applications. Compared to the other filter profiles, it has a more robust tuning. When the MTi is static, an automatic gyro bias estimation is performed in the background.	• Ships/vessels • Automotive • Ground vehicles outdoor • Outdoor mapping with vehicles
General#2	Xsens Sirius VRU and AHRS	This filter profile behaves like the General filter profile implemented for the previous generation of Xsens Products (e.g. MTi-30). It is more sensitive to magnetic field changes. It does not perform an automatic gyro bias estimation in the background. This filter profile cannot be combined with the FixedMagRef heading behaviour.	• Automotive • Ground vehicles outdoor • Outdoor mapping with vehicles

Heading Behaviour

Name	Product	Description	Typical applications
NorthReference	Xsens Sirius AHRS	This heading behaviour assumes a homogeneous magnetic environment that can be used to estimate a stable north-referenced#3 heading.	All applications that require a north-referenced heading and are used in a homogeneous magnetic field.
FixedMagRef	Xsens Sirius AHRS	This heading behaviour is based on the idea that the heading is not necessarily referenced to the local magnetic north. Instead, it maintains a fixed heading reference frame based on what is defined when the MTi is powered up (based on the initially observed magnetic field). This means that there is no drift with respect to the starting frame when the local magnetic field changes. For example, when moving from room A to room B, where room B has a different local magnetic field direction than room A, the heading output of the MTi does not change. This is in contrast to the NorthReference heading behaviour, which forces the MTi to estimate the heading based on the local magnetic field.	All applications are used in environments where different magnetic fields are present (e.g. mixed indoor/outdoor applications).
VRU	Xsens Sirius VRU and AHRS	The yaw is unreferenced. This means that it is initialized at 0° when the MTi is powered up and the yaw will be computed relative to this initial orientation. The magnetic field is not used to estimate the yaw. Because of small inaccuracies that originate when integrating gyroscope data, the Yaw output will contain an error that builds up over time, also known as “drift”. Note however, that because of the working principle of the sensor fusion algorithm, the drift in yaw will be much lower than when gyroscope signals are simply integrated.	Applications where only roll and pitch is of interest and/or applications that are used in environments where the magnetic field cannot be trusted (e.g. stabilized antenna platforms or pipeline inspection tools).
VRUAHS	Xsens Sirius VRU and AHRS	This heading behaviour activates the Active Heading Stabilization (AHS) on top of the above-described VRU behaviour. AHS is a software component within the sensor fusion engine designed to give a low-drift unreferenced heading solution, even in a disturbed magnetic environment. The yaw remains unreferenced, but the drift is limited.#4	Scenarios where the magnetic field cannot be trusted completely, but a stable yaw is needed.

Data output

The Xsens Sirius series product variants can output many different data types at many different frequencies. Below is a summary of the most relevant data and maximum output data rates. A full overview is available in the *MT Low Level Communication Protocol Documentation*.

Output data rates

Data Type	Max Output Data Rate
Orientation data (Euler angles, Rotation Matrix, Quaternions)	400 Hz
DeltaQ, DeltaV	400 Hz
Acceleration, Rate of Turn, Free Acceleration	400 Hz
Acceleration HR (High Rate)	2000 Hz
Rate of Turn HR (High Rate)	2000 Hz

Xbus output

The Xbus protocol is Xsens' standard output protocol utilizing the MTDATA2 data message structure. This output provides a lot of flexibility and enables users to access all functionality of the MTi product range. The Xbus output format is shared with all other MTi products in the Xsens portfolio, so switching between hardware platforms is very easy. More information is available in the *MT Low Level Communication Protocol Documentation*.

NMEA output

NMEA output is a string output mode which outputs data in the commonly used NMEA 0183 format. More information is available in the *MT Low Level Communication Protocol Documentation*.

CAN output

The CAN output is an industrial standard interface over which the Xsens Sirius series can output its data. CAN-FD functionality is also available with firmware version 1.3.0 or higher. More information on the CAN output can be found in the *MT CAN Protocol Documentation*.

Magnetic interference

Magnetic interference can be a major source of error for the heading accuracy of any AHRS, as an AHRS uses the magnetic field to reference the estimated orientation on the horizontal plane with respect to the (magnetic) North#3. A severe and prolonged distortion in that magnetic field will cause the magnetic reference to be inaccurate. The Xsens Sirius series has several ways to cope with these distortions to minimize the effect on the estimated orientation, which are discussed in the sections below.

Magnetic Field Mapping (MFM)

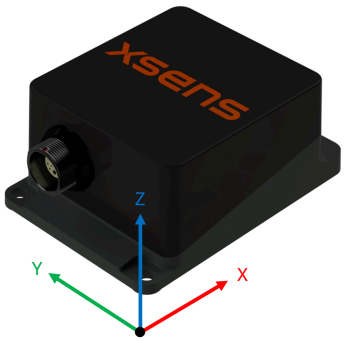
When the distortion moves with the MTi (i.e. when a ferromagnetic object solidly moves with the MTi module), the MTi can be calibrated for this distortion. Examples are the cases where the MTi is attached to a car, aircraft, ship or other platforms that can distort the magnetic field. It also handles situations in which the sensor has become magnetized. These types of errors are usually referred to as soft and hard iron distortions. The Magnetic Field Mapping procedure compensates for both hard iron and soft iron distortions.

The magnetic field mapping (calibration) is performed by moving the MTi mounted on the object/platform that is causing the distortion. The results are processed on an external computer (Windows or Linux), and the updated magnetic field calibration values are written to the non-volatile memory of the Xsens Sirius series. The magnetic field mapping procedure is extensively documented in the *Magnetic Calibration Manual*.

Frames of reference

The Xsens Sirius series uses a right-handed coordinate system. The default sensor-fixed frame (S_{xyz}) is defined as shown in the figures below. The frame is also printed on the back side of robust trackers. For a more exact location of the sensor frame origin, refer to Design and Packaging. When the sensor is rigidly attached to another object or vehicle, it is possible to rotate the sensor-fixed frame S_{xyz} to an object coordinate frame (O_{xyz}).#5 The default local earth-fixed frame (L_{XYZ}) is East-North-Up (ENU). In addition, the Xsens Sirius series have predefined output options for North-East-Down (NED) and North-West-Up (NWU). Since the Xsens Sirius VRU and AHRS cannot

receive real time positioning from a GNSS receiver, the user must set correct positional coordinates to allow the Xsens Sirius VRU and AHRS to construct the reference frame, magnetic and gravity models.



Default sensor fixed coordinate system(S_{xyz}) for the Xsens Sirius Robust Trackers

[1] Refer to the BASE article: Recording a data file to be reprocessed in MT Manager.
[2] The General filter profile is only recommended for users who are looking for similar behaviour to the previous generation Xsens products in the typical applications suggested in the table. Using the General filter profile is not recommended for new designed applications.
[3] Note: Under default settings, Yaw (heading) equals 90 degrees when the X-axis of the MTi points north.
[4] For more information on the capabilities of AHS, refer to the BASE article: AHS. Note that in the previous Xsens products, AHS was activated by means of a separate setting.
[5] How to define a new object coordinate system can be found in the *Family Reference Manual*.